AGNICO EAGLE

HOPE BAY MINE

Operations, Maintenance and Surveillance Manual: Doris Tailings Impoundment Area

JANUARY 2026
VERSION 9

Revisions

Version #	Date	Section	Summary of Changes	Author
0	June 2016	Entire Document	Initial Document	TMAC
1	August 2016	Entire Document	References added	TMAC
3	February 2017	Section 1.5, Table 3	List updated	TMAC
4	November 2017	Section 2.1, Table 4	List updated	TMAC
5	March 2022	Section 3.3.5, 3.10	Added contingency pumping for excess mine water	Agnico Eagle
6	September 2022	Section 3.4.3, Section 3.8, Table 6	Removed optionality of constructing Interim Dike; Added construction timing of Interim Dike	Agnico Eagle
7	September 2022	Section 4.4	Added approval process for alternate chemical dust suppressants	Agnico Eagle
8	November 2025	Section 4.5	Reference water management during Care and Maintenance	Agnico Eagle
		Section 5.3.1	Added Figure 12 pertaining to shoreline protection measures	
		Section 6.4, 6.5.4	Added tailings geochemical monitoring	
		Section 6.5.3	Referenced TIA water quality monitoring	
		Section 7	List updated	
		Figures	Added new Figure 12 and renumbered remaining Figures 13 through 17	
		Appendix A	Included appendix information previously omitted	
2	November 2017	Entire Document	Changes made to account for Phase 2 TIA requirements	TMAC
3	August 2020	Entire Document	Document format updated. Updates post construction of the Phase 1 South Dam. Report still accounts for Phase 2 requirements. Updates to meet new Mining Association of Canada (MAC) guidelines.	TMAC
4	February 2022	Entire Document	Updated to include Agnico Eagle Governance of Critical Infrastructure , change of ownership, TARP levels	Agnico Eagle
5	April 2022	Section 3.6	Updated Spillway and Interim Dike section for activities as listed in the Care and Maintenance Plan	Agnico Eagle

6	March 2023	Entire Document	Updated structure of document to reflect incorporation into the Dam Safety Management System. Updated the DEP. Linked OMS to ERP Updated contact information. Updated with new TIA infrastructure.	Agnico Eagle
7	March 2024	Entire Document	Updated to include the construction of the Interim Dike, updated water elevation TARPs, links to updated ERP and updated contact information.	Agnico Eagle
8	March 2025	Entire Document	Annual update.	Agnico Eagle
9	January 2026	Throughout	Changes throughout this version of the Plan represent interim/annual updates for permitting requirements. Additions are marked in the right-hand margin as follows: 	Agnico Eagle
		Section 1.2	Added text to “Related Documents” section indicating that broad updates are expected in coming years as the site transition from Care and Maintenance back to Operations.	
		Section 2.2	Updated contact information for new Engineer of Record and Mine Manager.	
		Section 3.0	Updated to reference ongoing updates in deposition plan, mine plan, and water licence application – referenced future design updates to TIA that will trigger OMS updates.	
		Section 5.1	Added specific qualifiers that apply during Care and Maintenance period. Added mitigation measures to be considered in the event of “excessive water inventory”.	
		Section 5.6	Added text referring to future updates coming in water management plans (updates to be documented in future revisions of the OMS Manual).	

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Glossary

Term	Definition
AEO	Accountable Executive Officer
AEP	Annual Exceedance Probability
AGI	Annual Geotechnical Inspection
Agnico Eagle	Agnico Eagle Mines Limited
BAP	Best Applicable Practices
BAT	Best Available Technology
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
DE	Design Engineer
DEP	Dam Emergency Plan
DSMS	Dam Safety Management System
DSR	Dam Safety Review
E&I	Energy and Infrastructure Department
EOR	Engineer of Record
ERP	Emergency Response and Crisis Management Plan
FEIS	Final Environmental Impact Statement
FSL	Full Supply Level
GCL	Geosynthetic Clay Liner
IDF	Inflow Design Flood
IIBA	Inuit Impact and Benefit Agreement
IOL	Inuit-Owned Lands
IRB	Hope Bay Independent Review Board
KitIA	Kitikmeot Inuit Association
MAC	Mining Association of Canada
MDMER	Metal and Diamond Mining Effluent Regulations
NIRB	Nunavut Impact Review Board
NTI	Nunavut Tunngavik Inc.
NWB	Nunavut Water Board
PAG	Potentially Acid Generating
PGA	Peak Ground Acceleration
PMF	Probable Maximum Flood
ROQ	Run of Quarry
RP	Responsible Person
SGE	Site Geotechnical Engineer
SOP	Standard Operating Procedure
TARP	Trigger Action Response Plan
The Mine	Hope Bay Mine
This Manual	TIA OMS Manual

TMS	Tailings Management System
TPD	Tonnes Per Day
WAD	Weak Acid Dissociable
WMMP	Wildlife Monitoring and Mitigation Plan
WRSF	Waste rock storage facility

1. Introduction

This Operations, Maintenance, and Surveillance (OMS) manual is for the Doris Tailings Impoundment Area (TIA). It was originally prepared by SRK Consulting (Canada) Inc. in 2016. Since 2021 the document has been updated by Agnico Eagle Mines Limited (Agnico Eagle) in accordance with various water licenses, operational updates and external guidelines pertaining to Agnico Eagle and associated with developments throughout the Hope Bay region.

The current version of this manual reflects the current Care and Maintencance Phase for Hope Bay, the manual will be updated accordinly as the site and TIA transitions back into the operations phase.

Objectives	This manual outlines the framework and procedures Agnico Eagle and its contractors use to ensure: • OMS of the TIA are carried out safely, • Best practices for minimizing potential environmental impacts and liabilities with respect to the Doris TIA are followed, and, • The water licence conditions are met.
Structure	This document is structured to function as a standalone manual that provides guidance on all aspects of the OMS of the Doris TIA. It incorporates Industry Standards as well as Agnico Eagle Corporate Standards and Policies on Tailings and Water Management. This document plays a critical role in the Dam Safety Management System (DSMS) at Hope Bay. **Note:** In the event of a new water licence or an existing licence amendment, only the portions of this manual pertaining to that licence will need to be revised in this TIA OMS Manual (This Manual).
Contents	In addition, this Manual defines and describes the: • Roles and responsibilities of personnel assigned to the TIA; • Procedures and processes for managing change; • Key components of the TIA; • Procedures required to operate, monitor performance, and maintain the TIA to ensure that it functions in accordance to its design, meets regulatory and corporate policy obligations, and links to emergency planning and response; and, • Requirements for analysis and documentation of the performance of the TIA.

1.1. Managing Updates

When to Update	The procedures required to operate and maintain the TIA can change in response to changes in site conditions or changes to mining operations. Because this Manual is a controlled documents, it is a “living document” that will be updated to reflect those changes. Annual Updates This Manual is reviewed annually as required by the Agnico Eagle governance policy for critical infrastructure, with input from appropriate Agnico Eagle site staff, based on recommendations from: • The Engineer of Record (EOR); • The Responsible Person (RP) and the Site Geotechnical Engineer (SGE); • The Design Engineer (DE); • The Hope Bay Independent Review Board (IRB); and,

<table>
<tr><td></td><td>
Third party Dam Safety Review (DSR)
Other Update Triggers
Revisions or updates can be triggered by activities such as:

Changes in dam classification;
Operational performance;
New facility construction;
Personnel or organizational structure;
Mine ownership;
Regulatory or social considerations; and,
Life cycle or design philosophy.

</td></tr>
<tr><td>Update Procedure</td><td>
Updates to this Manual are carried out annually as follows:
<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>The RP or an individual designated by the RP is to submit proposed changes to the EOR for review and authorization.</td></tr>
<tr><td>2</td><td>If changes are related to TIA design elements as stipulated in Section 3 (specifically 3.10), submit them to the DE and EOR for review and approval.</td></tr>
<tr><td>3</td><td>The RP is responsible for communicating any changes that are going to be made to this OMS by e-mail to the control copy distribution list; for all areas regardless of if they fall under the ‘design’ or ‘operation’ categories.</td></tr>
<tr><td>4</td><td>Once approved, incorporate changes into the Manual.
Revisions to the OMS are to be clearly documented in the revision control table (found at the beginning of this OMS).
Once revisions have been made, the updated versions are to be distributed to all parties listed in Section 2.1 and placed on Intelex. Out-of-date materials are to be removed and archived.</td></tr>
</table>
</td></tr>
<tr><td>Control Copy Locations and Responsibilities</td><td>
Copies of this Manual are available at these locations. The latest version is available digitally on Agnico Eagle servers
<table>
<tr><th>Copy Location</th><th>Position</th></tr>
<tr><td>Site Incident Command Center (Dam Emergency Plan Only)</td><td>H&S General Supervisor</td></tr>
<tr><td>External</td><td>Design Engineer (SRK)</td></tr>
</table>
</td></tr>
<tr><td>Digital Control Copy</td><td>A digital control version of this OMS (pdf) is uploaded by Agnico Eagle to the following server location: W:\Environment\Emergency, Spill and WRT Response. The digital version is only considered “controlled” at this one online location.</td></tr>
<tr><td>Uncontrolled Copies</td><td>Printed or electronic copies of the OMS Manual found at other locations will be considered uncontrolled versions.</td></tr>
</table>

1.2. Related Documents

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The documents below should be used in conjunction with this manual.

As of December 2025, Agnico Eagle is in the process of completing engineering studies, design updates and operational document updates for the next phase of operations. Additional documents will be added to this list below as they become available, broad updates are expected in future revisions of this document.

Operating Procedures	• North Dam Monitoring: Standard Operating Procedures – Revision 4 (2024) – North Dam Monitoring Standard Operating Procedures (SOPs) • South Dam Monitoring: Standard Operating Procedures – Revision 1 (2024) – South Dam Monitoring SOPs • For Interim Dike Operating Procedures see Section 4 and Section 7.8
Emergency Planning and Dam Safety Management System	• **Emergency Response and Crisis Management Plan** – Describes Incident Command System and actions relating to all surface emergencies. • **Dam Emergency Plan** – Describes emergency response related to TIA components. See Appendix F. • **Trigger Action Response Plans (2024)** – Details trigger values and associated actions for TIA monitoring and monitoring instrumentation. See Appendix G. See Section 4 for a detailed overview of the DSMS
Design Documentation	• **Preliminary Tailings Dam Design (2007)** – North Dam design documentation (SRK 2007) • **North Dam As-Built Report (2012)** – North Dam as-built documentation (SRK 2012) • **Doris Tailings Impoundment Area Interim Dike Filter Trade-off Study (2016)** – Memo clarifying the purpose of the Interim Dike and a trade-off study of two different filter designs (SRK 2016). Interim dike not part of Phase 2 plans. • **Doris Tailings Management System Phase 2 Design, Hope Bay Project (2017)** – Report documents TMAC's proposed changes to currently permitted TMS to accommodate additional volume of tailings produced as part of Phase 2 development (SRK 2017b) • **Engineering Drawings for the South Dam – Phase 1 (2017)** – South Dam – Phase 1 Issued For Construction Engineering Drawings • **Doris Tailings Management System Phase 2 Design (2017)** – Report overviews the Phase 2 design of the Doris Tailings Management System and Facility (SRK 2017b). • **South Dam Design Report (2019)** – formal documentation for the South Dam design (SRK 2019a) • **South Dam Phase 1 As-Built Report (2019)** – South Dam as-built documentation • **Doris TIA – 2022 Interim Dike** – Design report for Interim Dike (SRK 2022b)
Environmental	• **Climate and Hydrological Parameters Summary Report (2017 and 2022) –** Climate and hydrological parameters and analysis for the Doris and Boston sites (SRK 2017c). An updated climate study was completed in April 2022 (SRK 2022c).
Water Management	• **Doris and Madrid Water Management Plan –** Describes the water management procedures including discharge from the TIA and associated water quality criteria • **Groundwater Management Plan –** Describes the groundwater inflow predictions and associated management procedures for handling this water • **Groundwater Inflow and Quality Model (2015) –** Describes results of hydrogeological modeling to estimate the potential quantity and quality of groundwater flow into the mine (SRK 2015c). An informal groundwater inflow audit was completed in 2022 (SRK 2022a) • **Site-Wide Water and Load Balance (2023) –** Water and load balance to evaluate water management needs and predict water quality at the Project and downstream receptors (SRK 2022d)
Tailings and Waste Management	• **Doris North Project Tailings Management System Design (2015) –** South Dam and Interim Dike design and tailings management plan (SRK 2015a) • Geochemical Characterization of Tailings from the Doris Deposits and FEIS Characterization (2015) – Geochemical characterization of the tailings to be deposited into the TIA (SRK 2015b) • **Hope Bay Waste Rock and Ore Management Plan –** Management plans for waste rock and ore at the Hope Bay project sites

2. Roles and Responsibilities

2.1. Governance and Individual Responsibilities

Agnico Eagle is committed to the protection of the public, the environment and its personnel. The company has developed a governance policy for its critical infrastructure to ensure their management in an appropriate and responsible manner (Agnico Eagle 2020). The primary elements of the policy are:

- The development of specific roles with specific responsibilities;
- Regular and consistent reporting;
- Accountability at all levels, from operations to corporate;
- The use of Best Available Technology (BAT) and Best Applicable Practices (BAP); and
- The use of a risk-based approach to manage the risks associated with critical infrastructure.

The persons responsible for operations, maintenance, surveillance, emergency preparedness, and emergency response along with the governance policy are listed below and in Appendix A, which also provides the site management structure. Agnico Eagle provides training on "chance-find" procedures to relevant field staff to ensure that any archaeological sites that were not identified during pre-development surveys are recognized and treated in an appropriate manner i.e., in accordance with the *Heritage Resources Protection Plan*.

Accountable Executive Officer (AEO)	As emphasized by the Mining Association of Canada (MAC; 2019), the accountability for decisions related to tailings management rests with the Owner's Board of Directors of Governance Level. The Board of Directors or Governance Level is expected to designate an AEO for tailings management. More specifically, the following responsibilities are assigned to the AEO: • Needs to be aware of key outcomes of water management risk assessment and of how these risks are being managed; • Has accountability and responsibility for putting in place appropriate management structure; • Assigns responsibility and appropriate budgetary authority for tailings management; • Defines the personnel duties, responsibility and reporting relationships, supported by job description and organisational charts to implement the tailings management system through all stages in the facility life cycles; and • Provide assurance to Agnico Eagle and its Community of Interest that tailings are managed responsibly.
Mine General Manager	• Identify the scope of work and budget requirement for all aspects of tailings management; • Approve budget for operations, maintenance, and surveillance related activity; • Establish an organizational structure with Roles and Responsibilities that meets the Governance Standard on Critical Infrastructure; • Identify and retain a RP; and • Liaise with IRB as required.

General Superintendents and Supervisors	• Ensure the OMS responsibilities delegated to the departments they oversee are carried out as described in this section of the Manual.
Engineer of Record (EOR)	The function of EOR is to support Agnico Eagle in ensuring that mine waste and water management infrastructure are designed and operated properly. The owner, in assuring that these facilities are safe, has the responsibility to identify and retain an EOR, who provides technical direction on behalf of the owner. Having an EOR for mine waste and water infrastructure is recognized as one of the best practices for responsible management of mine waste and water management facilities. In accordance with the Agnico Eagle Governance Policy for Critical Infrastructure, the EOR is an employee of Agnico Eagle. The EOR's responsibilities include: • Support and give technical advice to the RP and the AEP on geotechnical and operational challenges; • Participate if possible, in annual geotechnical inspections (AGIs) and associated reports for tailings facilities that include retention structures/dams; • Verify if the TIA, waste rock storage facility (WRSF), and water retaining infrastructures are designed and are operating in accordance with the best standards in the industry and the Agnico Eagle corporate standards; • Verify if the waste and water management plans are developed and followed to ensure safety of the operation and the business; • Review and provide agreement on the procedural documents related to waste and water management (including OMS, ERP and TARP); • Be available for the IRB; • Participate in IRB meetings and assist the RP in their preparation if required; • Participate in the facility's risk assessments; • Be available to participate in dam safety reviews; • Identify other internal or external professionals (such as hydrogeologists, geologists, hydrologists, etc.) to provide their support when required; and • Propose a schedule of site visits and required meetings during the course of the year.
Design Engineer (DE)	Engineer responsible for the design and annual inspection of the facilities. At Hope Bay, the DE plays an important role sin the management of critical infrastructure. • Advise on contemplated changes to the structure operation; • Advise on structure performance and mitigation work as required; and • Present during IRB meetings to provide input and context on the structure performance.
Responsible Person (RP)	The Responsible Person(s) identifies the scope of work and budget requirements (subject to final approval) for all aspects of tailings management, including the EoR, and will delegate specific tasks and responsibilities for aspects of tailings management to qualified personnel. The RP is directly responsible for the management of critical infrastructure on a specific site with the objective of compliance with the Governance. The management of critical infrastructure includes design, construction, operation and closure. The RP may delegate specific tasks and responsibilities for aspects of tailings management to qualified personnel (MAC 2019). • Ensure the implementation and sustainability of the Governance model at the site level; • Management of critical infrastructure, as well as appurtenant structures that may affect the critical infrastructure; • The management of personnel, budget and external resources for the critical infrastructure (external resources include the DE, IRB< and any other necessary consultants/contractors); • Close collaboration with the EOR and communication with the DE and IRB; • Preparation for, and coordination of, IRB meetings and site visits; • Preparation for, and coordination of, AGIs;

	• Responding to, and implementation of, the recommendations of the IRB; • Annual review and update of the OMS Manual in collaboration with the EOR; • Continued application of the requirements of the OMS; • In collaboration with the EOR, preparation of an annual report on the status of the critical infrastructure; • Management of all documents and data related to design, construction, operation, closure, surveillance and monitoring in a secure, accessible and permanent manner; and • Revise and update the OMS Manual to reflect as-built conditions and any other changes. Review and update the OMS Manual into Intelex. Maintain up to date distribution list of the OMS Manual.
Site Geotechnical Engineer (SGE)	The SGE is designated by the RP and is responsible for specific tasks and responsibilities for aspects of tailings management that are delegated by the RP. The SGE works closely with the RP and EOR. At Hope Bay the responsibilities of the SGE include: • Support the implementation and sustainability of the Governance model at the site level; • Management of critical infrastructure, as well as appurtenant structures that may affect the critical infrastructure; • Support the management of personnel, budget and external resources for the critical infrastructure (external resources include the DE, IRB and any other necessary consultants/contactors); • Close collaboration with the EOR and communication with the DE and IRB; • Preparation for, and coordination of, IRB meetings and site visits; • Preparation for, and coordination of, AGIs; • Responding to, and implementation of, the recommendations of the IRB; • Annual review and update of the OMS Manual in collaboration with the EOR and RP; • Continued application of the requirements of the OMS; • In collaboration with the EOR, preparation of an annual report on the status of the critical infrastructure; • Management of all documents and data related to design, construction, operation, closure, surveillance and monitoring in a secure, accessible and permanent manner; • Review, revise and update the OMS Manual to reflect as-built conditions and any other changes. Review and update the OMS manual into Intelex. Maintain up to date distribution list of the OMS Manual; • Ensure that required maintenance work (predictive, preventive and corrective) is identified and carried out on the earthwork and instrumentation system in collaboration with the Site Services Department; • Ensure that the surveillance data is reviewed and analyzed to evaluate dike performance with respect to design parameters; and • Ensure surveillance of the structures is carried out as required in the OMS Manual (visual inspection and instrument monitoring).
Independent Review Board (IRB)	IRBs are a mechanism to obtain independent, expert commentary, advice, guidance and where appropriate, recommendations to assist owners/operators in identifying, understanding, and managing risks associated with tailings storage facilities, WRSFs, water/waste storage facilities, heap leach facilities and water-retaining infrastructures. The Independent Reviewer(s) does not have decision-making authority. Accountability and responsibility for decisions rests with Agnico Eagle. • Review mine waste management strategy (including tailings and waste rock storage facilities); • Review water management infrastructure designs and performance (including water retaining infrastructures); • Review on-going construction works and monitoring data;

	• Comment on implementation progress of proposed mine waste management improvement measures; • Provide opinions and guidance to the operation on the physical integrity, safety, behavior, and performance of the confinement systems for mine waste and water retaining infrastructures; and • Comment on management systems, emergency preparedness and overall management approach of the different mine waste management facilities and water retaining infrastructures.
Process Operations Superintendent (Not applicable during Care and Maintenance)	The Process Plant Department is the owner of the process plant. They work in close collaboration with the other stakeholder to ensure the success of tailings management. The Process Plant Superintendent is in charge if the Process Plant and ensures that: • The Process Plant team has sufficient resources (qualified workforce, material, budget, training) to fulfill the OMS obligation defined in this Manual; • A structure is in place that define the roles and responsibilities, qualifications, training requirements and a staffing strategy to fulfill the obligation of the OMS Manual; • The process plant operates and maintains the infrastructure required to produce and transport (i.e pump) the tailings to the TIA; • The process plant tracks the parameters and characteristics of the tailings produced to ensure that targets are reached; • The process plant operates the reclaim water system and tracks the water consumption to ensure that targets are reached; and • The process plant stops the transport of tailings if required in case of upset or emergency conditions.
Environment Superintendent and overall Environment Department	The Environment Superintendent and designates in the Hope Bay Environment Department, ensures compliance with Environment Regulations and the Water Licenses and is the owner of the water and tailings infrastructures outside of the process plant. The Environment Superintendent is responsible for reporting and liaison with the Nunavut Impact Review Board (NIRB), Nunavut Water Board (NWB), and other government agencies. The Environment Superintendent ensures that: • The Environment team has sufficient resources (qualified workforce, material, budget, training) to fulfill the OMS obligations defined in this Manual; • A structure is in place that defines the roles and responsibilities, qualifications, training requirements and a staffing strategy to fulfill the obligation of the OMS Manual; • Environment review monitoring data for compliance with Water License and regulations and to determine dike performance with respect to design parameters; and • SGE has required support.
Energy and Infrastructure (E&I) Superintendent or designate	The E&I Department has the workforce and equipment to manage road, electricity, and dewatering at the Hope Bay site. They fulfill the planning done in collaboration with the Environment team to ensure the fulfilment of the OMS requirements. The E&I Superintendent is in charge of the Site Services Department and ensures that: • The Site Services team has sufficient resources (qualified workforce, material, budget, training) to fulfill the OMS obligation defined in this Manual; • A structure is in place that defines the roles and responsibilities, qualifications, training requirements and a staffing strategy to fulfill the obligation of the OMS Manual; • Site Services maintain access to the structure and tailings management systems - this includes making road repairs, controlling dust and managing snow and water; • Site Services install, operate, maintain and monitor all the components of pumps and piping system associated with water management. They also perform operation, maintenance and surveillance work on the piping system. This work is planned in collaboration with the Environment Department; • Update and maintain a list of operational pumping equipment; and

	• Install, operate, maintain and monitor all the components of pumps and piping system associated with water management. They also perform operation, maintenance and surveillance work on the piping system. The Site Services Department has the workforce and equipment to maintain mobile equipment and pumps. They fulfill maintenance of some of the mechanical equipment components of the dewatering dike as requested by the Site Services department. The Site Services Superintendent is in charge of the Site Services Department and ensure that: • Ensure preventive, predictive and corrective maintenance is carried out regularly on pumping equipment related to water management as requested by Site Services; and • Keep records of maintenance performance on pumping equipment.
Health and Safety Superintendent or designate	The Health and Safety Department is responsible to update and manage the site wide emergency response plan. The Health and Safety Superintendent is in charge of the Health and Safety Department and ensures that: • The *Emergency Response Plan* (ERP) is updated and is aligned with the OMS Manual; and • The trigger to raise an emergency defined in the OMS Manual and the communication pathway to do so is understood and aligned with the ERP.
Water Management Specialist	TBD

2.2. Contact Information

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Environment and Critical Infra VP / AEO	Michel Julien |michel.julien@agnicoeagle.com 416-947-1212 x3738 514-244-5876
Engineer of Record (EOR)	Matthew Brenner | matthew.brenner@agnicoeagle.com 416-947-1212
Design Engineer (DE)	John Kurylo | jkurylo@srk.com 604-235-8541 Peter Luedke | pluedke@srk.com
Site Geotechnical Engineer (SGE)	TBD
Independent Review Board (IRB)	Bill Horne | bill.horne61@gmail.com Henri Sangam | henri.sangam@geomino.com
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Lab & Metallurgy Superintendent (inactive during Care and Maintenance)	TBD 819-759-3555 x 4600101
General Superintendent Mining	Philemon Desrochers-Gagnon | philemon.desrochers@agnicoeagle.com 819-759-3555 x4600155
Environment Superintendent (RP)	Cyril Jenkins | cyril.jenkins@agnicoeagle.com 819-759-3555 x4600102

	819-856-1823
E&I Superintendent	Dave Fuller | dave.fuller@agnicoeagle.com 819-759-3555 x4600131
Health and Safety Coordinator	Morgan Hjorth | morgan.hjorth@agnicoeagle.com 819-759-3555 x4600123

2.3. Communications, Reporting and Tracking

Communication Procedures	It is extremely important that monitoring and management policies are communicated to all parties involved with the site maintenance and surveillance. The RP must ensure that all the issues, concerns, or incidents are reported promptly in accordance with this Manual or applicable management plans. The RP must ensure clear, concise, and consistent communication so that emergency preparedness and response plans are effective, and the public is kept aware of possible hazards associated with the site, of its maintenance, and of its surveillance programs.
Documentation	The surveillance and inspection reports are prepared under the supervision of the SGE and reviewed by a qualified person. After being reviewed, records of all surveillance and inspection activities are kept on file for future reference.
General Guidance	See Section 1.1 for additional details on the Control Copy Locations and Responsibility for the OMS Manual.
Document Control	Reports of activities completed (see below for list) relevant to the operation, maintenance or surveillance of the Doris TIA must be submitted to the RP who will then notify the EOR and specialist consultants if further assessments are required. It is the responsibility of the SGE to ensure the following documents are securely stored and accessible to personnel involved in implementing requirements found in this OMS Manual: • As-built documentation related to the site; • Records of maintenance activities; • Previous site inspection summary reports; • Record of staff training; and • Relevant incident reports.
Inspections, Reporting and Tracking	Observations made during general and geotechnical inspections must be recorded in field books or in digital tablets or computers. For hardcopy documents, digital scans of the used pages of the field books must be stored on corporate drives and available to the team. Unless completely digitized, copies of field notes or field books must be stored at a designated location when not in use. It is the responsibility of: • Any personnel visiting the site to report any observed issues that require maintenance or repairs to the RP; and • The geotechnical inspector to prepare and properly file a memorandum for each geotechnical inspection, describing the observations made during the site visits, as well as any recommendations for maintenance activities to be completed. Electronic copies of the geotechnical inspections and maintenance events should be submitted to the RP within and an reasonable timeframe no later than 90 days following the completion of the inspection or maintenance event or immediately in the case of serious concerns. The reports must include: • Tabular summaries of all data generated; • A description of any restoration or reclamation work carried out (or since the previous inspection); • Results of any studies associated with restoration and reclamation; • A report on any inspection of site in accordance with water license requirements; and

	• Any other details requested by the SGE, RP or the EoR.
Tailings Spills and Pipeline Repairs (not applicable during Care and Maintenance)	All tailings line repairs, spills or leaks of any tailings line must be documented and reported to the RP. This report should include: • A description of the repair or damage; • Photos of the location; and • A coordinate (or figure mark-up) to show the location of the repair or damage.

Hard copies of all documents produced in the reporting and tracking process must be stored on Agnico Eagle computer systems in a location accessible to the team. All hard copy documents must be scanned and turned into electronic records at least annually.

2.4. Competencies and Training

Objectives	Relative to carrying out operations, maintenance, and surveillance activities for the TIA, Agnico Eagle ensures site personnel: have a clear understanding of and adequate competency for their roles and responsibilities, receive appropriate training, and are kept abreast of updates to this Manual. **Note:** Procedures for meeting these objectives follow.
Role-Specific Competencies	Agnico Eagle works to ensure personnel have the tailings management experience specific their job descriptions prior to appointment (especially those identified in Section 2.1); participate, if necessary, in training to remedy any deficiencies in competency (such as online tailings management courses offered by Edumine or conferences); and receive on-the-job training for relevant tasks such as those outlined in appropriate SOPs.
Site Orientation	All personnel involved in operational tailings management are required to receive a site orientation that provides them with an understanding of the general TIA management principles and visual indications of the TIA performance. During periods of Care and Maintenance, the site orientation may take the form of a field orientation delivered by the RP or designate.
Ongoing OMS Training	During periods of tailings deposition, Agnico Eagle develops and requires personnel involved in tailings management to attend a detailed, annual site-specific TIA orientation and training module based on this Manual and: • If necessary, following the AGI, a workshop conducted by the SGE that focuses on findings of the site inspection. During Care and Maintenance, the annual training is adapted to a more informal format that is appropriate based on the level of risk presented by the TIA and associated structures.

3. Tailings Facility Description

V9

3.1. Project Summary

Location	The Hope Bay Mine (the Mine), owned and operated by Agnico Eagle, is found 705 km northeast of Yellowknife, 153 km southwest of Cambridge Bay in Nunavut Territory, and east of Bathurst Inlet.
Mineralization Areas	Hope Bay is a gold mining, exploration and milling undertaking that consists of three distinct areas of known mineralization with extensive exploration potential and targets, including: Doris, Madrid, and Boston.
Project Licenses	**Doris and Madrid** Currently being carried out under an existing water licence. When the mine is in operation, includes mining activities and infrastructure development. **Boston** Includes mining and infrastructure. Boston is located 60 km due south of Doris, respectively (SRK 2017a).
Processing Methods	Ore processing includes cyanidation and flotation methods, with two separate streams of tailings being produced, both captured under the tailings management system (TMS). **Cyanidation Tailings** Cyanidation tailings are detoxified (cyanide destruction) then filtered and blended with waste rock then returned underground as backfill. **Flotation Tailings** Floatation tailings are produced at the Doris processing facility and deposited in the Doris TIA.
Tailings Deposition	**Phase 1** Phase 1 TMS (SRK 2015b) design realizes subaerial deposition of about 2.5 Mt of tailings into the Doris TIA. This area was a natural lake (Tail Lake), which is listed on Schedule 2 of the Metal and Diamond Mining Effluent Regulations (MDMER). **Phase 2** Phase 2 development expands the TIA to accommodate 18 Mt of tailings. An update to the tailings deposition plan is underway as of December 2025. Once finalized, the updated plan will replace Phase 1 and Phase 2 above, and this manual will be updated to reflect the changes.
TIA	To ensure environmental containment, the TIA is impounded through three dams: North Dam, South Dam, and West Dam. **North Dam** • Functions as a water retaining dam; and • Constructed in 2012 (SRK 2012) as a water retaining frozen core dam. **South and West Dams*** • Have tailings deposited against their upstream face to keep the Reclaim Pond away from the structures; • Designed as frozen foundation rock fill dams incorporating a geosynthetic clay liner; and • Phase 1 of the South Dam was constructed in 2018 (SRK 2019a). *South Dam is part of Phase 1 and will be raised as part of the Phase 2 development. The West Dam is a new structure. As of this version of this OMS, the West Dam has not yet been constructed. As part of the ongoing deposition plan updates, a new structure, the central dike, will be required. This Manual will be updated as the new plans are updated.
TIA Closure Process	The TIA current closure procedure has three core stages.

	Stage	Description
	Isolation Cover	The TIA will be closed by applying a 0.3m quarry rock isolation cover that mitigates tailings dust and prevents tailings contact with terrestrial wildlife.
	Water Discharge	Once the cover is applied, water discharge from the TIA must meet environmental discharge criteria, as demonstrated int eh water quality modeling (SRK 2017a).
	North Dam Breach	When water quality is confirmed, the North Dam will be breached, thus returning the natural outflow to its pre-mining elevation.

3.2. Mine History Highlights

Exploration	**1964** Work at the Mine site began. The first exploration focused on showings at Ida Point, Ida Bay, and Roberts Lake to the north. Three exploration companies continued work until exploration drilling started. **1992** Drilling led to the first site infrastructure at Boston in the form of an exploration camp on the northeastern shores of Aimaokatalok Lake. **1996 -1997** Underground development was carried out at Boston to extract a bulk sample. **1999** Exploration drilling expanded to Madrid and Doris. A new exploration camp was constructed on the eastern shore of Windy Lake. **2006** The project certificate (NIRB No. 003) was obtained to start a mine at Doris. **2007** The water licence (2AM-DOH0713) for Doris was issued.
Construction	**2007** Construction began but slowed as the Mine transitioned ownership. **2010** Construction resumed. **2011** Construction of the North Dam starts (until spring). **2012** Construction of the North Dam finished. The Mine was placed in Care and Maintenance before starting commercial production. **2013** Another ownership change happened, which resulted in recommencement of construction, with planned commercial production scheduled for early 2017. **2016** The water license was amended for the Doris Mine (2AM-DOH1323 – Amendment 1). **2018** Construction of Phase 1 of the South Dam. The current water license was amended for the Doris Mine (2AM-DOH1335 – Amendment 2). **2019** Ongoing development at the Doris North, as well as the Madrid areas. **2022**

	The Mine was placed in Care and Maintenance following an ownership change. **2023** Construction of the Interim Dike. Construction of early works to support the transition to the new mine plan. **2024** Continued early works construction. New portal developed at Madrid North. **2025** Continued early works construction at Doris, Madrid, and Patch 7. Mine plan updates and water license applications are ongoing.

3.3. Site Conditions

Climate	**Mean Annual Air Temperature** For the period 1991 to 2020, the mean annual air temperature is estimated to be −11.1°C at the Doris Site. **Wind at Doris and Boston** • predominately a west wind direction at Doris and west-northwest at Boston; • highest wind speeds between December to April, with a predominant westerly wind direction (general site trend); • velocity subsides with a tendency to be on the East-West axis but with no predominant direction otherwise from May to October (site trend); and • westerly in November and December (general site trend). **Precipitation** • 97.4 mm mean annual rainfall for both Doris and Boston • 182.4 mm mean annual snowfall (snow water equivalent, corrected for undercatch) • 279.5 mm estimated mean annual precipitation (water equivalent) **Lake Evaporation Estimation** • 284 mm/year at Doris • 291 mm/year at Boston **Reference:** (SRK 2017c, SRK 2022d)
Permafrost	The Mine is in a region of the Canadian Arctic that is underlain by continuous permafrost with the following parameters: • 570 m estimated continuous permafrost depth (SRK 2017a); • −8°C near surface temperature; and • 0.5–1.0 m thick typical active layer, depending on surface ground conditions (SRK 2015a).
Regional Geology	**Bathurst Block** The Mine area is in the faulted Bathurst Block, forming the northeast part of the Slave Structural Province, a geological sub-province of the Canadian Shield. **Archean Hope Bay Greenstone Belt** The region is underlain by a late Archean Hope Bay Greenstone belt that is 7-20 km wide, more than 80 km long in a north-south direction, and made up of mafic meta-volcanic (meta-basalts) and meta-sedimentary rocks that are bound by Archean granite intrusive and gneisses. **Greenstone Package** The Greenstone packages were deformed during multiple events and is transected by major north-south trending shear zones. **Note:** The zones appear to exert a significant control on the occurrence of mineralization, particularly where major flexures are apparent and coincident with anti-forms (SRK 2015a).

Hydrology	The TIA is in a sub-basin of the Doris Lake drainage basin. The catchment naturally drains northwest towards Doris Lake. Flows are consistent with all drainage basins within the Mine area. Peak flows occur during freshet. The mean annual runoff volume from this basin is 640,000 m3 (SRK 2017a).
Hydrogeology	**Groundwater Flow** Groundwater flow in a continuous permafrost environment is limited to shallow seasonal flow that takes place within the active layer and deep groundwater flow that takes place below the permafrost and in taliks (permafrost free zones) under larger water bodies and has elevated salinity, since the groundwater is ancient trapped seawater (connate water). **Relative to Mining** The Doris Mine includes mining in permafrost, as well as mining in the Doris Lake talik. Peak groundwater inflow to the mine is predicted to be 3,000 m3/day. Typical flows are approximately 1,600 m3/day. This water will be managed via the TIA and/or direct discharge to the ocean (SRK 2015c, 2017a). If predicted mine inflow exceeds 3,000 m3/day, the excess inflow will be temporarily stored in designated areas of the mine or pumped to the TIA. Excess pump capacity will be available to divert excess flow to the TIA (TMAC 2017). **Talik** The TIA hosts a talik; however, it is not known whether it is an open or closed talik. The permafrost free zone is expected to decrease as tailings freeze-back occurs (SRK 2015a).

3.4. Communities of Interest

The Hope Bay Mine and corresponding TIA are in a remote area of the Kitikmeot Region; the western part of Nunavut and the central part of the Canadian Arctic. Access to site is done almost entirely via plane but could also be access via boat in the summer or over ice in the winter. Most project impacts in Nunavut are predicated for the Kitikmeot region, that benefits from the location of the Mine in the region (TMAC 2017).

As outlined in the Final Environmental Impact Statement (FEIS) (TMAC 2017) the project development along the Hope Bay Belt cannot be done in isolation. Many partnerships are required and Agnico Eagle has been supported in its development goals by meaningful partnerships with two major Inuit organizations, Nunavut Tunngavik Inc. (NTI) and the Kitikmeot Inuit Association (KitIA). The NTI is the partner organization that coordinates and manages Inuit responsibilities set out in the Nunavut Agreement. NTI holds the surface title and mineral rights to Inuit-Owned Lands (IOL) in Nunavut, including the surface rights over the entire Hope Bay Property and mineral rights over selected portions of the Property. The KitIA administers the surface rights and the Inuit Impact and Benefits Agreement (IIBA) associated with Agnico Eagle's activities at the Property. The KitIA and Agnico Eagle will continue to share in existing and future benefits through partnerships and agreements already in place including the Framework Agreement, the IIBA and the Commercial Lease. Both organizations fill important roles on behalf of Inuit and they ensure, along with Agnico Eagle, that the existing Framework Agreement and other, future agreements as required, will provide continued social and economic benefits for Nunavummiut, Nunavut and Canada, while effective stewardship of the land is maintained.

As outlined in AMEC (2005), the region has seven communities. The Kitikmeot communities would be most impacted (beyond the immediate personnel on site) from the TIA and Hope Bay Mine as a whole. Cambridge Bay is the largest and is the regional centre and transportation hub. Kugluktuk, the second largest community, is situated 450 km south west of Cambridge Bay. Gjoa Haven, Taloyoak and Kugaaruk are located in the eastern part of the Region. The two smallest communities, Bathurst Inlet and Umingmaktok, south of Cambridge Bay, are the nearest communities to the TIA. Bathurst Inlet is approximately 150 km southwest and Umingmaktok is approximately 75 km west-southwest from the TIA.

As outlined in FEIS Land Use volume, the Hope Bay Mine has the potential to have an adverse effect on commercial land and resource use, and on local land use activities and knowledge. Commercial land users are mainly those engaged in the tourism industry (lodge operators, tour guides). Inuit (i.e., local land users) engaged in land use and harvesting activities depend on the land and environment to support their livelihoods. Traditional knowledge informs the ways in which Inuit engage with the land and environment and is continually evolving in response to changing landscapes. Because of the physical presence of the Mine, changes to levels of noise, dust, and visual aesthetics—and potential changes to the abundance, distribution and quality of animals and plants that are harvested—the Mine has the potential to adversely affect land use. Land use interests that are not associated with traditional activities, such as non-commercial land use (e.g., recreational use by southerners), are considered to occur as a commercial land use in conjunction with lodge operators and tour guides and is assessed as such. Therefore, non-commercial land uses are not considered further (TMAC 2017).

3.5. Relevant Legislation and Guidance

Jurisdiction	Government of Canada and KitIA
Governing Bodies	Authorities involved with permitting and regulating the design, construction, operation, maintenance, surveillance, and closure of the TIA include the following groups: • Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) • KitIA • NIRB • NWB • Workers Safety and Compensation Commission Chief Mines Inspector (per the Mine Health and Safety Act) and its associated regulations (Government of Nunavut 1995)
Regulating Authorities	Use of the TIA is authorized by the following: • Doris North Project NIRB Project Certificate No. 003 (NIRB 2006) • Doris North Project Type A Water Licence 2AM-DOH1335 – Amendment No. 2 (NWB 2018) • KitIA Commercial Lease #KTCL#313D001 • Schedule 2 of the MDMER
Governance of Manual's Contents	**Agnico Eagle** Corporate standard on the Governance of Critical Infrastructure (Agnico Eagle 2020) **Canadian Dam Association (CDA)** Dam Safety Guidelines (CDA 2013) – Guidance related to design and operation of dams

	Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams (CDA 2014) – Guidance related to design, operation and closure of tailings dams **MAC** A Guide to the Management of Tailings Facilities, V3.2 (2021) – Guidance related to the management of Tailings Facilities Developing an Operation, Maintenance, and Surveillance Manual for Tailings and Water Management Facilities, V 2.1 (2021) **NWB** Audit and Assessment of Tailings Facilities (2011) – Guidance for audit and inspection of tailings facilities Water License No: 2AM-DOH1335, Amendment No.2, Doris North Project, Nunavut (2018) – License to operate. Expires March 30, 2035. License updated December 7, 2018 with approval of amendment

3.6. Facility Components

North Dam	The North Dam impounds Reclaim Pond and was designed as a water retaining structure with the following parameters: • central frozen core with secondary upstream geosynthetic clay liner (GCL); • construction from local quarry rock consisting of processed fines for core, 150 mm nominal sized transition material, and run of quarry (ROQ) outer shell; and • key trench equipped with 12 horizontal thermosyphon evaporators to ensure frozen foundation conditions (SRK 2007, 2012, 2015a). **Note:** The North Dam has been in place since 2012. Design parameters are provided in Section 3.10 and Appendix D.
South Dam	The South Dam is a frozen foundation dam consisting of a compacted rock fill with an upstream GCL keyed into the permafrost overburden foundation. **Note:** As of 2018 the entire key trench of the South Dam (Phase 1 and 2) had been constructed, along with the minimum thermal protection over these sections. Above the original ground elevation, the minimal thermal protection over the key trench as well as the Phase 1 GCL and bulk rockfill are in place. **Construction Material** Construction materials are sourced from local rock quarries and include ROQ material and different grades of processed material attained through crushing and screening (SRK 2015a). **Tailings Deposition** Tailings are deposited as a beach from the face of the South Dam. At all times a minimum 100 m long beach is planned to be maintained. In Phase 2, to accommodate the increased tailings quantities, the South Dam will be raised by 8 m in a downstream configuration to reach a crest elevation of 46.0 m. **Note:** Design parameters in Section 3.10 and Appendix D.
West Dam	The West Dam is planned to be a frozen foundation dam with a key trench and GCL liner keyed into permafrost. **Note:** As of 2022 the West Dam was not required for tailings containment and has therefore has not been constructed. **Construction Material** Construction material consists of: bedding, transition, and ROQ material and granular fill produced on site from approved local quarries. **Note:** Complete geological, mineralogical and geochemical details of these quarry sites are documented in SRK (2007, 2008). **Tailings Deposition**

	West Dam is planned to be constructed in a single raise and is about 470 m long with a maximum height of 5 m (crest elevation 46.0 m). **Note:** Design parameters in Section 3.10 and Appendix D.
Temporary Water Filled Portable Dam	In summer 2022, and temporary water-filled portable dam (Aquadam) was constructed within the TIA footprint to segregate different streams of contact water on site. As of 2023 the Aquadam has been decommissioned.
Interim Dike	In 2023 a more robustly engineered structure, the Interim Dike, was constructed as a replacement for the Aquadam, with an identical function and a design life of 3-5 years. The Interim Dike is designed to: be a homogeneous ROQ rock-fill dike with a GCL liner, layer of compacted tailings; used as a method of segregating waste streams and managing water quality within the TIA; be constructed within the confines of the TIA directly on the existing deposited tailings without dewatering the TIA; and not interfere with the originally planned tailings deposition philosophy.
Central Dike	The central dike will be a rockfill structure designed to support tailings deposition and facilitate reclaim water operations. More details to be included in future updates as the updated deposition plan is finalized.
Emergency Overflow Channel	An operational emergency overflow channel was originally designed for the TIA at the North Dam, but was not required due to the freeboard of the North Dam being adjusted to account for an inflow design flood (IDF) of probable maximum flood (PMF). Following any updated IDF requirements, the emergency overflow channel will be constructed prior to or concurrent with the resumption of tailings production with support from the EOR and DE.
Tailings Deposition System	Tailings with an initial solids content of about 38% are pumped to the TIA via a heat-traced and insulated pipeline. Daily production rates are variable expected between 1,200 tonnes-per-day (TPD) (first year) to an allowance of up to 4,000 TPD (dependent on the mine life). **Deposition** Deposition is subaerial using single point spigots, start from the crest of the South and West Dams to create beaches that push the supernatant water away from these structures, and once these beaches are created, the spigot points will be moved to the east flank of the TIA, where deposition should begin from elevation 49.5 m. **Note:** If saline water (such as from the underground) is deposited behind the Interim Dike into the TIA then this should be preferential deposited towards the center of the facility (i.e. away from the South Dam crest and upstream of the primary North Dam pond). **Note:** As the site is presently in a period of Care and Maintenance no tailings deposition is occurring. **Note:** Prior to the resumption of tailings production, the existing tailings deposition plan will be reviewed and updated.
Reclaim Water System (not applicable during Care and Maintenance	**Source and Method** Reclaim water (for re-use in the Process Plant during operations) is drawn from the TIA Reclaim Pond, through submerged suction lines feeding a low-suction head pump installed in an on-shore enclosure location at the Reclaim Pond. The pipeline is heat traced and insulated, and follows the Secondary Road from the Reclaim Pond to the Doris mill. **Reclaim Pond Capacity** The Reclaim Pond will reduce in size over the life of the Mine. The Reclaim Pond will have enough capacity to allow year-round reclaim water to be drawn from the TIA, including under ice conditions in the winter. Near the end of the Mine's life, the pond will be reduced in size such that increased volumes of fresh make-up water and more TIA discharge will be required, and the full supply level (FSL) may have to be lowered to accommodate the IDF. The construction of an Emergency Overflow Channel near the North Dam will mitigate the risk to the North Dam associated with the reduced size of the reclaim pond. **Discharge Setting** Water in the Reclaim Pond will continue to be managed via active pumping to the TIA / Roberts Bay Discharge System in accordance with TIA operating criteria until the closure environmental

	discharge criteria can be met at which time, the water in the Reclaim Pond will be pumped down to its pre-mining elevation of 28.3 m and the North Dam will be breached.
TIA Discharge System	**Source and Method** In accordance with its approvals, the TIA water is discharged year-round to Roberts Bay (subject to meeting water quality requirements) via a discharge pump that is located adjacent to the reclaim pump and pumps water along a pipeline following the same route as the reclaim water pipeline. The TIA discharge water may be co-disposed (blended) with Doris Mine underground flows and may be treated in the Effluent Water Treatment Plant (operational in June 2023) and is pumped along an overland pipeline to the Robert Bay Outfall Structure and continues along the submarine pipeline to the Roberts Bay diffuser.

3.7. Construction Timing

North Dam	Construction of the North Dam was carried out during the winter months of 2010/2011 and 2011/2012 by an experienced earthworks contractor with rigorous quality control. Quality assurance was carried out by SRK (SRK 2012).
South Dam	Construction started on the South Dam (Phase 1) in 2018. Excavation and backfill of the key trench for both Phase 1 and Phase 2 was completed during winter of 2018. This was done to thwart issues caused by thawing of the soft overburden soils and to ensure that a thermal blanket is completed to protect the permafrost in the foundation. Bulk fill of the Phase 1 portion of the South Dam was done during the late winter to spring of 2018. The Phase 2 bulk fill can now be completed during any season.
West Dam	Excavation of the West Dam key trench must be completed in the winter. Bulk fill can be completed during any season. The West Dam has yet to be built (as of 2025).
Aquadam and Interim Dike	The Aquadam was installed in June 2022. The Aquadam was decommissioned in June 2023 following the completion of the Interim Dike construction. Construction of the Interim Dike began in January 2023 and the bulk of the earthworks was completed by June 2023. Monitoring instrumentation was installed in November 2023. SRK and the SGE performed quality assurance for key phases of the construction.
Future TIA Construction	The next phase of TIA construction will be dictated by the update deposition plan, currently in draft for as of January 2026. Details to be included in subsequent updates to this manual.

3.8. Tailings Properties

Tailings properties consist of geotechnical characteristics and geochemistry described below.

Tailings Geotechnical Characteristics

Several campaigns of tailings geotechnical testing have been carried out since 2003. Definitive geotechnical design data for the Mine with respect to tailings properties are provided below.

Parameter	Value
Specific gravity	2.85
% Fines (<0.075 mm)	65%
% Silt	52%
% Clay	13%
Void ratio (e) – slurried tailings	1.2

	Void ratio (e) – drystack tailings	0.6
	Deposited dry density (tonnes/m^3) – slurried tailings	1.30
Tailings Geochemistry	Phase 1 of the Mine includes deposition of flotation tailings from the Doris deposit whereas Phase 2 includes the Doris, Madrid and Boston deposits. Based on the mine schedule, tailings from the Madrid South deposit is scheduled to be on the surface of the TIA at closure. The geochemical characterization programs for tailings and process water from Doris, Madrid North, Madrid South and Boston are documented in SRK 2015b and SRK 2017e. Flotation tailings from all deposits are classified as non-Potential Acid Generating (PAG). Sulphur content is determined to be highest for Madrid North, which was higher than Boston and Doris (which are roughly equivalent), with Madrid South having the lowest Sulphur content. Pyrite was the primary sulphide mineral in all tailings types from all deposit areas. The pH of all humidity cell tests of flotation tailings remained neutral to alkaline for the duration of the tests. Arsenic leaching is the primary metal leaching concern for both Madrid North and Boston and was highest for Madrid North flotation tailings. Arsenic leaching was not related to tailings type, sulphide content or arsenic content. Process water from the mill is a mixture of flotation and detoxified tailings process water and is discharged to the TIA. A comparison of the mixed tailings process waters for Doris, Madrid North, Madrid South[1] and Boston metallurgical samples were roughly equivalent with the following exceptions: Arsenic levels for Madrid North and Boston were approximately two orders of magnitude higher than Doris, with concentrations from Madrid North slightly higher than Boston. Madrid North and Boston were higher than Doris for the following parameters: sulphate, antimony (Boston only), chromium, selenium (Madrid North only), and vanadium (Boston only). Doris had the highest levels of manganese. Cyanide is a reagent additive that is part of the milling process thus explaining the presence of total and weak acid dissociable (WAD) cyanide in the detoxified tailings process water only. Decreases in total and WAD cyanide were observed over the duration of both the oxic and anoxic tests indicating degradation of residual cyanide in the samples. Ammonia is a degradation product of cyanide thus explaining the elevated ammonia levels. _____ [1] Where Boston is an analog for Madrid South.	

3.9. Dam Hazard Classification

The dams associated with the TIA area consist of:

- **North Dam**
- **South Dam**
- **West Dam (not constructed)**

The North, South, and West Dams were assigned a dam hazard classification in accordance with the CDA (2013) dam safety guidelines.

Dam Class	North Dam	South Dam	West Dam
Population at Risk	significant	significant	significant
Loss of Life	significant	significant	significant
Environmental and Cultural Values	high	high	high

Infrastructure and Economics	low	low	low
Overall Hazard Classification	high	high	high

- **Interim Dike** – The Interim Dike is not classified as a dam, as it is located entirely within the footprint of the existing TIA, and any loss of containment of the structures would pose no safety or environmental risk.

3.10. Overall TIA Design Criteria and Parameters

The basis of design, design criteria, and design parameters for the TIA outlined below (SRK 2017f). This table will be updated as design updates are completed to support the new mine plan and corresponding TIA design.

Description	North Dam	South Dam	West Dam
Secondary Seepage Barrier	GCL	GCL	GCL
GCL Deployment Slope	2.5H:1V	3H:1V (4H:1V for the raise)	3H:1V
Crest Centerline Length	220 m	515 m	470 m
Maximum Height	11.0 m	14.0 m	5.0 m
Final Crest Elevation	37.5 m	46.0 masl	46.0 masl
Initial Crest Elevation	n/a	n/a	n/a
Core/GCL Elevation	35.0 m	45.0 m	45.0 m
Full Supply Level	See section 4.5	44.5 masl	44.5 masl
Normal Operating Water Level	See section 4.5		
Total Freeboard	3.3 m	1.5 m	1.5 m
Hydraulic Freeboard	1.8 m	0.5 m	0.5 m
Thermal Protection above Frozen Core	2.5 m	n/a	n/a
Settlement and Allowance Foundation thaw of 1 m (partial thaw) Foundation thaw of 7 m (full thaw)	1 m	 0.47-0.67 m 2.45-3.85 m	 0.40-0.60 m 2.03-3.43 m
Deformation Allowance (Total Strain due to Creep)	<2%	n/a	n/a
Crest Width	13 m	10 m	10 m
Upstream Structure Slope	6H:1V	4H:1V	4H:1V
Downstream Structure Slope	4H:1V	2H:1V	2H:1V
Key Trench Depth	Varies	4.0 m	4.0 m
Key Trench Upstream Slope	0.5H:1V	2H:1V	2H:1V
Key Trench Downstream Slope	0.5H:1V	1H:1V	1H:1V
Dam Hazard Classification	HIGH	HIGH	HIGH
Design Life:			

Description	North Dam	South Dam	West Dam
Active use period as water retaining structure	17 years		
Design basis as active water retaining structure	22 years		
Active use period as solids retaining structure		17 years	17 years
Design basis as solids retaining structure		25 years	25 years
Total life until breach	22 years		
Tailings Production Rate (current mine plan)	1,200 tpd for first year; 2,400 tpd for next 2 years; 3,600 tpd for remaining mine life except last year of mining when production rate drops to 2,400 tpd		
Production Life	17 years		
Tailings Solids Content	35% solids (by weight) initially, increasing to 65%	37.5% solids (by weight)	37.5% solids (by weight)
Tailings Specific Gravity	2.85		
Deposited Tailings Dry Density	1.3 t/m^3(1)		
Ice Entrainment Allowance: Percentage of tailings capacity By volume	 20% 2.4 Mm^3		
Tailings Beach Slope: Subaerial tailings Sub-aqueous tailings	 1.0% 1.0%		
Annual Exceedance Probability (AEP) for Risk Based IDF	1/2475 (0.0004)		
AEP for Standards Based IDF	1/3 between 1/1000 and the PMF(1)		
Static Stability Factor of Safety Long-term (Drained Conditions)	1.3 during construction 1.5 during operation and closure 1.2 to 1.3 partial or rapid drawdown		
Stability Factors of Safety (Pseudo-Static)	1.0 during earthquake		
AEP for Earthquake Design Ground Motion	1.2 post earthquake		
Peak Ground Acceleration (PGA)	0.060g(2)	0.036g	0.043g
Mean Annual Air Temperature Climate Change	+6.8°C up to year 2100		
Thermal Design Freezing Point Depression Tailings Overburden Frozen core	 n/a -8°C -2°C	 0 to -1°C -2°C n/a	 0 to -1°C -2°C n/a
Seepage Allowance	78 m^3/day	50 m^3/day	<1 m^3/day

Notes:

(1) Value based on experiential engineered judgement.

(2) A peak ground acceleration for a 1/2475 return period was not available at the time of design of the North Dam, and therefore the PGA of 0.06 g was selected based on published data for Kugluktuk. This is further described in SRK (2007).

3.11. Dam Break Analysis

The Hope Bay Dam Emergency Plan includes details covering hypothetical dam breach scenarios for the purposes of emergency planning. The Dam Emergency Plan can be found in Appendix F.

3.12. Water Management

Contact Water	All site contact water is pumped or trucked to the TIA.
Underground Water	Saline underground water (i.e., mine water) may be pumped to the TIA or Roberts Bay at an expected maximum rate of 3,000 m^3/day (SRK 2015c). Saline water pumping to the TIA should be limited as much as practical / when possible to assist with maintaining lower operating levels in the TIA. **Note:** Standby pump capacity should be available on site in the event of mine water inflows greater than 3,000 m^3/day, wherein excess mine water may be pumped to the TIA.
Mill Water	During operations, mill make-up water is drawn from the Reclaim Pond to extend possible.
Excess Water	Year round (any season) as long as the site water quality requirements (MDMER) are met. Any excess water in the TIA during operations should be discharged to Roberts Bay for ocean discharge. Prior to discharge to Roberts Bay, all water must meet MDMER limits (SRK 2017a).
Non-Contact Water	There are no non-contact surface water diversions upstream of the TIA. The TIA is in an isolated catchment, and the benefits of any diversions are outweighed by the relative cost and complexity of constructing them.
General Guidance	A site wide water and load balance, including the TIA, has been developed for the Mine and forms the basis for the *Water Management Plan* (SRK 2017a). The water and load balance is validated annually. The site wide water and load balance and the overall water management strategy is currently under review and will be updated to support the new mine plan (currently in development). When updates are finalized, this section of this manual will be updated accordingly.

3.13. Tailings Facility Performance

All data collected as part of the dam monitoring SOPs, currently the North Dam data and South Dam data (SRK 2022a) are uploaded monthly onto the site TIA web portal / viewer.

The Environmental and Geotechnical Data Management and GIS Map Viewer System is found online at: https://maps.srk.com/HopeBay/

When initially accessing the site, personnel will need to register as a new user. This can be requested through the web link show above. Once access is set up, currently managed through SRK, a confirmation email is sent to the user.

Note: if a user does not receive a confirmation access email then they should check their junk mailbox. If it does not appear in this location, then they should email the DE and re-request access to the online portal and GIS viewer.

As of the end of 2025 the following information was available, and updated monthly, on the web portal:

North Dam	Ground temperature cables Inclinometer data Datalogger battery levels and temperatures Survey Monitoring
South Dam	Ground temperature cables Survey Monitoring Aerial satellite photos of tailings deposition (Sentinel-2 data)
TIA Reservoir	TIA-2 water level TL-1 water quality

Relevant documents related to the TIA as listed in Section 1.2, such as this OMS, the design reports, as-built reports, annual inspections, and SOPs are also available on the web portal for reference.

In addition, ongoing data reviews are completed jointly by the DE and SGE. Data review are complete on a monthly basis at a minimum. A detailed annual review of all performance data is completed as part of the AGI.

4. Dam Safety Management System

Definition	The DSMS is a collection of related operational documents and that defines the safe operation and management of the North Dam and South Dam at the Doris TIA. The Doris TIA OMS Manual is a part of the DSMS, its function with respect to other key documents is outlined in Section 4.1 below.
Objectives	Act as a prescriptive framework of documents that can be referenced by site staff to support the safe and effective management and operation of the dams. The documents work together to define the approach to dam safety at Hope Bay.
Components	The key documents comprising the DSMS include: • Doris TIA OMS Manual; • Doris TIA Trigger Action Response Plan; • Dam Monitoring Standard Operating Procedures; • Dam Emergency Plan; and • Emergency Response and Crisis Management Plan.

4.1. TIA Dam Safety Management System Key Documents

The function of each document is described in Table 4-1 below. The relationship and references between the documents are outline in Figure 4-1 below.

Table 4-1 – DSMS Key Document Definitions

Document	DSMS Function
Doris TIA OMS Manual (this document)	Main operational document for the Doris TIA. Defines the Dam Safety Management System framework for Hope Bay. Contains (as Appendices) or references other key DSMS documents such as the DEP (see below).
Doris TIA Trigger Action Response Plan (TARP)	Appendix G of the Hope Bay TIA OMS Manual. Defines the conditions and thresholds corresponding to each trigger level for the North Dam, South Dam, and the TIA Reclaim Pond Water Elevation. Defines initial actions to be taken for operational trigger levels: • Green: Normal Operating Conditions • Yellow: Early Warning Conditions • Orange: Corrective Action Conditions • Red: Emergency/Uncontrolled Condition Specific conditions and thresholds are defined for instrumentation data readings, as well as visual observations from inspections.

Dam Monitoring Standard Operating Procedures	Appendix H of the Hope Bay TIA OMS Manual. Describe in detail the requirements and procedures for dam monitoring under normal operating (Green) conditions.
Dam Emergency Plan	Activates in the event of an emergency at any of the dams on site. Appendix F of the Hope Bay TIA OMS Manual. Further defines the initial response to an emergency condition at the dams (Red Trigger Level). Includes the personnel, equipment and communication systems available to respond to an emergency situation at the dams. Is linked the Hope Bay ERP.
Emergency Response and Crisis Management Plan	Stored on Hope Bay server (W:\Procedures and Policies\01. Safety\300x - ERT\Plan) and physical hardcopies located in the admin boardroom and goehub. Activates in the event of an emergency on site. Defines the initial response to an emergency. Includes the personnel, equipment and communication systems available to respond to an emergency situation.

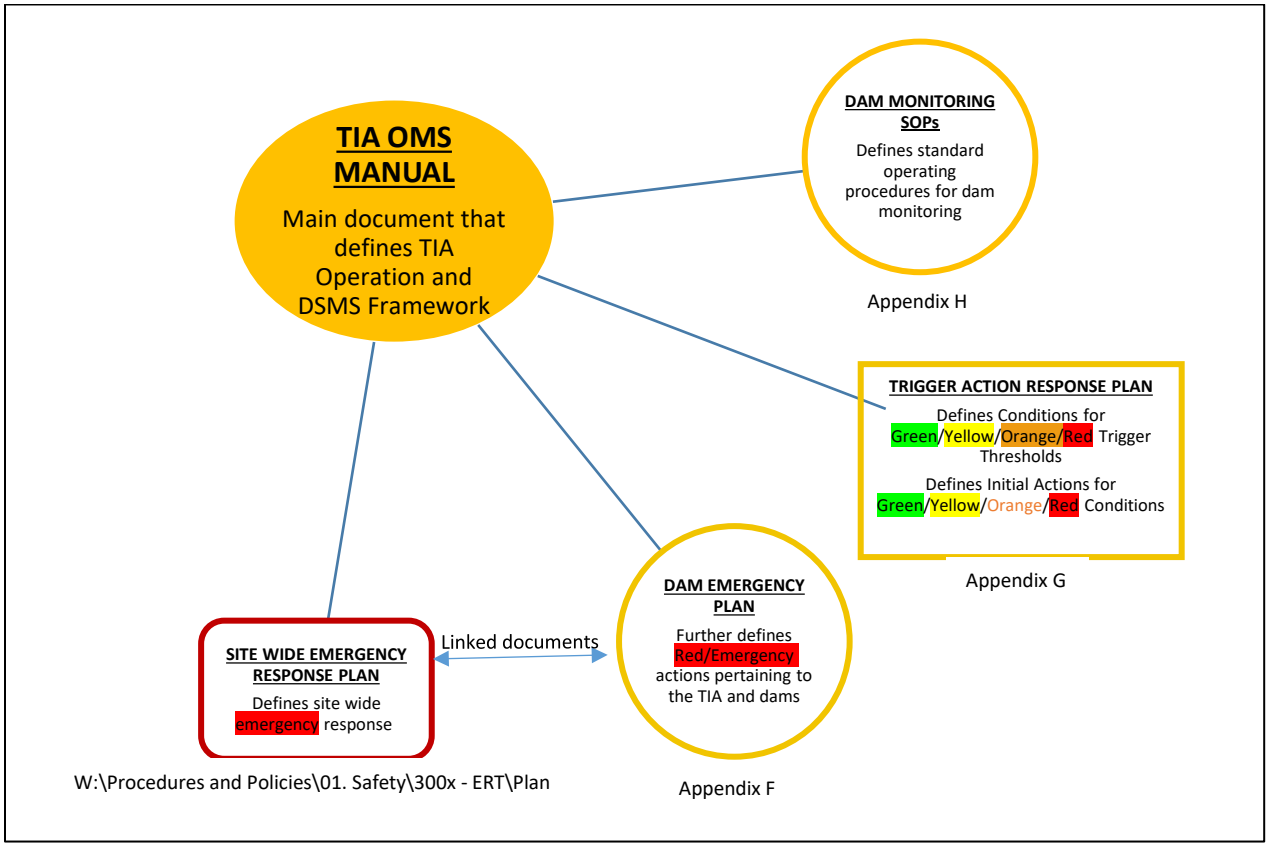

Figure 4-1 - DSMS Document Relationships

4.2. Trigger Action Response Plan Levels

The Trigger Action Response Plan (TARP) defines the initial actions to be taken in response to specific conditions observed at the TIA and dams. The TARP includes detailed thresholds for each Green/Yellow/Orange/Red Conditions observed or recorded at the Dams and TIA. Table 4-2 provides encompassing definitions for each of the trigger levels for the Hope Bay Mine.

The complete TARP be found in Appendix G.

Table 4-2 – Definition of Trigger Levels

Trigger Level	Condition	Definition
Green	Normal Operating Condition	Maintain normal operating procedures.
Yellow - Level 1	Early Warning Condition	Areas of concern identified - Requires further investigation to determine **requirements for increased monitoring**
Orange - Level 2	Corrective Action Condition	High Risk Situation - Requires mitigation actions or operational controls to prevent an emergency situation from developing. **Implement Level 2 Actions.**
Red - Level 3	Critical Condition	Emergency Situation - Immediate threat to health and safety or environment that is uncontrollable through operational controls or mitigation actions. **Implement the site wide Emergency Response Plan and/or Dam Emergency Plan**

4.3. DSMS Communication and Decision Making

Figure 4-2 illustrates the communication and decision processes used when the threshold criteria are met and when pre-defined actions need to be implemented. Table 4-3: Communication Procedure to Change TARP Level indicates the communication procedure to follow when changing the TARP level.

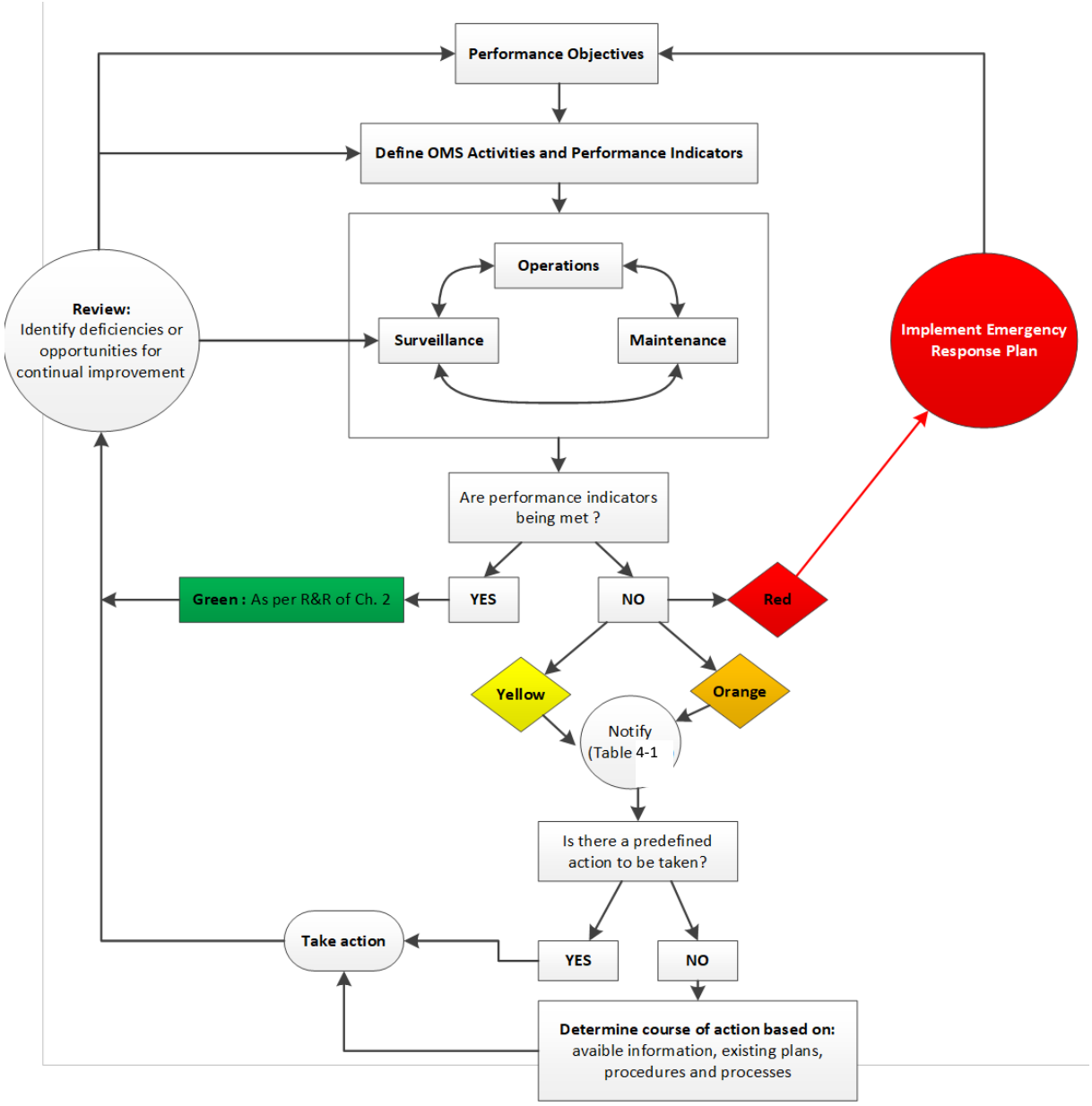

Figure 4-2: Communication and Decision Process for Water Management Infrastructure TARP

Table 4-3: Communication Procedure to Change TARP Level

Category	Notify	Timeline	Method of Communication
Green	On-Site team → Responsible person → Independent Review Board Designer General Manager EOR AEO	Elevated TARP levels can be returned to GREEN after two consecutive weeks of GREEN TARP conditions	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status Brief memo sent by e-mail to officialise TARP change
Yellow	On-Site team → Responsible person → EOR	Within 24 hours of the TARP level condition being met	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status. If RP can't be joined the on-site team will try to contact these people in this order: Site Geotechnical Engineer, EOR, AEO
	Responsible person → Independent Review Board Design Engineer General Manager EOR Process Plant Superintendent	Within 72 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation if required
	EOR → AEO	Within 1 week of TARP level change	Left to the EOR discretion
Orange	On-Site team → Responsible person → EOR	Immediately upon discovering TARP level triggers change	Phone Call, E-mail and meeting to inform on status change. If RP can't be joined the on-site team will try to contact these people in this order : Site Geotechnical Engineer, EOR, AEO
	Responsible person → Independent Review Board Design Engineer General Manager EOR AEO Health & Safety Superintendent Process Plant Superintendent	Within 24 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation
RED	On-Site team → Emergencies Response Team Once an emergency is declared refer to the ERP. Emergency response is out of scope of this document	Immediately when the emergency is discovered. If there is currently a risk to Env or Health and Safety	Emergency – Emergency Emergency and road channel Or at Emergencies 911
		Immediately when the emergency is discovered.	Phone call to ERT coordinator (103) & Health and Safety Superintendent

Category	Notify	Timeline	Method of Communication
		If there is imminent risk to Env or Health and Safety	

4.4. North Dam and South Dam Operating and Monitoring Criteria

The operating criteria for the North Dam and South are defined by the TARP, and the Dam Monitoring SOPs.

Operational Document	Location (within TIA OMS manual)
North Dam Monitoring SOP	Appendix H
North Dam TARP	Appendix G, Table 1
South Dam Monitoring SOP	Appendix H
South Dam TARP	Appendix G, Table 2

Table 4-4 below summarizes the instrumentation and visual monitoring completed at the North and South Dam. The Dam monitoring SOPs (Appendix H), provide details of dam monitoring procedures.

Table 4-4 – Dam Monitoring Summary

Monitoring Component	Monitoring Frequency	North Dam	South Dam	Interim Dike
Visual Walkover Inspections	Weekly	Yes	Yes (Monthly during Care and Maintenance)	Monthly
Deformation Survey Monitoring	Monthly (May to November)	Yes	Yes	As required by the SGE
Inclinometer Deformation Monitoring	Monthly	Yes	No	No
Ground Temperature Cable Thermal Monitoring	Continuous/Monthly	Analog Thermistors Continuous Logging, Monthly Download and Data Review	Digital GTCs Continuous logging and satellite transmission, monthly Data Review	Spot readings (monthly or as required by the SGE)
TIA Reclaim Pond Water Elevation	Continuous/Daily	Yes	No	Saline water storage water elevation collected via GPS survey as required by the SGE

4.5. TIA Operating Criteria and Freeboard Requirements

4.5.1. TIA Water Reclaim Pond Operating Criteria and Thresholds

Water Elevation and Thermal Performance Indicators

In general, the water level in the TIA should be kept as low as practical to reduce the thermal loading and frozen core and frozen foundation of the North Dam. Along with the risk of overtopping due to a sudden inflow, thermal performance is an equally or more important risk indicator for the North Dam. When evaluating the performance of the North Dam, the water elevation TARPs should be read in conjunction with the thermal performance TARPS, which can be found in Appendix G Table .

The operating criteria for the TIA water reclaim pond elevation is presented in Table 4-5 below. The water reclaim elevation criteria are also included in the TARP (Appendix G, Table 3).

The *Water Management Plan* provides an overview of the site wide water management strategy.

Table 4-5 – TIA Water Reclaim Pond Operating Criteria and Thresholds

Structure	Freeboard to crest (m)		Maximum tailings elevation (m)	Operational Water level (m)			Corrective Action Level (m)	Critical Condition Level (m)
	Tailings	Water		Minimum (MinOWL)	Normal (NOWL)	Maximum (MOWL)		
North Dam	N/A	2.0	N/A	30.0	<34.0	34.0 – 34.5	34.5 – 35.0	>35.0
South Dam	1.5	N/A	33.5	N/A	N/A	N/A	N/A	N/A
Water El. TARP Level*	N/A				Green	Yellow	Orange	Red
Response	N/A			Stop TIA dewatering activities	Standard operations	Inform stakeholders (Table 4-3) Refer to TARP (Appendix G)	Immediately take action to stop increase and lower water level. Inform stakeholders (Table 4-3)	Trigger ERP and DEP (Section 8)

4.5.2. North Dam and South Dam Freeboard Requirements

North Dam

The North Dam is operated as a water retaining dam with the parameters indicated below.

Component	Elevation (m)
crest elevation	37.5
top of frozen core and GCL	35.3
Maximum normal operating water level	34.0
total freeboard	3.7
normal freeboard	1.5

Note: These freeboard numbers include a 1 m allowance for dam deformation (SRK 2015a). Total freeboard also includes required area to store a storm volume at least 1/3 between 1/1000 and the PMF (see Section 3.10).

South and West Dams

The South and West Dams are not water retaining structures with the parameters indicated below.

Component	Elevation (m)
crest elevation – Phase 1 (current elevation) crest elevation – Phase 2	38.0 44.5
top of GCL – Phase 1 (current elevation) top of GCL – Phase 2	36.5 45.0
Max normal operating water level	34.0
freeboard	1.5

Note: Tailings beaches along the upstream slope of these dams creates a final topography that free-drains towards the Reclaim Pond ensuring no water will pond adjacent to these structures. Tailings deposition discharges from points located near the dam crest. The tailings level at the South and West dam is designed to be above the normal operating water level (which is governed by the elevation of the North Dam).

5. TIA Operations

<table>
<tr><td>Definition</td><td>At Hope Bay, operations are the group of tasks required at the mine site to ensure the necessary actions are taken to keep the site facilities and processes working safely and effectively. It includes the process of managing many intermediate and long-term activities in and around the mine site to facilitate the production of a mineral product. In the case of this Manual, operations are the activities around the done to ensure appropriate TIA performance while facilitating the TIA use for waste and water management. “Operations” as used in this document also applies to required activities that occur during periods where there is no active tailings deposition to the TIA. Related documents and SOPs are reference in Section 1.2 of this Manual.</td></tr>
<tr><td>Objectives</td><td>The operational objectives for the Doris TIA are to implement controls that enable the facility to operate within its intended design and meet performance targets during Care and Maintenance, operations, closure, and post-closure.</td></tr>
<tr><td>Components</td><td>Operation of the TIA involves the following periods.
<table>
<tr><th>Periods</th><th>Description</th></tr>
<tr><td>Operation</td><td>During periods of tailings production, tailings slurry will be subaerially deposited into the TIA and water from the Reclaim Pond will be simultaneously recovered.</td></tr>
<tr><td>At Closure</td><td>Water in the Reclaim Pond will continue to be discharged directly to Roberts Bay until water quality in the TIA meets Doris Creek water quality discharge criteria as listed in the water licence (SRK 2017a). Once criteria are met, the North Dam will be breached and exposed tailings surface will be covered with a ROQ rock cover, and the Interim Dike (if constructed) will be lowered to match the cover elevation (SRK 2015a).</td></tr>
<tr><td>Care and Maintenance and Active Closure</td><td>During Care and Maintenance and active closure, the following will be maintained and monitored to ensure their performance within stipulated design and operating limits:
North, South, and West Dams
Interim Dike
Tailings feed pipelines
Reclaim water pipelines
Discharge pipeline</td></tr>
<tr><td>Post-Closure</td><td>After a period of post-closure confirmatory monitoring, site presence will cease.
Note: Triggers for determining cessation of post-closure monitoring will be determined by Agnico Eagle as part of future closure plan updates and will be submitted to the NWB for approval.</td></tr>
</table></td></tr>
<tr><td>Components Operating Outside Parameters</td><td>TIA components operating outside of design or performance parameters will be investigated and remedied by one or more of the following actions:
Conducting appropriate maintenance;
Modifying surveillance methods;
Revising operational procedures; and
Implementing remedial measures revisiting the design.
The TARP in Appendix G provides additional site-specific guidance for remedial actions and lines of communication to be initiated as soon as regularly monitored parameters exceed normal operating limits.</td></tr>
</table>

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5.1. TIA Operating Criteria and Performance Indicators

The following section describes several key performance indicators for the TIA. Section 4 – Dam Safety Management System and Appendix G, TARP should also be referenced with respect to TIA operating criteria.

Deformation, Cracks and Seepages – North Dam	**Trigger** Excessive thaw of foundation. See Section 4 – Dam Safety Management System, for comprehensive outline of operating criteria. **Operational and Preventative Maintenance** Maintain lowest possible water level in TIA. Ensure thermosyphons are operational. Maintain core at −2˚C and foundation at −8˚C. Ongoing review of thermistor, inclinometer and survey information **Possible Mitigation Strategies** Clear snow off dam face during winter. Install white poly material to dam face during summer. Construct coarse rock convection berm at downstream toe. Convert thermosyphons to active thermosyphons. Activate active cooling system (See Appendix E). Construct upstream berm.
Deformation, Cracks and Seepages – South and West Dams	**Trigger** Excessive thaw of foundation. See Section 4 – Dam Safety Management System, for comprehensive outline of operating criteria. **Operational and Preventative Maintenance** Maximize beach development from dam. Maintain lowest possible water level in TIA. Maintain foundation at −2˚C. Implement seepage pump-back system. Ongoing review of thermistor, and survey information **Possible Mitigation Strategies** Flatten downstream dam slope. Construct downstream toe berm Clear snow at downstream toe during winter. Construct coarse rock convection berm at downstream toe. Retrofit dam with vertical thermosyphons.
Water Balance	**Trigger** Reclaim water shortage (not applicable during Care and Maintenance). **Operational and Preventative Maintenance** Manage annual discharge to maintain minimum required operating water level. See Section 4.5 for operational water level and freeboard requirements. **Possible Mitigation Strategies** Increase make-up water demand from Doris Lake.
	Trigger Excessive water inventory.

	See Section 4 – Dam Safety Management System, for comprehensive outline of operating criteria. **Operational and Preventative Maintenance** Manage discharge to not exceed normal operating water level water level. **Possible Mitigation Strategies** Increase discharge capacity. Increase/modify water treatment (if / as required). Construct emergency overflow channel. Emergency discharge.
Load Balance	**Trigger** Reclaim water shortage (not applicable during Care and Maintenance). **Operational and Preventative Maintenance** Manage annual discharge to maintain minimum required operating water level. **Possible Mitigation Strategies** Increase make-up water demand from Doris Lake.
	Trigger Excessive inventory or poor water quality. **Operational and Preventative Maintenance** Manage discharge to not exceed maximum required operating water level. **Possible Mitigation Strategies** Increase discharge capacity (if possible). Increase water treatment (if / as required). Increase residence / storage time in TIA (may vary seasonally).
Tailings Deposition (during Operations)	**Trigger** Improper beach development. **Operational and Preventative Maintenance** Survey existing beaches and used data to recalibrate deposition modeling to develop new deposition plan. Track tailings beach development with satellite surveys (e.g. Sentinel-2). **Possible Mitigation Strategies** Add additional spigot points as required by the revised deposition plan. Relocation tailings preferentially to upstream face of South and West Dam.
Reclaim Pump Failure	**Trigger** Wear and tear, improper pump operation, operating pump outside design range. **Operational and Preventative Maintenance** Inspect and maintain pumps. **Possible Mitigation Strategies** Reconfigure pumps. Relocate reclaim pump pad. Install backup pumps.
Pipeline Freezing – Tailings, Reclaim, and Discharge	**Trigger** Winter period pump stoppage. **Operational and Preventative Maintenance** Maintain minimum flow velocities of 1 m/sec. Heat tracing and insulation of pipelines. Mobile backup pumps. Drain line when not in use. **Possible Mitigation Strategies**

	Installation of secondary pipeline(s). Complete repairs of any damaged insulation in summer (pre-winter).
Pipeline Breakage or Leakage – Tailings, Reclaim, and Discharge	**Trigger** Fatigue, corrosion, or accident. **Operational and Preventative Maintenance** Implement visual inspection procedure. Establish barricades where appropriate. Provide secondary containment in high risk areas. **Possible Mitigation Strategies** Stop pumping and implement site spill response plan.
Pipeline Sanding Up – Tailings	**Trigger** Pump stoppage for extended periods. **Operational and Preventative Maintenance** Mobile backup pumps. Flush pipeline immediately following pump stoppage. **Possible Mitigation Strategies** Installation of secondary pipeline. Dismantling affected section of pipeline and flushing or replace.
Tailings Dust	**Trigger** Wind and equipment traffic, exposed dry tailings surface. **Operational and Preventative Maintenance** Minimize use of equipment on tailings beaches. Apply water to tailings surface. **Possible Mitigation Strategies** Apply chemical dust suppressants as appropriate. Implement physical mitigation strategies to reduce dust.
Animal Access	**Trigger** Terrestrial mammals entering TIA area. **Operational and Preventative Maintenance** Implement Wildlife Monitoring and Mitigation Plan (WMMP). **Possible Mitigation Strategies** Refer to WMMP.
People Safety	**Trigger** Uninformed people accessing TIA area. **Operational and Preventative Maintenance** Conduct site specific orientation and training. **Possible Mitigation Strategies** Implement access controls through signs and road barricades. Promote awareness, through training and information sessions and site inductions on site. Require all vehicles do radio 'call-ins' / checks when entering the Tail Lake Road from camp.

5.2. Tailings Transport and Deposition (during Operations)

Deposition	During operation periods deposition should be subaerial using single point spigots and placed as follows. Step | Placement

	1	Place tailings starting from the crest of the South and West Dams. **Note:** The placement should create beaches that push the supernatant water away from the dams. Tailings deposition is expected to result off the dam crests during the non-ice-covered months (e.g. summer to fall).
	2	After the beaches are created, move the spigot points to the east and west flank of the TIA. **Note:** This should create a long, even tailings surface that slopes toward the North Dam and ensures the is displaced towards the north away from the South Dam. Deposition at locations upstream of the South and West Dam crest is expected to be done during the colder months when ice is apparent on the TIA reservoir (e.g. winter and spring). This is done to allow for the tailings beach to cool over the winter to better protect the frozen foundations, and to avoid excessive spigot movement in the winter that may lead to increased ice entrainment.

Double-Walled Pipeline Placement

As an added environmental protection measure against spill containment, the pipeline must be double-walled at the following locations (SRK 2015a):

- where the pipeline crosses Doris Creek at the Doris Creek bridge and
- at the three locations along the Doris to Windy all-weather road between Madrid North and the Doris North TIA (SRK 2017d).

Staged Tailings Deposition

A series of plans showing the staged tailings deposition for from the projected end of 2020 and then for the end of the active tailings deposition (end of Phase 2) is presented in SRK (2020a). This is based on latest bathymetry data and updated tailings deposition plans. Updated tailings stage storage curves are to be generated annually and incorporated into the operational water and load balance tool to track tailings storage capacity, and plan for annual spigot deposition point moves as directed by the DE.

The most recent update of the deposition plan occurred in April 2021, prior to the cessation of tailings deposition in October 2021 (SRK 2021).

The stage storage data for the Doris TIA as of the start of 2020 is approximately as follows:

Lower Elevation (m)	Upper Elevation (m)	Volume (m^3)	Cumulative Volume (m^3)	Plan Area (m^2)
19.5	22	0	0	0
22	23	27,000	27,000	53,000
23	24	178,000	178,000	203,000
24	25	440,000	440,000	310,000
25	26	816,000	816,000	429,000
26	27	1,295,000	1,295,000	524,000
27	28	1,860,000	1,860,000	605,000
28	29	2,509,000	2,509,000	690,000
29	30	3,243,000	3,243,000	770,000
30	31	4,061,000	4,061,000	874,000
31	32	5,042,000	5,042,000	1,057,000
32	33	6,169,000	6,169,000	1,185,000
33	34	7,417,000	7,417,000	1,307,000
34	35	8,785,000	8,785,000	1,418,000
35	36	10,257,000	10,257,000	1,528,000
36	36.75	11,434,000	11,434,000	1,609,000

Deposition Planning Compliance	At the end of each month, the recorded tailings deposition performed must be validated against the performance indicator in the table above to verify if the deposition is on track. This compliance analysis is documented monthly in the SRK monthly dashboards. It should be noted that the deposition plan and performance indicators will be updated prior to resuming operations.

5.3. Ongoing Construction

Ongoing construction at the TIA is managed in accordance with water license requirements governing the construction of water or mine waste management structures, and also the design and operating criteria of the TIA.

Any construction projects at the TIA are to be carried out such that the operation of the TIA is not impacted by the construction works. If this is not possible, interim operating documents and criteria will be developed for the impacted period.

5.4. North Dam Active Cooling System

In July 2024, an active cooling system was installed to retrofit the existing passive thermosyphons. The operating plan is for the active cooling system to be turned on in April or May each year, and operated until November.

The SGE in collaboration with the DE will determine the specific dates each year to turn the system on and off (based on site climate data). The E&I Superintendent will be responsible for executing the powering on and off of the system and will be part of the communication plan. See Appendix E for the Operations and Maintenance Manual for the active cooling system.

5.5. Dust Management

Control Measures	The tailings deposition plan was developed, as far as practical, to minimize the area of exposed inactive tailings surface that may be prone to dusting. Nevertheless, when needed, application of environmentally suitable chemical dust suppressants should be applied annually in general, applied more frequently if needed as discharge locations change, and reviewed on an ongoing basis to ensure at-risk areas are adequately covered. Dust may become particularly prevalent during long periods without fresh tailings deposition. Consider applying water to tailings or covering exposed tailings with snow during winter to mitigate windblown dust generation. **Note:** Appendix B provides a comprehensive assessment of possible dust management practices for the tailings surface.
Control Products	While the effectiveness of dust suppression fluctuates depending on how deposition points vary during the winter season, dust should be controlled using packed snow when available and practical, chemical suppressants, and water cannons to wet areas of concerns when other methods prove temporarily ineffective. **Note:** Attachment C contains details on the product that has been outlined as preferred by Agnico Eagle. Use dust suppression products is permitted upon receipt of approval from the NWB.

5.6. Water Management

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<table>
<tr><td>Contact Water</td><td>In addition to tailings slurry, the following sources of mine contact water may be pumped to the TIA during operations:
underground mine water;
contact water pond water;
sedimentation pond water;
landfill sump water;
bulk fuel storage sump water;
treated sewage effluent; and
other industrial water collected from various locations.
It should ne noted that the water management strategy will be updated in accordance with the new mine plan. Once the mine plan and water management strategy are finalized, the site Water Management Plan, and this Manual will be updated accordingly.</td></tr>
<tr><td>Supernatant Water</td><td>Drains into the TIA Reclaim Pond and reclaimed for use in mill operations.</td></tr>
<tr><td>Excess Water</td><td><table><tr><th>If in…</th><th>then excess water discharges to Roberts Bay…</th></tr><tr><td>Operations</td><td>year round</td></tr><tr><td>Care and Maintenance</td><td>year round</td></tr></table>Note: Site specific water quality requirements (MDMER) must be met before any discharge. See Water Management Plan.</td></tr>
<tr><td>General Guidance</td><td>Complete water management procedures are provided in the Water Management Plan and the Site Wide Water Management Tool.</td></tr>
</table>

5.7. Site Access and Security

Access	The Doris Mine is accessed by air via an all-weather air strip and water via a barge sealift resupply in Roberts Bay annually during the open water season.
Security	Access to the TIA is restricted to authorized employees, contractors, and consultants. **Note:** All workers accessing the facility are trained and knowledgeable about hazards at and near the TIA.

5.8. Environmental Protection

Aquatic and Terrestrial Environment	Protection of the aquatic and terrestrial environment was incorporated into the design of the facility through: • Trigger Action Response Plan (Appendix G); • Selection of a dam classification criterion; • Dust management strategies; • Water management planning; • Active cooling system at the North Dam; • The incorporation of a low-permeability liner within the North, South and West Dams; and

	• Secondary pipeline containment along the extent of the Doris Creek crossing and along the creek crossing form Madrid North to the Doris TIA along the all-weather access road. **References:** SRK 2015a, 2015d, 2017d.
General Guidance	Environmental protection is achieved through the continued implementation of measures outlined in this OMS Manual and related operational documents and management plans.

5.9. Freeboard Requirements and Operating Levels

Freeboard requirements and operating water levels are a key part of the TIA Dam Safety Management system and are outlined in Section 4.5.

Freeboard and operating water levels for the Interim Dike are outlined in Section 5.11.

5.10. Communication and Decision Making

Operational communication and decision making will be carried out in accordance with the Roles and Responsibilities outlined in Section 2.1 and 2.3, and the decision making and communication process outlined in Section 4.3.

5.11. Closure Overview

The overall objectives of the *Conceptual Closure and Reclamation Plan* are to leave the site in a manner safe for humans, wildlife, and the environment that meets future land use goals. This will be done by establishing stable chemical and physical conditions and ensuring the future use and aesthetics of the site following reclamation meet the requirements of Indigenous, Federal and Territorial governments, landowners, local communities and regulatory authorities.

The tailings surface will be covered with a nominal waste rock cover of 0.3 m thickness. The function of the cover is to prevent dust and to minimize direct contact by terrestrial wildlife. Once the water quality in the Reclaim Pond has reached the required discharge criteria, the North Dam will be breached as originally intended for Phase 1. The TIA once breached will discharge into Doris Lake which in turn discharges into Doris Creek.

The TIA will only contain flotation tailings which are non-PAG with abundant neutralization potential and thus buffering capacity. Although several metals in the tailings solids occur at concentrations more than crustal abundances, many of these metals are associated with sulphides and as such will primarily partition into the detoxified tailings which means they will not be of concern in the TIA.

Long-term humidity cell tests indicate that after the initial flushing of the samples, an increased tendency for neutral pH metal leaching may develop, with arsenic being of concern. The TIA water and load balance (SRK 2017a) suggests that possible neutral metal leaching does not pose a limitation in ensuring that the water quality in the TIA meet site specific closure water quality criteria, and therefore no infiltration

reduction cover is required on the exposed tailings surface. The tailings surface will, however, be susceptible to wind erosion with the resultant effect of dust exposure. Similarly, although the tailings surface is landscaped to allow free drainage, the tailings are susceptible to hydraulic erosion, which will mobilize tailings towards the Reclaim Pond with a resultant increase in total suspended solids.

The tailings cover that functions to prevent wind and water erosion will be constructed over the entire tailings surface. The minimum thickness of cover that can practically be placed over the tailings surface would be about 0.3 m thick, and therefore the cover design has been set at 0.3 m thick ROQ material.

5.12. Interim Dike Operating Criteria

The Interim Dike is operated as water management infrastructure with the purpose of segregating saline underground mine water from the rest of the TIA.

The Interim Dike is fully contained within the TIA, such that any uncontrolled release of impounded water would not result in any impacts to safety or the environment.

The Interim Dike is equipped with an emergency spillway with the capacity to pass the PMF.

5.12.1. Operational Water Levels

General Guidance

In general, the water level in the Interim Dike should be kept as low as possible to reduce the thermal loading and hydraulic gradients on the dike and tailings foundation.

Each year prior to freshet (May-June), reduce water level in the Interim Dike to as low as practical to provide inventory for anticipated freshet inflows. Water levels will need to be drawn down to as low as practical the previous year, prior to freeze-up.

	Interim Dike Operational Water Levels (masl)		
	Normal (NOWL)	**Maximum (MOWL)**	**Emergency Spillway**
Elevation	34.0	34.3	>=34.3
Freeboard (Dike Crest)	1.0 m	0.7 m	0.7 m
Freeboard (Spillway)	0.3 m	-	-
Description	Target maximum water level under normal operating conditions	Emergency spillway invert elevation	Emergency spillway will control water elevation at 34.3 masl.
Action	Normal Operations	Take action to reduce water level to NOWL	Take action to stop spillway flow. Then, inspect spillway for erosion and carry out maintenance in accordance with Section 6.2 as required.

6. Maintenance

Definition	Maintenance is an ongoing process of activities to maintain (uphold) the proper function of the TIA, thereby ensuring compliance with safety regulations. Ongoing maintenance can consist of items such as housekeeping, small repairs and regular inspection of the dam structures and proper operation of all components linked to the TIA. Good maintenance habits can lead to early detection of deficiencies, help reduce the risk of failures, and extend the useful life of the dams, dikes and TIA system as a whole.
Objective	The objective of the maintenance program is to ensure all TIA components operation according to their performance criteria by carrying out routine and preventative maintenance (such as to address minor settlement) and event-driven maintenance (such as after a large storm event).
Components	The Doris TIA components that require maintenance include the pipeline systems, including the ocean discharge system and North Dam, South Dam, and West Dam (not yet constructed), and the Interim Dike.

6.1. Pipeline Systems Maintenance

Scope	Routine and preventative maintenance should be carried out on pumps, pipelines, drain outlet pipes, valves, and flow and hour meters. The type and frequency of maintenance shall be appropriate to the operational status of the pipeline systems.
Person(s) Responsible	E&I Superintendent
Frequency	Varies by component (see below)
Documentation	Maintenance records for each component are communicated to the E&I Superintendent, kept by maintenance and include the following: • up-to-date logs of in-service equipment and facilities; • maintenance schedules; • maintenance history; • inspection logs; • repair records; • frequency and cause of problems, and planned mitigation; • component reliability records; • photographic evidence of repairs; • inventory of spares, material, tools, and equipment; and • critical spares list.
Reporting	Hard or digitally accessible copies of all documents produced in the reporting and tracking process must be stored at the project safe-keeping location. All hard copy documents must be scanned and turned into electronic records at least annually. All electronic documents must be saved on a safe computer or network drive.
Pumps	Maintain pumps (including seals, controls, instrumentation, and electrics) per the manufacturer's specifications.
Pipelines	Flush pipelines completely with fresh water every six months (or as needed). Pressure test pipelines to check for leaks annually.
Drain Outlet Pipes	Monitor drain outlet pipes during drainage. **Important!** If a flow rate drop-off is detected, flush the pipe using hydraulic cleaning equipment.
Valves	Maintain isolating and check valves per the manufacturer's specifications.

Flow and Hour Meters	Service flow and hour meters annually, recalibrating them to the manufacturer's specifications.

6.2. Dam and Dike Maintenance

Scope	Dam maintenance needs shall be determined after completion of the annual geotechnical inspection, or more frequently following weekly or monthly dam walkover inspections. However, ongoing maintenance of instrumentation, the foundations, downstream toe, and thermosyphons can be expected to be required each year.
Person(s) Responsible	RP, SGE, E&I Superintendent .
Frequency	Annually or as required.
Documentation	As-built survey pick-up and a written and document event log (outlining the approach taken for any maintenance as well as the element and location) will be required. If fill materials are placed, then volume estimated (truck counts and as-built surveys before and after) should be completed.
Reporting	A record of all maintenance activities should be kept on site and reviewed at least annually by the SGE. For any notable earthworks, or areas where maintenance is done over a larger special extent, (e.g. to clean up a tailings spill, fill placement for buttressing or crack repair etc…) the EOR must be notified and as-built survey pick-ups must be completed.
General Guidance	The annual geotechnical inspection reports (as performed by the EOR and/or design engineer) must be consulted for examples of past maintenance and for general guidance.
Instrumentation	Repair or replace worn, damaged, or defunct instrumentation as needed and recalibrate.
Foundations	**Background** Thermal modeling for the dams suggests that although the dam core and its foundation will remain frozen, the upstream and downstream foundations will gradually thaw and lead to settlement of those sections of the dam. **Maintenance** Based on the findings of the DSI, areas that have undergone settlement may have to be repaired by adding more fill (SRK 2007, 2015a).
Downstream Toe	**Background** Snow drifts on the downstream toe of the dams must be managed or prevented as the snow cover will result in an insulating effect on the downstream toe, which may lead to more rapid thaw of the downstream foundation. **Maintenance** To maximize dam performance beyond what the thermal modelling may suggest, clear snow regularly from this area.
Thermosyphons	Inspect thermosyphons visually for performance deficiencies. If needed, recharge with CO_2 if needed and repair or replace any damaged radiator fins. See Appendix E of the Operations and Maintenance Manual for the active cooling system.

6.3. Event-Driven Maintenance

Scope	The TIA must be inspected after unusual or extreme events such as • heavy rainfall (exceeding 20mm per 24 hrs), • wind storms (wind speeds > 100 km/hr),

	• flooding or exceedance of the full supply level, • severe icing, • rapid snowmelt, or • earthquakes.
Person(s) Responsible	RP, SGE, E&I Superintendent.
Frequency and Timing	After unusual or extreme events.
Documentation	Records for all event driven maintenance must be summarized in a deliverable format similar to what is required for the visual site inspections (Section 7.1).
Reporting	For event-driven maintenance, the EOR must be notified to ensure maintenance activities and plans are appropriate to uphold the design integrity of the TIA components. As-built surveys will be required to be gathered before and after any even-driven maintenance. All digital files along with notes and photos of the maintenance work performed should be submitted to the EOR for review.
General Guidance	Review the design criteria (Section 3.10) to better understand what triggers the need for event-driven maintenance. **Important!** To a large extent, the judgement of persons responsible on site governs specific event-driven maintenance. When in doubt contact the SGE, Environmental Superintendent and/ or the EOR for additional guidance or clarification.

7. Surveillance

<table>
<tr><td>Definition</td><td>Surveillance is the process of gathering information through visual inspections, monitoring performance, safety audits, and data collection.</td></tr>
<tr><td>Objectives</td><td>The objectives of the Doris TIA surveillance program are to:
regularly monitor the operational performance of the TIA and its components,
consistently report observations,
regularly review and interpret surveillance data, and
inform preventative maintenance by generating qualitative and quantitative surveillance information.</td></tr>
<tr><td>Components</td><td>The surveillance elements for the Doris TIA includes:
visual site inspections,
instrumentation monitoring (thermal, deformation, and water balance),
tailings geochemistry monitoring when in operations,
water quality monitoring,
annual geotechnical inspections, and
dam safety reviews.</td></tr>
<tr><td>Data Management</td><td>Qualified staff performing inspections and collecting monitoring data must complete the following actions to manage monitoring data.<table><tr><th>Step</th><th>Action</th></tr><tr><td>1</td><td>Back up all monitoring data electronically.</td></tr><tr><td>2</td><td>Scan manual notes and save together with raw and transposed data.</td></tr><tr><td>3</td><td>Immediately following collection, qualified staff shall review data to:
confirm integrity of the instrumentation and
ensure the TIA is performing to expectations and monitoring guidelines specified in the dam surveillance SOPs.</td></tr></table>The RP or designate is responsible for ensuring that the ongoing monitoring as documented in the dam surveillance SOP is carried out. If determined necessary, the Environmental Superintendent may consult with the EOR to complete a safety inspection outside of the routine annual AGI.</td></tr>
</table>

7.1. Visual Site Inspections

Scope	Visual inspections must be carried out on the TIA structures including dams, dikes, pump stations, pipelines, and spigots.
Person(s) Responsible	Qualified person under the direction of the SGE or designate.
Frequency	Weekly or as specified in Section 4.4 and dam monitoring SOPs (may be decreased to monthly during Care and Maintenance).
Documentation	All inspections and observations are recorded in the appropriate site logbooks or recorded electronically.
Reporting	As directed by the Environmental Superintendent and SGE personnel will be trained and assigned to complete ongoing weekly visual inspection. **Reporting Notable Changes** Notify the SGE and/or EOR immediately after any inspection where notable changes to any of the TIA facilities outside of normal operating criteria are observed. If changes are noted at the North or South

<table>
<tr><td></td><td>Dams, or the TIA water level, follow the notification procedure in accordance with the TARP for the TIA (See Section 4 and Appendix G). The SGE and EOR shall, in consultation with operations staff, assess the situation and develop any actions plans deemed appropriate.
Annual Reporting
In accordance with the relevant water licenses, visual site inspection information (along with instrumentation monitoring information) shall be included in the annual geotechnical inspection report and submitted no later than March 31 each year (submitted as part of the annual water license requirements).</td></tr>
<tr><td>General Guidance</td><td>A monitoring checklist is presented in the dam surveillance.</td></tr>
<tr><td>All Structures</td><td>Visually inspect all TIA structures, taking note of
any signs of settlement,
water levels drops which are unaccounted for,
signs of seepage,
sinkholes, cracking or other surface changes, and
any signs of damage or vandalism to instrument clusters.</td></tr>
<tr><td>Dams</td><td>Monitor creep deformation (in accordance with Dam monitoring SOPs) within the North Dam and South Dam, as these structures may be susceptible to creep deformation and or thermal degradation of the foundations (all dams) or core (specifically for the North Dam) in the long term. Refer to the Dam monitoring SOPs for specific means of monitoring creep deformation.</td></tr>
<tr><td>Pump Stations</td><td>Inspecting staff are to complete the following actions when visually inspecting pump stations.<table><tr><th>Step</th><th>Action</th></tr><tr><td>1</td><td>For each pump, verify whether it is operating properly, hours operated, and discharge and suction pressures.</td></tr><tr><td>2</td><td>Check for leaks and spillages.</td></tr><tr><td>3</td><td>Confirm oil levels for all pumps.</td></tr><tr><td>4</td><td>Inspect water pump seals on tailings pumps.</td></tr><tr><td>5</td><td>Note alarms and messages.</td></tr></table></td></tr>
<tr><td>Pipelines</td><td>Inspecting staff are to complete the following actions when visually inspecting pipelines.<table><tr><th>Step</th><th>Action</th></tr><tr><td>1</td><td>For each pipeline, verify
whether it is operating properly,
hours operated,
flowmeter data, and
operating pressures along each pipeline.</td></tr><tr><td>2</td><td>Check for leaks and spillages.</td></tr><tr><td>3</td><td>Note hazards along pipeline route.</td></tr><tr><td>4</td><td>Verify where tailings deposition has taken place (i.e. within the past 24 hours).</td></tr><tr><td>5</td><td>Note alarms and messages.
Example: Malfunction of electric heat tracing cable inside the pipeline during freezing temperatures.</td></tr></table></td></tr>
<tr><td>Spigots</td><td>Stringent monitoring of the two spigots situated on the east flank of the TIA is required during operations since both spigots are above the crest elevation of the South Dam.
Important! Spigot elevations are typically lower than the crest elevation of containment structures.</td></tr>
</table>

7.2. Instrumentation Monitoring

Scope	Instrumentation monitoring is carried out on the North, South dams (both constructed), and West Dam (when constructed) and include • thermal, settlement, and other general deformation monitoring such as inclinometers, deep survey monitoring points, and surficial survey monitoring points, and • thermal monitoring of the tailings profile to confirm tailings freeze-back assumptions.
Person(s) Responsible	Qualified person under the direction of the SGE.
Frequency and Timing	As specified in Section 4.4.
Documentation	Consult latest North Dam and South Dam monitoring SOPs documents for additional details and inspections forms.
Reporting	**Monthly Instrumentation Review** Under supervision of the SGE, conduct a monthly instrumentation review and communicate any changes in data that may suggest and impact to the performance of the structures. Currently, monthly instrumentation reviews are conducted jointly by the DE (SRK Consulting) and the SGE.
General Guidance	Additional guidance on the required instrument monitoring (how to perform and frequency) is presented in the dam surveillance SOPs (Appendix H).
North Dam	The locations of North Dam monitoring instruments are shown in Appendix D.
South Dam	The locations of South Dam monitoring instruments are shown in Appendix D.
Interim Dike	The locations of the Interim Dike monitoring instruments are shown in Appendix D.

7.3. Tailings Geochemistry Monitoring

Background	To be completed during operational periods. Flotation tailings geochemical characterization testing has confirmed that due to the high neutralization potential and low sulfur content, acid rock drainage potential is considered low; however, there is potential for neutral pH metal leaching, particularly for arsenic (SRK 2015b and SRK 2017e).
Scope	Sample collection for the preparation of a monthly composite sample that will be analysed for • total metals by aqua regia digestion followed by ICP finish, • total sulphur by Leco furnace, and • direct measurement of total inorganic carbon.
Person(s) Responsible	Coordination through Environment Superintendent.
Frequency	Weekly during operations.
Documentation	Sampling and testing results and analysis presented in annual waste rock, quarry and tailings monitoring reports.
Reporting	In accordance with the relevant water licenses, an annual geochemical monitoring report should be submitted no later than March 31 each year.
General Guidance	Recent annual waste rock, quarry and tailings monitoring reports (SRK 2020d).

7.4. Water Quality Monitoring

Scope	TIA water quality is monitored at compliance station TL-1 at the Reclaim Water pump station. Ongoing review of water quality trends and a comparison to MDMER limits are completed each year. In additional to the above, weekly sampling and geochemical analysis of any North Dam or South Dam toe seepage is to be completed when present.
Person(s) Responsible	Coordination through Environment Superintendent.
Frequency	Monthly (minimum) water quality monitoring for the TIA is described in the Doris and Madrid *Water Management Plan*. Seepage typically sampled during ice free / summer months (around June to October) if present.
Documentation	Monthly water quality reports prepared by Agnico Eagle.
Reporting	In accordance with the relevant water licenses, data should be presented as part of annual reporting.
General Guidance	Water quality monitoring for the TIA is described in the Doris and Madrid *Water Management Plan*.

7.5. Annual Geotechnical Inspection (AGI)

Scope	The AGI is a physical surveillance of the TIA including North and South Dams, and Interim Dike.
Person(s) Responsible	The EOR and/or DE —or another qualified professional engineer authorized by the EOR—must complete the inspection.
Frequency and Timing	The annual geotechnical inspection shall be carried out • Annually, and • within the summer (ice free) months.
Documentation	Records of annual inspections and detailed review of monitoring data by the EOR —or another qualified professional engineer authorized by the EOR— presented in a TIA AGI. These are submitted annually and are a permit requirement for the Mine.
Reporting	The DE and/or EOR shall prepare a detailed AGI report that includes their findings and recommendations on the performance of the dams and accounts for review and analysis of collected monitoring data and inspection observations. **Note:** The report should be delivered within 90 days of inspection to Agnico Eagle (RP) so any maintenance and mitigation can be carried as early as possible and to meet submission requirement to NWB.
General Guidance	See recent AGIs for additional details (SRK 2024).
Significant Concerns	Any areas of significant concern shall be immediately communicated to Agnico Eagle at the time of the AGI.

7.6. Dam Safety Review

Scope	The dam safety review is a physical surveillance of the Doris TIA with a focus on the North, South, and West Dams. This systematic assessment shall consider all aspects of the Doris TIA's design, construction, maintenance, operation, processes, and systems affecting its safety. **Note:** This review should use state-of-practice principles as opposed to those used when the facilities were designed.
Person(s) Responsible	An independent third party must complete the inspection.
Frequency	The dam safety review shall be carried out every seven years (in accordance with CDA guidelines) in addition to the AGI. **Key Date:** The next dam safety review should be completed in 2028.
Documentation	Records of the dam safety review must be documented in a stand-alone dam safety review report.
Reporting	An independent third party professional engineer will prepare a detailed report that documents a complete systematic review and evaluation, of all aspects of design, construction, operation, maintenance, and surveillance, and other relevant processes and systems affecting a dam, to evaluate the design criteria with current standards, operational compliance with design intent, stability and functionality of the dam, and to identify appropriate remedial measures (if / as applicable).
General Guidance	See MAC 'A Guide to the Management of Tailings Facilities' (2021) and the CDA 'Dam Safety Review Technical Bulletin' (2016).
Significant Concerns	Any areas of significant concern shall be immediately communicated to EOR and Agnico Eagle at the time of the dam safety review.

7.7. Independent Review Board (IRB) Meeting

Scope	The IRB shall meet to discuss the following topics • Site visit of all infrastructure covered by the scope of the IRB, in accordance with Agnico Eagle's governance policy for the management of critical infrastructure; • Review of on-going construction works and monitoring data; • Comment on implementation progress of proposed mine waste management improvement measures; • Provide opinions and guidance to the operation on the physical integrity, safety, behavior, and performance of the confinement systems for mine waste and water retaining infrastructures; and • Comment on management systems, emergency preparedness and overall management approach of the different mine waste management facilities and water retaining infrastructures.
Person(s) Responsible	The SGE will organize the meeting.
Frequency	A meeting will be held annually, typically following the site visit. During periods of Care and Maintenance, the site visit may be conducted every 2 years.
Documentation	Presentation material and meeting notes.
Reporting	The IRB will submit a report following their observation and recommendation following each meeting. The SGE will ensure that an action plan is developed to address the recommendation and will transmit the report and the action plan to the EOR.

General Guidance	See Agnico Eagle's Governance for Critical Infrastructure (Agnico Eagle 2020) – Terms of Reference for IRB.
Significant Concerns	Any areas of significant concern shall be immediately communicated to EOR and Agnico Eagle at the time of the IRB annual visit and/or meeting.

7.8. Interim Dike Monitoring

This section details the monitoring program requirements for the Interim Dike.

Monitoring Method	Frequency	Documentation Notes
Visual Walkover Inspections	Weekly (June to November) Monthly (December to May)	Completed inspection forms and photos shall be saved here: W:\Environment\Inspections – Completed\TIA Interim Dike
Deformation Survey Monitoring	As required – starting in May and continuing until snow covers the structure.	Send completed survey data to: hopebaymonitoring@srk.com pluedke@srk.com
Ground Temperature Cable Thermal Monitoring	Monthly (May to November) Monthly (December to April)	Save ground temperature data here: W:\Environment\Compliance Program Data\Geotechnical\TIA GTC Spot Readings
SWS Pond Water Elevation	Monthly (ice free months) Frequency may be increased at the discretion of the SGE and/or EOR	Send monitoring data to the SGE: TBD

8. Emergency Management

Objectives	The TIA emergency management procedures below have two key objectives: • avoid injury or death of persons working on or near the TIA, and • prevent or minimize environmental damage.
Emergency Response and Crisis Management Plan	This section outlines links with the site ERP and the Dam Emergency Plan (DEP). The ERP and the DEP area stand-alone plans and are complimentary to this OMS document. The DEP can be found in Appendix F of this document, and the ERP can be is stored on Hope Bay server (W:\Procedures and Policies\01. Safety\300x - ERT\Plan). Physical hardcopies of both plans are located in the admin boardroom and goehub. As outlined in the Dam Safety Management System (See Section 4), the ERP and DEP are to be activated/consulted during emergency conditions at the TIA and Dams (including Red TARP conditions). The ERP and procedures are provided in Appendix E and include information on the following: • Activation of the ERP • Agnico Eagle Crisis management plan • Different levels of emergencies • Organization and job responsibilities, and contact information • Emergency response equipment • Communication systems • Emergency measures for The Mine General Manager and Site Health and Safety Coordinator is responsible for updating the ERP as deemed practical; this includes small tasks such as updating the contact lists as necessary. Revisions should be issued to all affected agencies identified as document holders (as a minimum everyone outlined in Section 2.1). It is the responsibility of all personnel visiting the site to ensure personal and worker safety. In cases of injuries, medical help must be called. If safe to do so, personnel on site may attend to injured person and, if qualified, administer first aid.
Dam Emergency Plan	The DEP (Appendix F) addresses dam specific emergencies at Hope Bay. The DEP is a standalone document that is a part of the Doris TIA DSMS as outlined in Section 4.

8.1. Activation of an Emergency Response

Emergency response is activated following the activation of the HOP-HSS-PRO-3001 Code 1. The procedure is triggered when an employee contacts the Incident Commander by pushing the Red Button on any radio, Calls 460-0911, or in person.

The Incident Commander acknowledges that this situation requires triggering an Emergency Response. From there, Emergency Response Team will be dispatched, Manager on Duty contacted, and the On-site Emergency Management and Corporate Crisis Management Teams may be triggered if the situation requires it as per the incident commanders assessment and in collaboration with the Manager on Duty.

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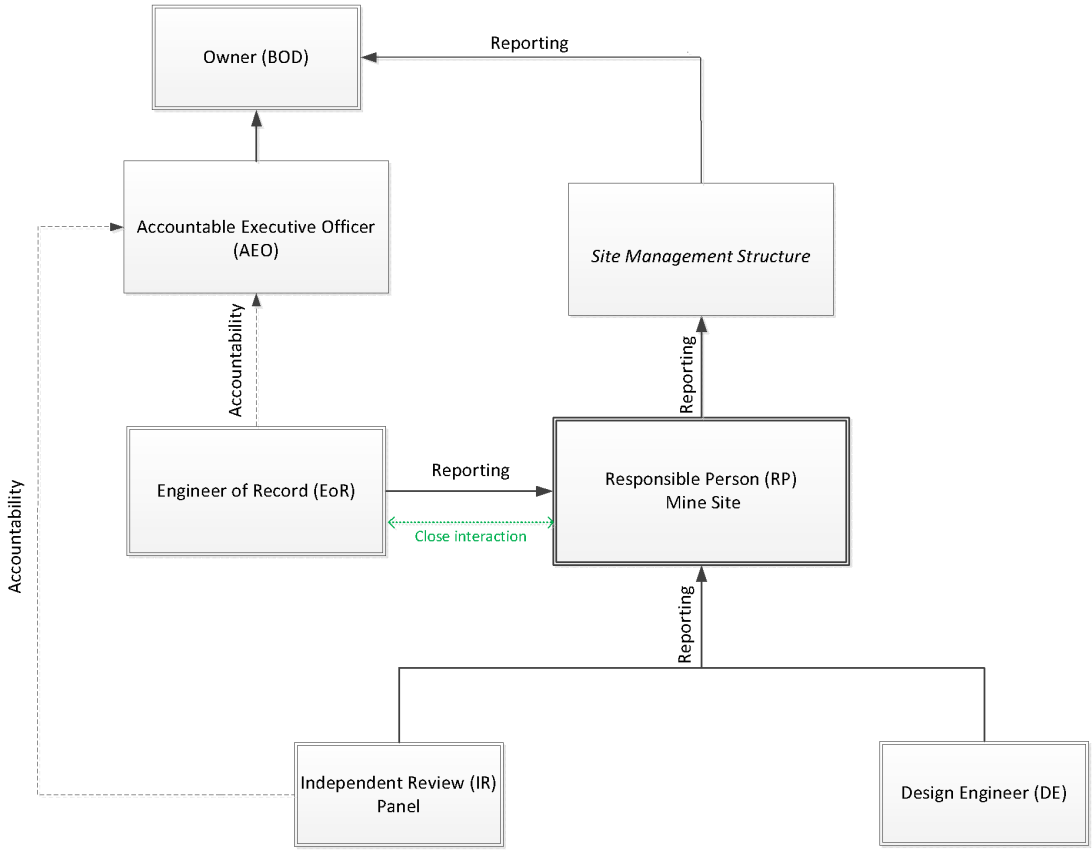
Appendix A: Agnico Eagle Governance Structure


Owner (BOD)
Reporting
Accountable Executive Officer (AEO)
Site Management Structure
Accountability
Reporting
Engineer of Record (EoR)
Reporting
Responsible Person (RP) Mine Site
Close interaction
Accountability
Reporting
Independent Review (IR) Panel
Design Engineer (DE)

Appendix B: Tailings Area Dust Control Strategy for Doris TIA

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Memo

To:	Project File	**Client:**	TMAC Resources Inc.
From:	Iozsef Miskolczi, PEng	**Project No:**	1CT022.004
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 13, 2016
Subject:	Hope Bay Project: Tailings Area Dust Control Strategy for Doris TIA		

1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km due south from Doris, respectively.

Two tailings storage areas are planned for Phase 2. The existing Doris tailings impoundment area (TIA) will be expanded, and a new Boston tailings management area (TMA) will be developed. The Doris TIA tailings deposition will consist of subaerial tailings deposition, while the Boston TMA will be comprised of filtered tailings developed as a dry-stack. This memo is addressing dust management strategies for the Doris TIA.

Two tailings streams will be produced; flotation tailings, comprising approximately 92-94% of the overall volume, and detoxified leach tailings (following cyanidation, and subsequent cyanide destruction), comprising about 6-8% of the overall volume. Only flotation tailings will be deposited in the Doris TIA. The detoxified leach tailings will be filtered, mixed with mine waste rock and used for underground mine backfill.

Upon closure, the tailings surface of the Doris TIA will be covered with a nominal waste rock cover of about 0.3 m thick. The function of the cover is to prevent dust and to minimize direct contact by terrestrial animals. Once the water quality in the Reclaim Pond has reached the required discharge criteria, the North Dam will be breached allowing the TIA to return to its pre-mining elevation of 28.3 m.

Throughout the operational phase, portions of the tailings surface will be exposed, and sufficiently inactive such that they would dry out and pose a dusting risk. This memo describes alternative dust management strategies that have been considered and presents the rationale for selection of the preferred strategy.

2 Definition of Dust

2.1 Fugitive Dust

Fugitive dust is particulate matter suspended in air by wind action and human activities. Within the Doris TIA, tailings will be deposited by hydraulic placement of a tailings slurry which does not generate any fugitive dust. Fugitive tailings dust will however be generated during the period when the tailings closure cover is being constructed.

2.2 Aeolian Dust

Aeolian dust is defined as particles that are transported as suspended load due to wind action on a surface. Although tailings are discharged wet, the surface eventually dries out as a result of evaporation or freezing of the tailings surface. As a result, at any given time, large areas of the tailings surface would expose dry tailings. Aeolian tailings dust is expected because the Project site is prone to high winds and the moderate surrounding topography does not offer effective protection from wind.

3 Typical Dust Control Methods

3.1 State of Practice

Dust control from operating and closed tailings impoundments is a significant concern in the mining industry, and as a result, the state of practice is quite advanced. There are three primary dust control strategies for fugitive and aeolian dust from exposed tailings areas: natural dust control, physical dust control and chemical dust control. Natural dust control specifically relies on maximizing the benefits offered by nature in the form of precipitation (rain and snow). While highly effective, these benefits are opportunistic and may not always be available at the times when it may be needed.

Physical dust control is by far the most effective strategy, as it relies on creating a physical barrier, such as a cover, that would preclude dusting. This may however not be a cost efficient strategy for an operating tailings impoundment, since any interim cover would occupy space within a tailings impoundment that would otherwise be required for tailings.

Chemical dust control relies on modification of the tailings surface that generates the dust. The effectiveness of this method is temporary, but its application is typically simple, making it a very good alternative for managing dust from an operating tailings impoundment.

The sections that follow provide a detailed description of all the dust control methods that are currently being used in the industry, with a specific focus towards their potential applicability for this Project.

3.2 Natural Methods

3.2.1 Snow Cover

If early in the fall season, wet snow falls directly on the exposed tailings surface and subsequently freezes, it will remain in place all winter protecting the tailing surface from dusting. Snow that falls later in the season is typically drier and more powdery and it tends to be subject to wind transport and redistribution (drifting). This means that portions of the tailings surface will become exposed and opportunity for dust release increases. This is exacerbated by the fact that during the winter the tailings surface gets extremely dry as a result of freezing, making it highly susceptible to dusting.

To maximize the potential benefits offered by snow as a natural dust control method, any snow that does fall on the tailings surface can be track compacted in areas where the tailings surface is trafficable. By mechanically compacting the snow, it will stay in place longer and will melt at a much slower rate in the spring, extending the useful life of the snow as a dust control method.

It is however important to minimize the amount of tailings that gets deposited over the compacted snow. If the compacted snow does not melt during the subsequent summer season due to the insulating blanket of the overlying tailings, ice lenses within the tailings impoundment are created which result in a loss of tailings storage space and possible instability.

There is sufficient snowfall at the Project site that this dust control method could be effectively used. In addition, there is a requirement at the Project site for snow removal in specific areas. Snow that is removed could be hauled to the TIA and used specifically for the purpose of creating a compacted snow cover over any temporarily inactive tailings surface areas. Due to the temporary nature of this dust control method, it will not be a complete solution, but would be a practical and complementary method.

3.2.2 Ice Cover

Similar to compacted snow, an ice cover will remain in place for the duration of the winter and thus temporarily mitigate dust migration. Ice cover on exposed tailing surfaces can be achieved by various methods, including ponding water during freezing weather and mechanical placement of ice blocks imported from a different source (contact water ponds).

Water can be held back in specified locations and retained there during the shoulder seasons when freezing weather will create an ice cap. Once the ice cap is achieved the open water beneath the ice can be drained off, leaving an ice cap.

The ice cap can also be created mechanically by loading ice from contact water ponds (or fresh water streams) into haul trucks and dumping the ice on the tailings surface.

Similar to compacted snow, care must be taken to ensure that the amount of tailings deposited over an ice cover is limited to avoid entraining long-term ice in the TIA.

There are several contact water ponds throughout the Project site all of which must be managed such that they are normally empty. Contact water ponds are; therefore, unable to provide a reliable source of water to use to create an ice cover. Fresh water cannot be readily hauled to

the TIA to create an ice cover as the use of fresh water is governed by the Water License (2AM-DOH1323); therefore, creating an ice cover for dust control is not considered a viable practical alternative for application at the Project.

3.3 Physical Methods

3.3.1 Water – Surface Wetting

Water is by far the most common temporary dust control measure used in areas where water shortage is not of concern. The exposed surface is wetted up, preventing particles from becoming airborne. Since the water rapidly evaporates (in a matter of hours or days), it needs to be reapplied at a frequent interval to be effective. The surface wetting can be done using a conventional water truck, a water cannon fitted to a water truck, or a stationary sprinkler system. Naturally this dust control method is only applicable during non-freezing periods of the year.

For the Project, water could readily be obtained from the Reclaim Pond or can be hauled via water truck from other site contact water ponds. The tailings surface is however not expected to be trafficable in the short term and the only viable means of frequent tailings wetting would be via a water cannon, or a sprinkler system. While both of these methods are viable, the short useful life of every wetting cycle makes this a very labor intensive dust control method which is not preferred. This method will however be reserved as a last line of defence should any of the other dust control methods prove to be ineffective.

3.3.2 Water – Flooding

Flooding the tailings surface will naturally preclude any dust concerns. This is however not a viable strategy for the Project since the objective is to place tailings subaerially. At Doris, TIA portions of the tailings may be seasonally flooded as the water level in the Reclaim Pond rises; however, the water level will be managed such that a perpetual water cover will not be present.

3.3.3 Permanent Dry Cover

The most effective permanent dust control system is a permanent physical dust cover. Typically this is in the form of a layer of soil, or other suitable readily available cover material. This is however not practical until the tailings surface has reached its final elevation. In order to facilitate placement of a final dust cover as expediently as possible, any tailings deposition plan should be designed taking into consideration all opportunities for progressive reclamation.

In the context of the Doris TIA, the tailings deposition plan provides limited opportunity for progressive reclamation during the early Project life. This is predominantly driven by the surface topography and as a result there are no practical means to improve the design. The only viable permanent dust cover would be geochemically suitable waste rock, or quarry rock. Since all the Project waste rock is designated for use as structural underground backfill, only quarry rock can be considered a viable source for a permanent dust cover. While this will be the final closure dust control method, it is not considered a viable method during the operational phase of the Project.

3.3.4 Sacrificial Dry Cover

In extreme cases, nominal sacrificial covers such as a layer of sand or gravel are used to manage tailings dust when the final tailings surface has not yet been reached, but the period until tailings

deposition might resume at any particular spot may be extensive. When tailings deposition eventually returns to the covered area, these materials are not removed and tailings deposition proceeds to overtop the sacrificial cover. This can be very cost intensive and will only be practical if the tailings surface is readily trafficable.

There are no suitable natural sacrificial cover materials readily available at the Project site. Gravel could be produced from quarry rock; however, at great cost. This is therefore not considered a viable dust control strategy for the Project TIA.

3.3.5 Biodegradable Cover

Biodegradable material such as hay, wood mulch or sewage treatment sludge can be applied over exposed tailings surfaces to mitigate dust for a limited period (i.e. requiring occasional reapplication). Naturally this option is only economically viable if the organic source is readily available. The tailings surface must also be sufficiently trafficable to allow equipment to spread these materials. As these materials biodegrade and dry out, they themselves become prone to being part of the dust hazard.

There is no viable source of biodegradable materials at the Project site, and therefore this is not considered a viable dust control strategy for the Project.

3.3.6 Wind Barriers

A wind barrier (aka windbreak or shelterbelt) is a physical structure used to reduce the wind speed, which will reduce tailings from being re-mobilized from the TIA. Typically, a wind barrier consists of one or more rows of trees or shrubs. Trees and shrubs don't grow at the Project site (at least not to the size where they would be effective wind barriers), therefore, any wind barriers would have to be engineered structures. The efficiency of wind barriers is also a function of wind speed, and often, at very high wind speeds, wind barriers can fail since it is simply not cost effective to design and build these structures to withstand large wind velocities. As well, wind barriers only work effectively over a very narrow range of wind directions. Multiple wind barriers would need to be installed to cover all of the Project's prevalent wind directions so as to provide a comprehensive dust management system for the TIA.

Given the very high wind speeds and the multiple wind directions, experienced at the Project's TIA, engineered wind barriers are not be considered a viable dust control strategy for the Project's TIA.

3.3.7 Vegetation

Revegetating an exposed tailings surface is a very effective way to mitigate dust. In an arctic setting such as at the Project site, this is not a practical option since the growth season is simply too short to allow for rapid onset of effective vegetation. In addition, the tailings material may not be amenable to supporting vegetation without the addition of supplemental nutrients, which might preclude establishment of natural successional vegetation species. This is therefore not a viable dust control method for the Project.

3.4 Chemical Methods

3.4.1 Salt (Calcium Chloride)

"Salted" sand will not freeze at temperatures above -10˚C, and can be spread in a thin layer over exposed frozen tailings surfaces during the shoulder seasons when frost penetration is enough to support the spreader truck (or other suitable spreader mechanism). The calcium chloride in the sand acts to melt the frost on the exposed tailing surface and stops the fine particulate dust particles from becoming airborne.

There are no sources of sand at the Project site, requiring that both sand and salt would have to be imported at great cost. As runoff occurs from the tailings surface, the salt will dissolve reducing the efficiency; however, since this mitigation method is best used during freezing conditions this risk is limited. However, during freshet the salt is washed off towards the Reclaim Pond which results in an increased salt load to the TIA, which may limit the use of TIA reclaim water to the mill. This is therefore not a viable dust control strategy for the Project TIA.

3.4.2 Chemical Suppressants

There are many environmentally safe commercial chemical dust suppressants on the market. Although originally developed for other forms of fugitive dust management, they are routinely used for dust control on tailings surfaces. These products work in different ways, but principally they all either chemically bind dust, or alternately facilitate towards development of a crust to prevent particles from separating and becoming airborne.

The chemical suppressants are normally supplied in concentrated liquid form in containers of various sizes. They are typically water based and are diluted before application at a ratio of about nine parts water to one part suppressant. The solution is applied by means of a spray cannon mounted on a modified water truck, but can also be done via hand held sprayers. The application rate is typically about four liters per square metre.

Chemical suppressants have a useful life which is dependent on the concentration applied and local weather conditions. Normally, products are applied at a concentration which would render a useful life of approximately one year.

Of all the dust control methods, chemical suppressants offer the greatest flexibility for application at the Project TIA. The concentrated liquid can be shipped to site on an annual basis and solution can be mixed an applied on site as required. The relatively long useful life limits the amount of effort that needs to be exerted and therefore makes the dust control method practical.

4 Dust Control Procedures for Tailings

The primary dust control measures of the Project site tailings facilities will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure that any areas that may be at risk will be adequately covered. Generally, annual application of chemical suppressants will be applied; however it is recognized that more frequent applications may be required as discharge locations are changed throughout any year.

In addition to chemical dust suppressants, natural dust control in the form of packed snow when available will be used as far as practical. Again, the effectiveness will vary on a year by year basis depending on how deposition points vary for any given winter season.

Finally, if for any reason, any of the above dust control methods prove to be temporally ineffective, a suitable water cannon will be available to allow for dust suppression in the form of spraying of the areas of concern.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

Appendix C: Agnico Eagle Preferred Dust Control Product

Dust Stop Municipal Blend

100% Environmentally Friendly Non-Corrosive, Non–Toxic Cost Competitive Dust Control

Dust Stop Municipal Blend (DSMB) is a formula consisting of natural organic ingredients specifically engineered for all types of unpaved roads. Applicable to any soil type, it is applied using standard equipment and techniques. DSMB was designed to provide an environmentally friendly, non-corrosive and cost-competitive replacement for calcium and magnesium chloride. DSMB is not adversely affected by heavy rains or long periods of dry weather and has no adverse effect on the environment or vehicles, due to its non-corrosive properties.

- **Significantly reduces long term maintenance costs**
  - » Reduced need to grade treated roads
  - » Reduction in watering requirements
- **Non-corrosive and environmentally friendly**
  - » Will not cause rust on vehicles or application equipment
  - » No adverse impact on roadside vegetation
- **Increased water resistance resulting in better performance in all weather conditions**
  - » Reduction in maintenance requirements as a result of wet weather
  - » Does not get slippery when wet
- **Long lasting results**
- **Cost Competitive with chlorides**
- **DSMB treated roads show improved engineering properties**

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Dust Stop Municipal Blend

100% Environmentally Friendly Non-Corrosive, Non–Toxic Cost Competitive Dust Control

- **Haul Roads**
- **Access/Secondary Roads**
- **Logging Roads**
- **Construction Sites**
- **Parking Lots**
- **Back Lanes and Trails**
- **Tarmacs, Runways & Helipads**
- **Erosion Control**

Testimonial

"We have recently applied Cypher Environmental's new Dust Stop Municipal Blend (DSMB) product on La Verendrye Road within the municipality. DSMB was advertised to be competitive with chlorides in terms of cost and effectiveness and so far has performed well and exhibited excellent properties during and after rain. The product has stood up to the elements very well thus far, with several periods of rain and hot, dry and windy weather."

Grant Baker, Public Works Manager,
Rural Municipality of MacDonald, Manitoba

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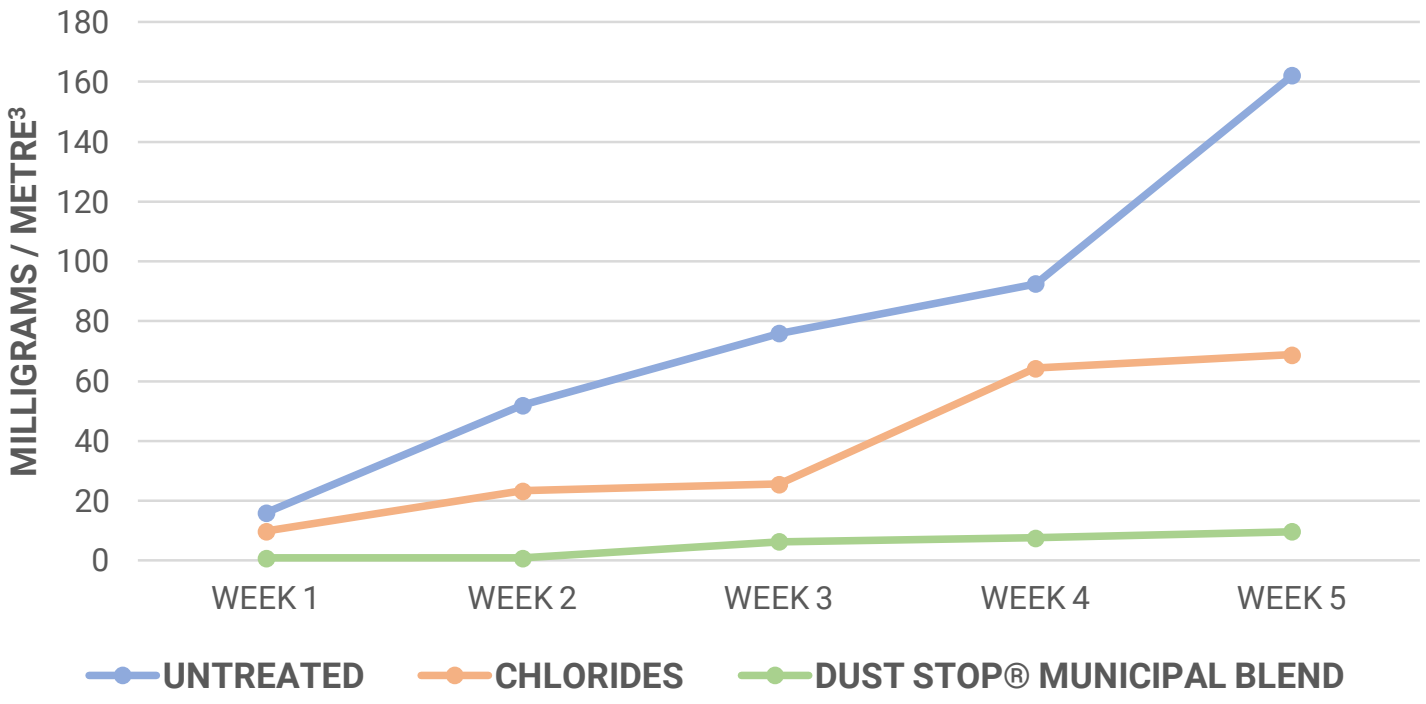
Superior dust control.

DUST STOP®
MUNICIPAL BLEND

REDUCE DUST POLLUTION BY UP TO 90% WITH DUST STOP® MUNICIPAL BLEND.

In order to measure the effectiveness of the dust control properties of Dust Stop® Municipal Blend, data was collected from a Turnkey® Dust Mate environmental dust detector during a series of controlled road tests over the period of several weeks. The Dust Mate Remote Vehicle Probe was installed on the wheel-well of our company vehicle, and dust concentration data was collected while controlling the speed of the vehicle and the elapsed time of each test. This data was collected on three road surface types on the same stretch of road (Untreated, Chlorides & Dust Stop® Municipal Blend) under the same conditions. These conditions included direction of travel, speed of travel, wind speed, wind direction, temperature, road conditions and traffic frequency.

AERIAL DUST CONCENTRATION



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Dust Stop Municipal Blend – How It Works

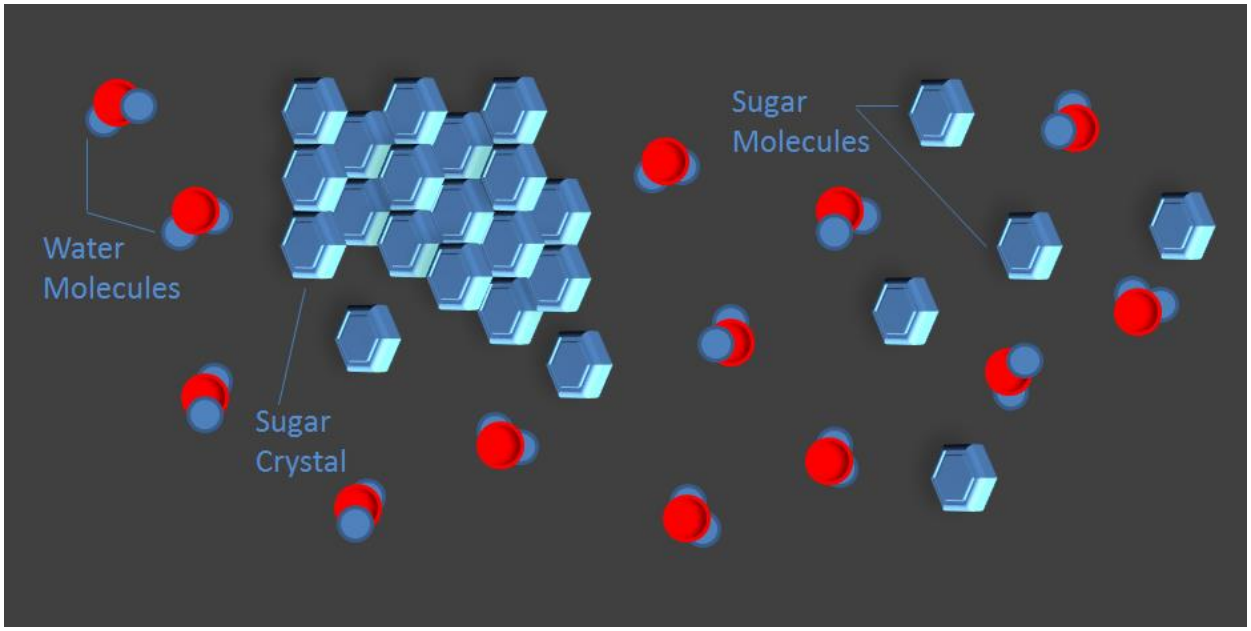
Introduction

Dust Stop Municipal blend contains three main constituents; sugars, starches, and minerals. These components are all commonly found in nature and play a big role in our everyday lives. Sugar is the universal term for sweet, short-chain, soluble carbohydrates that are primarily composed of the elements carbon, hydrogen, and oxygen. Sugars can be derived from multiple sources; simple sugars are called monosaccharides and include glucose (also known as dextrose), fructose, and galactose. Granulated sugar which is most customarily used in the food industry is sucrose, also known as a disaccharide.

The building blocks of Sugar- Greatest binding influence in DSMB

Hydrogen bonding is the greatest contributing factor to sugar's stickiness. When sugars are crystalline in structure they are unable to stick to other molecule but can be easily dispensed or poured. When a liquid such as water is added to crystalline sugar, the formerly strong oxygen-hydrogen bonds will begin to degrade and cause the newly available hydrogen atoms to seek out other materials to bind to.

Available hydrogen atoms have an opportunity to stick to the closest surfaces, some will be attracted to the hydrogen molecules in the liquid, and some will bind with another available hydrogen or oxygen atom present in the sugar. This bonding action results in the sticky nature of sugar. When the bonds in sugar are broken there is more opportunity for the molecules to grab onto whatever they're in contact with, including other sugar molecules and surrounding particles. The new bonds are more secure because there are so many of them. Therefore, it's harder to pull them apart.



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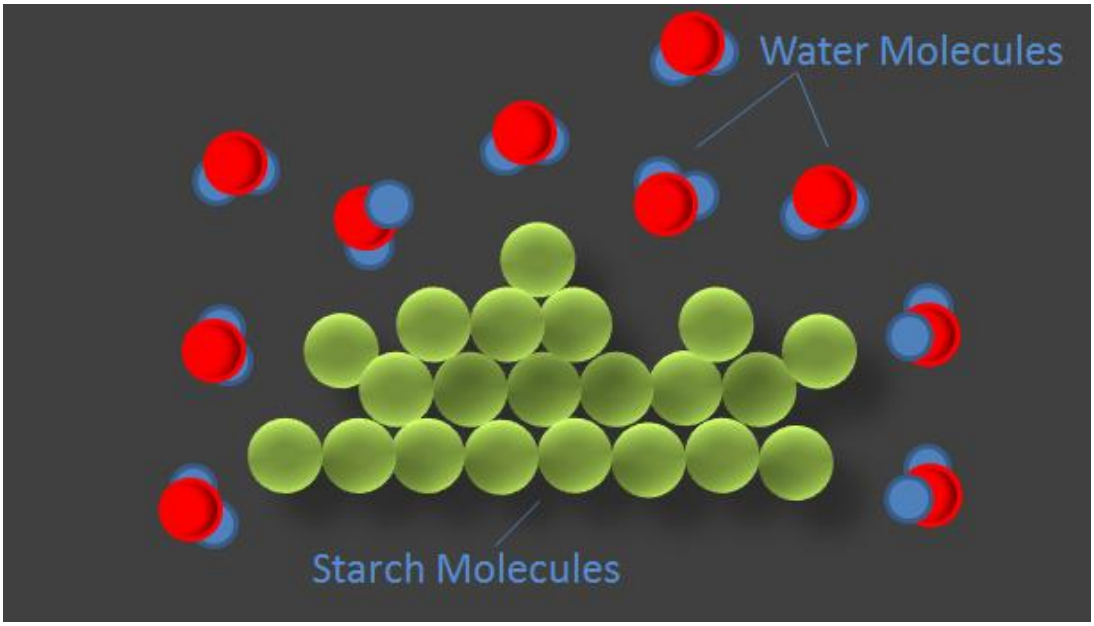
Starches and Minerals

Starch is a term with the following meanings “strong, stiff, strengthens, stiffen". Starches are comprised of polymeric carbohydrates consisting of a large number of glucose units joined by glycosidic bonds. They are insoluble in cold water and alcohol due to two types of molecules: the linear and helical amylose and the branched amylopectin. The minerals incorporated in DSMB are not unlike starches, due to their strong chemical makeup they are insoluble in water and have the opportunity to form bonds with other available molecules providing further strength and durability when applied. The bonds fashioned between the minerals, starches and sugars are, in most cases, stronger than the bond that would be formed between these components and water. Consequently, they are less likely to be dissolved or run of with the application of water.



How DSMB works

The unique blend of materials utilizes the functional properties of sugars, starches, and minerals allowing DSMB to bind and harden any loose particulate matter, decreasing dust on surfaces. DSMB is applied in a diluted form; water evaporates from the product as it dries. Dust control is achieved during this process as the high-viscosity, naturally adhesive material traps loose particulate.

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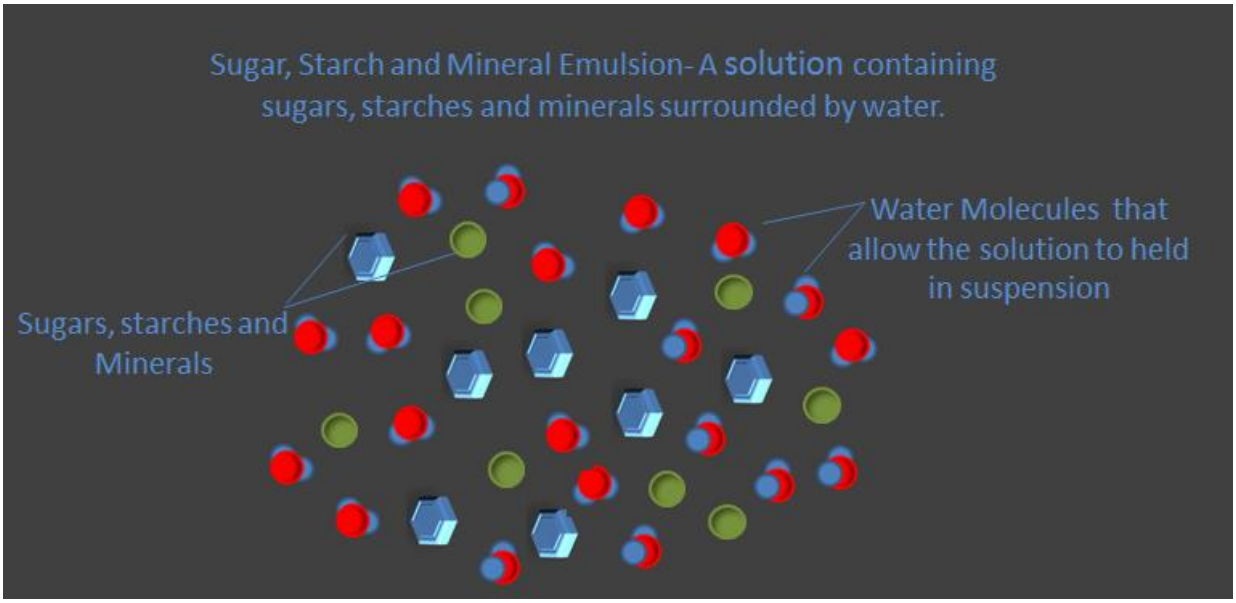
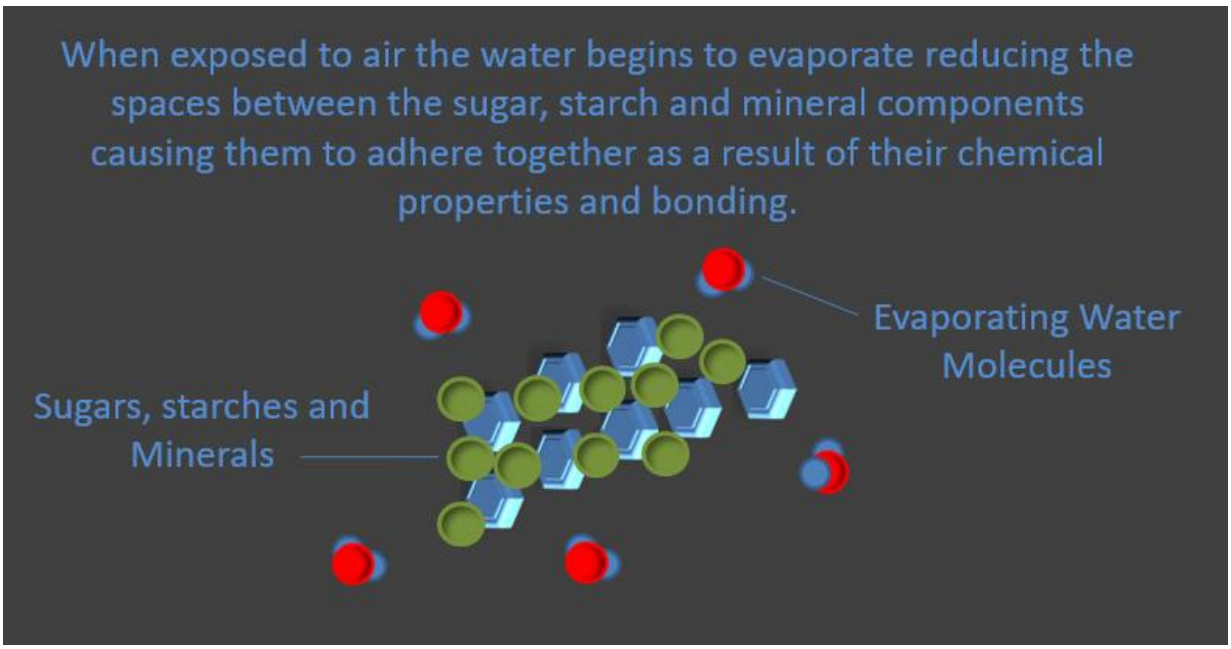
1) Water is added to the highly concentrated product allowing for suspension of the active inputs; sugars, starches, and minerals.



2) As water evaporates, the molecules bind together to form a cohesive matrix.



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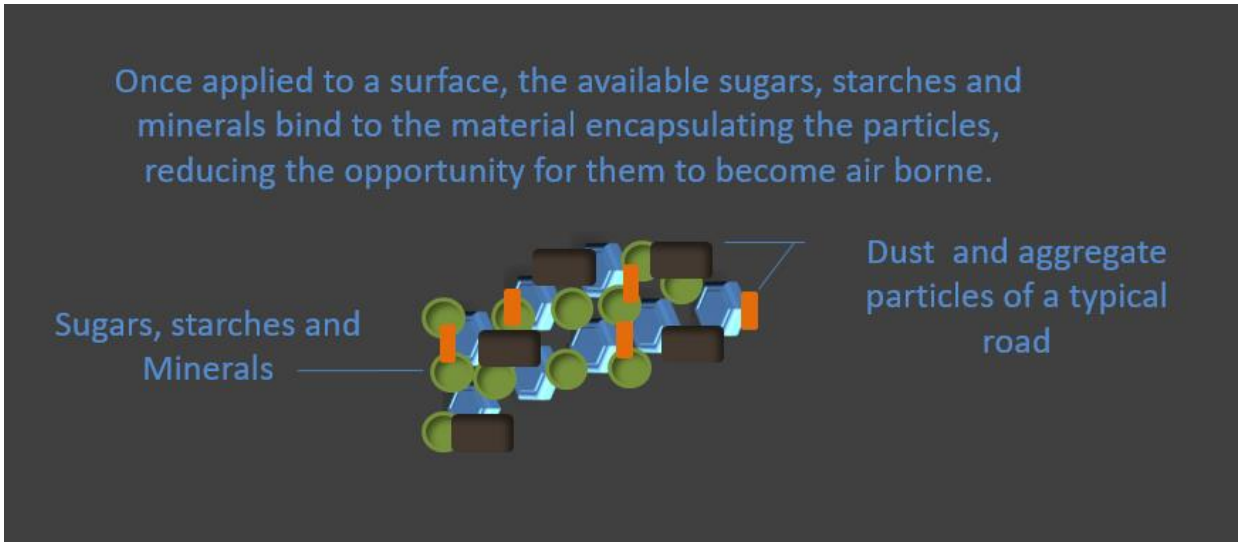
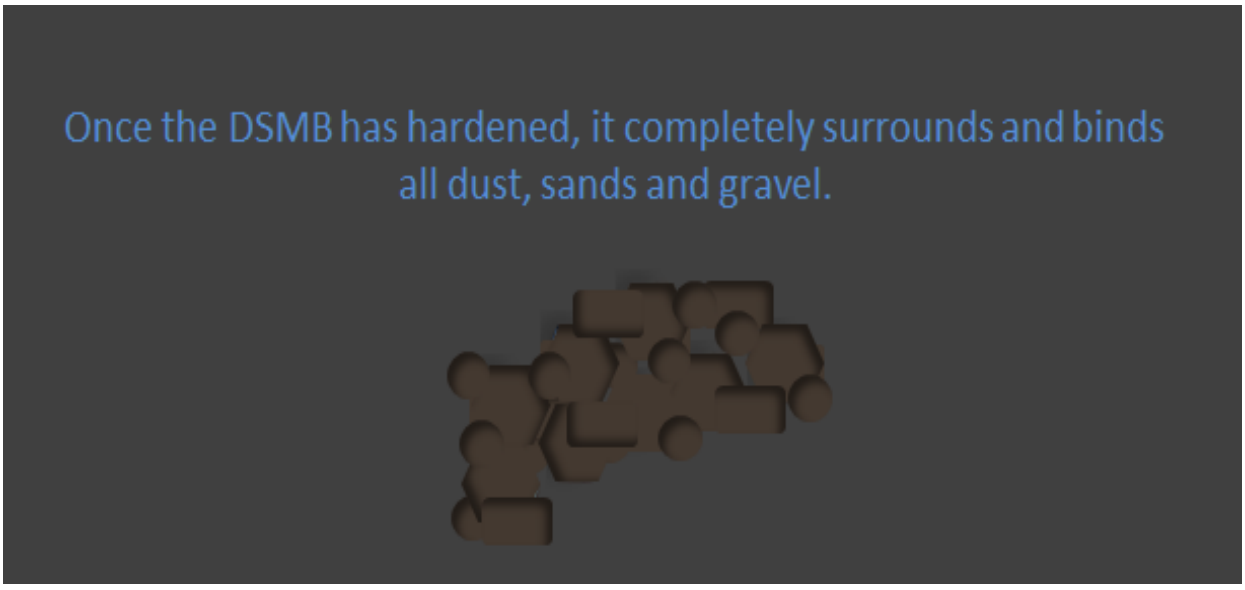
3) The newly formed matrix will now function to attract and bind the loose soil, dust or other particulates that may otherwise become air born and create dust.



4) Over time; as more water evaporates, the solution becomes firm and durable preventing any of the encapsulated dust generating material from becoming air born.



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The product's unique blend of materials also functions to reduce road surface issues in the rain or in wet conditions. The incorporated sugars compete for water making it less available to bind with other soil molecules while providing some minimal structural support and added road stability. The insoluble mineral component forms a bond with the sugar molecules creating some means of insolubility and will have less of a chance to run off in wet conditions. Once wet, the product will re-set once road surfaces dry, re-binding any loose materials. For these reasons, DSMB is not adversely affected by heavy rain, yet very effective and long lasting in dry weather, with no adverse effects on the environment or vehicles using the road due to its non-corrosive properties.

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DUST STOP MUNICIPAL BLEND (DSMB)

FREQUENTLY ASKED QUESTIONS

1) Why use Dust Stop Municipal Blend for dust suppression on your roads? 1
2) Why use a dust suppressant / dust control product? 4
3) What is the difference between Dust Stop Municipal Blend and other products on the market? 1
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6) What are the benefits of Dust Stop Municipal Blend? 2
7) What kinds of roads is Dust Stop Municipal Blend applicable for? 2
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10) Is Dust Stop Municipal Blend effective during long periods of dry weather? 3
11) Is Dust Stop Municipal Blend effective on all soil types? 3
12) How long will Dust Stop Municipal Blend last? 4
13) Will Dust Stop Municipal Blend have any adverse effects on the vehicles used to apply it? 4

1) Why use Dust Stop Municipal Blend for dust suppression on your roads?

Dust Stop Municipal Blend should be used on your roads because it is a non-corrosive and environmentally friendly alternative to chlorides. Dust Stop Municipal Blend is not only environmentally friendly and non-corrosive, but also highly effective on a variety of road and material types, applied using standard techniques and equipment, and does not run-off or get sticky in the rain. Products such as various oil based emulsions and chloride based products (magnesium chloride / calcium chloride) have been used in the past for dust suppression at the expense of the environment (Canadian Environmental Protection Act 1999-link below), none of which is a concern for Dust Stop Municipal Blend. The product is based on organic sugar and starch ingredients, as well as a proprietary mineral compound, providing effective dust control with no adverse impact on the environment.
http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2- lsp2/road_salt_sels_voirie/index-eng.php#a02

2) What is the difference between Dust Stop Municipal Blend and other products on the market?

Dust Stop Municipal Blend is specifically designed as a non-corrosive and environmentally friendly alternative to other dust control products such as magnesium chloride, calcium chloride, offering superior road dust control results. Dust Stop Municipal Blend is very cost-competitive with road salts, while being able to very effectively eliminate unwanted fugitive dust from unpaved roads of any soil type. While road salts are minimally effective, they are hygroscopic by nature, meaning they require moisture, which they attract to the road, to be effective, and are therefore not effective during long periods of dry weather, and can also run-off in the rain. Dust Stop Municipal Blend is not hygroscopic, so it is not burdened with the same issues road salts have during prolonged dry periods, or wet weather. The concentrated liquid formulation is easily mixed with several parts water prior to its application, allowing it to be easily transported and applied with standard water trucks. Once the solution is sprayed on the road and allowed to dry, immediate dust control results will be achieved. In comparison to other dust control products mentioned above, Dust Stop Municipal Bend requires a reduced application frequency further reducing application and maintenance costs.

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3) What is Dust Stop Municipal Blend made of?

Dust Stop Municipal Blend's proprietary formula is composed of an environmentally friendly blend of sugars, starches and minerals. Dust Stop Municipal Blend utilizes these main inputs in a concentrated liquid form to produce a very effective dust control product that is applicable to almost any material type.

4) How does Dust Stop Municipal Blend work?

The unique blend of materials utilizes the functional properties of sugars and starches allowing DSMB to bind and harden any loose particulate matter, decreasing dust in road surfaces. The product's unique blend of materials also functions to reduce road surface issues both during and after rain. The incorporated sugars compete for water making it less available to bind with other soil molecules, while providing some minimal structural support and added road stability. The product will re-set once road surfaces dry, re-binding any loose materials. For these reasons, DSMB is not adversely affected by heavy rain, yet very effective and long lasting in dry weather, with no adverse effects on the environment or vehicles using the road due to its non-corrosive properties.

5) What are the benefits of Dust Stop Municipal Blend?

Dust Stop Municipal Blend has numerous benefits associated with its use as a dust control product. Dust Stop Municipal Blend is supplied in concentrated liquid form, allowing for easier transportation as well as application. The ingredients in the product provide stability to the road surface that decrease maintenance requirements and significant dust reduction. The unique blend of materials utilizes the functional properties of sugars and starches allow DSMB to bind and harden any loose particulate matter, decreasing dust on road surfaces. These materials function to reduce road surface issues in both dry and wet conditions. Once wet, the product has the ability to re-set once the road surface becomes dry, re-binding any loose materials. Due to the specific blend of sugars and starches, it will rejuvenate with moisture allowing it last longer than other products on the market, yet not run-off in the rain. For these reasons application and maintenance costs can be reduced. Dust Stop Municipal blend is non corrosive, will not cause corrosion to equipment or vehicles and does not have any harmful effects to roadside vegetation making it safe to use in sensitive environmental areas.

6) What kinds of roads is Dust Stop Municipal Blend applicable for?

Dust Stop Municipal Blend is an effective dust control product on any unpaved roads or surfaces requiring dust suppression and temporary soil stabilization. Dust Stop Municipal Blend is effective on municipal roads, secondary roads, county roads, mine haul roads, access roads, runways, helipads, parking lots, driveways and a wide range of other applications that require dust suppression or temporary stabilization such as tailings piles, stockpiles, erosion control and open haulage situations.

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info@cypherenvironmental.com
www.cypherenvironmental.com

7) How do you apply Dust Stop Municipal Blend?

Dust Stop Municipal Blend is applied with standard road construction equipment and can be applied topically or mixed into the top layer of the road material. The first step involved in the application of Dust Stop Municipal Blend is to determine the area of the road / surface that you will be treating. Once you determine this you can calculate the amount of water and Dust Stop Municipal Blend that is required (please communicate with your local representative who will help you figure out the best application rate for your requirements). The next step in the application of the product is to add the Dust Stop Municipal Blend with water prior to the application of the product. Always add the water to the water truck prior to the Dust Stop Municipal Blend. Once the pre-determined amount of water is added to the truck, add the pre-determined amount of Dust Stop Municipal Blend. Once the product is added to the water truck it can immediately be sprayed on the road surface. Once the product is applied you will notice dust control results immediately, however traffic should stay off of the road until the product has time to dry (drying time can vary depending on the climatic conditions on the day of application, in many cases is around 1 hour on a warm day).

If mixing the product into the road surface, the addition of a road grader and rubber wheeled compactor needs to be added to the project. Generally performed during routine maintenance, the DSMB can be mixed into the soil once the top layer has been loosened to repair potholes and wash boarding. The prescribed mixture of water and DSMB should be applied evenly and lightly mixed into the soil prior to shaping and compacting. Shaping of the road surface is still important to ensure that water is quickly evacuated away from the road surface. Additional details and specifics can be discussed with your Cypher representative.

8) What happens to Dust Stop Municipal Blend when it rains?

There are no long term effects on Dust Stop Municipal Blend if it is subjected to rain. Dust Stop Municipal Blend contains a blend of soluble sugars, starches, and an insoluble mineral component that once cured are able to hold their strength in the presence of water. For these reasons, DSMB is not adversely affected by heavy rain, yet very effective and long lasting in dry weather, with no adverse effects on the environment or vehicles using the road due to its non-corrosive properties.

9) Is Dust Stop Municipal Blend effective during long periods of dry weather?

Yes, Dust Stop Municipal Blend is an effective dust control product during long periods of dry weather. One reason Dust Stop Municipal Blend is so effective in dry weather is that, unlike chloride-based products, it is not hygroscopic so it does not rely 100% on the ambient moisture in the atmosphere to work. The product derives its main efficacy through the hardening and binding power of its ingredients, which forms a physical barrier over the surface of the road, binding the dust particles down and providing long term dust control results.

10) Is Dust Stop Municipal Blend effective on all material types?

Yes, Dust Stop Municipal Blend is an effective dust control product on almost any material type. Dust Stop Municipal Blend will bond to any solid material it is exposed to, it will incorporate any particles it touches into the film once it cures. Therefore, almost any soil type can be treated with Dust Stop Municipal Blend. However, the application rate of Dust Stop Municipal Blend that is recommended may vary slightly depending on the material being treated.

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11) How long will Dust Stop Municipal Blend last?

Dust Stop Municipal Blend is a seasonal dust control solution, designed to reduce the frequency of treatments compared to other dust control methods, such as chlorides. Some variables that will affect the longevity of an application would be the application rate used, type of material, wet/rainy conditions, type and amount of traffic and climatic conditions. The application rate will have an effect on the longevity of dust control results you see; the stronger you apply Dust Stop Municipal Blend the longer it will last. Some Dust Stop Municipal Blend users apply it at rates that are much less concentrated and on a more frequent basis, therefore in essence making these applications maintenance doses and allowing for a more cost-effective long-term use of the product.

12) Will Dust Stop Municipal Blend have any adverse effects on the vehicles used to apply it?

No, Dust Stop Municipal Blend will not have any adverse effects on either the vehicles used to apply the product or the vehicles using the road. Dust Stop Municipal Blend has a pH that is almost neutral which is why it will have no corrosive effect on any vehicles it comes into contact with, or any damaging effect to road side vegetation. In fact, Dust Stop Municipal Blend 's use as a dust control product will eliminate harmful dust from having an abrasive effect on the moving parts of the vehicles traveling on the Dust Stop Municipal Blend treated roads therefore reducing their associated maintenance requirements. It is unlike corrosive and toxic products such as chlorides, it will not cause irreversible long term damage to equipment and vehicles.

13) Why use a dust control product?

Dust control should be used to minimize the risks involved with the generation and movement of dust particles emanating from any trafficked unpaved surfaces. Dust also represents the fines that are the essential binders that maintain the strength and stability of an unpaved surface, and help to lock down the aggregate road. It is estimated that for every vehicle traveling one mile of unpaved roadway once a day, every day for a year, one ton of dust is deposited along a corridor extending 500 feet out on either side of the road. This dust poses a threat to human health through inhalation into the lungs, as well as a threat to the safety of the people using the road due to the reduced visibility caused by the thick clouds of dust. The creation of dust is also quite costly because it represents significant annual losses in fine soil material and can cause damage via abrasion to moving parts of the vehicles traveling on the road. Applying a dust suppressant / dust control product, such as Dust Stop Municipal Blend, will help to minimize these threats and provide a much safer, healthier road environment.

Additional information can be found at www.cypherenvironmental.com. For questions, contact your regional distributor or Cypher Environmental Ltd.'s head office at info@CypherEnvironmental.com.

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DUST STOP LIQUID CONCENTRATE (DSLC) QUESTIONNAIRE DEFINITIONS

Cypher environmental prides itself in providing a customized approach to every project; we know that no two projects are the same, understanding the variables such as size, project type, material type, traffic frequency and traffic type are paramount to providing the best solution.

A significant amount of time and effort is placed on providing the best solution for the issue of dust control based on the circumstances of a particular project. Areas such as dimensions of the project are easily determined while others such as traffic type and traffic frequency are somewhat subjective. In order to provide some framework for understanding these terms, Cypher provides the following reference information:

Road Type:

Mine Haul	– A crude road built to facilitate the movement of people, equipment, and/or materials along the route of a job. – A road built to carry heavily loaded trucks (60-450 ton) at a good speed; the grade is limited and usually kept to less than 17% of climb. – Truck haulage cost amounts to between 30 and 50 per cent of total surface mining costs and up to 60 per cent of total forestry operation costs. The savings from appropriate design, construction and maintenance of haulage roads and utilization of the most suitable materials is thus significant.
Access Road	– A road providing a means of entry into a region or approach to another road, site or project; usually exposed to heavy traffic (not as significant as a haul road). – A road that provides access to a specific destination, as to a main highway or to a property that lies within another property.
Secondary Road	– A road supplementing a main road, usually wide enough and suitable for two-way, all-weather traffic at moderate or slow speeds (lighter vehicles than an access road).
Parking Lot	– A cleared unpaved area that is intended for parking vehicles, these surfaces can be exposed to additional shear forces not found on other road types due to static shear (static wheel forces when steering while stopped).
Erosion Control	– Is the practice of preventing or controlling wind or water erosion in agriculture, land development, coastal areas, river banks and construction. – Effective erosion controls are important techniques in preventing water pollution, soil loss, wildlife habitat loss and human property loss.

Tailings Pile	– Any static pile of material that is not exposed to vehicle or foot traffic. – Also includes storage piles.

Material Type:

The **Material Type** is a reflection of the size of the dominant aggregate particles in a road / soil, starting at the small end of the scale; Well Compacted Fines and getting larger as we reach the High Gravel Content end of the scale.

Sandy	– Granular material. – Finer than gravel and coarser than silt. – Particles range in diameter between 0.0625 mm to 2mm.
Well Compacted Fines	– High clay / silt content. – Cohesive soils (clay / silt) that are dense and tightly bound together.
Light Gravel Content	– Fine Sized / Dirty Gravel (more fines). – This is small (4–8 mm) particulate gravel.
Medium Gravel Content	– Medium Sized / Less Dirty (less fines). – This is medium (8-16 mm) particulate gravel.
High Gravel Content	– Coarse Gravel (Little to No Fines – difficult to compact) – This is larger (16-32 mm) particulate gravel.

Traffic Frequency:

The area i.e. dimensions of the surface are easily determined while other variables such as traffic type and traffic frequency are somewhat subjective. In order to provide some framework for understanding these terms, Cypher provides the following reference information:

Traffic Frequency	**Per hour**	**Per 8 hour**	**Per 12 hour**	**Per 24 hour**
Low	1 – 10	1 – 80	1 – 120	1 – 240
Medium	10 – 25	80 – 200	200 – 300	240 – 600
High	> 25	> 200	> 300	> 600
Constant	– Traffic that exceeds the 25 vehicles per hour and remains at a steady state for extended periods. Generally, traffic numbers are averages over a long period, encompassing high and low traffic periods. Constant traffic indicates regular passage of vehicles at stable intervals for long periods (e.g. every 2 minutes for 24 hours a day).			
Tailings Pile	– Any static pile of material that is not exposed to vehicle or foot traffic. – Also includes storage piles			

Traffic Type:

Traffic Type	Vehicle Weight (tons)	Vehicle Weight (kg)	Vehicle Weight (lbs)
Heavy	> 100	> 100,000	> 220,463
Medium	22 – 100	22,000 – 100,000	48,500 – 220,462
Light	< 22	< 22,000	< 48,500
Tailing Pile	– Any static pile of material that is not exposed to vehicle or foot traffic. – Also includes storage piles.		

Average Traffic Speed:

This represents the speed at which the majority of vehicles will travel on the road. Choose "Tailings Pile" for any projects that will not receive any traffic.

**Note that these definitions are for general familiarity; all roads will have a mixture of various sized aggregates in them but will have a visible maximum aggregate size that we are referring to here. If you are uncertain about the category of a road, a picture of the surface should be emailed to your Cypher representative for clarification.
**This information is provided as a guide only, specifics of the project should be discussed with your Cypher representative to clarify individual project details.

Dust Stop Municipal Blend

SECTION 1: IDENTIFICATION

Product Name:	Dust Stop Municipal Blend
Synonyms:	DSMB
CAS Number:	See Section 3
Product Use:	A water-based nonhazardous, environmentally friendly and biodegradable liquid used for dust control on roads
Manufacturer/Supplier:	Cypher Environmental Ltd.
General Information:	WHMIS Classification: Not Controlled
Address:	Cypher Environmental Ltd. 1149 St. Matthews Ave. Winnipeg Manitoba R3G 0J8 Canada
Emergency Number:	Tel: (204)-489-1214 Fax: (204)489-7372

Section 2: HAZARD IDENTIFICATION

Health Environmental Physical:	Biodegradable
Acute Toxicity:	Non- Toxic, pathogen free.
Skin/Eye Corrosion:	Contact with skin may result in mild irritation.
Mutagenicity/ Carcinogenicity/Devel opmental:	Non-mutagenic and non-carcinogenic Based on available information, none of the ingredients in Dust Stop Municipal Blend are regulated nor listed as potential cancer agents by Federal OSHA, NTP or IARC.
Reproductive/Develop mental:	Not Determined
Target Organ Toxicity (Repeated):	Not Determined
Toxicity:	Non-Toxic, pathogen free

GHS Label:

Signal Word: DANGER!

Hazard Statements:

WHMIS HAZARD RATING INFORMATION	FLAMMABILITY	HEALTH	REACTIVITY
0-Minimal 1-Slight 2-Moderate 3-Serious 4-Severe	0	1	0

Section 3: COMPOSITION / INFORMATION ON INGREDIENTS

Unique Identifiers

INGREDIENTS (Complex mixture)	% by weight	CAS NO.
Water	5-10	-
Proprietary Anionic Polyelectrolyte Additive	Proprietary	CAS Listed
Proprietary Additive	Proprietary	CAS Listed
Reduced Sugars	Proprietary	CAS Listed
Silicates and Carbonates	Proprietary	Mixture

* Based on available information, none of the ingredients in Dust Stop Municipal Blend are regulated nor listed as potential cancer agents/hazardous by Federal OSHA, NTP or IARC.

Section 4: FIRST AID MEASURES

Eye: A slight eye irritant.

Skin: Contact with skin may result in mild irritation, rinse with plenty of water.

Inhalation and Ingestion: Considered non-harmful by all exposure routs , if breathing is difficult remove to fresh air.

Signs and Symptoms of Exposure: None. Ingestion may cause mild nausea or diarrhea.

Section 5: FIRE FIGHTING MEASURES

Suitable Extinguisher Media:	Treat the same as water
Fire Fighting Procedures:	Isolate fire area and deny unnecessary entry, Soak thoroughly with water to cool and prevent re ignition. Cool surroundings with water to localize fire zone. Hand held carbon dioxide or dry chemical hazard may result from forceful application of fire extinguishing agents. Do not enter fire area with out protective equipment.

Section 6: ACCIDENTAL RELEASE MEASURES

PPE:	Eye: Safety goggles Respirator: Not applicable Clothing: Regular on-Site clothing
Emergency Procedures:	In case of accidental spill or discharge, take up and containerize for disposal according to state and local regulations. This product displays ultimate biodegradability under both aerobic and anaerobic conditions and if spilled should not cause any adverse short or long term environmental impacts. Ventilation requirements as normal
Methods and Materials For Containment and Cleaning Up:	For smaller spills, Wash contaminated area with water and flush into sewage system or any other disposal system. For large spills, soak up with sand or sweeping compound and dispose at solid waste

Section 7: HANDLING AND STORAGE

Handling: **Keep container closed when not in use. If container is being stored for extended periods, provide minimal to moderate agitation every few weeks ensuring re-homogenization of product.**

Storage:

Storage Temperature (Degrees C/F)
Minimum: 10°C (50°F)
Maximum: 20-25°C (68-77°F)
Application Temperature:
Minimum: 10°C (50°F)
Maximum: 57°C (135°F)
Optimum Working Temperature Range:
18-45°C (64-113°F)
*Store product in an area that is not exposed to direct sunlight and in an environment within the conditions stated above.

Section 8: EXPOSURE TO CONTROLS AND PERSONAL PROTECTION

OSHA PEL's:	Not Applicable
Exposure Limits:	Dust Stop Municipal Blend presents no health hazards to the user, other than mild eye and skin irritancy.

Engineering Controls:

	No specific engineering controls needed, it is recommended to handle concentrated product in a well ventilated area
PPE:	
Eye Protection:	Safety goggles, avoid eye contact or exposure to concentrated amounts of product
Skin Protection:	Regular on-Site clothing , rinse from skin when exposed to product
Respiratory Protection:	Respirator: Not applicable, ventilation as normal

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Flashpoint:	Not flammable; not combustible
Auto Ignition:	None
Boiling Point:	>100°C
Melting Point:	Liquid
Freezing Point:	<0°C
Vapor Pressure:	Not Determined
Miscibility with water:	Miscible in all proportions
Solubility in Water:	Soluble
Lower and Upper Flammability Limits:	Not flammable
Specific Gravity:	1.24 @ 25 °
Density:	1.4 g/cm^2 @ 25 °
pH:	9.19
Ultimate Biodegradability:	DOC reduction >90% after 28 days
Appearance:	Brown slightly viscous liquid
Odor:	Sweet organic odor
Composition:	A blend of carbohydrates, water-soluble polymers, and solid mineral.

Section 10: STABILITY AND REACTIVITY

Stability/ Incompatibility:	Stable for a minimum of two years when stored in proper conditions (see above section 7)
Hazardous Reactions/Decomposition Products	Not determined
Reactivity:	Not determined
Chemical Stability:	Stable
Conditions To Avoid:	Storage above 50°C (120°F) or below 0°C (32°F). Avoid contact with strong oxidizing and reducing agents.
Incompatible Materials:	None
Hazardous Decomposition Products:	Not determined, None

Section 11: TOXILOGICAL INFORMATION

Signs, Symptoms of Over Exposure and First Aid Treatment:

Eye Contact: Reddening may develop. Immediately rinse the eye with large quantities of cool water. Continue 10-15 minutes or until material has been removed. Be sure to remove contact lenses, if present, and lift upper and lower lids during rinsing. Get medical attention if irritation persists.

Skin Contact: Minimal effects, if any. Rinse skin with water. Rinse shoes and launder clothing before reuse.

Swallowing: Essentially non-toxic. Product may cause a slight laxative condition. Give several glasses of water to dilute if swallowed. Do not induce vomiting. If stomach upset persists, consult a physician.

Inhalation: Non-toxic. Prolonged exposure to product in a mist form (not recommended) could cause a mild irritation of the nasal passages and throat. Remove to get fresh air. Get medical attention if irritation persists.

Section 12: ECOLOGICAL INFORMATION

Bio Accumulative Potential: The product exhibits ultimate biodegradability under anaerobic conditions as defined by US EPA methods (40 CFR part 796.3180).

Section 13: DISPOSAL CONSIDERATIONS

See section 6

Section 14: TRANSPORTATION INFORMATION

This product is non-toxic, transport in conditions described in section 7 above.
INTERNATIONAL AIR TRANSPORTATION ASSOCIATION: this product is not regulated by IATA, when shipped internationally.

Section 15: REGULATORY INFORMATION

SARA/TITLE III – CERCLA List of Hazardous Substances and Reportable Quantities (40 CFR 304.4): This product **does not** contain an ingredient(s) listed as a hazardous ingredient for Emergency Release Notification under section 304.

SARA/TITLE III – List of Extremely Hazardous Substances for Emergency Planning and Notification (40 CFR 300 & 305): This product **does not** contain an ingredient(s) listed as an extremely hazardous substance (EHS) for Emergency Planning under sections 301-303 and for Emergency Release Notification under section 304.
SARA/TITLE III – List of Toxic Chemical subject to Release Reporting (Community Right to Know) (40 CFR 372): This product **does not** contain an ingredient(s) listed as a toxic chemical for Annual Release Reporting Requirements under section 313.

Section 16: OTHER INFORMATION

Date of SDS Preparation:	August 2016
Original or Revised Copy:	Last Updated August 2016 **Reasonable care has been taken to ensure information and advice contained in this data sheet is accurate at the time of printing. However, Cypher Environmental Ltd. Accepts no liability for any loss or damages suffered as a consequence of reliance on the information contained herein.**
Changes Made to Original SDS:	
Disclaimers:	Please contact the supplier for application instructions, the application rate/procedure may fluctuate depending on specific uses of product and applications.

The above information pertains to this product as currently formulated, and is based on the information available at this time. Addition of reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information.

SMI, Inc.

12219 SW 131 Avenue
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Phone: (305) 971-7047
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Attn: Adrianne Veters
Cypher Environmental Ltd
1149 St Matthews Ave 2nd Floor,
Winnipeg, MB R3G 0J8
Canada

Date: 29-Sep-2017

SMI/REF: 1707-047

Product: **DUST STOP MUNICIPAL BLEND** *(received 07-Aug-2017)*

Dilution: As received and 10% by volume

BOEING D6-17487 REVISION T

Exterior and General Cleaners and Liquid Waxes, Polishes and Polishing Compounds

Sandwich Corrosion Test	Conforms
Acrylic Crazing Test	Conforms
Paint Softening Test	Conforms
Hydrogen Embrittlement Test	Conforms

Respectfully submitted,

Patricia D. Viani, SMI, Inc.

Sandwich Corrosion Test : Specimen preparation, testing, and interpretation shall be in accordance with ASTM F1110 using the following materials and with the following exceptions:

a. Reagents and materials exception:
   (1). Clad 7075-T6 aluminum alloy in accordance with QQ-A-250/13 (AMS 4049 or AMS-QQ-A-250/13 optional) (2024-T3 Alclad specimens are neither required nor optional.)
   (2) Bare 7075-T6 aluminum alloy in accordance with QQ-A-250/12 (AMS 4045 or AMS-Q-A-250/12 optional) anodized in accordance with BAC 5019 or MIL-A-8625, Type I.
   (3) Anodize shall be sealed. (2024-T3 nonclad specimens are neither required nor optional).
   (4) Distilled or deionized water may be used in place of ASTM F1193, Type IV reagent grade water for control specimens.
   (5) The filter paper may be Whatman No. 5 or equivalent in place of Whatman GFA glass fiber paper.

b. Procedure exceptions:
   (1) The filter paper strips shall be 1 by 3 inches and shall be placed in the center of the sandwiched specimens.
   (2) Each sandwich specimen shall be held together with waterproof tape, with no more than 1 piece of tape (maximum width 0.75 inch) on each of two opposite edges.

c. Interpretation of result exceptions:
   (1) Leaching or lightening of the chromate sealed anodize coating shall not be cause for rejection.
   (2) Deposits or residues from the material being tested that are not products of corrosion of the test panel surface shall not be cause for rejection.
   (3) Special procedure for evaluation of fire extinguishing foams and liquids.

   Panels with very light darkening or staining, which have no obvious metal attack or pitting, may be swabbed (cotton-tipped swabs or cotton gauze) with a 0.26 mole/liter sulfuric acid solution and re-examined. If the coloration is substantially removed and there is no evidence of metal attack or pitting, the condition shall not be cause for rejection. (The 0.26 mole/liter sulfuric acid solution can be prepared by adding 1.5 cc of concentrated sulfuric acid (SG = 1.84) to 100 cc of distilled or deionized water.

   (4) Panels shall have a rating of 1 (no more than 5 percent of the surface area shall be corroded) or better in accordance with ASTM F 1110. The preferred method of determining the corroded area is by using image analysis. Other means approved by the purchaser may be substituted.
   (5) Any corrosion in excess of that shown by the control group shall be cause for rejection.

Sandwich Corrosion Test :continued

	Bare 7075-T6 (AMS 4045) Anodized per BAC 5019 (chromate seal) or MIL-A-8625 Type I with Dichromate Seal	Clad 7075-T6 Aluminum (AMS 4049)
CONCENTRATE	**1**	**1**
DILUTE	**1**	**1**
CONTROL	1	1

Result Conforms

Acrylic Crazing Test:

The material being tested shall not craze, crack, or etch acrylic test specimens when tested in accordance with ASTM F 484 using Type C (stretched acrylic plastic in accordance with MIL-P-25690) stressed to an outer fiber stress of 4500 psi.

Type C (MIL-P-25690) ***Concentrate: No crazing, cracking or etching.***
Dilute: No crazing, cracking, or etching.

Result Conforms

Paint Softening Test Procedure:

a. Testing shall be in accordance with ASTM F502 using the following coating systems.
   (1) BMS 10-79, Type II primer applied in accordance with BAC5882 plus BMS 10-60, Type II enamel in accordance with BAC5845.
   (2) BMS 10-79, Type III primer applied in accordance with BAC5882, plus BMS 10-100 coating in accordance with BAC5797.

b. Three specimens conforming to Section 12a.(1) and three specimens conforming to Section 12a(2) shall be used for each test condition.

c. The material being tested shall not produce a decrease in film hardness greater than two pencils, or any discoloration or staining.
   NOTE: Slight darkening of the BMS 10-100 surface is acceptable.

Concentrate: *Paint system 1: ≤ 1 pencil hardness change after 24 hour post-exposure dry time.*
Paint system 2: ≤ 1 pencil hardness change after 24 hour post-exposure dry time.

Dilute: *Paint system 1: ≤ 1 pencil hardness change after 24 hour post-exposure dry time.*
Paint system 2: ≤ 1 pencil hardness change after 24 hour post-exposure dry time.

Result Conforms

Hydrogen Embrittlement Test:

Hydrogen Embrittlement testing shall be in accordance with ASTM F 519 using cadmium plated Type 1a.2, Type 1c, or Type 2a specimens. All requirements of ASTM F519 for specimens, preparation, testing, and reporting shall apply. Type 1a.2 specimens shall meet the requirements of D6-4307.

Specimens: Type 1c, cadmium plated per MIL-STD-870.
(45% load, 150 hours, notched immersed for the duration, room temp.)

Concentrate:	***#1:***	***No failure occurred within 150 hours.***
	#2:	***No failure occurred within 150 hours.***
	#3:	***No failure occurred within 150 hours.***
	#4:	***No failure occurred within 150 hours.***
Dilute:	***#1:***	***No failure occurred within 150 hours.***
	#2:	***No failure occurred within 150 hours.***
	#3:	***No failure occurred within 150 hours.***
	#4:	***No failure occurred within 150 hours.***

Result Conforms

Cypher Environmental Ltd.
ATTN: Teaghan Wellman
1149 St. Matthews Avenue
2nd Floor
Winnipeg Manitoba R3G 0J8

Date Received: 03-FEB-17
Report Date: 10-FEB-17 13:06 (MT)
Version: FINAL

Client Phone: 204-489-1214

Certificate of Analysis

Lab Work Order #: L1886901

Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Judy Dalmaijer
Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1886901-1 40L OF 0.25% DUST STOP							
Sampled By: CLIENT on 03-FEB-17							
Matrix: LIQUID							
Miscellaneous Parameters							
Trout Bioassay LC50	See attached.					03-FEB-17	R3649799

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
TROUT-LC50-WP	Water	Trout Bioassay LC50	EPS 1/RM/13, EPS 1/RM/9

Certified, disease-free rainbow trout (Oncorhynchus mykiss) are exposed to several concentrations of a sample including full strength, under static conditions in order to estimate the median lethal concentration (LC50) - the concentration of the sample in water that is estimated to be lethal to 50% of the test organisms within a 96-hour exposure period.

Samples with excessive salinity (reported as conductivity greater than 13700 µmhos/cm) discharging into marine waters will require alternate testing.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Rainbow Trout Bioassay Test Report - LC50

Sample ID:	L1886901-1

Summary Results

96-hour LC50 v/v (%):	Non-Lethal
95% Lower Confidence Interval (%):	n/a
95% Upper Confidence Interval (%):	n/a
Method of Calculation:	n/a
Confirmed by Graph:	n/a

Sample Information

Sample Origin:	Cypher Environmental
Sample Description:	40L of 0.25% Dust Stop
Sampling Date and Time:	03-Feb-17
Sampling Method:	Grab
Sampled By:	Not Provided
Container(s) Description:	2 x 20L polyethylene pails without liners
Sample Volume:	40L
Date and Time Received:	03-Feb-17 14:40
Transit Irregularities:	None
Storage Temperature (˚C):	n/a

Test Information

Test Organism:	Oncorhynchus mykiss
Test Description:	Acute, 96-hour, Static, LC50
Reference Method(s):	EPS 1/RM/13, 2nd Ed. Dec. 2000, with 2007 and 2016 amendments, Environment Canada EPS 1/RM/9, May 1996 with May 2007 amendments, Environment Canada
Performed By:	AGJ
Starting Date and Time:	03-Feb-17 16:45
Deviations from Reference Method:	None

Initial Parameters

Observations

Colour:	Dark Brown					
Odour:	Mild					
Turbidity:	High					
Solids:	High					
Hardness (mg/L):	2.5	mL Titration Solution/	10	mL of Sample x 1000 =	250	
Alkalinity (mg/L):	1.4	mL Titration Solution/	10	mL of Sample x 1000 =	140	
Temperature (°C):	14.4	Thermometer		S/N 91154465		
Dissolved Oxygen (mg/L):	6.15	YSI Dissolved Oxygen Meter		S/N 15M102668		
Conductivity (µS/cm):	696	VWR Portable Conductivity Meter		S/N 51071543		
pH (5.5-8.5 pH units):	8.86	VWR SympHony pH Meter		S/N D01908		
pH Adjustment:	Not Adjusted					
pH Adjustment Procedure:	n/a					

Pre-Aeration

Aeration Time (min):	30					
Sample Test Concentration (v/v):	0.250%	0.125%	0.063%	0.031%	0.016%	0%
Aeration Rate (5.5-7.5 mL/min/L):	6.1 ± 0.2	6.1 ± 0.2	6.1 ± 0.2	6.1 ± 0.2	6.1 ± 0.2	6.1 ± 0.2
xygen (D.O.) Before Pre-Aeration (%):	75.7	n/a	n/a	n/a	n/a	93.4
Average D.O. After Pre-Aeration (%):	83.2	n/a	n/a	n/a	n/a	96.3

Test Organism Data

Lot Number:	11/01/17 T3
Weekly Mortality Preceeding Test (%):	0
Sample Size:	10

Conditions Common to All Concentrations During Test

Source of Holding/Dilution Water:	Dechlorinated UV Treated City of Winnipeg Tap Water
Container Description:	20 L Polyethylene Pail with Liner
Aeration Method:	Compressed air bubbled through silica-glass air diffuser
Aeration Rate (5.5-7.5 mL/min/L):	(as set during pre-aeration above)
Test Solution Volume (L):	20
Test Solution Depth (cm):	34
Number of Test Organisms per Container:	10
Loading Density (g/L):	0.23

Conditions During Test

Concentration (% v/v)	Temperature (˚C) (15 ± 1˚C)					Dissolved Oxygen (mg/L)					pH (pH units)				
	0h	24h	48h	72h	96h	0h	24h	48h	72h	96h	0h	24h	48h	72h	96h
0	14	n/a	n/a	n/a	14	9.81	n/a	n/a	n/a	9.72	7.51	n/a	n/a	n/a	7.68
0.016	14	n/a	n/a	n/a	14	9.93	n/a	n/a	n/a	9.66	7.58	n/a	n/a	n/a	7.38
0.031	14	n/a	n/a	n/a	14	9.79	n/a	n/a	n/a	9.59	7.61	n/a	n/a	n/a	7.42
0.063	14	n/a	n/a	n/a	14	9.43	n/a	n/a	n/a	9.57	7.84	n/a	n/a	n/a	7.52
0.125	14	n/a	n/a	n/a	14	8.52	n/a	n/a	n/a	9.37	8.18	n/a	n/a	n/a	7.52
0.25	14	n/a	n/a	n/a	14	6.78	n/a	n/a	n/a	7.21	8.86	n/a	n/a	n/a	7.36

Conc. (% v/v)	Conductivity (µS/cm)	Number of Fish Dead				Number of Fish Stressed			
	0h	24h	48h	72h	96h	24h	48h	72h	96h
0	332	n/a	n/a	n/a	0	n/a	n/a	n/a	0
0.016	355	n/a	n/a	n/a	0	n/a	n/a	n/a	0
0.031	394	n/a	n/a	n/a	0	n/a	n/a	n/a	0
0.063	452	n/a	n/a	n/a	0	n/a	n/a	n/a	0
0.125	546	n/a	n/a	n/a	0	n/a	n/a	n/a	0
0.25	700	n/a	n/a	n/a	0	n/a	n/a	n/a	0

Control Fish Information at End of Test

Mean Fork Length (mm):	38
Lower Range Fork Length (mm):	36
Upper Range Fork Length (mm):	40
Mean Wet Weight (g):	0.47

Mortality and Stressed Behaviour Information

Conc. (% v/v)	Mean Number of Fish at End of Test		Mean Rate of Fish at End of Test (%)	
	Dead	**Stressed**	**Dead**	**Stressed**
0	0	0	0	0
0.016	0	0	0	0
0.031	0	0	0	0
0.063	0	0	0	0
0.125	0	0	0	0
0.25	0	0	0	0

Median Lethal Concentration Results for Multi-Concentration Tests

LC50:	Non-Lethal
LC50 Lower 95% Confidence Limit:	n/a
LC50 Upper 95% Confidence Limit:	n/a
Statistical Method:	n/a

Note: Non-lethal = 0 mortality

Reference Toxicant Test Results

Reference Toxicant:	Zinc Sulfate
Date Reference Toxicant Initiated:	26-Jan-17
Recent 96h Reference Toxicant Test LC50 (mg/L Zinc):	0.33
Lower 95% Confidence Limit (mg/L Zinc):	0.23
Upper 95% Confidence Limit (mg/L Zinc):	0.46
Historic Geometric Mean LC50 (mg/L Zinc):	0.64
Lower 95% Confidence Limit (mg/L Zinc):	0.27
Upper 95% Confidence Limit (mg/L Zinc):	1.51
Method of Calculation:	Stephan LC50 Program, Probit
Confirmed by Graph:	Yes

Sublethal Biological Effects

No sublethal biological effects observed.

Observations/Comments

No toxicity observed.

10- 231632

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

L1886901

Page ____ of ____

Report To	**Report Format / Distribution**	**Service Request:** (Rush subject to availability - Contact ALS to confirm TAT)
Company: Cypher Environmental	Standard: X Other (specify):	Regu
Contact: Teaghan Wellman	Select: PDF X Excel Digital Fax	Priorit
Address: 1149 St. Matthews Ave	Email 1: teaghan@cypherenvironmental.com	Emer
	Email 2:	Same
Phone: 204-489-1214 Fax:		
Invoice To Same as Report ? (circle) Yes or (No) (if No, provide details)	**Client / Project Information**	(Indicate Filtered or Preserved, F/P)
Copy of Invoice with Report? (circle) (Yes) or No	Job #:	
Company: Cypher Environmental	PO / AFE:	
Contact: Maureen Sutherland	LSD:	
Address: 1149 St. Matthews Ave		
Phone: 204-489-1214 Fax:	Quote #:	
Lab Work Order # (lab use only)	**ALS Contact:**	**Sampler:**

L1886901-COFC

Contact Lee Ann for Test.

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Number of Containers
	40L of 0.25% Dust Stop.	2/3/17		liquid	2.

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by:	Date:	Time:	Temperature:	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF
				Feb 3/17	2:40p	29 °C				

THE RURAL MUNICIPALITY OF MACDONALD

October 7, 2016

To Whom It May Concern:

We have recently applied Cypher Environmental's new Dust Stop Municipal Blend (DSMB) product to on La Verendrye Road within the municipality. The site runs off the Perimeter Highway west, between Wilkes Avenue and McGillivray Blvd. and is a very heavily trafficked road. DSMB was advertised to be competitive with chlorides in terms of cost and effectiveness and so far has performed well and exhibited excellent properties during and after rain. The product has stood up to the elements very well thus far, with several periods of rain and hot, dry and windy weather.

We were also pleased with the great customer support, including both remotely and on-site assistance during the application of the product. We continue to see more than satisfactory results and are happy with the dust and erosion control provided.

We look forward to future projects involving Cypher Environmental.

Sincerely,

Grant Baker
Public Works Manager
Rural Municipality of MacDonald
161 Mandan Drive
Sanford, Manitoba, Canada
R0G 2J0
Phone: 204-736-2214
Email: gbaker@rmofmacdonald.com
www.rmofmacdonald.com

August 22, 2017

To Whom It May Concern:

We have recently applied Cypher Environmental's new Dust Stop Municipal Blend (DSMB) product to on Victor Avenue within the municipality. DSMB was advertised to be competitive with chlorides in terms of cost and effectiveness and so far has performed well and exhibited excellent properties during and after rain. The product has stood up to the elements very well thus far, with periods of rain and hot, dry and windy weather.

We were also pleased with the great customer support, including both remotely and on-site assistance during the application of the product. We continue to see more than satisfactory results and are happy with the dust and erosion control provided.

We look forward to future projects involving Cypher Environmental.

Sincerely,

Rick Gamble
Mayor
Village of Dunnottar
PO Box 321
Matlock, Manitoba, Canada
R0C 2B0
Phone: 204-389-4962
Email: info@dunnottar.ca
www.dunnottar.ca

Appendix D: Figures

AGNICO EAGLE

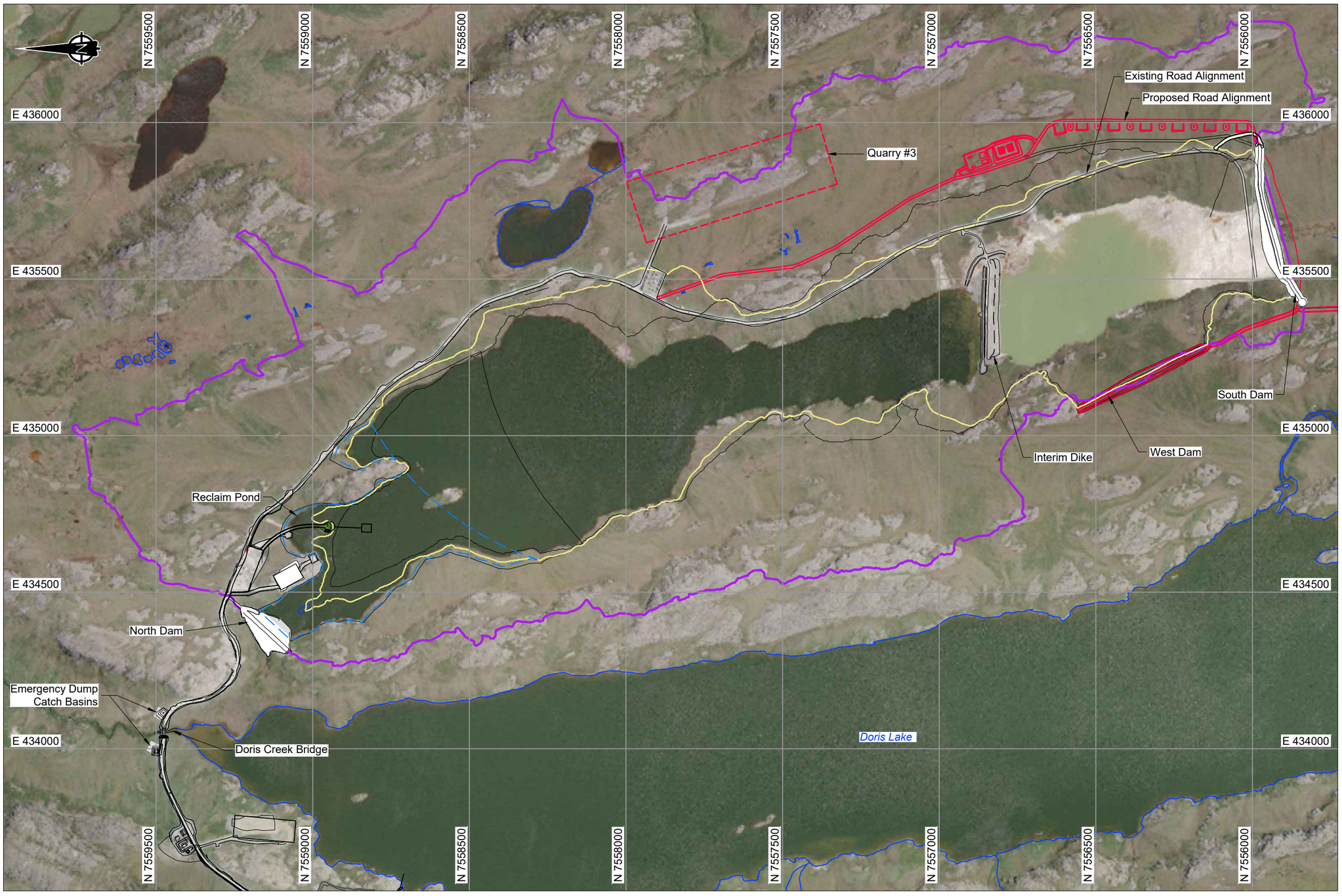
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

Site Location Plan

DATE:	APPROVED:	FIGURE:
March 2024	BJ	1

Original figure produced by SRK consulting (May 2016), updated by Agnico (March 2024).



LEGEND

- Existing Infrastructure
- Proposed Infrastructure
- Quarry
- Ultimate Reclaim Pond Extent
- Ultimate Tailings Extent
- Watershed Boundary

NOTES

1. All units are in meters unless otherwise specified.

REFERENCES

NAD83 UTM Zone 13.
NAD83 CSRS UTM Zone 13.
Maxar (Vivid) imagery from ESRI World Imagery, July 18, 2023.
Tailings Beach survey collected by drone LiDAR in August 2021, data provided by client.

0m 100 200 300 400 500

Original figure produced by SRK Consulting (June 2020), updated by Agnico (March 2024).

AGNICO EAGLE

Doris TIA

DORIS TIA OMS MANUAL

Site General Arrangement

DATE:	APPROVED:	FIGURE:
March 2024	BJ	2

N 7560000
N 7559000
N 7558000
N 7557000
N 7556000

Doris Creek Bridge
Secondary Road
North Dam
Existing Road Alignment
Doris Camp
Reclaim Pond
Doris Connector Vent Raise and Acess Road
Doris Central Vent Raise and Access Road
Planned Quarry #3
DORIS LAKE
Proposed Road Alignment
Doris-Windy Road
West Dam
South Dam
OGAMA LAKE

E 434000
E 435000

0m 100 200 300 400 500 600

NOTES

1. Contours shown at 0.5m Intervals.
2. NAD 83 UTM Zone 13

LEGEND

- Proposed Tailings Facility
- Proposed Dam/Dikes
- Existing Facilities
- Existing Doris Camp
- Proposed Road Realignment

AGNICO EAGLE

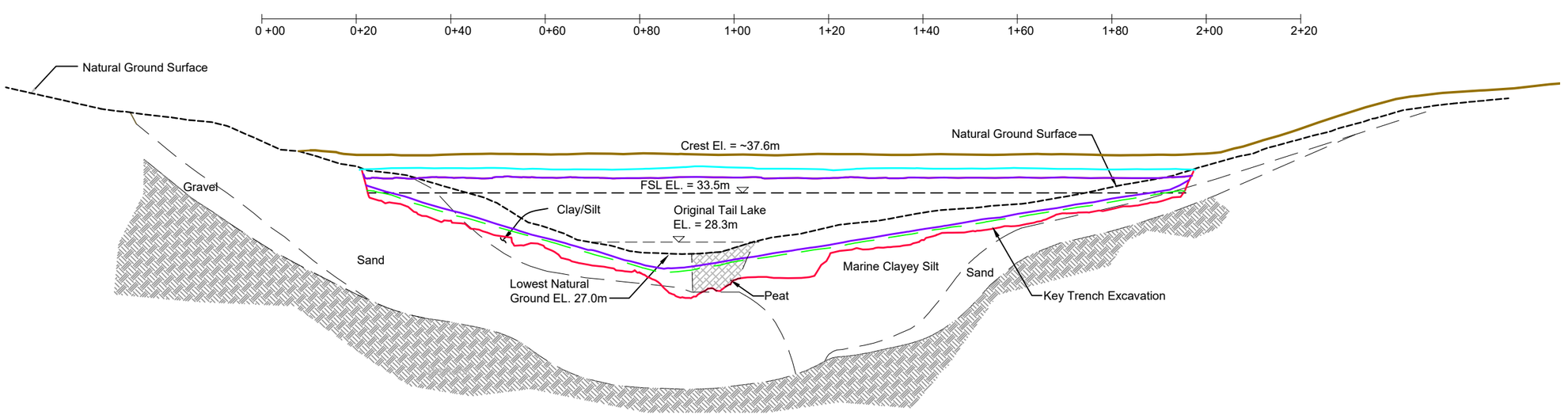
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

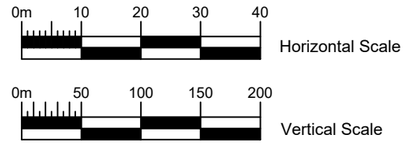
TIA Site Overview (End Phase 2)

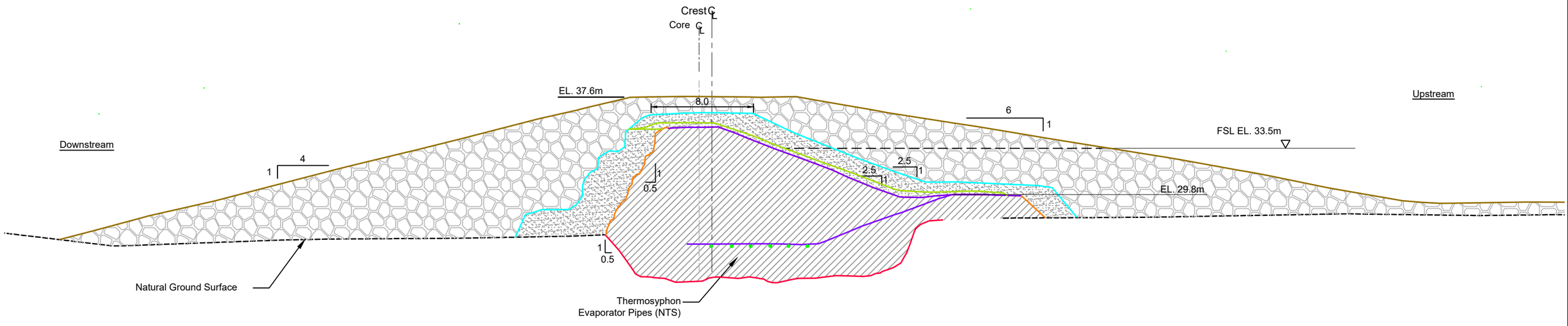
DATE:	APPROVED:	FIGURE:
March 2024	BJ	3

Original figure produced by SRK Consulting (May 2018), updated by Agnico (March 2024).

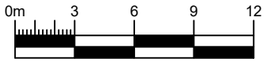


SECTION ALONG NORTH DAM CREST CENTERLINE





NORTH DAM TYPICAL SECTION



LEGEND

- Natural Ground
- Stratigraphic Boundary
- Core Material
- Transition Material
- Run of Quarry (ROQ)
- Surfacing Material
- Bedrock
- Peat
- Thermosyphon Evaporator Pipe (NTS)
- Geosynthetic Clay Liner (GCL)
- Core Material
- Key Trench
- GCL Cover Material
- Transition Material
- ROQ Material
- Thermosyphon Evaporator Pipes
- Thermosyphon Evaporator Pipes

NOTES

1. The subsurface geology has been extrapolated from a series of geotechnical investigations consisting of drill holes, auger holes and shallow test pits. Bedrock contact and geological unit contacts are therefore likely to vary somewhat.

REFERENCES

Diagram Source: 2021 Annual Geotechnical Inspections (SRK 2022)

Original figure produced by SRK Consulting (March 2020), updated by Agnico (March 2024).

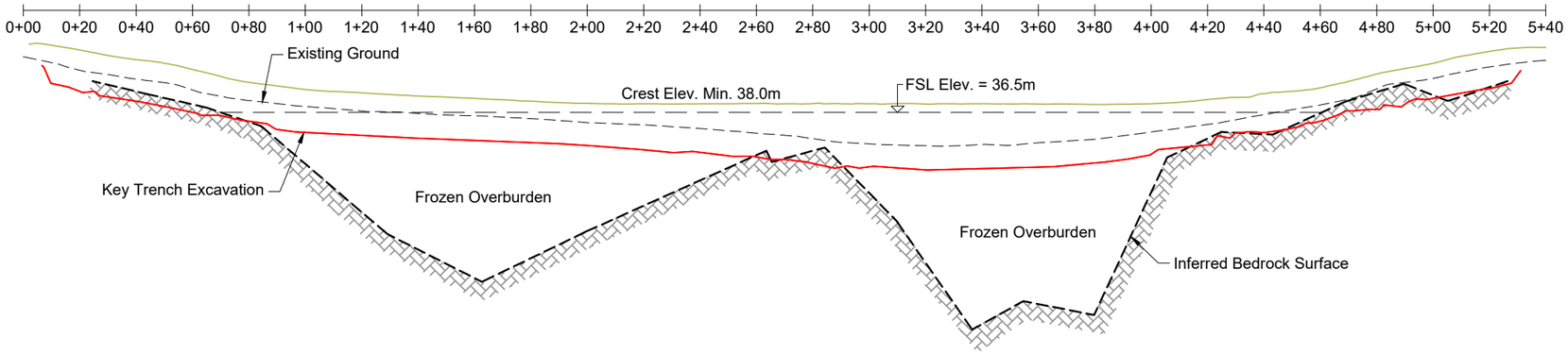
AGNICO EAGLE

Doris TIA

DORIS TIA OMS MANUAL

North Dam Foundation Conditions and Typical As-Built Section

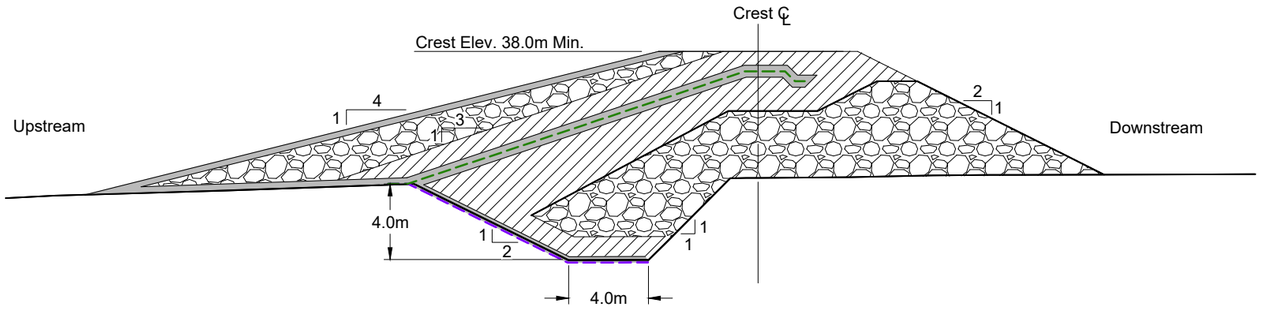
DATE:	APPROVED:	FIGURE:
March 2024	BJ	4



SECTION ALONG
SOUTH DAM CREST CENTERLINE

0m 20 40 60 80 Horizontal

0m 10 20 30 40 Vertical



SOUTH DAM TYPICAL SECTION

0m 3 6 9 12

LEGEND

- Thermistor Bead Location
- Lower GCL Liner
- Upper GCL Liner
- Bedding Material
- Transition Material
- Run of Quarry Backfill

NOTES

1. Topographic and as-built contour data from the terrain model was provided by the Client.
2. All units shown are in meters unless otherwise stated.

REFERENCES

Diagram Source: 2021 Annual Geotechnical Inspections (SRK 2022)

Original figure produced by SRK Consulting (March 2020), updated by Agnico (March 2024).

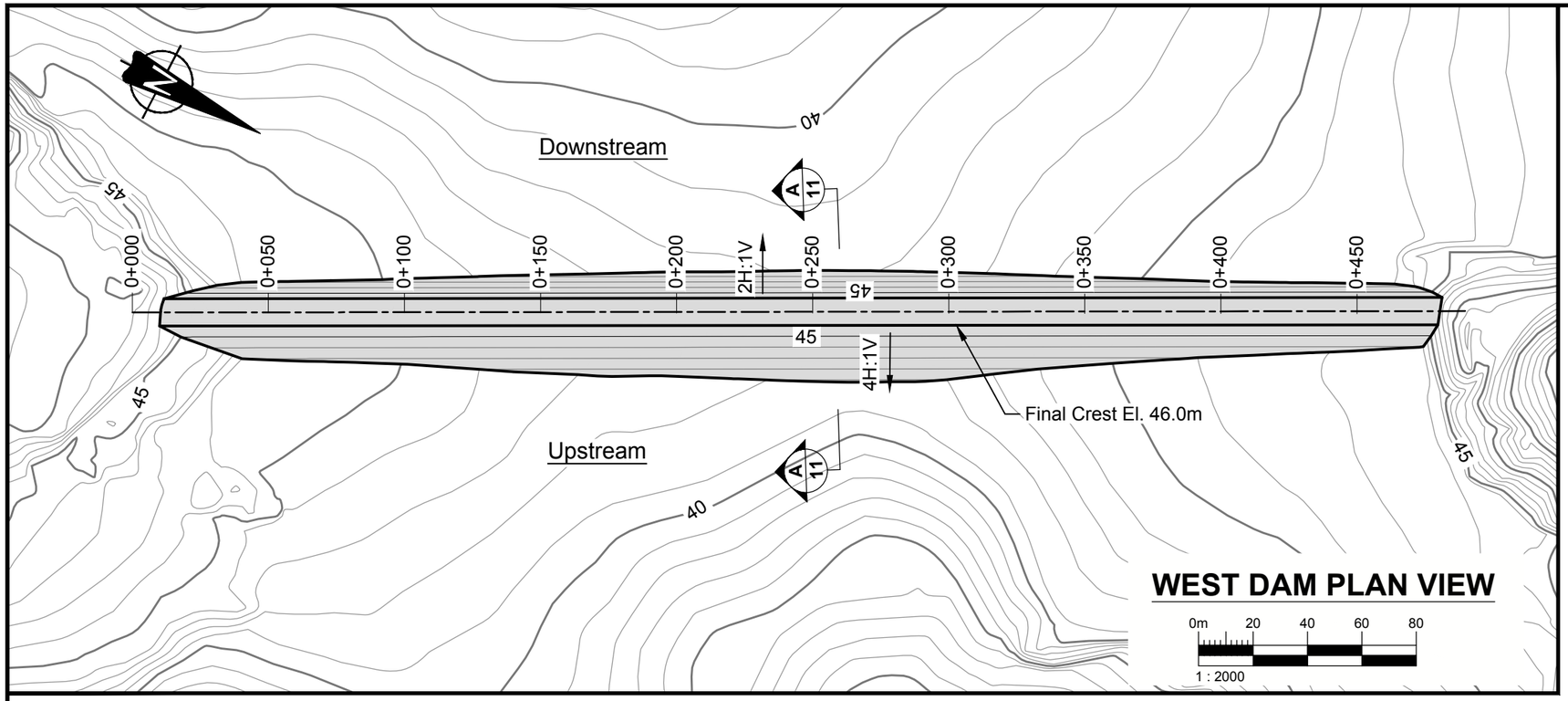
AGNICO EAGLE

Doris TIA

DORIS TIA OMS MANUAL

South Dam Foundation Conditions and Typical As-Built Section

DATE:	APPROVED:	FIGURE:
March 2023	BJ	5



WEST DAM PLAN VIEW

0m 20 40 60 80

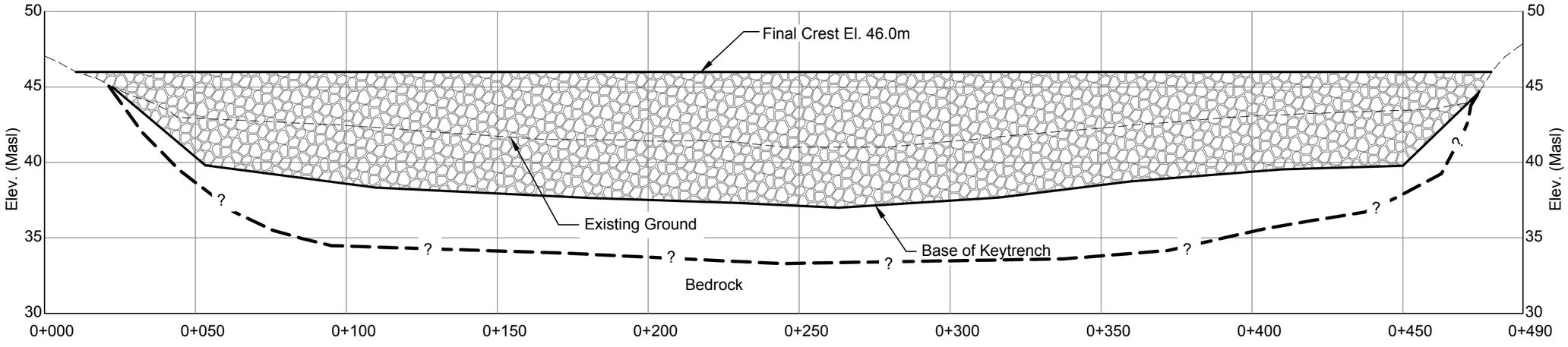
1 : 2000

LEGEND

- Natural Ground
- Approximate Stratigraphic Boundary
- Run of Quarry (ROQ)

NOTES

1. All dimensions and elevations are in meters unless stated otherwise.
2. The subsurface geology has been extrapolated from a series of geotechnical investigations. Bedrock contact and geological unit contacts are therefore likely to vary somewhat during final excavation.



WEST DAM PROFILE

5x EXAGGERATION

0m 10 20 30 40 50 60

Horizontal Scale

Original figure produced by SRK Consulting (May 2016), updated by Agnico (March 2024).

AGNICO EAGLE

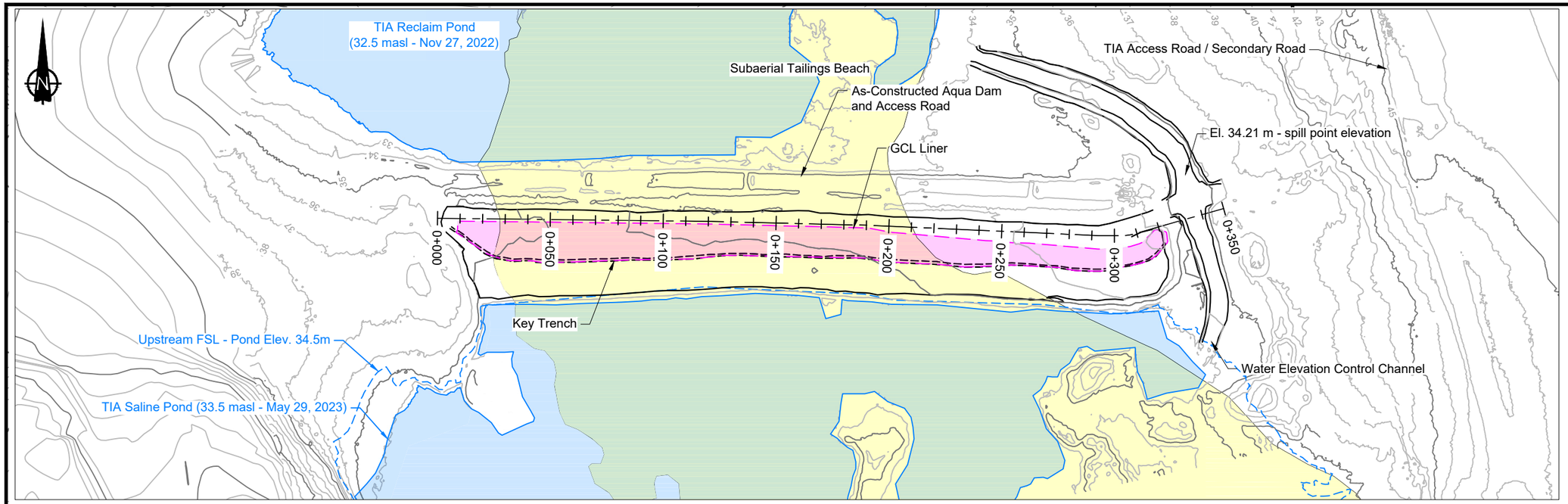
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

West Dam

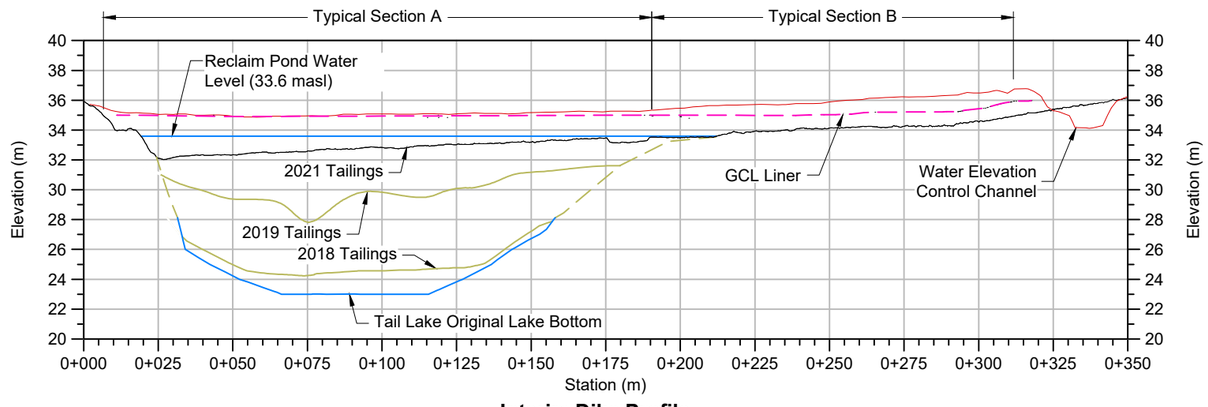
Plan and Profile

DATE:	APPROVED:	FIGURE:
March 2024	BJ	6



Interim Dike Plan View

0m 20 40 60 80



Interim Dike Profile

0m 4 8 12 16 Vertical

0m 20 40 60 80 Horizontal

LEGEND

- As-Constructed
- TIA Reclaim Pond Water Level
- Upstream Full Supply Level (Elev. 34.5m)
- Geosynthetic Clay Liner
- Subaerial Tailings Beach
- Shallow Submerged Tailings Beach

NOTES

1. Contours are shown at 1.0 m intervals.
2. All units are in meters unless otherwise specified.
3. The GCL shown in the drawings is an estimated extent based on the other survey information and site observation. No GCL survey was provided in the turnover package from the construction surveyor. Installation was witnessed by SRK representatives.

REFERENCES

NAD83 UTM Zone 13.
Record Surveys made from - Drone Survey provided by client. File name: "IRB 29052023_dsm_10cm.laz" and additional survey provided by client 20230608 and 20230829. File names: "AB-ROM.txt" and 230829_AB IRB_south toe dam.dwg

Original figure produced by SRK Consulting (Feb 2024), adapted by Agnico (March 2024).

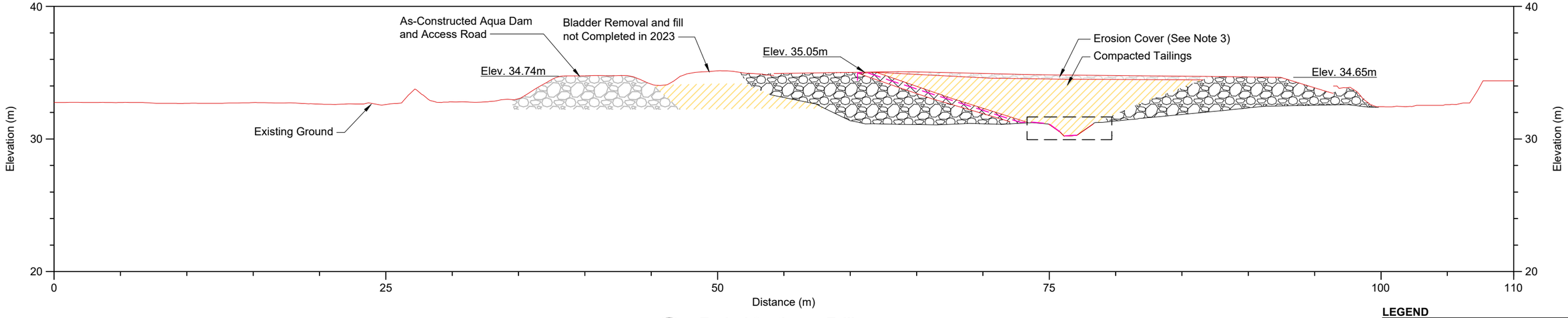
AGNICO EAGLE

HOPE BAY PROJECT

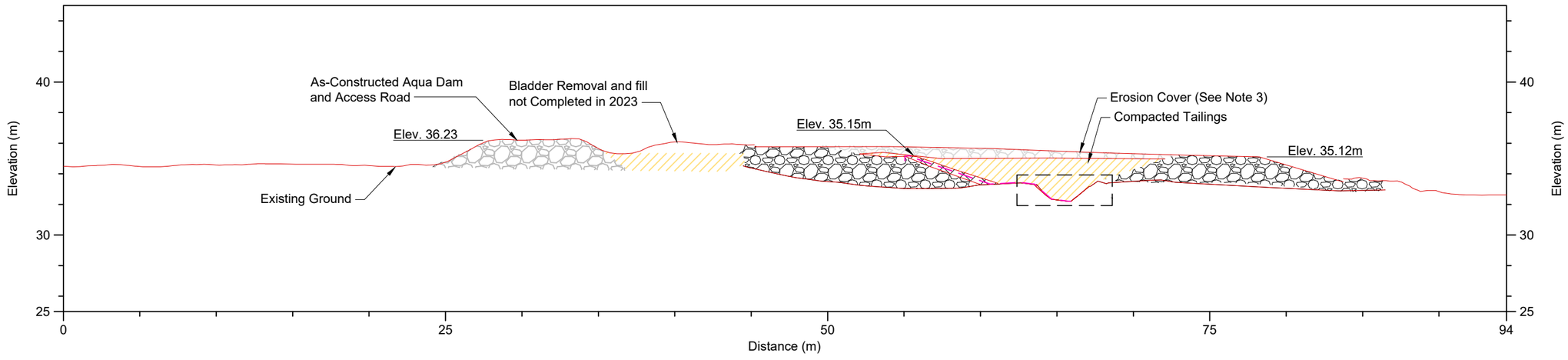
DORIS TIA OMS MANUAL

Interim Dike Plan and Profile

DATE:	APPROVED:	FIGURE:
March 2024	BJ	7



Typical Section on Tailings



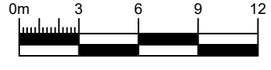
Typical Section on Overburden

LEGEND

- Geosynthetic Clay Liner
- Bedding / Transition Material
- Compacted Tailings
- Erosion Cover (ROQ)
- Waste Rock Fill

NOTES

1. All units are in meters unless otherwise specified.
2. The GCL shown in the drawings is an estimated extent based on the other survey information and site observation. No GCL survey was provided in the turnover package from the construction surveyor. Installation was witnessed by SRK representatives.
3. No survey provided for top of compacted tailing, transition to Erosion Cover is inferred.



AGNICO EAGLE

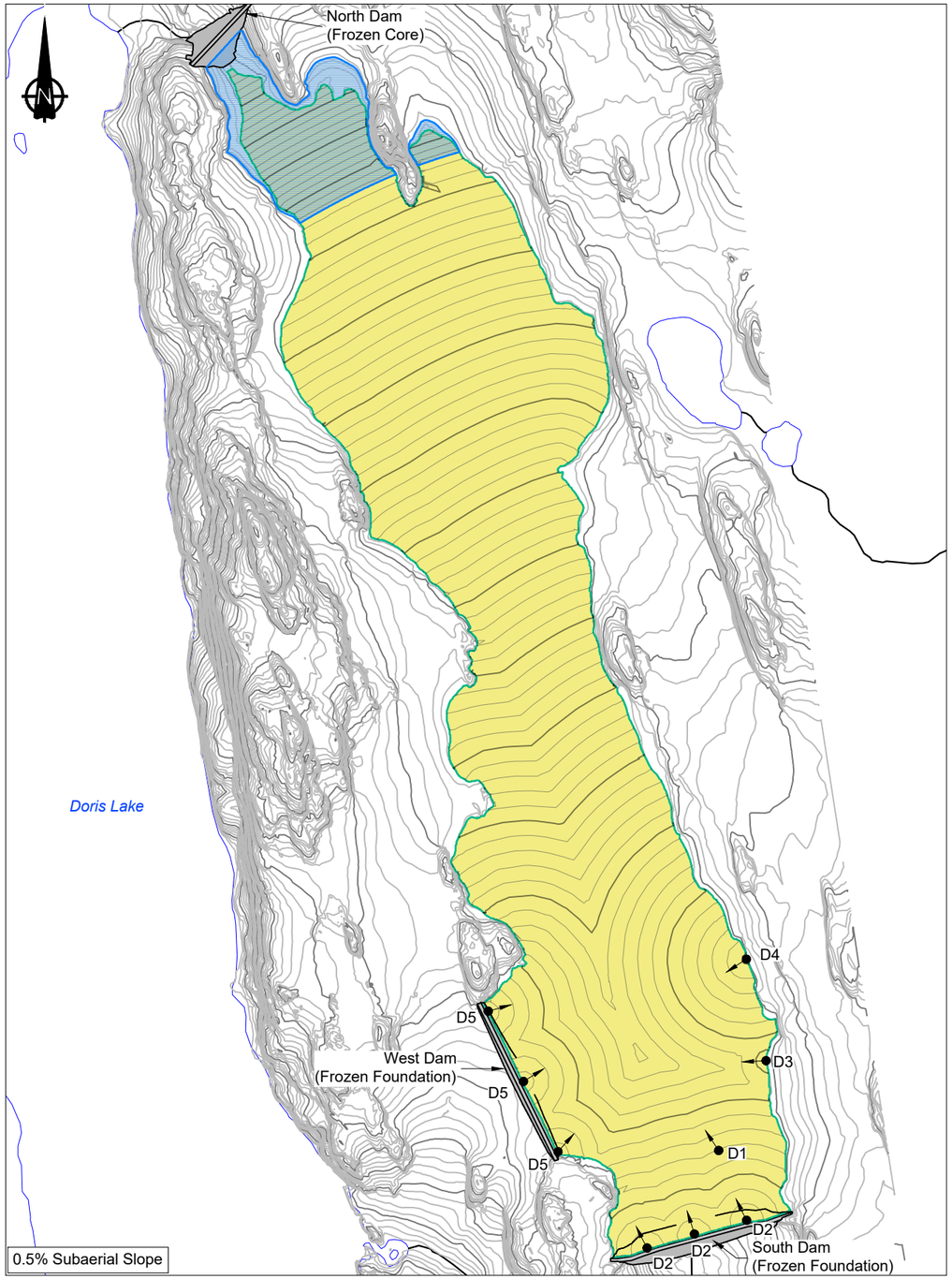
HOPE BAY PROJECT

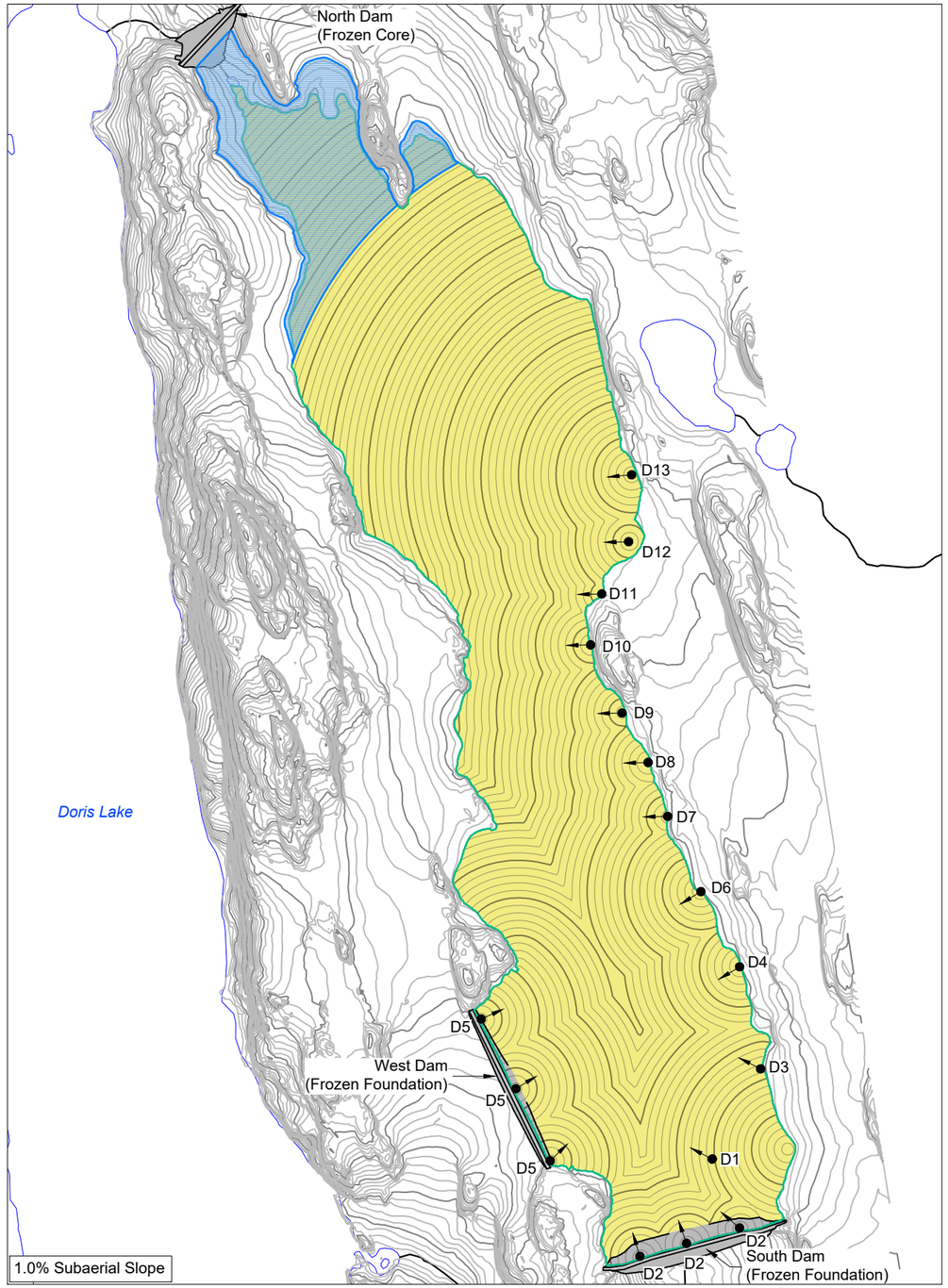
DORIS TIA OMS MANUAL

Interim Dike Typical Sections

DATE:	APPROVED:	FIGURE:
March 2024	BJ	8

Original figure produced by SRK Consulting (Feb 2024), adapted by Agnico (March 2024).





LEGEND

- Spigot Location
- Deposited Tailings

NOTES

1. Deposition durations are approximate and were based on the Mine Plan average production rates provided by TMAC Resources.
2. A deposited tailings dry density of 1.3t/m³ was used.
3. All tailings volumes presented include ice entrainment at 20% of production.
4. Dam elevations shown were assumed constant throughout deposition.
5. Total storage requirements includes Madrid and Boston Tailings (Tailings 11.6Mm³ + Ice Entrainment 2.3Mm³).

REFERENCE

NAD83 UTM Zone 13.

0m 3 6 9 12

Note:
Final tailings beach slope will be based on operation. Tailings beach will be somewhere between 0.5% and 1% slope; based on latest as-built survey and operations data (as of December 2019).

Original figure produced by SRK Consulting (April 2020), updated by Agnico (March 2024).

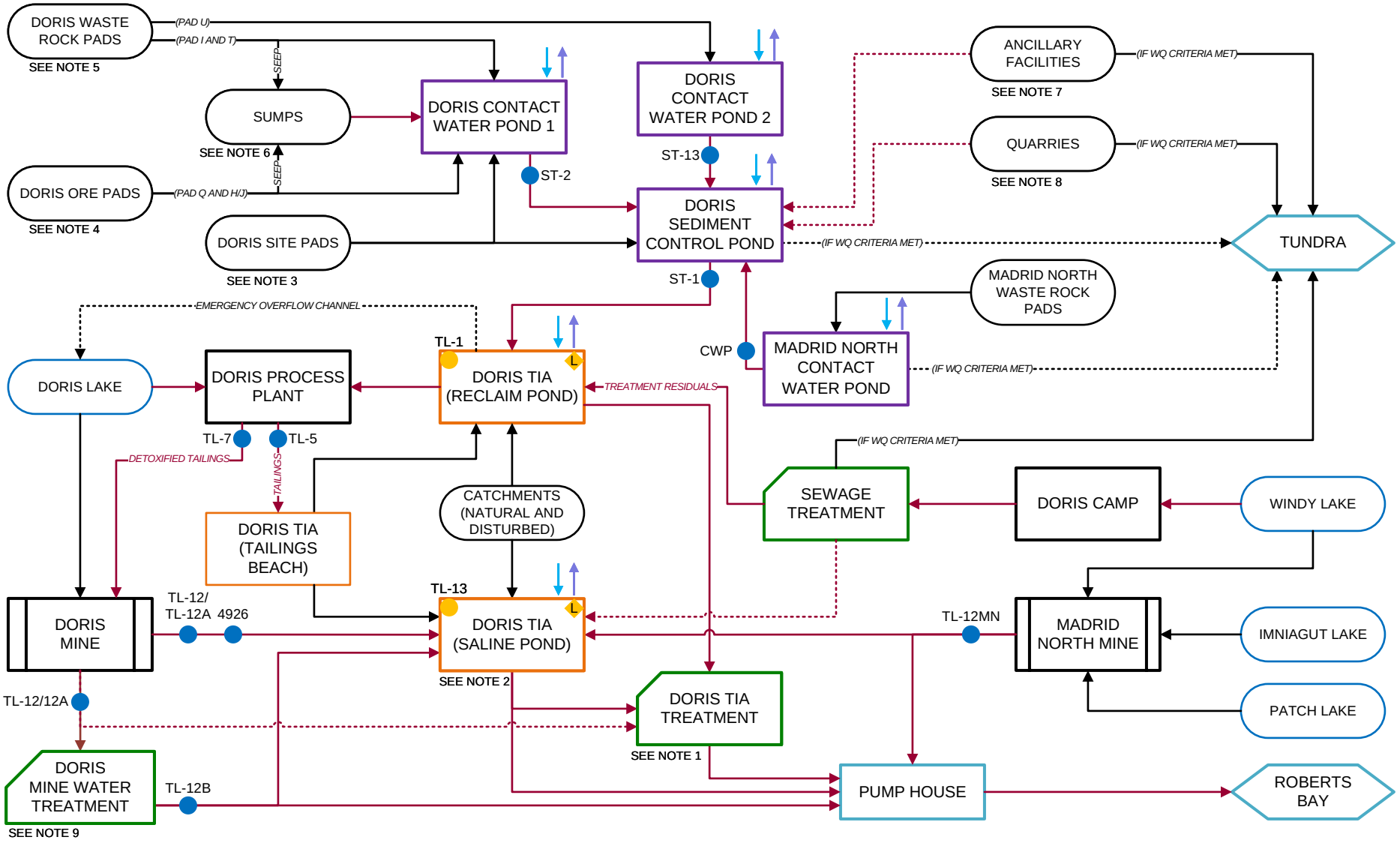
AGNICO EAGLE

Doris TIA

DORIS TIA OMS MANUAL

Planned Tailings Deposition
(Phase 1 & Phase 2) - End of Mine

DATE:	APPROVED:	FIGURE:
March 2023	BJ	9



NOTES

1. TSS TREATMENT IMPLEMENTED JULY, 2022, VIA BAG FILTER. SOLE FEED OF DORIS MINE WATER, SALINE POND OR TIA. TREATMENT RESSIDUALS FOR DORIS MINE WATER AND SALINE POND DEPOSITED INTO SALINE POND, FOR TIA DEPOSTIED IN TIA.
2. DORIS TIA SALINE POND LOCATED AT THE SOUTH TAILINGS BEACH; SEGREGATED FROM THE MAIN TIA USING AN AQUADAM UNTIL MAY 2023 THEN REPLACED WITH A ROCK EMBANKMENT.
3. DORIS SITE PADS INCLUDE SITE BUILDINGS, INFRASTRUCTURE, AND LAYDOWNS.
4. DORIS ORE PADS Q AND H/J.
5. DORIS WASTE ROCK PADS T AND I. PAD U TO BE CONSTRUCTED 2024.
6. SUMPS 1, 2, AND 3 USED TO COLLECT SEEPAGE.
7. ANCILLARY FACILITIES INCLUDE FUEL TANK FARM, LANDFARM, AND LANDFILL.
8. ACTIVE WATER MANAGEMENT FOR QUARRIES A, B, AND D. QUARRIES E, AI, AND 5 TO BE DEVELOPED STARTING 2023.
9. TREATMENT RESIDUALS PREVIOUSLY DEPOSITED IN SCP, NOW DEHYDRATED.

LEGEND

FLOW TYPES
- CONTROLLED
- GRAVITY/PASSIVE
- CONTINGENCY
- PRECIPITATION/EVAPORATION

MONITORING STATIONS
- FLOW AND WQ DATA USED AS INPUT
- WQ USED FOR CALIBRATION
- WATER LEVEL USED FOR CALIBRATION

AGNICO EAGLE

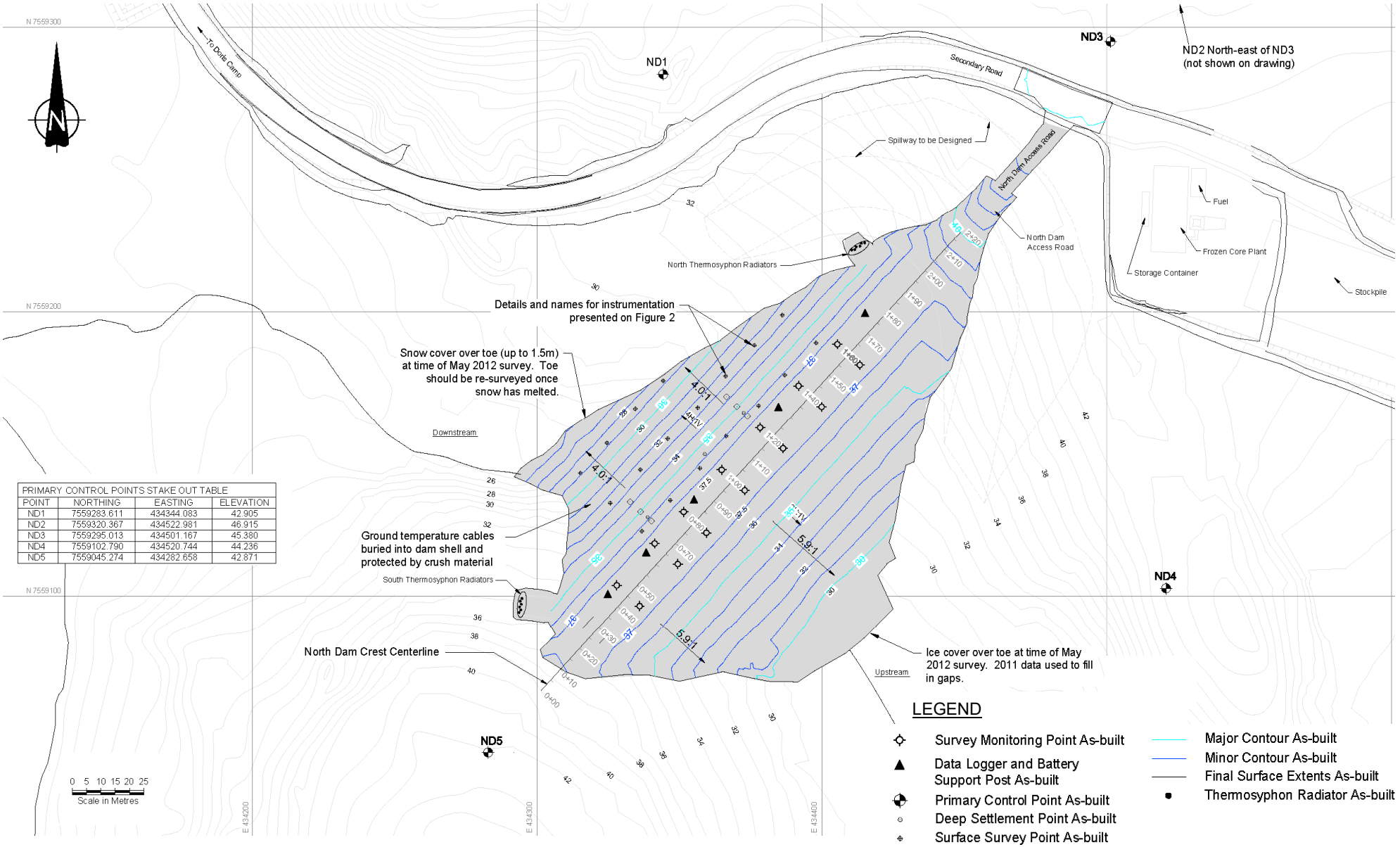
Doris TIA

DORIS TIA OMS MANUAL

Schematic of TIA Water Management

Date:	Approved:	Figure:
March 2024	BJ	10

Original figure produced by SRK Consulting (March 2024), adapted by Agnico (March 2024).



PRIMARY CONTROL POINTS STAKE OUT TABLE			
POINT	NORTHING	EASTING	ELEVATION
ND1	7559283.611	434344.083	42.905
ND2	7559320.367	434522.981	46.915
ND3	7559295.013	434501.167	45.380
ND4	7559102.790	434520.744	44.236
ND5	7559045.274	434282.658	42.871

LEGEND

- Survey Monitoring Point As-built
- Data Logger and Battery Support Post As-built
- Primary Control Point As-built
- Deep Settlement Point As-built
- Surface Survey Point As-built
- Inclinometer Location As-built
- Major Contour As-built
- Minor Contour As-built
- Final Surface Extents As-built
- Thermosyphon Radiator As-built

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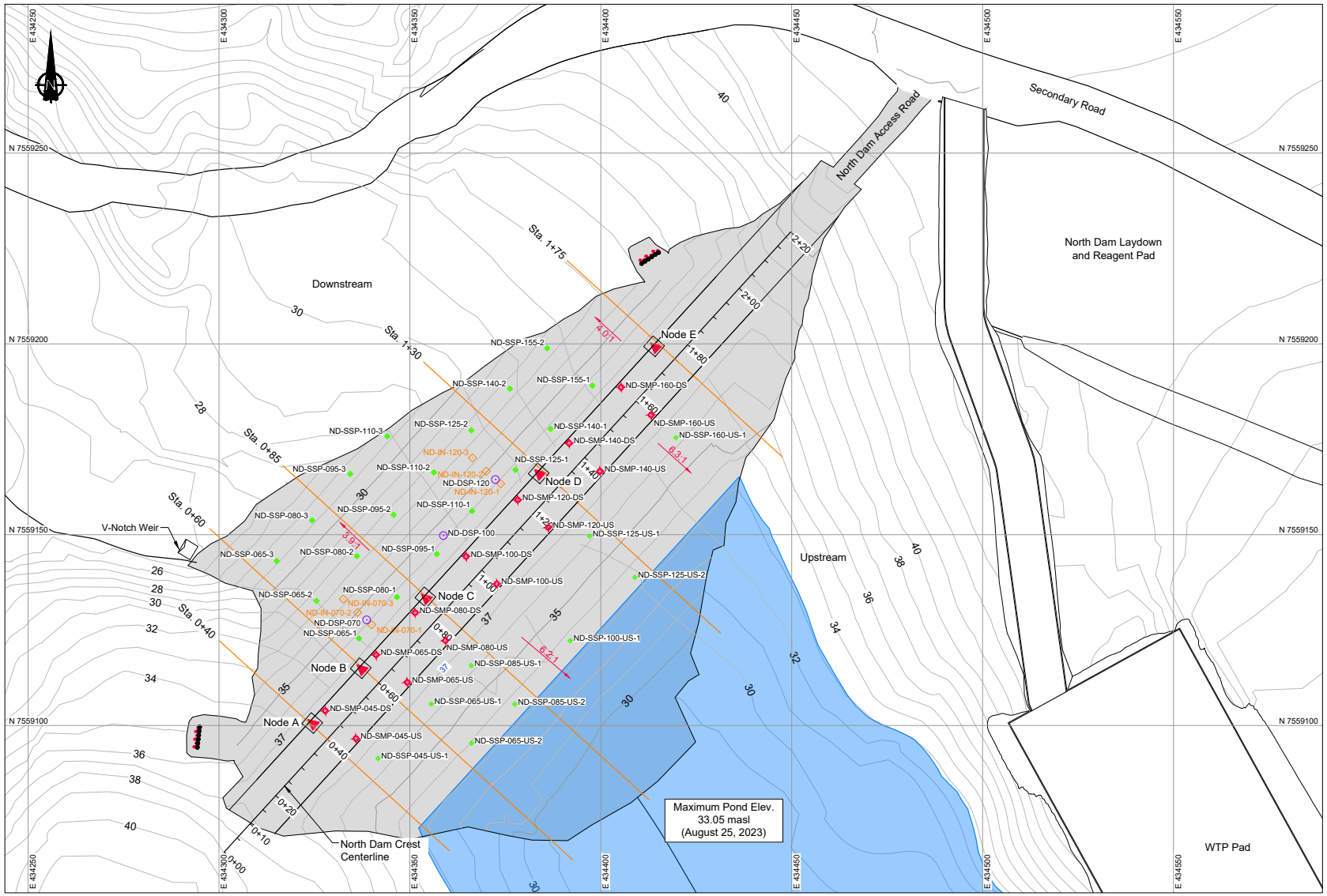
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

North Dam General Arrangement and Primary Control Points

Date:	Approved:	Figure:
March 2024	BJ	11

Original figure produced by SRK Consulting (May 2016), updated by Agnico (March 2024).



LEGEND

- Survey Monitoring Point (Crest)
- Deep Settlement Point
- Surficial Survey Point
- Inclinometer Location
- Datalogger Node
- Thermosyphon Radiator
- Full Supply Level (Elev. 33.5 masl)

NOTES

1. Topographic contour data was provided by the Client. As-Built contour data for the terrain model was provided by the Contractor.
2. Contours shown at 1.0 m intervals.

REFERENCES

NAD83 UTM Zone 13.

Original figure produced by SRK Consulting (March 2024), adapted by Agnico (March 2024).

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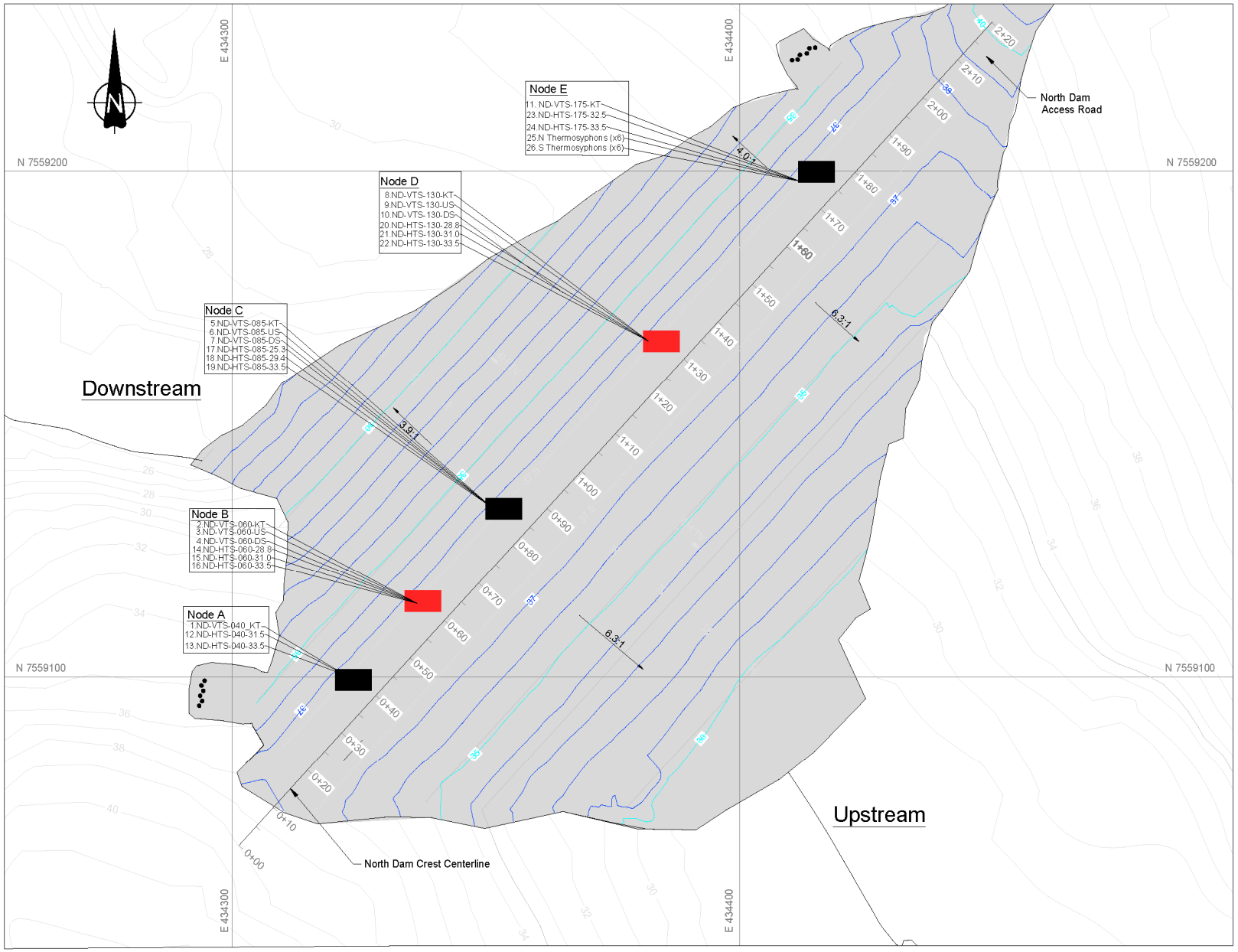
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

North Dam Instrumentation Layout

Date:	Approved:	Figure:
March 2024	BJ	12



LEGEND

- Major Contour As-built (5m)
- Major Contour As-built (1m)
- Final Surface Extents As-built
- Thermosyphon Radiator As-Built

Note: the two weatherproof enclosures which house the data loggers are shown in red.

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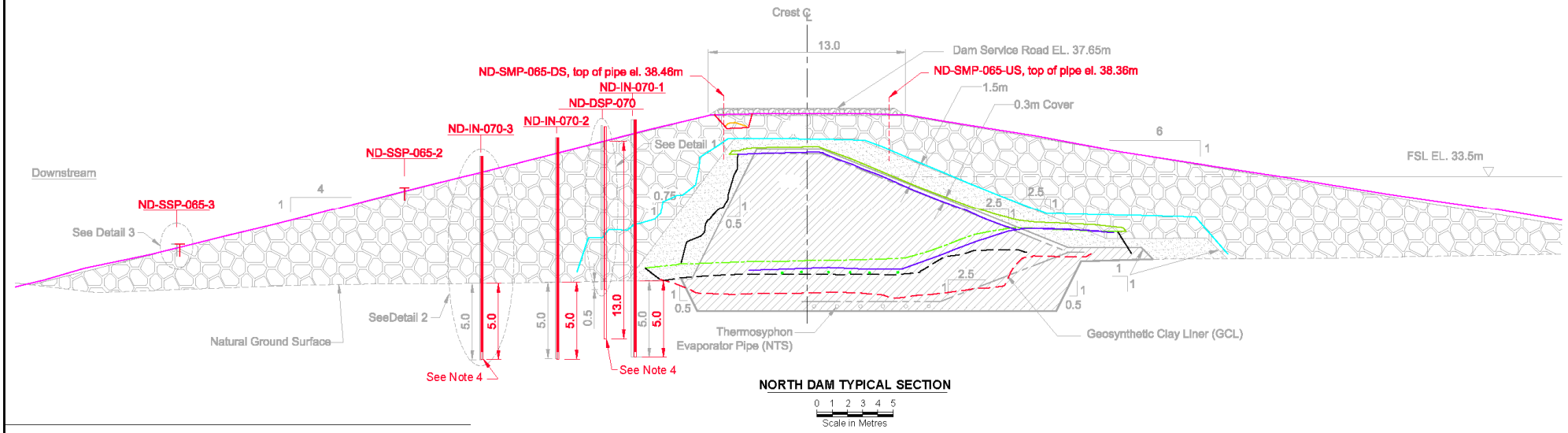
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

North Dam Ground and Thermosyphon Temperature Cable Locations

Date:	Approved:	Figure:
March 2024	BJ	13

Original figure produced by SRK Consulting (May 2016), updated by Agnico (March 2024).



NORTH DAM TYPICAL SECTION

0 1 2 3 4 5
Scale in Metres

- Core Material
- Transition Material
- Run of Quarry (ROQ)
- Surfacing Material
- Bedrock
- Peat

- GCL As-built
- Core Material As-built
- Core Material (2011) As-built
- Levelling Course (Core Material) As-built
- Instrumentation Trench Cover As-built
- Key Trench / Instrumentation Trench As-built
- GCL Cover Material As-built
- Transition Material As-built
- ROQ Material As-built
- Thermosyphon Evaporator Pipes As-built

Example of as-built instrumentation installed on the downstream of dam.

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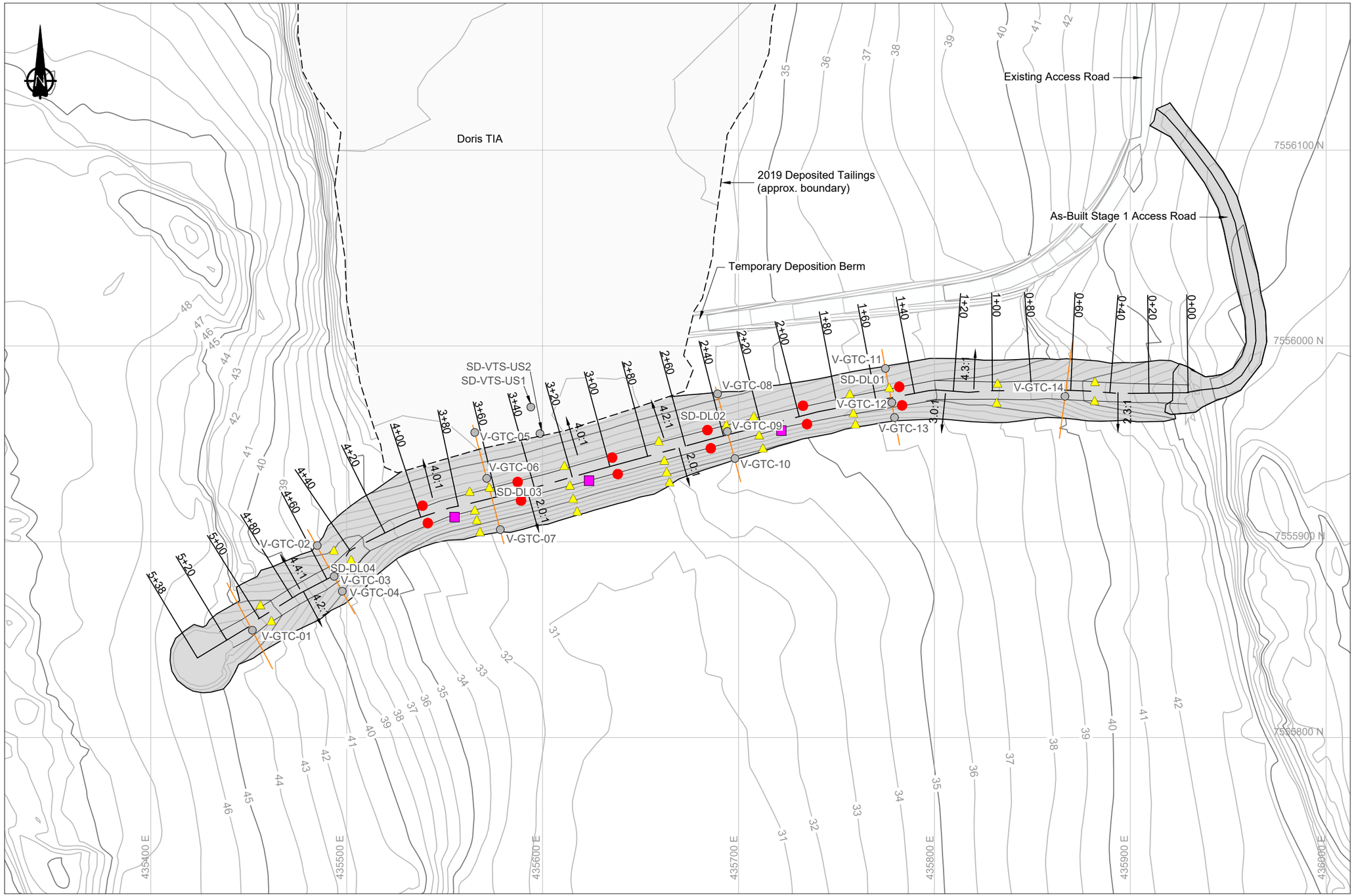
HOPE BAY PROJECT

DORIS TIA OMS MANUAL

North Dam Deformation Monitoring Instrumentation Layout

Date:	Approved:	Figure:
March 2024	BJ	14

Original figure produced by SRK Consulting (May 2016), updated by Agnico (March 2024).



LEGEND

- As-Built Survey Monitoring Point
- Design Surface Monitoring Point
- Design Deep Settlement Point
- Datalogger Location
- Vertical Ground Temperature Cable

NOTES

1. Topographic and As-built data was provided by the Client
2. Contours shown at 1.0m interval.
3. All units shown are in meters unless otherwise stated.

REFERENCES

NAD83 UTM Zone 13.

Original figure produced by SRK Consulting (April 2020), updated by Agnico (March 2024).

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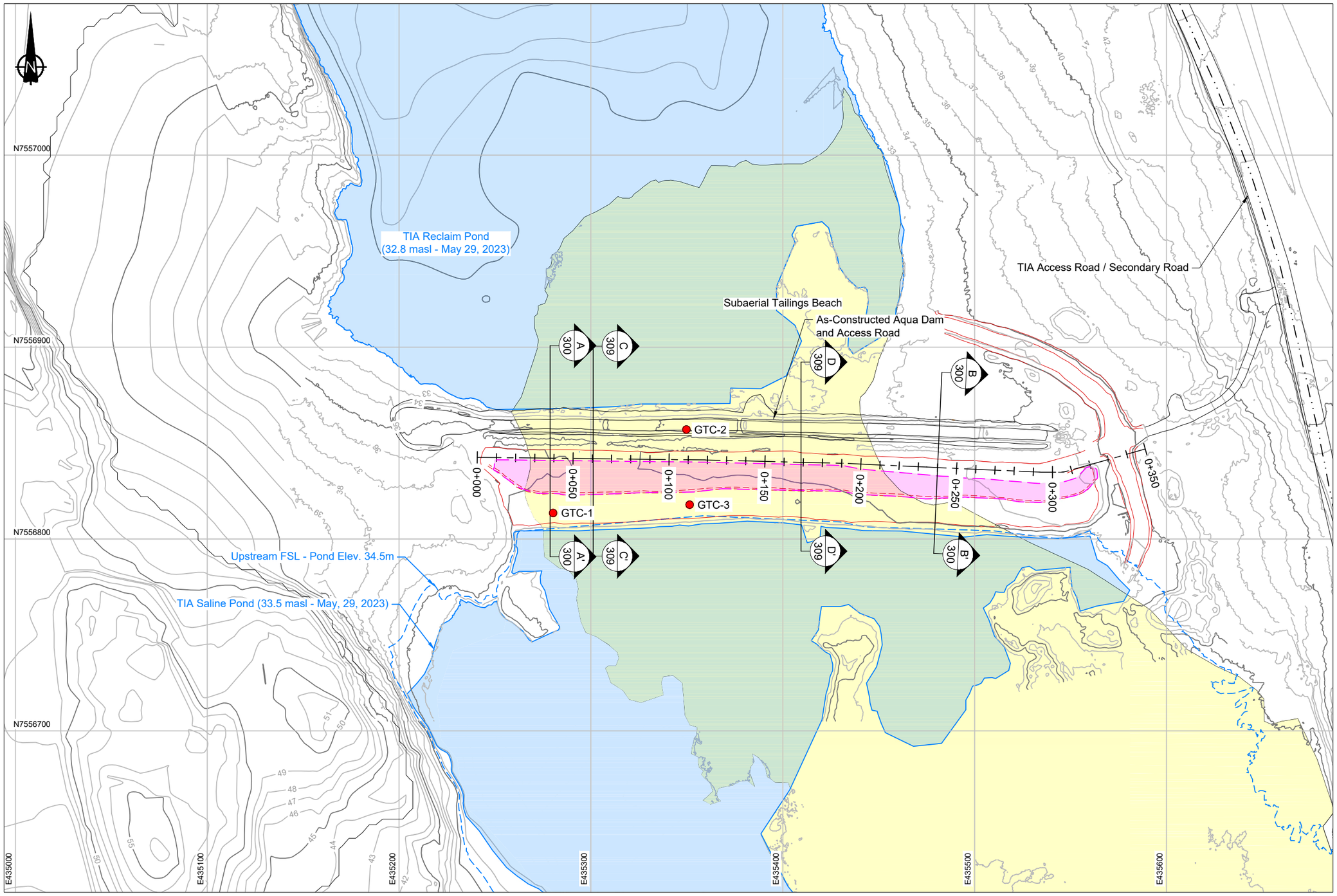
Doris TIA

DORIS TIA OMS MANUAL

South Dam General Arrangement and Instrumentation

DATE:	APPROVED:	FIGURE:
March 2024	BJ	15



LEGEND

- As-built Ground Temperature Cable
- TIA Reclaim Pond Water Level
- Upstream Full Supply Level (Elev. 34.5m)
- Geosynthetic Clay Liner
- Subaerial Tailings Beach
- Shallow Submerged Tailings Beach

NOTES

1. Contours are shown at 1.0 m intervals.
2. All units are in meters unless otherwise specified.
3. GTC-2 was installed in 2022 following construction of the Aquadam berm, GTC-1 and GTC-3 were installed in November 2023.

REFERENCES

NAD83 UTM Zone 13.
Record Surveys made from - Drone Survey provided by client. File name: "IRB 29052023_dsm_10cm.laz" and additional survey provided by client 20230608 and 20230829. File names: "AB-ROM.txt" and 230829_AB IRB_south toe dam.dwg

GTC INSTALLATION LOCATIONS

ID	Northing	Easting
GTC-1	7556844.49	435284.39
GTC-2	7556863.13	435322.19
GTC-3	7556841.48	435439.74

Original figure produced by SRK Consulting (Feb 2024), adapted by Agnico (March 2024).

AGNICO EAGLE

HOPE BAY PROJECT

DORIS TIA OMS MANUAL

Interim Dike Thermistor Locations

DATE:	APPROVED:	FIGURE:
March 2024	BJ	16

Appendix E: O&M Manual for Active Cooling

ARCTIC FOUNDATIONS OF CANADA

A Division of Encompass Inc.

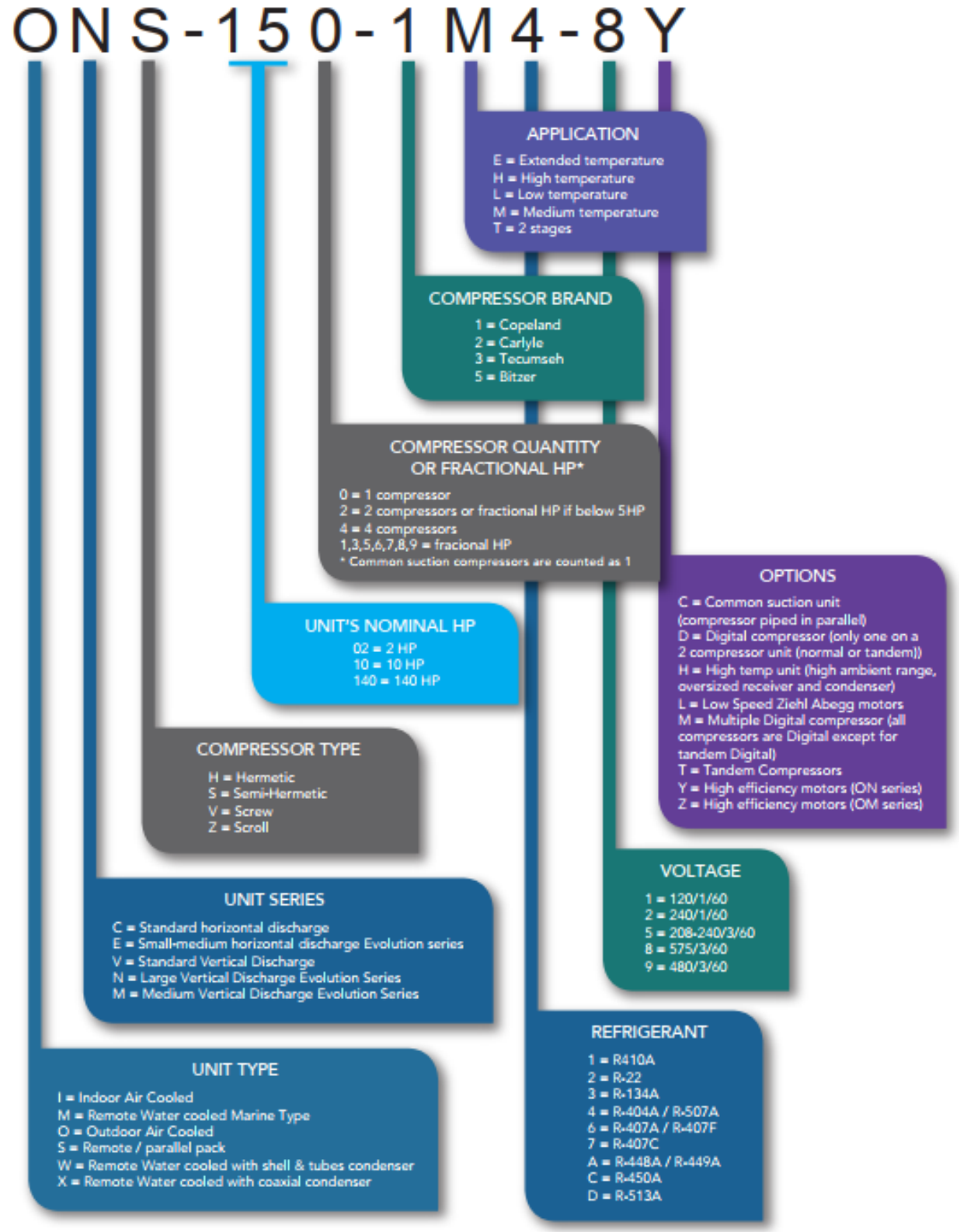
Operation & Maintenance Manual

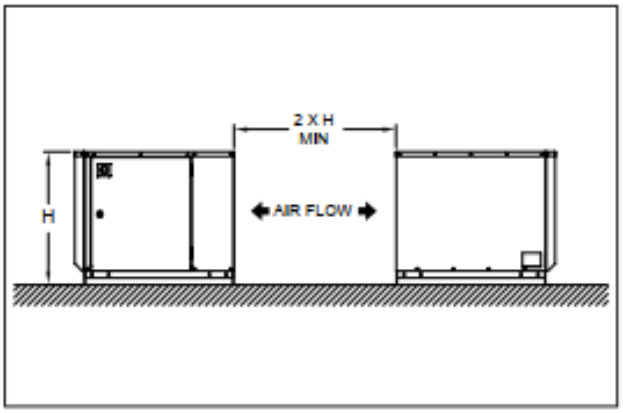
Agnico Eagle Mines Ltd.

Project: **Hope Bay, North Dam – Active Cooling Conversion**

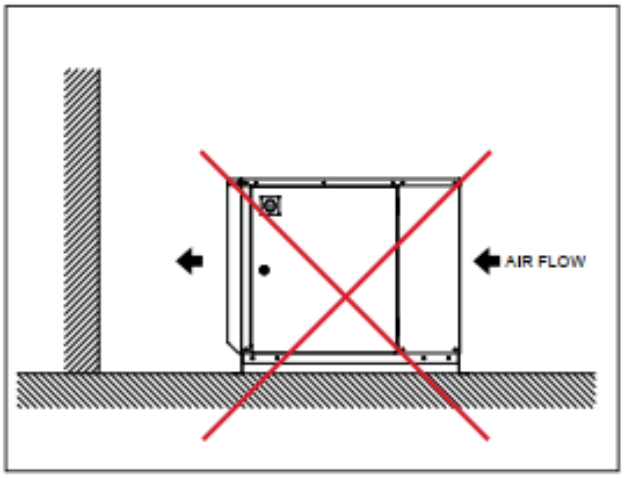
CONDENSER MODEL NO. OEZ-100-1LA-8

CU NOMENCLATURE

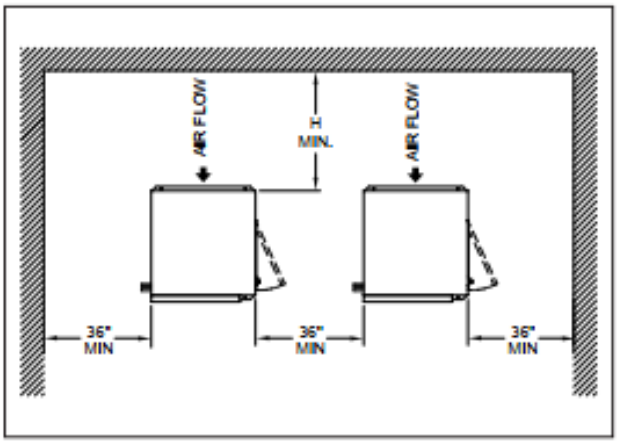




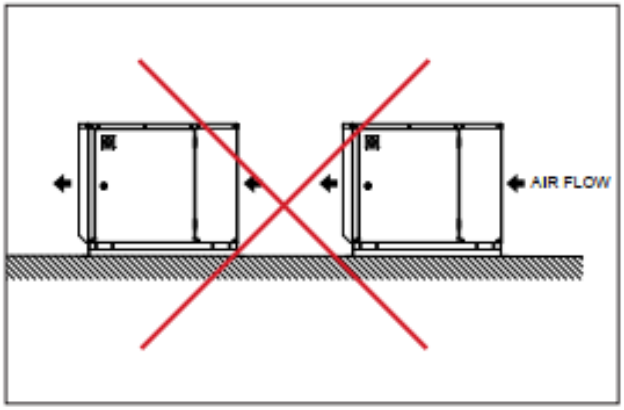
Proper OE(X) mounting arrangement



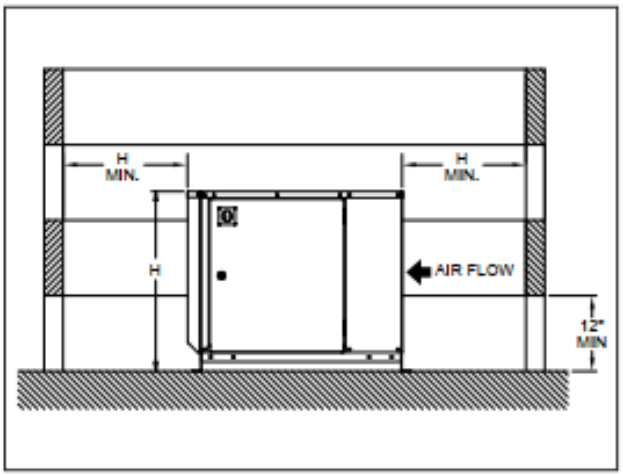
Improper OE(X) mounting arrangement



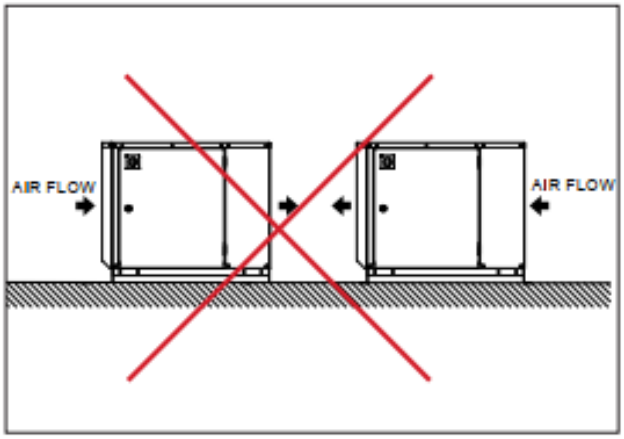
Proper OE(X) mounting arrangement



Improper OE(X) mounting arrangement



Proper OE(X) mounting arrangement



Improper OE(X) mounting arrangement

PROJECT OBJECTIVE

The Objective of this Conversion is to enhance the sub-grade cooling ability of Passive Thermosyphon system. By installing Active cooling, the probes have the ability to provide cooling during the summer season.

The intended use of this system is to keep the frozen core within original design specifications. As such, the timing for start and stop points should be determined in conjunction with the SRK design team while factoring in monitoring data and ambient temperatures.

Questions related to service or operating condition of the system can be directed to Arctic Foundations of Canada.

WINTER SHUTDOWN

Turn **PUMP DOWN** switch (Fig. 1) inside the right vent panel to the **OFF** position. If the unit is still running after 1-3 minutes the unit should shut off. Leaving the main disconnect (Fig. 2) in the ON position will only keep the trace heaters on. If shutdowns are to be for a long period of time, the main disconnect should be switched into the OFF position.

SUMMER STARTUP

Turn main disconnect (Fig. 2) to the **ON** position and leave for 12-24 hours to allow trace heaters to warm up. After 12-24 hours turn the **PUMP DOWN** switch (Fig. 1) to the **ON** position. Unit will now start up as needed.

Figure 1.

Figure 2.

SERVICE

System operating temperature, oil level, and system pressure should be checked and recorded periodically to ensure stable system operation. For any help, tips, and

questions pertaining to the condensing unit, refer to the troubleshooting chart.

Sight glass shown in Figure 3, should be clear. If bubbles are seen in sight glass this could indicate low refrigerant charge. **Check only when unit is Running.**

IMPORTANT: Disconnect all power before servicing

INPECTION

After one day of operation, check for any abnormal vibration in the unit.

IMPORTANT: Compressor hold-down bolts should be checked periodically and re-tightened if necessary.

Figure 3.

CLEANING

It is recommended that all condensers and evaporators of a refrigeration system be checked periodically for dirt accumulation. Grease and dust must be removed from fans, fan guards and drain pans.

Occasional cleaning of finned surfaces can be done by first dusting off the fins, then cleaning with a mild detergent and a warm water spray.

The inner face of the condenser coil may be cleaned through the access panel on the side of the units or by removing the fan guards.

IMPORTANT: Do not use alkaline or acid solution as it will damage the coils. The detergent must be completely rinsed before stopping the cleaning operation.

FAN MOTORS

Fan motors are permanently lubricated and thermally protected for service-free operation. An automatic internal thermal protection could be triggered if the coil is blocked. If the motors are inoperative, check the supply voltage at the motor leads before attempting any maintenance and service.

One fan will always be on when unit is running. Additional 2 condenser fan motors are set at 60°F and 85°F operating temperature (Fig. 6). Control fuses for condenser fans can be found in Electrical Panel (4, & 5). **CAUTION ELECTRICAL PANEL IS 600V. Main disconnect (Fig. 2) should be shut off when opening and working in electrical panel.**

The motors can start on the automatic thermal protector at any time.

Figure 4.

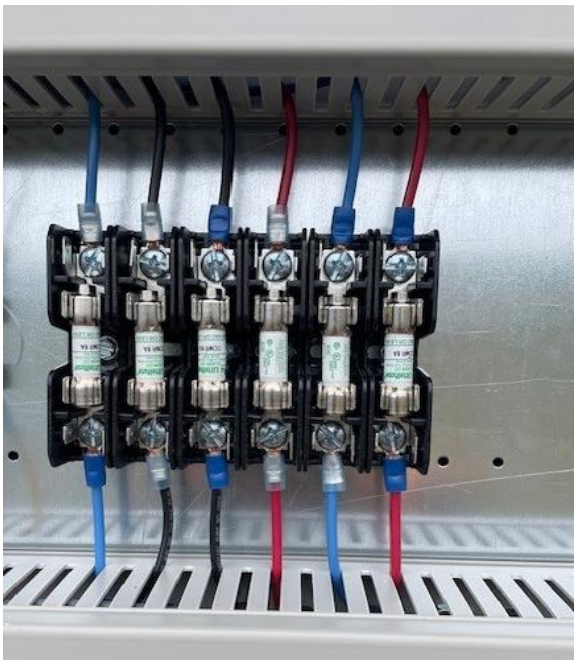


Figure 5.

Figure 6.

ADDING OIL

If oil is needed, allow the system to pump down.

1. Turn off all power to the unit.

2. Close the suction and discharge valves at the compressor.

3. Partially unscrew the filler hole pipe plug. Allow pressure to bleed before totally removing the plug. (The filler hole is located just above and to the left of the crankcase sight glass on most compressors.)

4. Add compressor manufacturer-approved oil through the filler hole. **Be sure oil has not been** exposed to air or other contaminants.

5. Replace and tighten filler hole pipe plug.

6. Re-open the compressor suction and discharge valves.

7. Restart the unit.

SCROLL COMPRESSOR

Oil level must be maintained at 1/8 to 1/2 full (Copeland compressor) as indicated on the sight glass. If oil level is low, add Manufacturer approved oil to the compressor. Do not over fill. Check oil level 2 hours and 2 days after the addition of oil.

Excessive oil quantity in a system may lead to liquid slugging and compressor damage.

A well-balanced unit should not require any additional oil after a week of operation. If the level does not stabilize, there is an oil logging problem. Check all piping for proper installation. Correct any defect that would prevent the oil from coming back. Remove excess oil if the level goes over 3/4 full sight glass.

<u>RECOMMENDED POE OIL FOR ALL HFC REFRIGERANTS</u>

Copeland Compressor: Copeland Ultra 22CC, Copeland 3MA, Mobil EAL ARTIC 22CC, ICI (Virginia KMP) EMKERATE RL 32CF.

Compressor diagnostic panel can be seen in Figure 7**.** Compressor contactor (Fig 8.) should be pulled in when unit is running ***CAUTION 600V*.**

See reference chart for any required troubleshooting.

Figure 7.

Figure 8.

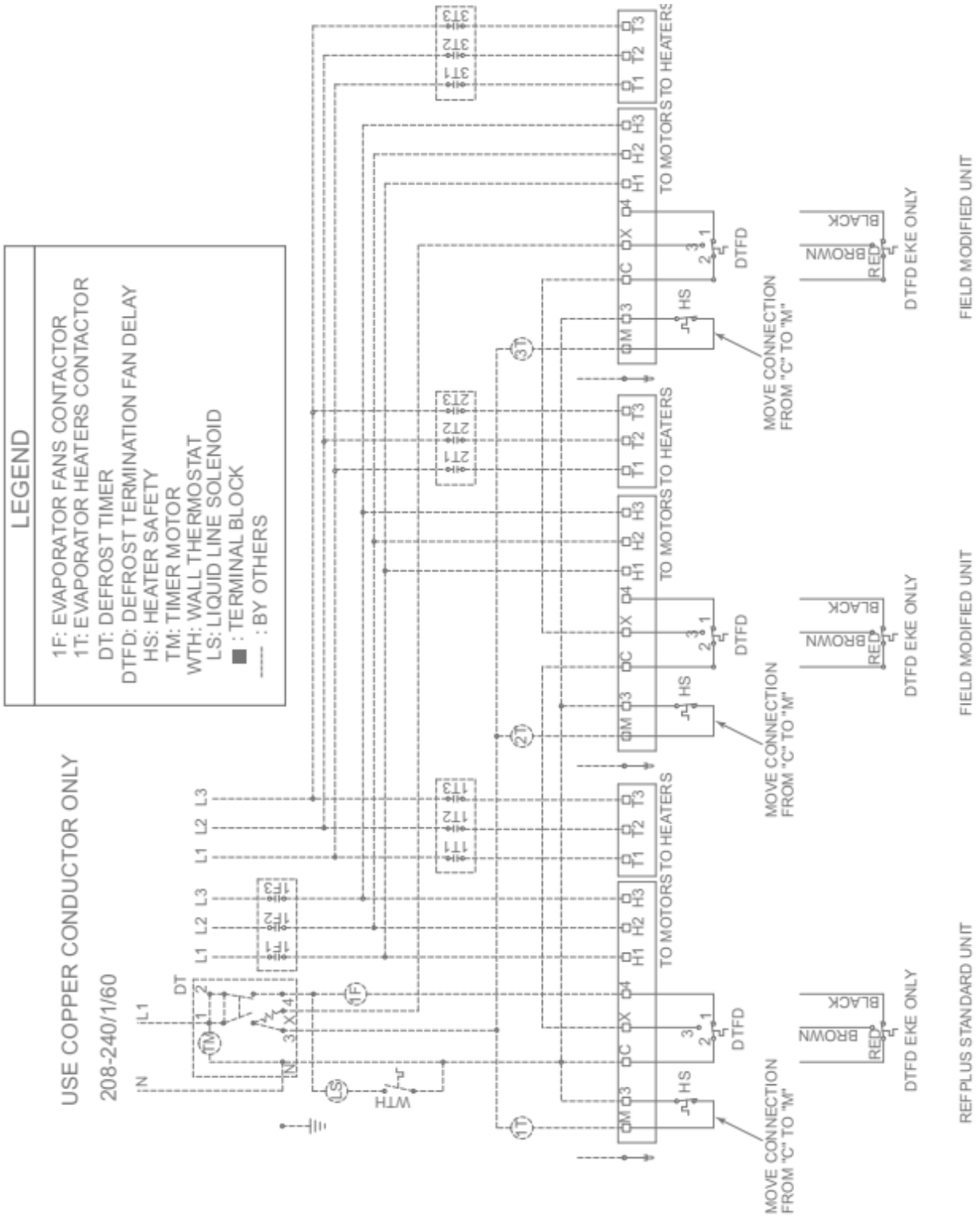
TROUBLESHOOTING CHART

PROBLEM	POSSIBLE CAUSES	POSSIBLE CORRECTIVE STEPS
Compressor will not run	1. Main switch open. 2. Fuse blown. 3. Thermal overloads tripped. 4. Defective contactor or coil. 5. System shut down by safety devices. 6. No cooling required. 7. Liquid line solenoid will not open. 8. Motor electrical trouble. 9. Loose wiring.	1. Close switch 2. Check electrical circuits and motor winding for shots or grounds. Investigate for possible overloading. Replace fuses after fault is corrected. 3. Overloads are automatically reset. Check unit closely when unit comes back on line. 4. Repair or replace defective parts. 5. Determine type and cause of shutdown and correct it before resetting safety switch. 6. None. Wait until unit calls for cooling. 7. Repair or replace coil. 8. Check electrical circuits and motor for open windings. Also check for a short circuit or motor burn out. 9. Check all wire junctions. Tighten all terminal screws.
Compressor is noisy or vibrating	1. Flooding of refrigerant into crankcase. 2. Improper piping support on suction, discharge or liquid line. 3. Worn compressor. 4. Scroll compressor rotation reversed.	1. Check setting of expansion valves. 2. Relocate, add or remove hangers. 3. Replace. 4. Rewire for phase change.
High-discharge pressure	1. Non-condensables in system. 2. System overcharges with refrigerant. 3. Discharge shutoff valve partially closed. 4. Fan not running. 5. Head pressure control setting. 6. Dirty condenser coil.	1. Remove the non-condensable. 2. Remove excess refrigerant. 3. Open valve. 4. Check electrical circuit. 5. Adjust control setting. 6. Clean condenser coil.
Low-discharge pressure	1. Faulty condenser temperature regulation. 2. Suction shut-off valve partially closed. 3. Insufficient refrigerant in system. 4. Low suction pressure. 5. Variable head pressure valve.	1. Check condenser control operation. 2. Open valve. 3. Check for leaks. Repair and add charge. 4. See corrective steps for low suction pressure. 5. Check valve setting.
High-suction pressure	1. Excessive load. 2. Expansion valve (TXV & EEV) overfeeding.	1. Reduce load or add additional equipment. 2. Regulate superheat. Check remote bulb (temp. and pressure).
Low-suction pressure	1. Lack of refrigerant. 2. Evaporator dirty or iced. 3. Clogged suction line or compressor suction gas strainers. 4. Clogged liquid line filter dryer. 5. Expansion valve (TXV & EEV) under-feeding. 6. Condensing temperature too low.	1. Check for leaks. Repair leak and add charge. 2. Clean evaporator. 3. Replace cartridge(s). 4. Replace liquid line filter dryer cartridge or filter dryer. 5. Regulate superheat. Check remote bulb (temp. and pressure). 6. Check means for regulating condensing temperature.

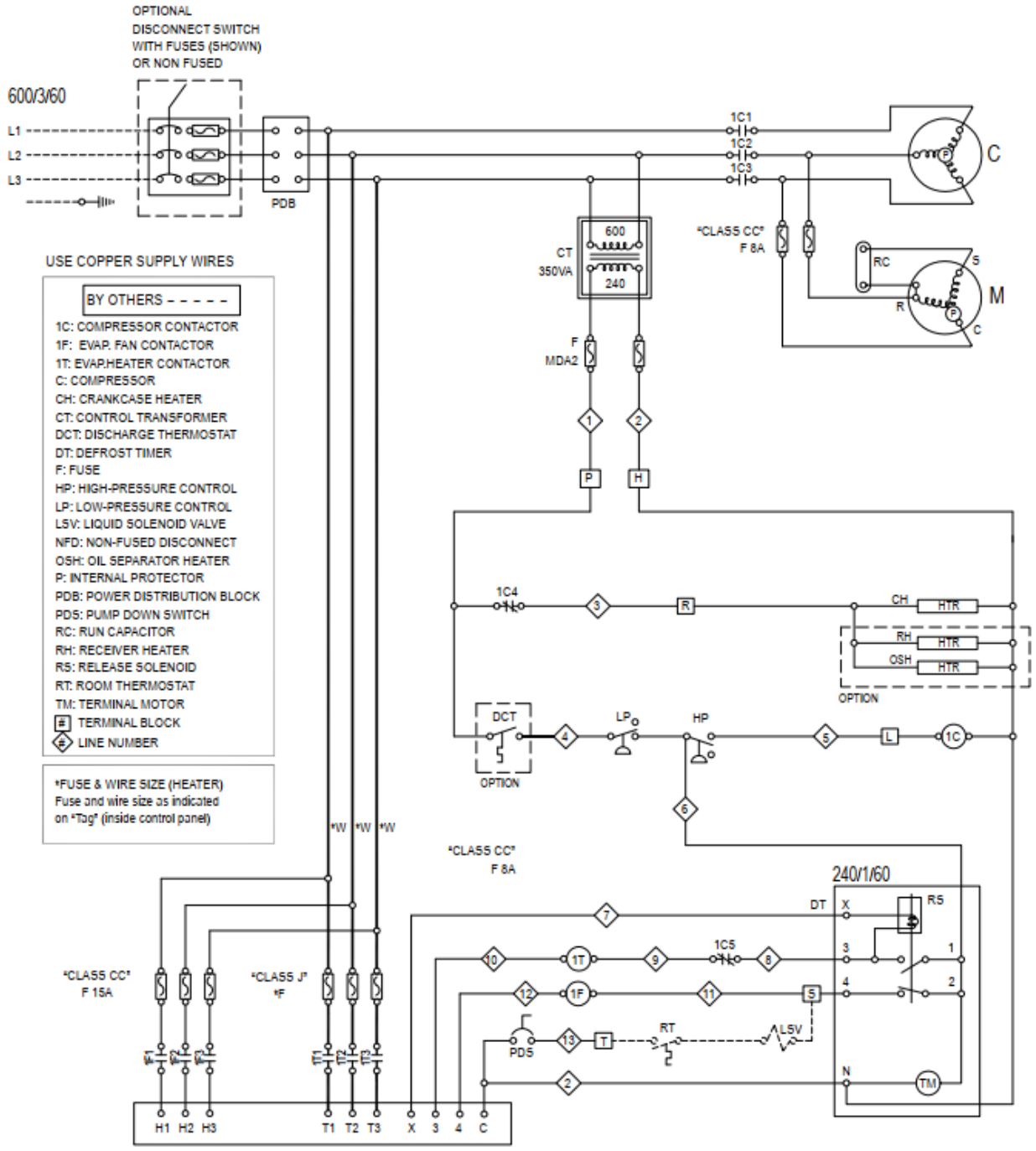
PROBLEM	POSSIBLE CAUSES	POSSIBLE CORRECTIVE STEPS
Low or no oil pressure	1. Clogged suction oil strainer. 2. Excessive liquid in crankcase. 3. Low oil pressure safety switch defective. 4. Worn oil pump. 5. Low oil level. 6. Crankcase oil filter is dirty or clogged. Oil pressure sensor is dirty. 7. Loose fitting on oil lines. 8. Pump housing gasket leaks.	1. Clean. 2. Check crankcase heater. Reset expansion valve for higher superheat. Check liquid line solenoid valve operation. 3. Replace oil pressure safety switch. 4. Replace oil pump. 5. Add oil. 6. Clean crankcase oil filter or sensor. 7. Check and tighten system. 8. Replace gasket.
Compressor loses oil	1. Lack of refrigerant. 2. Excessive compression ring blow-by. 3. Refrigerant flood-back. 4. Improper piping or traps.	1. Check for leaks and repair. Add refrigerant. 2. Replace valve plate. 3. Maintain proper superheat at compressor. 4. Correct piping.
Compressor thermal protector switch open	1. Operating beyond design conditions. 2. Discharge valve partially shut. 3. Blown valve plate gasket. 4. Dirty condenser coil. 5. Overcharged system.	1. Add facilities so that conditions are within allowable limits. 2. Open valve. 3. Replace gasket. 4. Clean coil. 5. Reduce charge.

REPLACEMENT PARTS

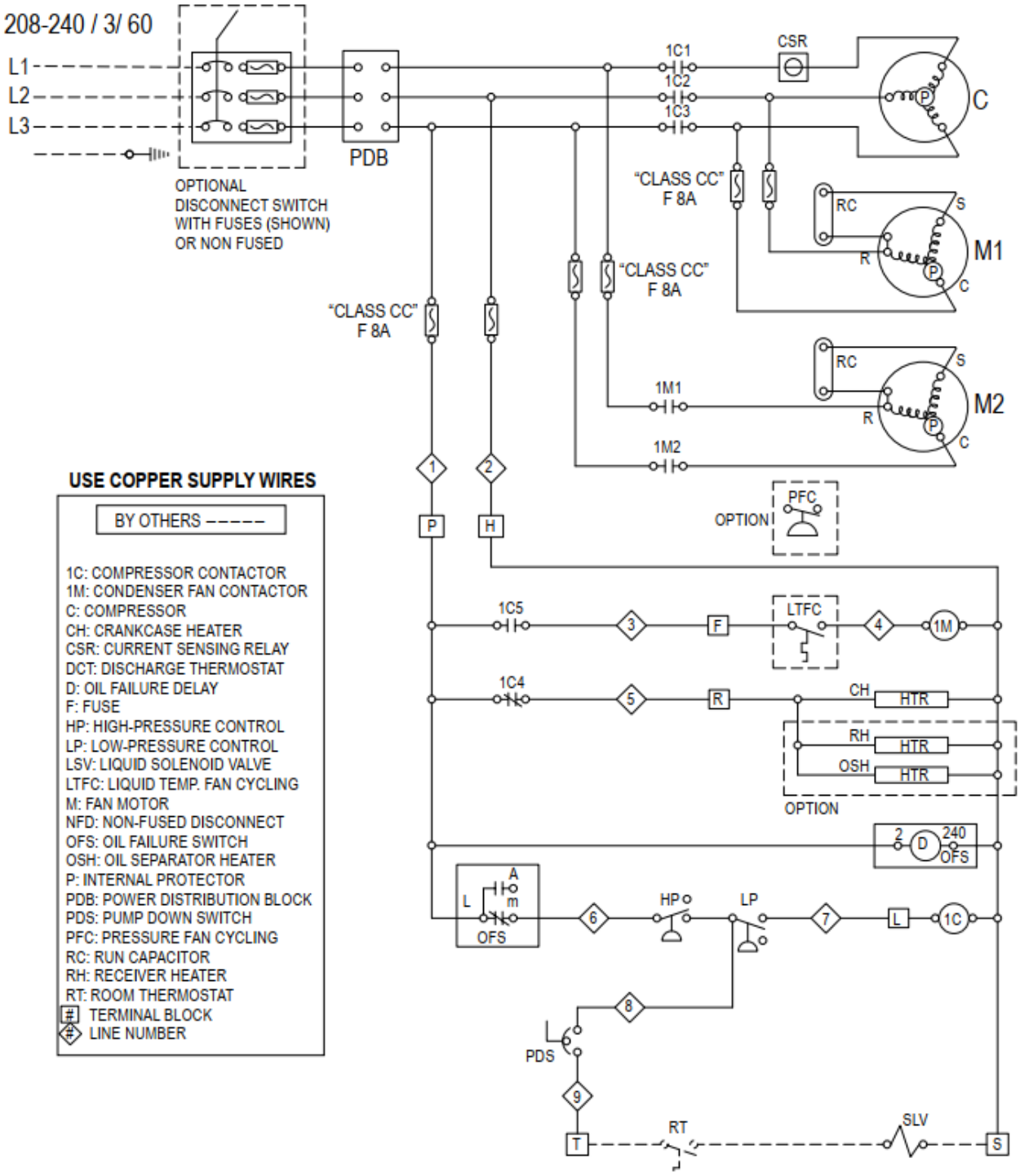
Download the parts manual at http://refplus.com/en/parts-services/



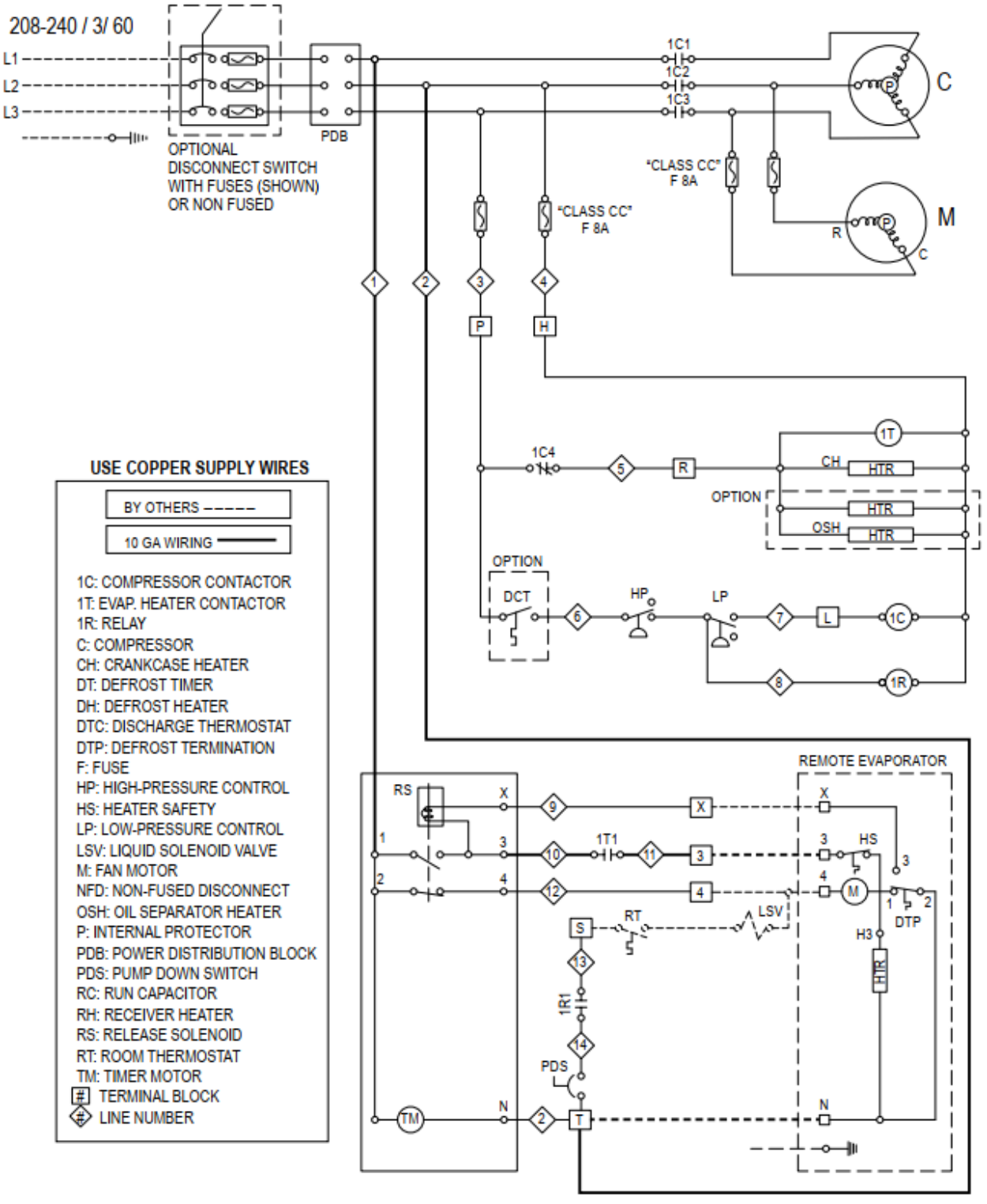
Typical wiring diagram (multiple electric defrost unit)



Typical wiring diagram (electric defrost kit - one evaporator)



Typical wiring diagram (two fans - coresense)



Typical wiring diagram (electric timer)

Appendix F: Dam Emergency Plan

HOPE BAY MINE
DAM EMERGENCY PLAN

AGNICO EAGLE

HOPE BAY, NUNAVUT

MARCH 2023

Hope Bay Mine Dam Emergency Plan

Plain Language Overview:

This Dam Emergency Plan (DEP) is a formal document identifying potential emergency conditions that may occur at Agnico Eagle Mines' Hope Bay Project dams and includes specific preplanned actions to minimize potential failure of the dam or minimize failure consequences including loss of life, property damage, and environmental impacts during an unusual or emergency event.

Hope Bay, Nunavut

Publication Date: March 2023

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Revisions

Revision #	Date	Section	Changes Summary	Author	Approver
0	April 2022	Whole Document	Broad update	AEM/SRK	AEM
1	March 2023	Whole Document	Broad update to align with AEM governance policy for critical infrastructure management and updated Dam Safety Management System including references to the site wide ERP.	AEM	AEM

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Glossary

Term	Definition
Abutment	That part of the valley side against which the dam is constructed. The left and right abutments of dams are defined with the observer looking downstream from the dam.
Acre-foot	A unit of volumetric measure that would cover 1 acre to a depth of 1 foot. One acre-foot is equal to 1,234 cubic meters.
Assembly Point Coordinator	The most senior employee at an assembly point or muster location during an emergency who takes control of the assembly point during an evacuation to take roll-call and account for each person at the assembly point.
Berm	A nearly horizontal step (bench) in the upstream or downstream sloping face of the dam.
Boil	A disruption of the soil surface due to water discharging from below the surface. Eroded soil may be deposited in the form of a ring (miniature volcano) around the disruption.
Breach	An opening through the dam that allows draining of the reservoir. A controlled breach is an intentionally constructed opening. An uncontrolled breach is an unintended failure of the dam.
Briefing Officer (BO)	The Briefing Officer is the liaison between the ICG and the ERT/MRT teams. The BO provides instructional direction to the ERT/MRT teams and is responsible for their safety during an emergency.
Conduit	A closed channel (round pipe or rectangular box) that conveys water through, around, or under the dam.
Consequence classification	A system that categorizes dams (extreme, very high, high, significant, or low) according to the degree of their potential to create adverse incremental consequences such as loss of life, property damage, or environmental impacts of a failure or mis-operation of a dam.
Control section	A usually level segment in the profile of an open channel spillway above which water in the reservoir discharges through the spillway.
Cross section	A slice through the dam showing elevation vertically and direction of natural water flow horizontally from left to right. Also, a slice through a spillway showing elevation vertically and left and right sides of the spillway looking downstream.
Dam	A barrier constructed for the purpose of enabling the storage or diversion of water diverted from a stream or an aquifer, or both and other works that are incidental to or necessary for the barrier.
Dam Emergency Plan	A formal document identifying potential emergency conditions that may occur at the dam and specifying preplanned actions to minimize potential failure of the dam or minimize failure consequences including loss of life, property damage, and environmental impacts.
Dam failure	An uncontrolled release of all or part of the water impounded by the dam, whether or not caused by a collapse of the dam.
Drain	A water collection system of sand and gravel and typically pipes along the downstream portion of the dam to collect seepage and convey it to a safe outlet. The drains can be located in the toe, foundation or drainage blanket.
Drainage area (watershed)	The geographic area on which rainfall flows into the dam.
Drawdown	The lowering or releasing of the water level in a reservoir over time or the volume lowered or released over a particular period of time.

Term	Definition
Emergency	A condition that develops unexpectedly, endangers the structural integrity of the dam and/or downstream human life and property, and requires immediate action.
Emergency Response Team (ERT)	A group of Hope Bay employee's and contractors who voluntarily prepare for and respond to any emergency incident.
Evacuation map	A map showing the geographic area downstream of a dam that should be evacuated if it is threatened to be flooded by a breach of the dam or other large discharge.
Filter	The layers of sand and gravel in a drain that allow seepage through an embankment to discharge into the drain without eroding the embankment soil.
Freeboard	Vertical distance between a stated water level in the reservoir and the top of dam.
Gate	A general term for any mechanical device to control the flow of water in intakes, outlet works and over controlled spillways.
Groin	The area along the intersection of the face of a dam and the abutment.
Height of dam	The vertical distance between the crest of the dam and the lowest point at the downstream toe, which usually occurs in the bed of the outlet channel.
Hydrograph	A graphical representation of either the flow rate or flow depth at a specific point above or below the dam over time for a specific flood occurrence. It can include inflow, outflow or a breach flow.
Incident Command Group (ICG)	Members of AEM management that assemble during an emergency to direct the response to the incident.
Incident Commander	The highest predetermined official available at the scene of an emergency situation.
Inundation area or map	The geographic area downstream of the dam that would be flooded by a breach of the dam or other large discharge.
Low-Level Outlet	A conduit through a dam to allow for controlled release of the reservoir contents. Also see "Outlet Works"
Mine Rescue	Mine rescue is a term used to refer to underground rescue operations performed by the Emergency Response Team.
Muster Station	A designated gathering area for the purpose of identifying and recording all occupants/evacuees present during an emergency and ensuring their safety until the emergency has ended.
Notification	To immediately inform appropriate individuals, organizations, or agencies about a potentially emergency situation so they can initiate appropriate actions.
Official-in-charge (OIC)	The Official-in-Charge is usually the General Manager, or most senior manager and oversees all decisions and emergency operations at Hope Bay.
OMS Manual	Operations, Maintenance, and Surveillance Manual
Outlet works	An appurtenant structure that provides for controlled passage of normal water flows through the dam. Combination of intake structure, gates, conduits, tunnels, flow controls and energy dissipation devices to allow the release of water from the dam,
Persons in the immediate vicinity of the dam:	Considered the persons located immediately downstream and adjacent to the dam where available warning time is very limited (where local emergency authorities could not be expected to respond in time).
Physician Assistant (PA)	Medical health care professional that provides overall site medical duties including critical care during emergency situations under the medical directive of a physician.

Term	Definition
Piping	The progressive destruction of an embankment or embankment foundation by internal erosion of the soil by seepage flows.
Probable Maximum Precipitation (PMP) and Prob. Max. Flood (PMF)	The theoretically greatest precipitation (PMP) or resulting flood (PMF) that is meteorologically feasible for a given duration over a specific drainage area or at a particular geographical location.
Reservoir	The body of water impounded or potentially impounded by the dam.
Riprap	A layer of large rock, precast blocks, bags of cement, or other suitable material, generally placed on an embankment or along a watercourse as protection against wave action, erosion, or scour.
Risk	A measure of the likelihood and severity of an adverse consequence.
Seepage	The natural movement of water through the embankment, foundation, or abutments of the dam.
Slide	The movement of a mass of earth down a slope on the embankment or abutment of the dam.
Spillway (emergency)	An additional spillway, which usually has a crest elevation somewhat higher than the main spillway, designed to activate during extreme flood events to avoid overtopping the dam.
Spillway (main)	The appurtenant structure that provides the controlled conveyance of excess water through, over, or around the dam.
Spillway capacity	The maximum discharge the spillway can safely convey with the reservoir at the maximum design elevation.
Spillway crest	The lowest level at which reservoir water can flow over or into the spillway.
Stop Work	An instruction broadcast over the radio system by the Official-In-Charge instructing specific work to stop.
Tailwater	The body of water immediately downstream of the embankment at a specific point in time.
Toe of dam	The junction of the upstream or downstream face of an embankment with the ground surface.
Top of dam (crest of dam)	The elevation of the uppermost surface of an embankment which can safely impound water behind the dam
WSCC	Workers' Safety and Compensation Commission

1 Overview

The purpose of this Dam Emergency Plan (DEP) is to clearly document the procedures for on-site staff, to be followed in the event of a potential dam emergency at the Agnico Eagle Mines Limited (AEM) Hope Bay Project (the Project). The Dam Emergency Plan is intended to function as part of the Hope Bay Dam Safety Management System (DSMS). This document is linked with the Site Wide Emergency Response Plan. Other key documents comprising the Hope Bay DSMS are the TIA OMS Manual, and the Trigger Action Response Plan, and the Dam Monitoring Standard Operating Procedures. The Hope Bay DSMS is outlined in Section 4.

Dams at the Hope Bay project include: North Dam, South Dam and Madrid North Contact Water Pond (CWP) Berm. This Hope Bay Dam Safety Management System has been prepared with the intent of being consistent with Canadian Dam Association (CDA) and Mining Association of Canada (MAC) guidance. Key components of the DEP include:

- A description of facility components,
- A description of the Hope Bay DSMS,
- Definition of the Emergency response structure and roles,
- Plausible dam-related emergency scenarios.

Notifications regarding an unusual or emergency event at the dam are based on the trigger levels and notification procedure outlined in the OMS Manual and in Section 4 of this document. The alert levels and notification procedure are reviewed annually, or more often if warranted by a change in operational or site conditions.

1.1 Relevant Legislation and Guidance

Jurisdiction	Government of Canada and Kitikmeot Inuit Association (KIA)
Governing Bodies	Authorities involved with permitting and regulating the design, construction, operation, maintenance, surveillance, and closure of the tailings impoundment area include the following groups: • Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) • Kitikmeot Inuit Association (KIA) • Nunavut Impact Review Board (NIRB) • Nunavut Water Board (NWB) • Workers Safety and Compensation Commission Chief Mines Inspector (per the Mine Health and Safety Act) and its associated regulations (Government of Nunavut, 1995)
Guidance of Contents	**Canadian Dam Association (CDA)** • Dam Safety Guidelines (CDA 2007) – Guidance related to development of Emergency Response Plans • Dam Safety Guidelines (CDA 2013) – Guidance related to design and operation of dams

- Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams (CDA 2019) – Guidance related to design, operation and closure of tailings dams
- Note: Although the Madrid North CWP is designed to be operated with a maximum two week residence time, it still meets the definition of a mining dam and thus the CDA guidelines have been consulted for best practice.

Mining Association of Canada (MAC)

- Developing an Operations, Maintenance and Surveillance Manual for Tailings and Water Management Facilities (2019) – Guidance related to the management of Tailings Facilities and Water Management Facilities

Nunavut Water Board (NWB)

- Water License No: 2AM-DOH1335, Amendment No. 2, Doris-Madrid Project, Nunavut (2013). Amended December 7, 2018. Expires March 30, 2035.

1.2 Related Documents

The documents listed in Table 1.1 are expected to be referenced and utilized in conjunction with the DEP.

Table 1.1. List of Documents Related to the Hope Bay Mine Dam Emergency Plan

Document Title	Year	Relevance
Hope Bay Project Emergency Response Plan	June 2022	Part of the Hope Bay DSMS. Provides information about required action to handle emergencies at the Hope Bay site in compliance with Nunavut Mine Health and Safety Regulations 8.32
Operations, Maintenance and Surveillance Manual: Hope Bay Project, Phase 2, Doris Tailings Impoundment Area	2022	Part of the Hope Bay DSMS. Describes how AEM will manage and monitor the tailings impoundment area, including the impoundment dams, tailings and water pump and pipeline systems.
Doris TIA Trigger Action Response Plan	2022	Part of the Hope Bay DSMS. Defines specific conditions and thresholds corresponding to each trigger level for the dams and water reclaim pond. Outlines initial actions to be taken at each trigger level, and includes the notification procedure for communication changes in trigger levels.
Operations, Maintenance and Surveillance Manual: Hope Bay Project, Madrid North Contact Water Pond	2022	Describes how AEM will manage and monitor the Madrid North CWP, including the stability of the berm, contact water in the pond basin, and ancillary structures such as seepage collection sumps at the waste rock pile that pump back to the contact water pond.

North Dam Monitoring: Standard Operating Procedure	2022	Provides monitoring requirements for North Dam and includes facility specific guidance on determining alert levels.
South Dam Monitoring: Standard Operating Procedure	2020	Provides monitoring requirements for South Dam and includes facility specific guidance on determining alert levels.
Hope Bay Project Spill Contingency Plan	2022	Outlines spill response procedures and actions to be taken in the event an emergency incident involves a spill of hazardous materials
Hope Bay Project Hazardous Waste Management Plan	2020	Reference for management of hazardous waste that may be generated during an emergency response
Hope Bay Project Non-Hazardous Waste Management Plan	2020	Reference for management of non-hazardous waste that may be generated during an emergency response
Oil Pollution Prevention Plan and Emergency Plan	2020	Outlines specific spill response procedures and actions to be taken in the event an emergency incident involves a spill of fuel during the annual sealift fuel transfer
Hope Bay Project Explosives Management Plan	2017	Reference for management of explosives material handling
Doris and Madrid Water Management Plan	2022	Describes the water management procedures including discharge from the TIA and associated water quality criteria

1.3 Plan Management

The Crisis Management Team (CMT) is responsible for directing all work performed and managing all resources during an emergency incident. The CMT is typically formed by senior management or designates performing the various required functions to ensure the safety of all personnel involved. The CMT draws on resources from Safety, Operations, Technical Services, Environment and Maintenance personnel as necessary to complete emergency response tasks.

The Responsible Person or their designate is responsible for reviewing and revising this Plan annually.

2 Facility Components

North Dam

The North Dam impounds the Reclaim Pond and was designed as a water retaining structure with the following components:

- central frozen core with secondary upstream GCL
- construction from quarry rock including processed fines for core, 150 mm nominal sized transition material, and run of quarry (ROQ) outer shell
- key trench equipped with 12 horizontal thermosyphon evaporators to ensure frozen foundation conditions

Note: The North Dam has been in place since 2012. Design criteria and parameters are provided in Section 1.6.

South Dam

The South Dam is a frozen foundation dam design to retain tailings solids consisting of:

- construction from quarry rock including ROQ, transition material and overliner material placed along the GCL liner.
- an upstream GCL keyed into the permafrost overburden foundation.

Note: The South Dam has been in place since 2019. Design Details are provided in Section 1.6.

Construction Material

Construction materials are sourced from local rock quarries and include

- ROQ material and
- different grades of processed material attained through crushing and screening.

Tailings Deposition

Tailings are deposited as a beach from the face of the South Dam. At all times a minimum 100m long beach will be maintained. In Phase 2, to accommodate the increased tailings quantities, the South Dam will be raised

- by 8 m in a downstream configuration
- to reach a crest elevation of 46.0 m.

Note: Design details are provided in Section 1.6.

Madrid North CWP

A CWP is required at the Madrid North site to intercept and manage contact water runoff from the Madrid North waste rock pile (WRP). The design of the CWP incorporates a run-of-quarry (ROQ) berm with a geomembrane liner on the upstream face to contain contact water. The CWP liner is anchored and sealed to bedrock at the toe of the berm's upstream slope. The berm was founded on exposed bedrock and areas of frozen overburden soil. Permafrost present within the berm foundation will be maintained due to the thermal protection of the berm fill. The CWP design is presented in SRK (2019).

The CWP is formed by a 200 m long embankment of maximum height 7.5 m. The CWP is located 250 m south of the Madrid mine portal and associated facilities. The pond is designed to be operated with a two-week residence time and pumped regularly to remove accumulating water. The pond has the capacity to retain a volume up to 12,200 m^3.

Based on hypothetical dam breach studies the Madrid CWP is a low-consequence dam. An embankment failure at the Madrid CWP would not lead to an emergency scenario threatening loss of life, or irreversible damage to the environment.

2.1 Directions to Facilities

The dam facilities at Hope Bay are accessible by light vehicle year-round. Operating light vehicles at Hope Bay requires Site Driver Training. Access routes to the facilities is detailed below

North Dam

From the airstrip, follow the Primary Road south towards Doris Camp. Follow the Primary Road around the perimeter of Doris Camp to the east, then follow the TL Access Road east for approximately 2 km to reach the North Dam.

South Dam

From the airstrip, follow the Primary Road south towards Doris Camp. Follow the Primary Road around the perimeter of Doris Camp to the east, then follow the TL Access Road east for approximately 6 km to reach the South Dam.

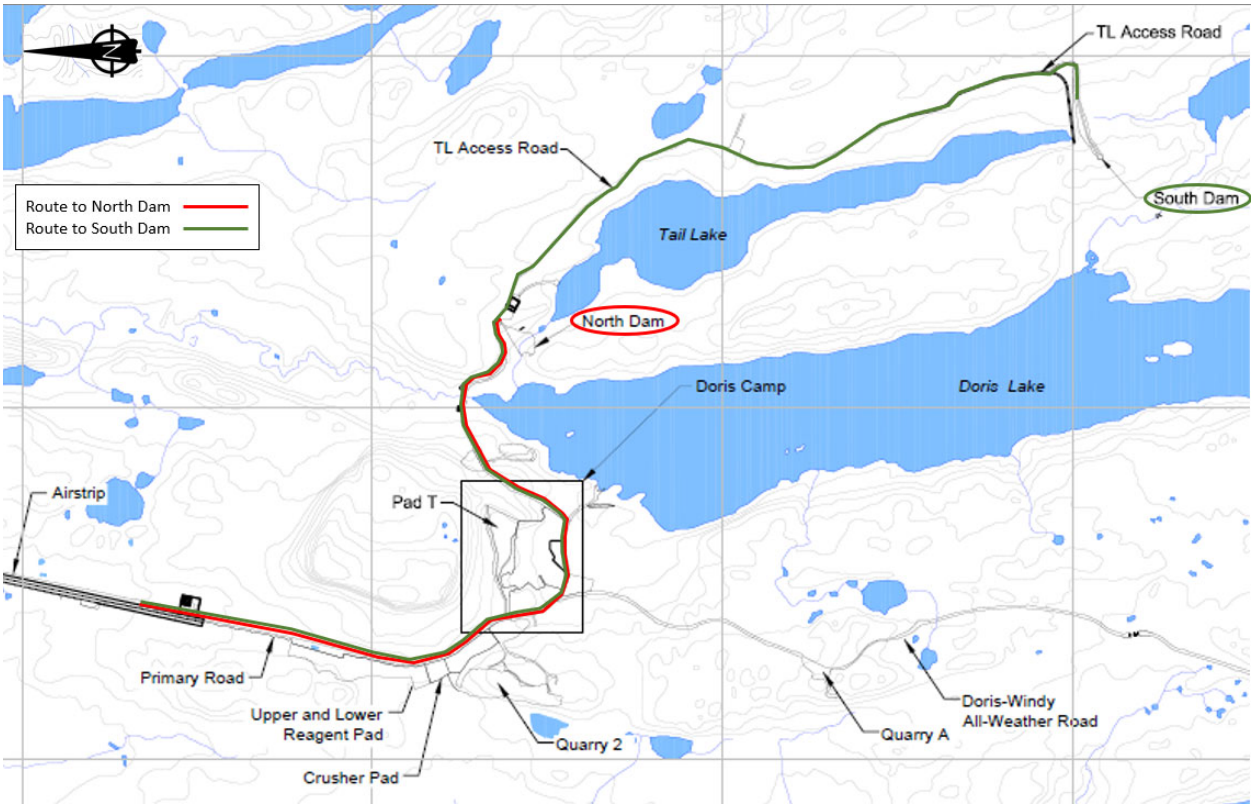


Figure 2-1 – North and South Dam Access Routes

Madrid Contact Water Pond

From the airstrip, follow the Primary Road south towards Doris Camp. Continue past Doris Camp to the south, then follow the Doris-Windy All Weather Road for approximately 12 km to reach the Madrid North CWP.

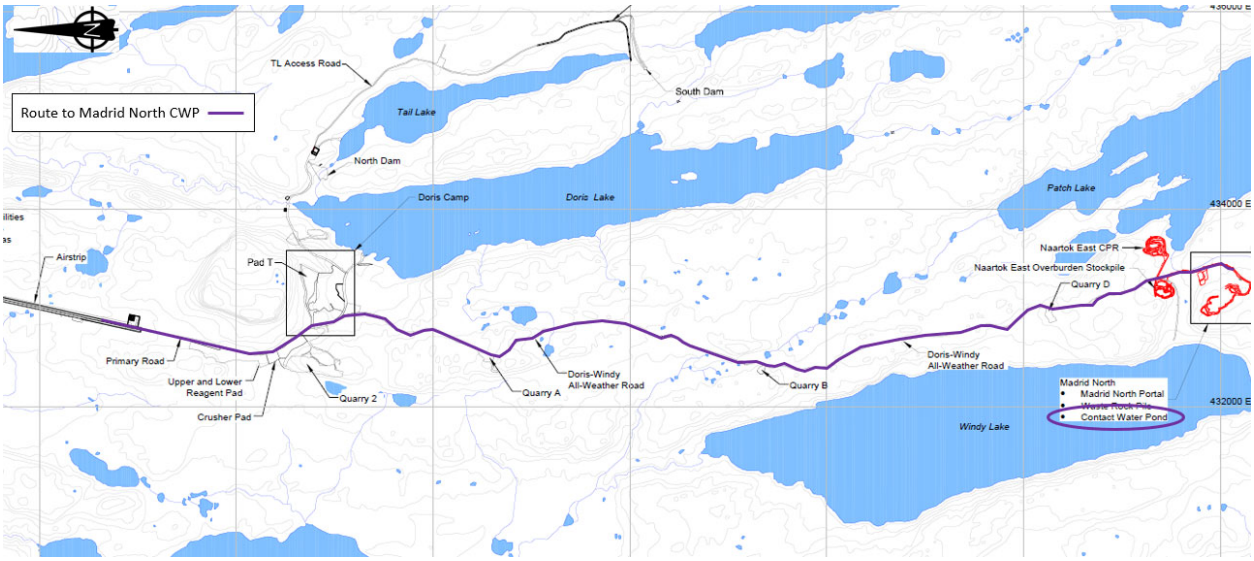


Figure 2-2 – Madrid North CWP Access Route

2.2 Dam Hazard Classification

The dams associated with the TIA area consist of

- **North Dam** - Frozen core rock fill dam with GCL
- **South Dam** – Frozen foundation dam with GCL. Constructed in two phases with downstream raises of GCL and rock fill.

The North and South Dams were assigned a dam hazard classification in accordance with the CDA (2013) dam safety guidelines, as well as the CDA Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014, CDA 2019).

	North Dam	**South Dam**
Population at Risk	significant	significant
Loss of Life	significant	significant
Environmental and Cultural Values	high	high
Infrastructure and Economics	low	low
Overall Hazard Classification	**high**	**high**

The Madrid CWP is a low-consequence dam. a Dam Safety Review is not required for low-consequence dams. However, the consequences of failure should be reviewed periodically, since the consequences may change with downstream development. If the classification increases, or if it is found that the CWP is not being operated as a dry facility, then a Dam Safety Review may be required.

2.3 Design Criteria and Parameters

The basis of design, design criteria, and design parameters for the TIA dams are outlined below (SRK 2017).

Description	North Dam	South Dam
Secondary Seepage Barrier	GCL	GCL
GCL Deployment Slope	2.5H:1V	3H:1V (4H:1V for the raise)
Crest Centerline Length	220 m	515 m
Maximum Height	11.0 m	14.0 m
Final Crest Elevation	37.5 m	46.0 masl
Initial Crest Elevation	n/a	n/a
Core/GCL Elevation	35.0 m	45.0 m
Full Supply Level	33.5 masl	44.5 masl
Normal Water Level	Typically 32m masl, or lower, against the North Dam. Targets set annually and documented in the TIA Annual Geotechnical Inspection reports.	
Total Freeboard	3.3 m	1.5 m
Hydraulic Freeboard	1.8 m	0.5 m
Thermal Protection above Frozen Core	2.5 m	n/a
Settlement and Allowance	1 m	0.47-0.67 m (Foundation thaw of 1 m) 2.45-3.85 m (Foundation thaw of 7 m)
Deformation Allowance (Total Strain due to Creep)	<2%	n/a
Crest Width	13 m	10 m
Upstream Structure Slope	6H:1V	4H:1V
Downstream Structure Slope	4H:1V	2H:1V
Key Trench Depth	Varies	4.0 m
Key Trench Upstream Slope	0.5H:1V	2H:1V
Key Trench Downstream Slope	0.5H:1V	1H:1V
Dam Hazard Classification	HIGH	HIGH
Design Life: Active use period as water retaining structure Design basis as active water retaining structure	 17 years 22 years	

Description	North Dam	South Dam
Active use period as solids retaining structure Design basis as solids retaining structure Total life until breach	 22 years	17 years 25 years
Production Life	17 years	
Tailings Solids Content	35% solids (by weight) initially, increasing to 65%	37.5% solids (by weight)
Tailings Specific Gravity	2.85	
Deposited Tailings Dry Density	1.3 t/m^3(1)	
Ice Entrainment Allowance: Percentage of tailings capacity By volume	 20% 2.4 Mm^3	
Tailings Beach Slope: Subaerial tailings Sub-aqueous tailings	 1.0% 1.0%	
Annual Exceedance Probability (AEP) for Risk Based IDF	1/2475 (0.0004)	
AEP for Standards Based IDF	1/3 between 1/1000 and the Probable Maximum Flood (PMF)(1)	
Static Stability Factor of Safety Long-term (Drained Conditions)	1.3 during construction 1.5 during operation and closure 1.2 to 1.3 partial or rapid drawdown	
Stability Factors of Safety (Pseudo-Static)	1.0 during earthquake	
AEP for Earthquake Design Ground Motion	1.2 post earthquake	
Peak Ground Acceleration (PGA)	0.060g(2)	0.036g
Mean Annual Air Temperature Climate Change	+6.8°C up to year 2100	
Thermal Design Freezing Point Depression Tailings Overburden Frozen core	 n/a -8°C -2°C	 0 to -1°C -2°C n/a
Seepage Allowance	78 m^3/day	50 m^3/day

Notes:
(1) Value based on experiential engineered judgement.
(2) A peak ground acceleration for a 1/2475 return period was not available at the time of design of the North Dam, and therefore the PGA of 0.06 g was selected based on published data for Kugluktuk. This is further described in SRK (2007).

2.4 Dam Break Analysis

In determining the dam hazard classification, in the context of the TIA Dams, consideration was given to tailings supernatant water and tailings solids reaching the receiving environment. In the context the Madrid North CWP, consideration was given to mine contact water reaching the receiving environment. Based on the hypothetical dam breach studies the Madrid CWP (Appendix A) is a low-consequence dam. An embankment failure at the Madrid CWP would not lead to an emergency scenario threatening loss of life, or irreversible damage to the environment.

The breach scenarios described below are intuitive, although likely extremely conservative. Nonetheless, these scenarios were adopted in assigning the dam hazard classification for the structures. A high-level dam breach analysis was completed for the North and South Dam in 2019 by SRK. Results are available in Appendix B.

North Dam

Breaching of the North Dam would reach

- Tail Lake outflow,
- Doris Lake, Doris Creek,
- and Little Roberts Lake further downstream.

Supernatant Water

Supernatant water could conceivably reach the entire north downstream catchment all the way to Roberts Bay.

Note: under a conservative case where the largest possible volume of supernatant water (over 12 Mm^3) is discharged rapidly over a period of less than 8hrs, then the Doris Creek Bridge would also be damaged.

Tailings Solids

Based on the current deposition plans (off the South and West dams on the south end of the TIA) there is no conceivable chance of tailings mass solids being released as a result of a breach of the North Dam.

South Dam

Breaching of the South Dam would reach

- Ogama Lake,
- Ogama Lake outflow, and
- Subsequently, Doris Lake.

Supernatant Water

Supernatant water would eventually progress all the way along the drainage network to Roberts Bay.

Tailings Solids

A breach of the South Dam could result in tailings solids releasing

- into Ogama Lake and
- though a remote chance, into the Ogama Lake outflow and ultimately Doris Lake.

Tailings solids would not be expected to be transported any further than Doris Lake, with most tailings between the South Dam and down to and into Ogama Lake.

Madrid North CWP

The modelled scenario is for a worst-case hypothetical condition where the Probable Maximum Precipitation (PMP) event occurs while the CWP is partially full due to a pumping or water management failure. During this

hypothetical event, it is assumed that the pond would overtop causing a hydraulic failure of the embankment and releasing the stored water and PMP volume.

Results show the potential for a flow path to the current Madrid portal area. However, the risk to personnel, vehicles, and infrastructure by this flow is very low. Maximum flow depths in the location are less than 0.2 m.

3 Dam Safety Management System

Definition

The Hope Dam Safety Management System (DSMS) is a collection of documents and system that define the safe operation and management of the North Dam and South Dam at the Doris TIA. This Dam Emergency Plan is a part of the DSMS, its function with respect to other key documents is outlined in Section 3.1 below.

Objectives

- Act as a prescriptive framework of documents that to be referenced during operations
- The documents work together to define the approach to dam safety at Hope Bay

Components

The key documents comprising the DSMS include:

- Hope Bay Doris TIA OMS Manual
- Doris TIA Trigger Action Response Plan
- Dam Monitoring Standard Operating Procedures
- Hope Bay Project Dam Emergency Plan
- Hope Bay Project Emergency Response Plan

3.1 Dam Safety Management System Key Documents

The function of each document is described in Table 3-1 - DSMS Key Document Definitions below. The relationship and references between the documents are outline in Figure 3-1Table 3-1 below.

Table 3-1 - DSMS Key Document Definitions

Document	DSMS Function
Hope Bay Doris TIA OMS Manual	• Main Operational document for the Doris TIA • Defines the Dam Safety Management System framework for Hope Bay • Contains (Appendices) or references other key DSMS documents

Doris TIA Trigger Action Response Plan	• Appendix G of the Hope Bay TIA OMS Manual
	• Define the conditions and thresholds corresponding to each trigger level for the North Dam, South Dam, and the TIA Reclaim Pond Water Elevation
	• Defines initial actions to be taken for operational trigger levels:
	  ○ Green: Normal Operating Conditions
	  ○ Yellow: Early Warning Conditions
	  ○ Orange: Corrective Action Conditions
	  ○ Red: Emergency/Uncontrolled Condition
	• Specific conditions and thresholds are defined for instrumentation data readings, as well as visual observations from inspections.

Dam Monitoring Standard Operating Procedures	• Appendix H of the Hope Bay TIA OMS Manual • Describe in detail the requirements and procedures for dam monitoring under normal operating (Green) conditions
Hope Bay Project Dam Emergency Plan (this document)	• Appendix F of the Hope Bay TIA OMS Manual • Activates in the event of an emergency at any of the dams on site. • Further defines the initial response to an emergency condition at the dams (Red Trigger Level). • Includes the personnel, equipment and communication systems available to respond to an emergency situation at the dams. • Is linked the Hope Bay Project ERP
Hope Bay Project Emergency Response Plan	• Appendix E of the Hope Bay TIA OMS Manual • Activates in the event of an emergency on site. • Defines the initial response to an emergency. • Includes the personnel, equipment and communication systems available to respond to an emergency situation.

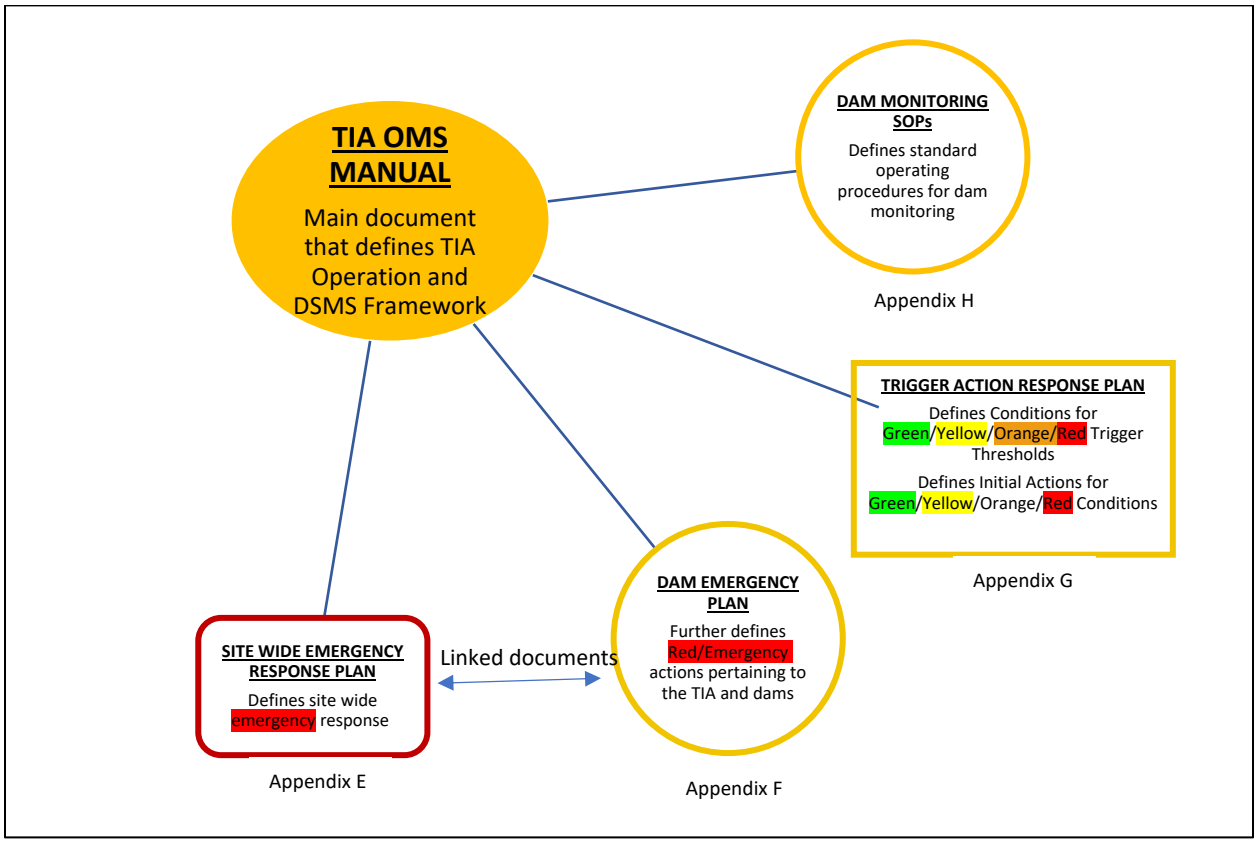


Figure 3-1 - DSMS Document Relationships

3.2 Definition of the Trigger Action Response Plan Levels

The Trigger Action Response Plan defines the initial actions to be taken in response to specific conditions observed at the TIA and dams. The following table defines each of the trigger levels for the Hope Bay Project.

Table 3-2 - Definition of Trigger Levels

Trigger Level	Condition	Definition
Green	Normal Operating Condition	Maintain normal operating procedures.
Yellow - Level 1	Early Warning Condition	Areas of concern identified - Requires further investigation to determine **requirements for increased monitoring**
Orange - Level 2	Corrective Action Condition	High Risk Situation - Requires mitigation actions or operational controls to prevent an emergency situation from developing. **Implement Level 2 Actions.**
Red - Level 3	Critical Condition	Emergency Situation - Immediate threat to health and safety or environment that is uncontrollable through operational controls or mitigation actions. **Implement the site wide Emergency Response Plan and/or Dam Emergency Plan**

3.3 DSMS Communication and Decision Making

Figure 3-2 indicates the communication and decision processes when the threshold criteria are met and when pre-defined action need to be implemented. Table 3-3 : Communication Procedure to Change TARP Level indicates the communication procedure to follow when changing the TARP level.

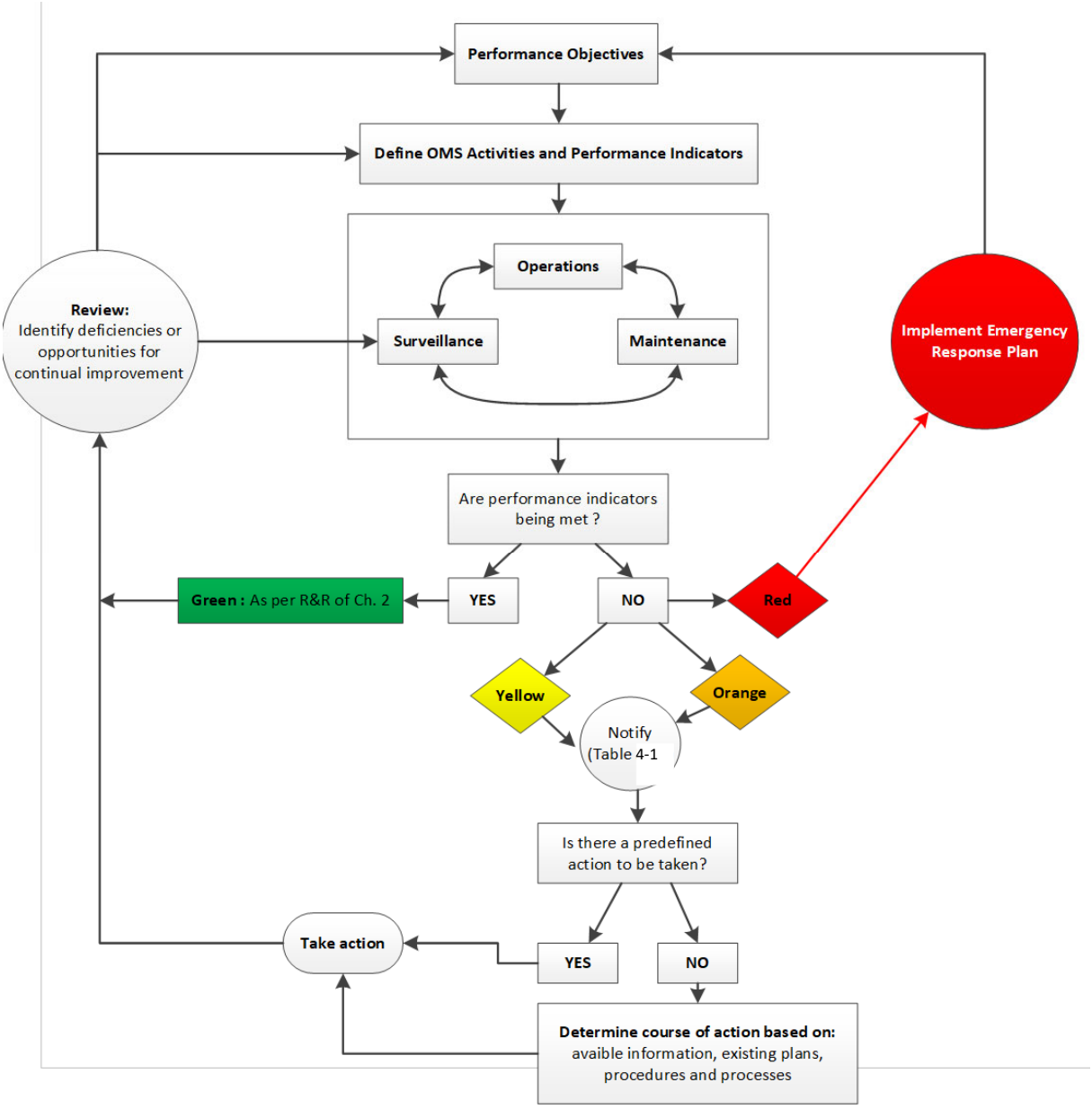


Figure 3-2: Communication and Decision Process for Water Management Infrastructure TARP

Table 3-3 : Communication Procedure to Change TARP Level

Category	Notify	Timeline	Method of Communication
Green	On-Site team → Responsible person → • Independent Review Board • Designer • General Manager • EOR • AEO	The trigger are back to green for more than 2 weeks	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status Brief memo sent by e-mail to officialise TARP change

Category	Notify	Timeline	Method of Communication
Yellow	On-Site team → Responsible person → • EOR	Within 24 hours of the TARP level condition being met	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status. If RP can't be joined the on-site team will try to contact these people in this order : Site Geotechnical Engineer, EOR, AEO
	Responsible person → • Independent Review Board • Designer • General Manager • EOR • Process Plant Superintendent	Within 72 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation if required
	EOR → • AEO	Within 1 week of TARP level change	Left to the EOR discretion
Orange	On-Site team → Responsible person → • EOR	Immediately upon discovering TARP level triggers change	Phone Call, E-mail and meeting to inform on status change. If RP can't be joined the on-site team will try to contact these people in this order : Site Geotechnical Engineer, EOR, AEO
	Responsible person → • Independent Review Board • Designer • General Manager • EOR • AEO • Health & Safety Superintendent • Process Plant Superintendent	Within 24 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation
RED	On-Site team → Emergencies Response Team Once an emergency is declared refer to the ERP. Emergency response is out of scope of this document	Immediately when the emergency is discovered. If there is currently a risk to Env or Health and Safety	Emergency – Emergency Emergency and road channel Or at Emergencies 911
		Immediately when the emergency is discovered. If there is imminent risk to Env or Health and Safety	Phone call to ERT coordinator (103) & Health and Safety Superintendent

3.4 North Dam and South Dam Operating Criteria

The operating criteria for the North Dam and South are defined by the Trigger Action Response Plan, and the Dam Monitoring Standard Operating Procedures.

North Dam Monitoring SOP	TIA OMS Manual Appendix H
North Dam Trigger Action Response Plan	TIA OMS Manual Appendix G, Table 1
South Dam Monitoring SOP	TIA OMS Manual Appendix H
South Dam Trigger Action Response Plan	TIA OMS Manual Appendix G, Table 2

Madrid North CWP Operating Criteria	Madrid North CWP OMS Manual

3.5 TIA Operating Criteria and Freeboard Requirements

3.5.1 TIA Water Reclaim Pond Operating Criteria and Thresholds

The operating criteria for the TIA water reclaim pond elevation is presented in Table 3-4 below. The water reclaim elevation criteria are also included in the Trigger Action Response Plan (Appendix G, Table 3).

The Hope Bay Water Management Plan. provides an overview of the site wide water management strategy.

Table 3-4 - TIA Water Reclaim Pond Operating Criteria and Thresholds

Structure	**Freeboard to crest (m)**		**Maximum tailings elevation (m)**	**Operation Water level (m)**		**Corrective Action Condition** **Max = Full Supply Level (m)**	**Critical Condition Level (m)**
	Tailings	**Water**		**Normal**	**Early Warning level (m)**		
North Dam	N/A	2.0	N/A	<31.5	31.5-32.5	32.5-33.5	>33.5
South Dam	1.5	N/A	33.5	N/A	N/A	N/A	N/A
TARP Level	N/A			Green	Yellow	Orange	Red
Response	N/A			Standard operations	Inform stakeholders (**Table 3-3**)	Immediately take action to stop increase. Inform stakeholders (**Table 3-3**)	Trigger ERP and DEP (Section 8)

3.5.2 North Dam and South Dam Freeboard Requirements

North Dam

The North Dam is operated as a water retaining dam with the parameters indicated below.

Component	Elevation (m)
crest elevation	37.5
top of frozen core and geosynthetic clay layer	35.3
full supply level	33.5
total freeboard	4.2
normal freeboard	2

Note: These freeboard numbers include a 1 m allowance for dam deformation (SRK 2015a). Total freeboard also includes required area to store a storm volume at least 1/3 between 1/1000 and the PMF (see Section 3.10).

South and West Dams

The South and West Dams are not water retaining structures with the parameters indicated below.

Component	Elevation (m)
crest elevation – Phase 1 (current elevation) crest elevation – Phase 2	38.0 44.5
top of geosynthetic clay liner – Phase 1 (current elevation) top of geosynthetic clay liner – Phase 2	36.5 45.0
full supply level	33.5
freeboard	1.5

Note: Tailings beaches along the upstream slope of these dams creates a final topography that free-drains towards the Reclaim Pond ensuring no water will pond adjacent to these structures. Tailings deposition discharges from points located near the dam crest. The tailings level at the South and West dam is designed to be above the full supply level (which is governed by the elevation of the North Dam).

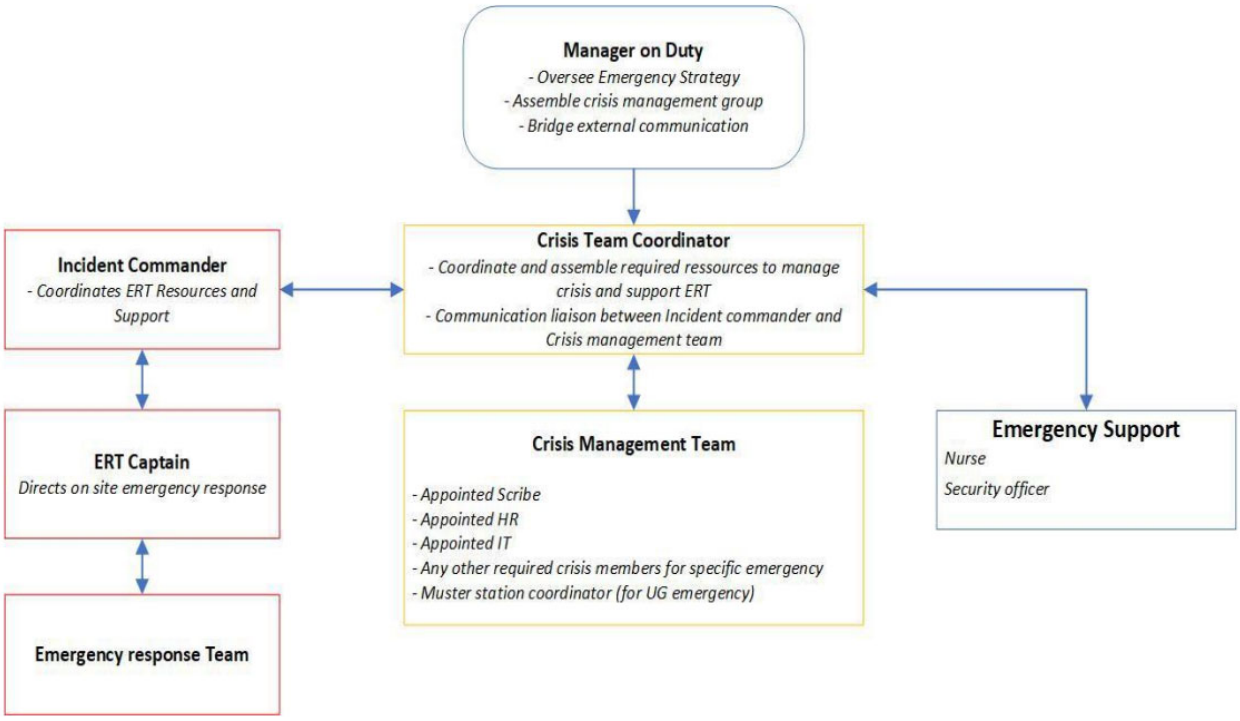
4 Emergency Response Structure and Roles

Response to dam related emergencies will use the same emergency response structure and crisis management as described in the Hope Bay Project Emergency Response Plan. Hope Bay crisis management is summarized in the subsections below. Additionally, roles and responsibilities outlined in Section 2 of the TIA OMS Manual also apply to dam related emergencies.

4.1 Crisis Management Team

The Crisis Management Team (CMT) is responsible for directing all work performed and managing all resources during an emergency incident. The CMT is typically formed by senior management or designates performing the various required functions to ensure the safety of all personnel involved. The CMT draws on resources from Safety, Operations, Technical Services, Environment and Maintenance personnel as necessary to complete emergency response tasks. The Structure of the CMT is outlined in Section Depending on the nature of the emergency, additional managers and personnel may be added to the CMT. For a detailed description of the roles and responsibilities of CMT members, refer to section 3 of the Hope Bay Emergency Response Plan.

4.1.1 Crisis Management Team Command Structure



4.1.2 Crisis Management Centre

Crisis management operations will be directed out of the Crisis Management Centre located at the Administration Board Room. Location will depend on the nature and circumstances of the emergency.

• Key decisions will be made, and operations will be managed.
• Technical information to direct emergency activities will be provided.
• A communications centre will be established for emergency operations and to communicate with other organizations.
• Resource procurement will be provided, and resource use will be directed.
• Information on the emergency will be logged for accuracy and disseminated to all necessary internal and external parties.

All responses and mitigation efforts developed at the Crisis Management Team will be implemented through the IC. In the event of an emergency, security personnel may be required to establish and maintain a security perimeter to prevent or minimize injury to personnel, to preserve evidence for investigation, or to prevent unauthorized access to the scene.

4.1.3 Emergency Response Contact Information

An accurate list of available responders will be kept updated as required and communicated to stakeholders.

ERT Roster May 25 to June 1, 2022

Active			
Room	D/N	Company	Name
B4	D	AEM	Sanderson, Jason
B32	D	AEM	Gentile, Evan
G13	D	KCMD	Stoddart, Jason
G7	D	KCMD	Andrews, Jamie
G17	D	KCMD	Levac, Leo
G10	D	KCMD	Misponas, Sheldon
B20	D	AEM	Mercer, Mervin
E1	D	AEM	Dunn, Sarah
B11	D	AEM	Britnell, Troy
B6	D	AEM	Hill, Jonathan
B8	D	AEM	Adlem-Qilluniq, Scott
C9	D	AEM	Trahan, Derek
B22	D	AEM	O'Neill, Ron
B15	D	AEM	Munyoro, Edwin

Total Active ERT On Site

AGNICO EAGLE HOPE BAY

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©Captains ©			
Room	D/N	Company	Name
C9	D	AEM	Trahan, Derek
B4	D	AEM	Sanderson, Jason
	D		
	D		

Incident Command & Control On Site			
Room	D/N	Position	Name
C4	D	General Superintendent	Desrochers-Gagnon Philemon
C2	D	Health & Safety	Towle, Brad
E13	D	Enviro General Supervisor	Dufor, Guy
C3	D	Exploration Superintendent	Dix, Conrad

Medic On Site	Radio Channel 6		
Room	D/N	Company	Name
C10	D	AEM	Hamlin, Vicky

ERT Coordinator			Radio channel 2
Room	D/N	Company	Name
B4	D	AEM	Sanderson, Jason

Security			Radio channel 2
Room	D	Company	Name
B4	D	AEM	Sanderson, Jason

Pandemic Coordinator			
			Tonia Ajijola

WILDLIFE RESPONSE TEAMS

Radio channel 1 for reporting dangerous sightings IE: Grizzly

Radio Channel 7 for reporting non threatening wildlife encounters

WRT Team #1			
Room	D/N	Company	Name
C9	D	AEM	Trahan, Derek
B4	D	AEM	ontVanderwinkle, Guillau

WRT Team spare			
Room	D/N	Company	Name

WRT Team #2			
Room	D/N	Company	Name
B4		AEM	Jason Sanderson
B32		AEM	Gentile, Evan

WILDLIFE RESPONSE TEAM LEAD*			Radio Channel 7
Room	D/N	Company	Name

Table 3.1: Emergency Response Contact Information Chart

Name	Position	Office Phone	Mobile Phone	E-Mail
Eric Steinmetzer	General Mine Manager	819.759.3555 x4600104	(819) 763-0187	eric.steinmetzer@agnicoeagle.com
Philemon Desrochers-Gagnon	General Superintendent	819.759.3555 x4600106	(819) 355-0815	philemon-desrochers@agnicoeagle.com
Emma Geist	Human Resources Superintendent	819.759.3555 x4600138	(819) 860-2898	emma.geist@agnicoeagle.com
Brad Towle	Health & Safety Superintendent	819.759.3555 x4600138	403-714-1350	brad.towle@agnicoeagle.com
Conrad Dix	Exploration Superintendent	819.759.3555 x4600126	(905) 975-6150	conrad.dix@agnicoeagle.com
Philippe Lapointe	Engineering Superintendent	819-759-3555 x4600106	(819) 860-2898	philippe.lapointe@agnicoeagle.com
Dan Izzard	Materials & Logistics Superintendent	819-759-3555 x4600154	(780) 245-4293	dan.izzard@agnicoeagle.com

Table 3.2: Hope Bay Phone Numbers

Health and Safety		
Medics	Vicky Hamelin / Todd MacDonald	4600105
Health & Safety Manager/Super	Brad Towle	4600138
ERT Coordinator		4600103/4600196
Medic's Room	After Hours ****EMERGENCY ONLY****	4600115
Trainer	Don Harvey / Jason Sanderson	4600110
Security Officer	Bob Fogarty / John Fitzgerald	4600165
Pandemic Counselor	Louis-Philippe Gélinas	4600174
Surface Operations		
General Manager	Eric Steinmetzer	4600104
Maintenance General Supervisor	Cody Kerr	4600131
Electrical/Inst. Supervisors		4600117
Site Services Supervisor	Derek Trahan / Nelson Bell	4600126
Powerhouse	Norm Bertholds / Scott Adlem-Qilluniq	4600127
Warehouse Superintendent	Dan Izzard	4600154
Warehouse Team Lead	Dave Thomas / Jerry Gill	4600172
Warehouse (General)		4600158
Logistics Coordinator	John Pruden / Kevin Rutter	4600134
Mechanical Lead Hand		4600140
Light Vehicle Shop		4600157
Electrical Shop		4600139
Plumber's Shop		4600109
Electrical Planner		4600177
Mobile Planner		4600186
Mobile Maintenance Supervisor		4600130
Projects		4600122
Human Resources Superintendent	Emma Geist	4600159
Human Resources	Amanda Markmeyer / Tasha Robichaud	4600160
WTP		4600143
Mine Dept.		
Manager of Mining		4600179
Agnico Shift Supervisors / Wicket		4600163
Chief Mine Engineer		4600125
Core Shack		4600148
Senior Mining Engineer	Jian Yong Chen	4600100
Mine Planning	Mike Tanasa	4600132
Surveyor	Mervin Mercer	4600129
Senior Geology	Chris Annan	4600128
Geology		4600161/4600164
Tech Services/Mining Superint.	Philemon Desrochers / Phil Lapointe	4600106
Exploration Logistics	P.-O. Lamontagne / Sheldon Cameron	4600124
Explo Superintendent & Coordinator	Conrad Dix / Guillaume Beaudoin	4600135
KCMD Superintendent	Rod Keats / Charlie Riley	4600113
KCMD Safety/Trainer	Jason Cole / Jason Stoddart	4600119
Mill		
Process Plant Superintendent		4600145
Assay Lab Supervisor		4600173
Mill Control Room		4600150
Mill Shifters & Training		4600152
Mill Metallurgy		4600153
Mill Refinery		4600188
Mill Process Control		4600169

IT		
IT Coordinator	Stephan Quessy	4600178
IT HelpDesk	Yaser Imtiaz / Ali Hasnain	4606717
	hb.it@agnicoeagle.com	
Enviro Dept.		
Enviro Superintendent / Gen Sup	Nancy Duquet-Harvey / Guy Dufour	4600102
Environment Coordinator	Guillaume Vandewinkel / Jamie Power	4600101
Environment Tech	William Nalley / Tyler Lausch	4600101
Waste Management	Rob Bond / Jason Silverwood	4600187
Site Contractors		
Kitikmeot Catering Manager	Mike Hollick / Allan Lingwood	4600107
Geotech Supervisors	Michel/James	4600108
Geotech UG Supervisors	Derwin/Glen	4600191
Geotech Health & Safety	Dan Pearson / Steven Pereira	4600114
Geotech Shop		4600170
Public Phones		
Outside Kitchen	Public #1	4600111
Outside Kitchen	Public #2	4600112
Camp	Public #3	4600120
Camp	Public #4	4600121
D Wing	Public #5	4600136
D Wing	Public #6	4600137
E Wing	Public #7	4600181
E Wing	Public #8	4600182
G Wing	Public #9	4600183
G Wing	Public #10	4600184
G Wing	Public #11	4600185

Table 3.3: External Emergency Phone Numbers

WSCC Accident Reporting Line (24 hours) Use 1st	1-800-661-0792
WSCC General Mines Inspector	867-669-4412
WSCC General line (Yellowknife)	867-920-3888
WSCC General line (Iqaluit)	867-979-8500
Stanton Hospital (Emergency)	867-669-4100
Stanton 24-hour hot line	867-669-4115
Stanton Hospital (General Inquires)	867-669-4111
Cambridge Bay Health Center	867-983-4500
RCMP Cambridge Bay	867-983-0123 867-983-1111
RCMP Yellowknife	867-669-1111
RCMP Iqaluit	867-979-0123 867-979-1111
Nunavut Coroner's Office	867-975-7292 867-222-0393
Yellowknife Coroner's Office	867-920-8713
Adlair (Cambridge Bay)	867-983-2569 867-983-2247
Air Tindi	867-669-8218 (Ext. 8292)
Summit Air	867-669-9789 (Ext. 221)
Arctic Sunwest	867-873-4464
Great Slave Helicopters	867-873-2081
Nunavut Emergency Management "Medevac"	800-693-1666
Keewatin Air Medevac	1-867-9202400 1-867-920-2300

4.2 Governance and Individual Responsibilities

Agnico Eagle is committed to the protection of the public, the environment and its personnel. The company has developed a governance policy for its critical infrastructure to ensure their management in an appropriate and responsible manner (AEM 2020). The primary elements of the policy are:

- The development of specific roles with specific responsibilities;
- Regular and consistent reporting;
- Accountability at all levels, from operations to corporate;
- The use of Best Available Technology (BAT) and Best Applicable Practices (BAP); and
- The use of a risk-based approach to manage the risks associated with critical infrastructure

The persons responsible for operations, maintenance, surveillance, emergency preparedness, and emergency response along with the governance policy are listed below and in Appendix A, which also provides the site management structure.

Accountable Executive Officer (AEO)	As emphasized by MAC (2019), the accountability for decisions related to tailings management rests with the Owner's Board of Directors or Governance Level. The Board of Directors or Governance Level is expected to designate an Accountable Executive Officer (AEO) for tailings management. More specifically, the following responsibilities are assigned to the AEO: • Needs to be aware of key outcomes of water management risk assessment and of how these risks are being managed • Has accountability and responsibility for putting in place appropriate management structure • Assign responsibility and appropriate budgetary authority for tailings management • Define the personnel duties, responsibility and reporting relationships, supported by job description and organisational charts to implement the tailings management system through all stages in the facility life cycles Provide assurance to AEM and its Community of Interest that tailings are managed responsibly
Mine General Manager	• Identify the scope of work and budget requirement for all aspects of tailings management • Approve budget for operations, maintenance, and surveillance related activity • Establish an organisational structure with Roles and Responsibilities that meets the Governance Standard on Critical Infrastructure • Identify and retain a Responsible Person (RP)

	• Liaise with independent reviewer (IRB) as required
General Superintendents	Ensure the OMS responsibilities delegated to the departments they oversee are carried out as described in this section of the OMS Manual
Engineer of Record (EoR)	The function of EoR is to support AEM in ensuring that mine waste and water management infrastructure are designed and operated properly. The owner, in assuring that these facilities are safe, has the responsibility to identify and retain an EoR, who provides technical direction on behalf of the owner. Having an EoR for mine waste and water infrastructure is recognized as one of the best practices for responsible management of mine waste and water management facilities. In accordance with the AEM Governance Policy for Critical Infrastructure, the EoR is an employee of AEM. The EoR's responsibilities include: • Support and give technical advice to the RP and the AEO on geotechnical and operational challenges • Participate if possible, in Dam Safety Inspections and associated reports for tailings facilities that include retention structures/dams • Verify if the Tailings Impoundment Area (TIA), waste rock storage facility (WRSF), and Water Retaining Infrastructures are designed and are operating in accordance with the best standards in the industry and the AEM corporate standards • Verify if the waste and water management plans are developed and followed to ensure safety of the operation and the business; • Review and provide agreement on the procedural documents related to waste and water management (including OMS, ERP and TARP); • Be available for the Independent Review Board (IRB); • Participate in IRB meetings and assist the RP in their preparation if required; • Participate in the facility's risk assessments; • Be available to participate in dam safety reviews; • Identify other internal or external professionals (such as hydrogeologists, geologists, hydrologists, etc.) to provide their support when required; • Propose a schedule of site visits and required meetings during the course of the year.
Design Engineer (DE)	Engineer Responsible for the design and annual inspection of the facilites. At Hope Bay, the DE plays an important role in the management of critical infrastructure. • Advise on contemplated changes to the structure operation • Advise on structure performance and mitigation work as required • Present during independent review board meeting to provide input and context on the structure performance

Responsible Person	The Responsible Person(s) identifies the scope of work and budget requirements (subject to final approval) for all aspects of tailings management, including the Engineer of Record (EoR), and will delegate specific tasks and responsibilities for aspects of tailings management to qualified personnel." The RP is directly responsible for the management of critical infrastructure on a specific site with the objective of compliance with the Governance. The management of critical infrastructure includes design, construction, operation and closure. The RP may delegate specific tasks and responsibilities for aspects of tailings management to qualified personnel (MAC 2017). • Ensure the implementation and sustainability of the Governance model at the site level; • Management of critical infrastructure, as well as appurtenant structures that may affect the critical infrastructure; • The management of personnel, budget and external resources for the critical infrastructure (external resources include the Design Engineer (DE), Independent Review Board (IRB) and any other necessary consultants/contactors); • Close collaboration with the EoR and communication with the Design Engineer and Independent Review Board); • Preparation for, and coordination of, IRB meetings and site visits; • Preparation for, and coordination of, annual geotechnical inspections; • Responding to, and implementation of, the recommendations of the IRB; • Annual review and update of the OMS Manual in collaboration with the EoR; • Continued application of the requirements of the OMS; • In collaboration with the EoR, preparation of an annual report on the status of the critical infrastructure; • Management of all documents and data related to design, construction, operation, closure, surveillance and monitoring in a secure, accessible and permanent manner; • Revise and update the OMS Manual to reflect as-built conditions and any other changes. Review and update the OMS manual into Intelex. Maintain up to date distribution list of the OMS Manual
Site Geotechnical Engineer (EIT)	The Site Geotechnical Engineer (or EIT) is designated by the RP and is responsible for specific tasks and responsibilities for aspects of tailings management that are delegated by the RP. The Site Geotechnical Engineer works closely with the RP and EOR. At Hope Bay the responsibilities of the Site Geotechnical include: • Support the implementation and sustainability of the Governance model at the site level;

	• Management of critical infrastructure, as well as appurtenant structures that may affect the critical infrastructure; • Support the management of personnel, budget and external resources for the critical infrastructure (external resources include the Design Engineer (DE), Independent Review Board (IRB) and any other necessary consultants/contactors); • Close collaboration with the EoR and communication with the Design Engineer and Independent Review Board; • Preparation for, and coordination of, IRB meetings and site visits; • Preparation for, and coordination of, annual geotechnical inspections; • Responding to, and implementation of, the recommendations of the IRB; • Annual review and update of the OMS Manual in collaboration with the EoR and RP; • Continued application of the requirements of the OMS; • In collaboration with the EoR, preparation of an annual report on the status of the critical infrastructure; • Management of all documents and data related to design, construction, operation, closure, surveillance and monitoring in a secure, accessible and permanent manner; • Review, revise and update the OMS Manual to reflect as-built conditions and any other changes. Review and update the OMS manual into Intelex. Maintain up to date distribution list of the OMS Manual • Ensure that maintenance work (predictive, preventive and corrective) is identified and carried out on the earthwork and instrumentation system in collaboration with the Site Services Department • Ensure the surveillance of the structures as required in the OMS Manual (visual inspection and instrument monitoring) is carried out • Ensure the maintenance work (predictive, preventive and corrective) on the earthwork and instrumentation system is identified and performed • Ensure that the surveillance data is reviewed and analyzed to evaluate dike performance with respect to design parameters • Ensure surveillance of the structures is carried out as required in the OMS Manual (visual inspection and instrument monitoring)
Independent Review Board (IRB)	Independent Review Boards are a mechanism to obtain independent, expert commentary, advice, guidance and where appropriate, recommendations to assist owners/operators in identifying, understanding, and managing risks associated with TSF, WRSF, WSF, HLF and water-retaining infrastructures. The

	Independent Reviewer(s) does not have decision-making authority. Accountability and responsibility for decisions rests with AEM. • Review mine waste management strategy (including tailings and waste rock storage facilities); • Review water management infrastructure designs and performance (including water retaining infrastructures); • Review on-going construction works and monitoring data; • Comment on implementation progress of proposed mine waste management improvement measures; • Provide opinions and guidance to the operation on the physical integrity, safety, behavior, and performance of the confinement systems for mine waste and water retaining infrastructures; and • Comment on management systems, emergency preparedness and overall management approach of the different mine waste management facilities and water retaining infrastructures.
Process Operations Superintendent	The Process Plant Department is the owner of the process plant. They work in close collaboration with the other stakeholder to ensure the success of tailings management. The Process Plant Superintendent is in charge of the Process Plant and ensure that: • The Process Plant team as sufficient resource (qualified workforce, material, budget, training) to fulfill the OMS obligation defined in this manual • A structure is in place that define the R&R, qualification, training requirement and a staffing strategy to fulfill the obligation of the OMS Manual • The process plant operates and maintains the infrastructure required to produce and transport (i.e pump) the tailings to tailings impoundment area • The process plant tracks the parameters and characteristics of the tailings produced to ensure that targets are reached • The process plant operates the reclaim water system and tracks the water consumption to ensure that targets are reached • The process plant stops the transport of tailings if required in case of upset or emergency condition
Environment Superintendent	The Environment Department ensures compliance with Environment Regulation and the Water License and is the owner of the water & tailings management infrastructures outside of the process plant. They ensure reporting and liaison with the NIRB, NWB, NGO's and other government agencies. The Environment Superintendent is in charge of the Environment Department and ensure that:

	• The Environment team has sufficient resources (qualified workforce, material, budget, training) to fulfill the OMS obligations defined in this manual • A structure is in place that defines the R&R, qualification, training requirement and a staffing strategy to fulfill the obligation of the OMS Manual • Environment review monitoring data for compliance with Water License and regulations and to determine dike performance with respect to design parameters • Support the Site Geotechnical Engineer
Site Services Superintendent or designate	The Site Services Department has the workforce and equipment to manage road, electricity and dewatering at the Hope Bay Site. They fulfill the planning done in collaboration with the Environment team to ensure the fulfilment of the OMS requirement. The Maintenance Superintendent is in charge of the Site Services Department and ensure that: • The Site Services team has sufficient resources (qualified workforce, material, budget, training) to fulfill the OMS obligation defined in this manual • A structure is in place that defines the R&R, qualification, training requirement and a staffing strategy to fulfill the obligation of the OMS Manual • Site Services maintain access to the structure and tailings management systems. This include making road repairs, controlling dust and managing snow and water. • Site Services install, operate, maintain and monitor all the components of pumps and piping system associated with water management. They also perform operation, maintenance and surveillance work on the piping system. This work is planned in collaboration with the Environment Department. • Update and maintain a list of operational pumping equipment • Install, operate, maintain and monitor all the components of pumps and piping system associated with water management. They also perform operation, maintenance and surveillance work on the piping system. The Site Services Department has the workforce and equipment to maintain mobile equipment and pumps. They fulfill maintenance of some of the mechanical equipment component of the dewatering dike as requested by the Site Services department. The Site Services Superintendent is in charge of the Site Services Department and ensure that: • Ensure preventive, predictive and corrective maintenance is carried out regularly on pumping equipment related to water management as requested by Site Services

	• Keep records of maintenance performance on pumping equipment
Health and Safety Superintendent	The Health and Safety Department is responsible to update and manage the site wide emergency response plan. The Health and Safety Superintendent is in charge of the Health and Safety Department and ensure that: • The emergency response plan is updated and is aligned with the OMS manual • The trigger to raise an emergency defined in the OMS manual and the communication pathway to do so is understood and aligned with the ERP

4.3 Contact Information

Environment and Critical Infra VP / Accountable Executive Officer	Michel Julien |michel.julien@agnicoeagle.com 416-947-1212 x3738 514-244-5876
Engineer of Record (EoR) / Technical Specialist, Environmental Management	Thomas Lepine | thomas.lepine@agnicoeagle.com 418-473-8077
Design Engineer	John Kurylo | jkurylo@skr.com 604-235-8541
Site Geotechnical Engineer	Brennan Jay| brennan.jay@agnicoeagle.com 867-988-6882 x 4600122
Independent Review Board	Bill Horne | bill.horne61@gmail.com Henri Sangam | henri.sangam@geomino.com
Mine General Manager	Eric Steinmetzer | eric.steinmetzer@agnicoeagle.com 867-988-6882 x 4600104 819-763-0187
Lab & metallurgy Superintendent (currently inactive)	TBD 867-988-6882 x 4600101
General Superintendent - Mining	Philemon Desrochers-Gagnon | philemon.desrochers@agnicoeagle.com 867-988-6882 x4600106

	819-355-0815 Philippe Lapointe | philippe.lapointe@agnicoeagle.com 867-988-6882 x4600106 819-860-2898
Environment Superintendent (Responsible Person)	Nancy Duquet-Harvey | nancy.harvey@agnicoeagle.com 867-988-6882 x4600102 819-856-4385
Maintenance General Supervisor (Dewatering Superintendent)	Cody Kerr | cody.kerr@agnicoeagle.com 867-988-6882 x4600131
Health and Safety Superintendent	Jake Murdoch | jake.murdoch@agnicoeagle.com 867-988-6882 x4600123

4.4 Mutual Aid

Agnico Eagle Mines has a signed Mutual Aid Agreement with the following regional operations:

- Dominion Diamond Mines
- Diavik Diamond Mines
- De Beers Canada - Gahcho Kue
- Deton'Cho / Nuna JV (Giant Mine)
- Yellowknife Fire Department (YKFD)

Each mine recognizes that having Crisis and Emergency Response capability is essential in the event that extraordinary circumstances put human life, operational infrastructure or the environment in extreme danger.

Each operation also recognizes that, at times, the scale of an emergency or crisis may overwhelm their individual resources. It is both desirable and prudent to establish terms for a combined response should such circumstances arise.

4.4.1 Mutual Aid Contacts

Agnico Eagle Mines Limited (Meadowbank and Meliadine):

Call (819) 860-6258 or (819) 759-3555 ext. 6720 Meadowbank, or

Call (819) 759-3555 ext. 3911 Meliadine.

State that the call is a mutual aid request for the Mine Manager (or designate – Manager on Duty). Person will transfer the telephone call to the requested Mine Manager immediately and the ERT team will be paged, or the ERT Coordinators contacted.

Meadowbank ERT Coordinators are Richard Jackson and Philippe Beaudoin. Office phone number is (819) 7593555 ext. 6809

Meliadine ERT Coordinators are Dave Loder and Ken Ludwig. Office phone number is

(819) 759-3555 ext. 3906

Diavik Diamond Mines Inc.

Call (867) 669-6500 Ext. 5903. Phone number is monitored by Security Control 24 Hours a day.

State that the call is a mutual aid request for the Chief Operating Officer (or Duty Manager on the weekend). Security will transfer the call to the requested Manager. He or She will contact the ERT Advisor to coordinate the requested mutual aid.

DDMI ERT Advisors: Richard Kretzschmar and Dave Arthur (867) 669-6500 ext. 5462

Deton'Cho / Nuna JV (Giant Mine Reclamation Project):

Call (867) 669-3702 or Cell (867) 446-2387. Mine Manager Joe Heimbach

Call (867) 669-3722 or Cell (867) 445-2884. Safety Coordinator Randy Thompson

State that the call is for a mutual aid request for the Mine Manager.

Mine Manager is Doug Hayes. Office (867) 669-3715, Cell (867) 444-0355

ERT Coordinator is Steve Millar, Office (867) 669-3717, Cell (867) 445-5620

De Beers Canada – Gahcho Kué:

Call (416) 645-1695 Ext. 6699. Phone number is monitored by Security Control 24 Hours a day.

State that the call is a mutual aid request for the President/COO (or Manager on the weekend). Security will transfer the call to the requested Manager. Security will contact the ERT Advisor to coordinate the requested mutual aid.

Gahcho Kué ERT Advisors: John Gale and Richard Church (416) 645 1695 extension 6701

Dominion Diamond Mines:

Call (867) 880-2201 or (867) 880-4400. Both phone numbers are answered and monitored by Dominion Diamond Mines Security Control 24 hours a day.

State that the call is a mutual aid request for the Mine Manager (or designate on the weekend). Security will transfer the telephone call to the requested Mine Manager immediately and the ERT team will be paged, or the ERT Coordinators contacted.

Dominion Diamond Mines ERT Coordinators are David English and Nathan Pitre. Office phone number is (867) 880-2394.

Yellowknife Fire Department (YKFD):

YFFD would be utilized for backfilling the ERT for surface emergencies. This allows Ekati ERT members to focus on an underground incident or for emergency assistance on large surface emergencies.

Call the 867-873-2222 (Yellowknife Fire Department Dispatch) and request that the on-call command officer call the BRT Team leader for a mutual aid request. If a message is taken for relay (after hours) to the designated person, provide a telephone number that is guaranteed to be answered by the Operations Manager (IMT).

4.5 Emergency Response Equipment

The Incident Commander & Emergency Response Team members will be familiar with the emergency equipment and tools available and keep up to date of the status and location of emergency equipment.

Emergency Equipment and Tools			
Location	**Category**	**Unit**	**Quantity**
Mine Rescue Room	SCBA	Draeger Pss-5000	8
		4500 Psi Composite Cylinders	16
	CCBA	Draeger BG4	15
		Composite O2 Cylinder	30
		Draegersorb	500 lb.
		Ocenco	2
	Oxygen Therapy	Care vent	2
		BVM	1
	Rope Rescue	Static Rope 300 Ft	2
		MPD	3
		Carabiner	20
		Large Carabiner	2
		Prussic Long	4
		Prussic Short	4
		Break Rack Bar	2
		Single Pulley	6
		Double Pulley	6
		Figure 8	2
		Rope Grab	2
		Rescue Harness	2
	Gas Monitors	Draeger X-AM 5000	1
		Draeger Pac-7000	1
	Extrication Tools	Power Hawk Extrication Set Jaws Cutter Spreader Power Pusher Rams	 1 1 1 3
	First Aid	Stretcher Basket	2
		Backboard	2

Emergency Equipment and Tools			
Location	**Category**	**Unit**	**Quantity**
		Ferno Head Restraint	2
		First Aid Kits	8
		Arm Speed Splints	4
		Leg Speed Splints	2
		Blankets	9
	Confined Space	FAN8-12V Portable Ventilating Fan	1
		FAN-7004CL 25 Ft. Canister Duct	1
	Bunker Gear	Bunker Gear Set	12
	Nozzles	VIPER X 2 30 to 125 GPM	1
		ELKHART X 2 60 TO 150 GPM	1
		Fire Caddy 12 foam inductor	1
		Gated Y's 2 inch to 1.5 inch	3
		Gated Y's 2.5 inch to 2.5 inch	2
	Lay Flat Hose	lengths 2.5" rubber lined 50ft	11
		lengths 1.5" rubber lined 50ft	8
		lengths 1.5" fiber 50ft	2
	Ventilation Fans	Electric air pusher on wheels 110volt	1
		Electric air pusher carry only 110volt	1
		Gas powered air pusher on wheels	1
	Ice Water Rescue Gear	Ice water rescue suits	2
		100ft ice water rescue rope	1
		20ft ice water rescue throw rope	1
		Life jackets	10
		Ice rescue flotation rescue back board	1
	Confined space	Sked rescue body wraps	2
	First Aid	Trauma kits with oxygen	2
Fire Truck	CABINET 1	2.5" inch to 1.5" adaptors	3
		2.5" to 2.5" male female couplers	3
		2.5" to 2.5" female to female couplers	2
		2.5 female cam-lock to 2.5" threaded male adaptor	1
		4" female y to 2.5" male ends	1
		2.5" threaded to 2.5" male cam-lock	1

Emergency Equipment and Tools			
Location	**Category**	**Unit**	**Quantity**
		2.5" female to 1.5" female cam-lock	1
		6" female cam-lock to 4" male cam-lock adaptor	1
		4" female to 2.5" male cam-lock	1
		2.5" end cap cam-lock	1
		2.5" female gated y to 1.5" male ends	2
		Twist lock to a 2.5" threaded female end	1
		30-125 psi water flow 1.5" nozzles	3
		90-250 psi water flow 2.5" nozzle	1
		foam tube adapter to 1.5" nozzle	1
		2.5" hose wrenches	2
		1.5" foam educator	1
		Small pry bars	2
		Flashlight with spare battery	1
		Large pry bar on top cabinet	1
		1.5" hose wrenches on top of cabinet	2
	CABINET 2	1.5" ground mount 1.5" hose connection fan sprayer	1
		50FT 1.5" Fire hose	4
		10ft rubber lined 1.5" fire hose	1
		100ft 1.5" fire hose	1
		1.5" 20ft hard suction line with no connections	1
		Fire extinguishers	2
	CABINET 3	5 gallon can fuel	1
	TOP OF TRUCK	2.5" 50ft fire hose	1
		2.5" 100ft fire hose	1
		1.5" 50ft fire hose	1
		1.5" 100ft fire hose	1
	CROSS LAY	1.5" 100ft rubber fire hose	1
		1.5" 100ft fire hose	1
	CABINET 4	Toolbox	1
		Pail 2% foam	1

Emergency Equipment and Tools			
Location	**Category**	**Unit**	**Quantity**
	CABINET 5	2.5" 50ft fire hose	3
		Tank / drum plug kit	1
		bolt cutter	1
		3/4" foam hose	2
		2.5" hose wrenches	3
		Cleaning brush	1
	TOP	Large Halogen Bar	1
		Broom	1
		Large pry bar	1
		Hockey stick electrical	1
		Pick pole	1
	INSIDE CAB	PFD	3

4.6 Emergency Response Initiation and Communications

SECTION 2 - ACTIVATION OF AN EMERGENCY RESPONSE

Emergency response is activated following the activation of the Code 1 protocol. The protocol is triggered when an employee contacts the incident commander through the radio on Emergency Channel 1 and the Incident Commander acknowledges that this situation requires initiation of the Emergency Response Team. From there, ERT will be dispatched, and crisis management can be triggered if the situation requires it as per the incident commander's assessment.

SECTION 5 - COMMUNICATION SYSTEMS

The primary basis for communication will be the phone system; back-up communication will be available via satellite phones. For on-site communication, hand-held radios will be available for all employees working or travelling in remote areas from the main camp. Back-up power sources and replacement batteries for communication equipment will be available to provide continuous, uninterrupted operation either at fixed facilities or at emergency sites.

Key site personnel will be accessible at all times by either portable radios, radios in vehicles, or office radios. The Health Care Provider will carry a hand-held radio and will be available at all times. Designated personnel will monitor the emergency channel during day and night.

Lists of employees trained in first aid, mine rescue, and Emergency Response will also be posted.

5 Dam Emergency Scenarios

5.1 Dam Break or Uncontrolled Environmental Discharge – *Extreme Case*

An emergency or "Red" condition is defined as a situation where there is a credible threat to the health and safety or an uncontrollable discharge of tailings/contact water resulting in irreversible environmental impacts.

5.1.1 Breach of the North Dam

In the event of a breach of the North Dam. Access to the North Dam via Doris Bridge should be immediately restricted via **activation of the site wide ERP.**

Based on conservative dam breach scenarios, Doris bridge may be impacted by a dam breach event (Appendix B).

5.2 Potential Actions in the Event of a Dam Breach

If time permits, the following emergency remedial actions should be **considered**. Immediate implementation of these remedial actions may delay, moderate, or prevent the failure of the dam. Several of the listed adverse or unusual conditions may be apparent at the dam at the same time, requiring implementation of several modes of remedial actions. Close monitoring of the dam must be maintained to confirm the success of any remedial action taken at the dam. Time permitting, any remedial action should be developed through consultation with AEM's Engineer of Record.

Embankment Overtopping

1. If the water level in the reservoir is no longer rising, place sandbags along the low areas of the top of the dam to control wave action, reduce the likelihood of flow concentration during minor overtopping, and to safely direct more water through the spillway.

2. Cover the weak areas of the top of the dam and downstream slope with riprap, sandbags, plastic sheets, or other materials to provide erosion-resistant protection.

Seepage and Sinkholes

1. If the entrance to the seepage origination point is observed in the reservoir (possible whirlpool) and is accessible, attempt to reduce the flow by plugging the entrance with readily available materials such as cocomatting, bentonite, soil or rockfill, or plastic sheeting.

2. Cover the seepage exit area(s) with several feet of sand/gravel to hold fine-grained embankment or foundation materials in place. Alternatively, construct sandbag or other types of ring dikes around seepage exit areas to retain a pool of water, providing backpressure and reducing the erosive nature of the seepage.

3. Prevent vehicles and equipment from driving between the seepage exit points and the embankment to avoid potential loss from the collapse of an underground void.

Embankment Movement

1. Open outlet(s) and lower the reservoir to a safe level at a rate commensurate with the urgency and severity of the condition of the slide or slump. If piping is damaged or blocked, pumping or siphoning may be required.

2. Repair settlement of the crest by placing sandbags or earth and rockfill materials in the damaged area to restore freeboard.

3. Stabilize slides by placing a soil or rockfill buttress against the toe of the slide.

Earthquake

1. Immediately conduct a general overall visual inspection of the dam.

2. Perform a field survey to determine if there has been any settlement and movement of the dam embankment, spillway, and low-level outlet works.

3. Drain the reservoir, if required.

6 DEP Maintenance

6.1 Training

Personnel outlined in Section 4.1 and 4.2 should be trained in problem detection, problem evaluation and appropriate remedial (emergency and non-emergency) measures. This training is essential for

proper evaluation of developing situations at all levels of responsibility (initial evaluation is usually based on on-site observations).

Testing is an integral part of emergency preparedness, to ensure that both the documents and the training of involved parties are adequate. Tests can range from a limited pen and paper exercise to a full-scale simulation of an emergency and can include multiple failure scenarios. Revisions

The DEP should be reviewed on an annual basis and revised if any of the relevant contacts and/or roles and responsibilities have changed. A full update the DEP is expected to be conducted at minimum every 10 years for significant and high failure consequence classification dams. The responsible person or designate is responsible for updating the DEP.

The DEP document held by AEM is the master document. When revisions occur, the AEM will provide the updates to all the DEP document holders as required. The document holders are responsible for revising any outdated copy of the respective document(s) whenever revisions are received. Outdated documents shall be immediately destroyed to avoid any confusion with the revisions.

6.2 Testing

The Canadian Dam Association recommends DEP training for all dam personnel and testing the DEP through internal exercises and periodic review and/or exercise of the DEP. Periodic exercise may consist of a simple review by AEM and key personnel (i.e. emergency, principal, alternate contacts the dam owner's technical experts) or a more thorough exercise that could include external organizations such as the local emergency authorities and others with responsibilities listed in the DEP.

A tabletop exercise usually involves a facilitator presenting a scenario of an unusual or emergency event at the dam. The scenario should be developed prior to the exercise. Once the scenario has been presented, the participants will discuss the responses and actions that they would take to address and resolve the scenario. The facilitator controls the discussion, ensuring realistic responses and developing the scenario throughout the exercise.

HOPE BAY MINE DAM EMERGENCY PLAN

HOPE BAY, NUNAVUT

Appendix A: CWP Hypothetical Dam Breach Study

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2

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F: +1.604.687.5532
vancouver@srk.com
www.srk.com

Memo

To:	File	**Client:**	TMAC Resources Inc
From:	David Moran	**Project No:**	1CT022.043
Reviewed:	Ryan Williams, John Kurylo, Mauricio Herrera	**Date:**	October 29, 2019
Subject:	Madrid North Contact Water Pond – Hypothetical Dam Breach		

1 Introduction

As part of the development at Madrid, a contact water pond (CWP) is required at the Madrid North site to intercept and manage contact water runoff from the Madrid North waste rock pile (WRP). The design of the CWP incorporates a run-of-quarry (ROQ) berm with a geomembrane liner on the upstream face to contain contact water. The CWP liner is anchored and sealed to bedrock at the toe of the berm's upstream slope. The berm was founded on exposed bedrock and areas of frozen overburden soil. Permafrost present within the berm foundation will be maintained due to the thermal protection of the berm fill. The CWP design is presented in SRK (2019).

The CWP is formed by a 200 m long embankment of maximum height 7.5 m. The CWP is located 250 m south of the proposed Madrid mine portal and associated facilities which prompted the need to evaluate a potential dam breach of the CWP. The pond is designed to be operated with a two-week residence time and pumped regularly to remove accumulating water. The pond has the capacity to retain a volume up to 12,200 m^3.

2 Dam Breach Model

The modelled scenario is for a worst-case hypothetical condition where the Probable Maximum Precipitation (PMP) event occurs while the CWP is partially full due to a pumping or water management failure. The 24-hr spring PMP was estimated to be 115 mm (SRK 2017). During this hypothetical event, it is assumed that the pond would overtop causing a hydraulic failure of the embankment and releasing the stored water and PMP volume.

To evaluate this dam breach scenario a HEC-RAS 2D model was developed to simulate downstream flow routing. Model input parameters are outlined in Table 2-1, and Figure 2-1 shows the inflow hydrograph used in the hydraulic model which was produced based on the release volume, time to peak and a typical unit hydrograph shape.

Table 2-1: Hydraulic Model Input Parameters

Parameter	Data	Reference
Topography	1 m DEM including SRK designed infrastructure	Generated for study
Manning's *n*	0.05 (Scattered brush, heavy weeds)	Chow, 1959
Breach Height	7.5 m (full embankment)	Measured
Breach Width	22.9 m[1]	VT & G, 1990
Time to Peak	0.05 hrs[1]	Froehlich, 1995a
Release Volume	15,900 m^3	SRK, 2017

Note 1: A suite of five parametric equations were used with the worst-case selected

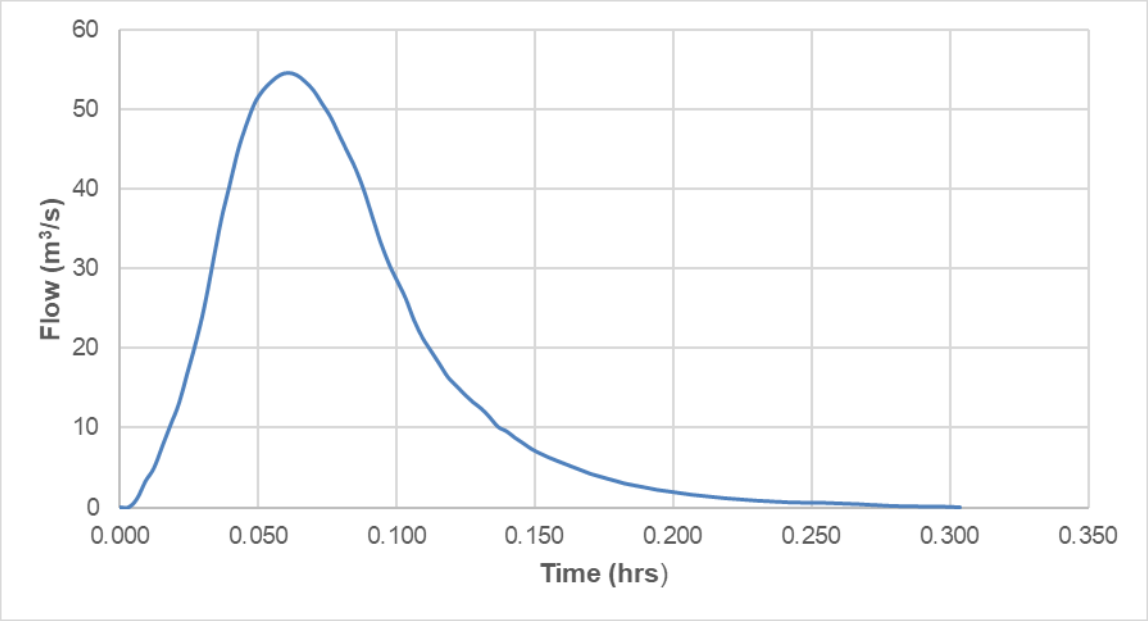

Figure 2-1: Dam Breach Hydrograph

3 Results

The results of the hydraulic model are presented in Maps 1, 2 and 3 (Appendix A). These figures show the peak arrival time, hazard classification and maximum water depth. The hazard classification map uses a combination of maximum depth and maximum velocity results to generate the risk classification in accordance with FEMA guidelines (FEMA, 2004).

The results show the potential for a flow path to the mine portal area. However, the risk to personnel, vehicles, and infrastructure by this flow is very low. Maximum flow depths in the location are less than 0.2 m. If this risk is deemed unacceptable a diversion berm would be an appropriate mitigation option. Further consideration would be required to determine the height, location and design of the diversion berm needed.

4 Summary

SRK has completed a hypothetical dam breach of the CWP in line with industry best practice standards. The analysis was completed for the conservative scenario assuming the pond is partially full, followed by the occurrence of a PMP event. The results of the analysis conclude:

- It is possible that a small amount of flow released from the CWP during a hypothetical breach would flow towards and reach the Madrid mine portal.
- The risk that flow poses to personnel, vehicles, and infrastructure in the portal area is very low, based on the hazard classification results.
- If TMAC prefer to eliminate the risk entirely of flow reaching the portal area, a small diversion berm would be required upstream of the proposed portal location.

5 References

Chow, Ven Te. 1959. Open Channel Hydraulics.

Federal Emergency Management Agency (FEMA), Federal Guidelines for Dam Safety, Hazard Potential Classification System for Dams, April 2004.

Froehlich, David C., 1995, “Embankment Dam Breach Parameters Revisited,” Water Resources Engineering, Proceedings of the 1995 ASCE Conference on Water Resources Engineering, San Antonio, Texas, August 14-18, 1995, p. 887-891.

SRK Consulting (Canada) Inc. 2017. Climate and Hydrological Parameters Summary Report, Hope Bay Project. November 2017.

SRK Consulting (Canada) Inc., 2019. Detailed Design of the Contact Water Pond Berm at Madrid North, Hope Bay Project. Report Prepared for TMAC Resources Inc., 1CT022.043. March 2019.

Von Thun, J. Lawrence, and David R. Gillette, 1990, Guidance on Breach Parameters, unpublished internal document, U.S. Bureau of Reclamation, Denver, Colorado, March 13, 1990, 17 p.

Appendix A – Model Results Maps

433200

433450

7550250

7550000

N

Portal Pads

Proposed Portal Location

Assumed Breach Location

Madrid North Waste Rock Pile Footprint

Contact Water Pond Berm

Madrid South All-Weather Road

LEGEND

Peak Arrival Time

(hours)

- < 0.1
- 0.1- 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 <

0 50 100

Meters

Notes:
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Aerial Imagery Provided by TMAC (Dated 2007)

srk consulting

Project No: 1CT022.043

Filename: 1CT022.043.100_DamBreach_Fig01_rev03

TMAC RESOURCES

HOPE BAY PROJECT

Madrid CWP Hypothetical Dam Breach

Flood Wave Peak Arrival Time

Date:	Approved:	Figure:
Oct. 2019	RW	1

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433200

433450

7550250

7550000

Portal Pads

Proposed Portal Location

Assumed Breach Location

Madrid North Waste Rock Pile Footprint

Contact Water Pond Berm

Madrid South All-Weather Road

LEGEND

Hazard Classification

- Low
- Medium
- High
- Very High
- Extreme

0 50 100

Meters

Notes:
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Aerial Imagery Provided by TMAC (Dated 2007)

srk consulting

Project No: 1CT022.043

Filename: 1CT022.043.100_DamBreach_Fig02_rev03

TMAC RESOURCES

HOPE BAY PROJECT

Madrid CWP Hypothetical Dam Breach

Flood Wave Hazard Classification

Date:	Approved:	Figure:
Oct. 2019	RW	2

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433200

433450

7550250

7550000

Portal Pads

Proposed Portal Location

Assumed Breach Location

Madrid North Waste Rock Pile Footprint

Contact Water Pond Berm

Madrid South All-Weather Road

LEGEND

Maximum Depth

(m)

- 0.0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

0 50 100

Meters

Notes:
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Aerial Imagery Provided by TMAC (Dated 2007)

srk consulting

Project No: 1CT022.043

Filename: 1CT022.043.100_DamBreach_Fig03_rev01

TMAC RESOURCES

HOPE BAY PROJECT

Madrid CWP Hypothetical Dam Breach

Flood Wave Maximum Depth

Date:	Approved:	Figure:
Oct. 2019	RW	3

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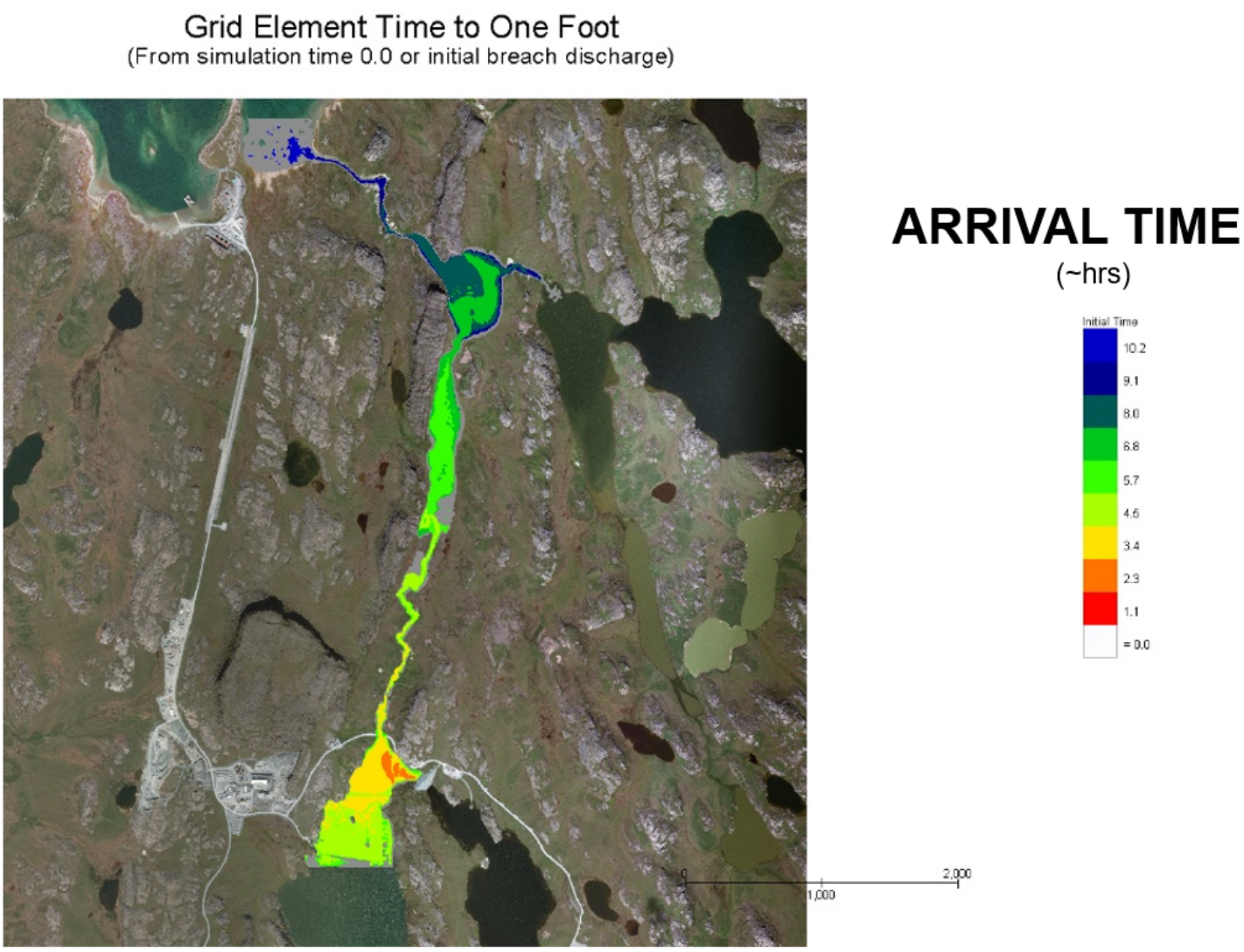
HOPE BAY MINE DAM EMERGENCY PLAN

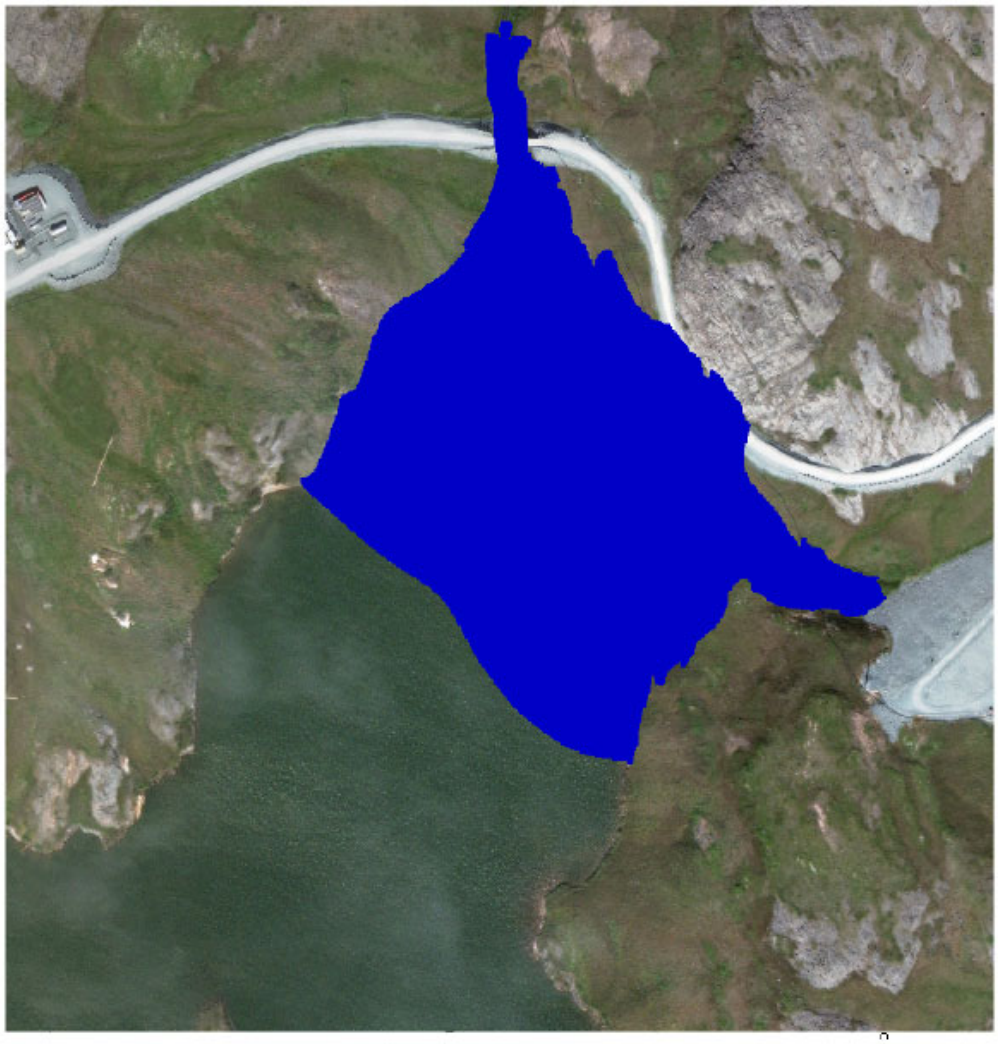
HOPE BAY, NUNAVUT

Appendix B: North Dam Inundation Maps


Grid Element Time to One Foot
(From simulation time 0.0 or initial breach discharge)
ARRIVAL TIME
(~hrs)
Initial Time
10.2
9.1
8.0
6.8
5.7
4.6
3.4
2.3
1.1
= 0.0
0
1,000
2,000

AGNICO EAGLE

Grid Element Flow Depth (3600 sec.) [1:0:0]



~ 60 mins

Appendix G: Trigger Action Response Plan (TARP)

Hope Bay TIA - Draft TARPs Rev_6
25-Mar-24

Table of Contents

Table 1 - North Dam TARP
Table 2 - South Dam TARP
Table 3 - Water Elevation TARP
TARP Notification Procedure

Trigger Level	Condition	Definition
Green	Normal Operating Condition	Maintain normal operating procedures.
Yellow - Level 1	Early Warning Condition	Areas of concern identified - Requires further investigation to determine **requirements for increased monitoring**
Orange - Level 2	Corrective Action Condition	High Risk Situation - Requires mitigation actions or operational controls to prevent an emergency situation from developing. **Implement Level 2 Actions.**
Red - Level 3	Critical Condition	Emergency Situation - Immediate threat to health and safety or environment that is uncontrollable through operational controls or mitigation actions. **Implement the site wide Emergency Response Plan and/or Dam Emergency Plan**

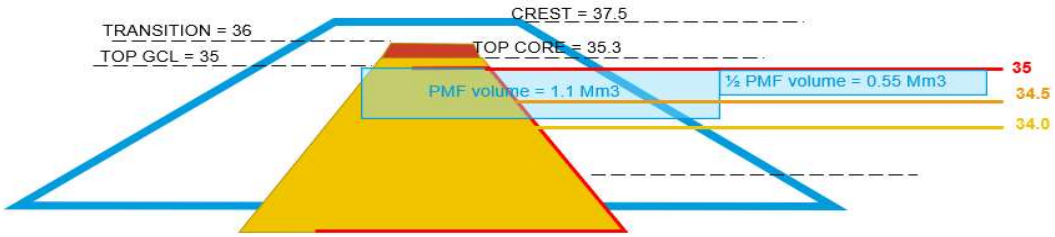
Procedure for changing trigger levels:
Refer to the TARP Notification Procedure tab for the decision making process and notification procedure that lists key personnel to be contacted when there is a change in trigger level.

Dam Safety Criteria/Parameter	Observation/Monitoring Method	Operational Trigger Level Criteria			
		Green **Normal Operating Condition**	**Yellow** **Areas of Concern**	**Orange** **High Risk Situation**	**Red** **Emergency Situation**
Deformation or Displacement	Inclinometer	Within typical maximum of past 24 months	Displacement of 0.1 m per month over two survey periods (0.2 m) or greater than 0.5m total, with a credible trend.	Displacement of 0.15 m per month over four survey periods (0.6m) or greater than 0.5 m total, or if strain is greater than 10% in any area, with a credible and continuous or accelerating trend. 3 or more surrounding instruments must support this.	Displacements of over 0.8 m. Must be supported by visual observations of displacement/deformation.
	Suvey Monitoring Points (SSP, CSP, DSP)	Total displacement within typical maximum range of past 24 months	Vertical, horizontal or total displacement of 0.1 m per month over two survey periods (0.2 m) or greater than 0.5 m total, with a credible trend that is supported 3 or more surrounding instruments.	Vertical, horizontal or total displacement of 0.15 m per month over four survey periods (4 months) or greater than 0.5 m total with a credible and continuous or accelerating trend. 3 or more surrounding instruments must support this.	Displacements of over 0.8 m. Must be supported by visual observations of displacement/deformation. Measurements from SSPs must be supported by measurements from other suvey points or inclinometers.
Cracking	Visual Inspection	None	New and expanding observed cracking, >= 5 cm wide, >= 10 m long, and deeper than 5 cm.	Expanding cracking 5 - 15 cm wide, 50 m long, deeper than 15cm but not in a clear orientation that would suggest a failure mechanism (semicircular, perpendicular or parallel to crest) but potential to propagate. Multiple aligned smaller cracks could be considered one larger crack.	**Evidence of clear imminent failure**, large cracking > 50 m long, > 30 cm deep, extending across or through the crest of the dam.
Depressions, settlement, erosion		None	Newly observed displacement, typically associated with cracking, (10-20 cm deep or 10-20 m2 in area)	New or progressing displacement observed (greater than 20 cm deep or greater than 20 m2 in area)	**Evidence of clear immentint failure**, progression of previously observed displacement (greater than 50 cm deep or greater than 20 m2 in area, expanded since previous inspection or supported by similar trends in nearby instrumentation)
Bulging/Sloughing/Discplacment at toe		None	Bulging at toe, parallel to dam centreline	Large bulge (> 50 m long) with excess water at toe, parallel to dam centreline, continuous over a significant portion of the dam, accompanied by tension cracking in the slope. Must be confirmed by instrumentation readings suggesting foundation thaw or active layer progression.	Similar observations as the orange trigger but must be accompanied by visual observations of cracking and settlement, with progressively worsening conditions with **evidence of clear imminent failure.**
Seepage (water quality downstream of toe)	Visual Inspection/Seepage Sampling/Lab Results	No seepage indicated by water quality results.	Seepage or ponding at the toe during otherwise site conditions. Must be confirmed by water quality results.	Turbid seepage or an increase in seepage at the toe during otherwise dry site condtions. Must be confirmed by water quality results.	Uncontrollable seepage toe, notably higher flow rate than in past seasons (typically a small stream of water during freshet) with high TSS (visibly sediment laden) and a tailings signature confirmed by water quality results.
Critical Zone - Core Temperature	GTC	Temperatures colder than -3°C	Temperature exceeding -3°C , for multiple beads showing a credible warming trend. Check list of excluded beads.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend. (suggesting flowing water in contact with the sensors)	Temperatures exceeding orange criteria for a prolonged period within the critical zones, with a warming trend identified in multiple sensors, accompanied by data from other instruments and observations that show **evidence of clear immenint failure.**
Critical Zone - Foundation Temperature		Temperatures colder than -8°C	Temperature exceeding design criteria of -8°C , for multiple beads with a credible trend. Check list of excluded beads.	Temperature exceeding -2°C, for multiple beads with a rapid warming trend. (suggesting flowing water in contact with the sensors)	
Non-Critical Zone - Foundation Temperature		Below typical maximum of past 24 months	Warming trend that persists for more than 3 months, that exceeds typical seasonal trends of the past 2 years and exceeds temperatures predicted by thermal modelling. Check list of excluded beads.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend that persists for more than 3 months, with potential to impact critical zone temperatures.	N/A
Excluded Beads (excluded from the rest of the trigger levels and are monitored independantly.)			Warming trend that persists for more than 3 months, that exceeds typical seasonal trends of the past 2 years and exceeds temperatures predicted by thermal modelling.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend that persists for more than 3 months, with potential to impact critical zone temperatures.	
Initial Actions:		• Continue operation, maintenance, surveillance and monitoring as per standard operating procedure	• Notify required personnel per the Notification Procedure • Document location, photograph, survey, and inscrease inspection or monitoring frequency as appropriate • Conduct engineering review to assess further risk and determine next steps	• Notify required personnel per the Notification Procedure • Continue procedures established for Yellow conditions • Conduct engineering review to assess further risk and determine remedial/mitigative actions to be taken • Reassess thresholds and conditions for Red (Emergency) Level, taking into account current observations and conditions	• Implement the Hope Bay Project Emergency Response and Crisis Management Plan • Consult Hope Bay Dam Emergency Plan • Notify personnel working downstream of the dam • Restrict Access to Doris Bridge andTail Lake Road • Restrict Access to the Dam Crest

Dam Safety Criteria/Parameter	Observation/Monitoring Method	Operational Trigger Level Criteria			
		Green **Normal Operating Condition**	**Yellow** **Areas of Concern**	**Orange** **High Risk Situation**	**Red** **Emergency Situation**
Deformation or Displacement	Suvey Monitoring Points (SSP, CSP, DSP)	Total displacement within typical maximum range of past 24 months	Displacement of 0.1 m per month over two survey periods (0.2 m) or greater than 0.5 m total, with a credible trend. Measurements from SSPs must be supported by measurements from CSPs or DSPs.	Displacement of 0.15 m per month over four survey periods (0.6m) or greater than 1.0 m total, or if strain is greater than 10% in any area, with a credible and continuous or accelerating trend. 3 or more surrounding instruments must support this. Measurements from SSPs must be supported by measurements from CSPs or DSPs.	Displacements of greater than 1.5 m. Must be supported by visual observations of displacement/deformation. Measurements from SSPs must be supported by measurements from CSPs or DSPs.
Cracking	Visual Inspection	New or exisitng small cracks < 5 cm wide, < 10 m long, and shallower than 5 cm.	Newly observed or expanding cracking, > 5 cm wide, > 10 m long, and deeper than 5 cm.	New or expanding cracking > 15 - 30 cm across, > 50 m long, deeper than 15cm but not in a clear orientation that would suggest a failure mechanism (semicircular, perpendicular or parallel to crest) but potential to propagate. Multiple aligned smaller cracks could be considered one larger crack.	**Evidence of clear imminent failure**, large cracking > 100 m long, > 0.5 m deep, extending across or through the crest of the dam.
Depressions, settlement, erosion		Seasonal movement confined to the downstream slope and toe areas that can be clearly associated with the permafrost active layer.	Newly observed displacement, typically associated with cracking, (20-40 cm deep or 20-40 m2 in area)	New or progressing displacement observed (greater than 40 cm deep or greater than 40 m2 in area)	**Evidence of clear imminent failure**, progression of previously observed displacement with evidence of migartion of tailings. Displacements greater than 100 cm deep or greater than 40 m2 in area, expanded since previous inspection or supported by similar trends in nearby instrumentation.
Bulging/Sloughing/Discplacment at toe		Seasonal movement that can be clearly associated with the permafrost active layer.	Bulging at toe, parallel to dam centreline	Large bulge (> 50 m long) with excess water at toe, parallel to dam centreline, continuous over a significant portion of the dam, accompanied by tension cracking in the slope. Must be confirmed by instrumentation readings suggesting foundation thaw or active layer progression.	Similar observations as the orange trigger but must be accompanied by visual observations of cracking and settlement, with progressively worsening conditions with **evidence of clear imminent failure.**
Ponded water at downstream toe of dam	Visual Inspection/Seepage sampling	Small ponds < 10 m in length and < 20 m in depth near the downstream toe of dam	Ponded water against toe of dam > 10 m in length and > 0.2 m in depth.	Continuous ponded water against toe of dam approx 100m long with depth > 0.5 m, with flow of water downstream with an identifiable tailings signature	Uncontrolled accumulation of water against toe of dam or any water with tailings signature downstream of the dam with **evidence of clear imminent failure.**
Critical Zone - Foundation Temperature	GTC	Temperatures colder than -3°C	Temperature exceeding -3°C , for multiple beads showing a credible warming trend. Check list of excluded beads.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend. (suggesting flowing water in contact with the sensors)	Temperatures exceeding orange criteria for a prolonged period within the critical zones, with a warming trend identified in multiple sensors, accompanied by data from other instruments and observations that show evidence of **clear imminent failure.**
Non-Critical Zone - Foundation Temperature Upstream and Downstream		Below typical maximum of past 24 months	Warming trend that persists for more than 3 months, that exceeds typical seasonal trends of the past 2 years and exceeds temperatures predicted by thermal modelling. Check list of excluded beads.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend that persists for more than 3 months, with potential to impact critical zone temperatures.	N/A
Non-Critical Zone - Key Trench Temperature		Below typical maximum of past 24 months	Warming trend that persists for more than 3 months, that exceeds typical seasonal trends of the past 2 years and exceeds temperatures predicted by thermal modelling. Check list of excluded beads.	Temperature exceeding -0°C, for multiple beads with a rapid warming trend that persists for more than 3 months, with potential to impact critical zone temperatures.	
Excluded Beads (excluded from the rest of the trigger levels and are monitored independantly.)					
Upstream Tailings Temperature		Cooling trend showing tailings freezeback in accordance with design/performance criteria	Need to set after instrument installs	Need to set after instrument installs	N/A
Tailings beach length	Visual Inspection	Beach length 100 - 80 m	Beach length < 80 m	Water against dam	N/A
Initial Actions:		• Continue operation, maintenance, surveillance and monitoring as per standard operating procedure	• Notify required personnel per the Notification Procedure • Document location, photograph, survey, and inscrease inspection or monitoring frequency as appropriate • Conduct engineering review to assess further risk and determine next steps	• Notify required personnel per the Notification Procedure • Continue procedures established for Yellow conditions • Conduct engineering review to assess further risk and determine remedial/mitigative actions to be taken • Reassess thresholds and conditions for Red (Emergency) Level, taking into account current observations and conditions	• Implement the Hope Bay Project Emergency Response Plan • Consult Hope Bay Dam Emergency Plan • Notify personnel working downstream of the dam • Restrict Access to the Dam Crest

Structure	Freeboard to crest (m)		Maximum tailings elevation (m)	Operational Water Level (m)			Corrective Action Level (m)	Critical Condition Level (m)
	Tailings	Water		Minimum (MinOWL)	Normal (NOWL)	Maximum (MOWL)		
North Dam		2.0	N/A	30	<34.0	34.0 – 34.5	34.5 – 35.0	>35.0
South Dam	1.5	N/A	33.5	N/A	N/A	N/A	N/A	N/A
TARP Level	-				Green	Yellow	Orange	Red
Response	-				Standard operations	Inform stakeholders (Table 4-3 of TIA OMS)	Immediately take action to stop increase and lower water level. Inform stakeholders (Table 4 3)	Trigger ERP and DEP (Section 8)

FREEBOARD DIAGRAMS OPTION 1A



USING PMF TO DEFINE YELLOW LEVEL, USING ½ OF THE PMF TO SET ORANGE LEVEL

Level Definition	Water Elevation	Remaining Volume below 35 masl
Yellow TARP Level	**34.0**	1.3 Mm3
PMF Storage	34.2	1.1 Mm3
Orange TARP Level	**34.5**	0.67 Mm3
½ PMF Storage	34.6	0.55 Mm3
Red TARP Level (Top of GCL)	**35.0**	**0 m3**

20JUN23 – checked these values with updated SSC from SRK

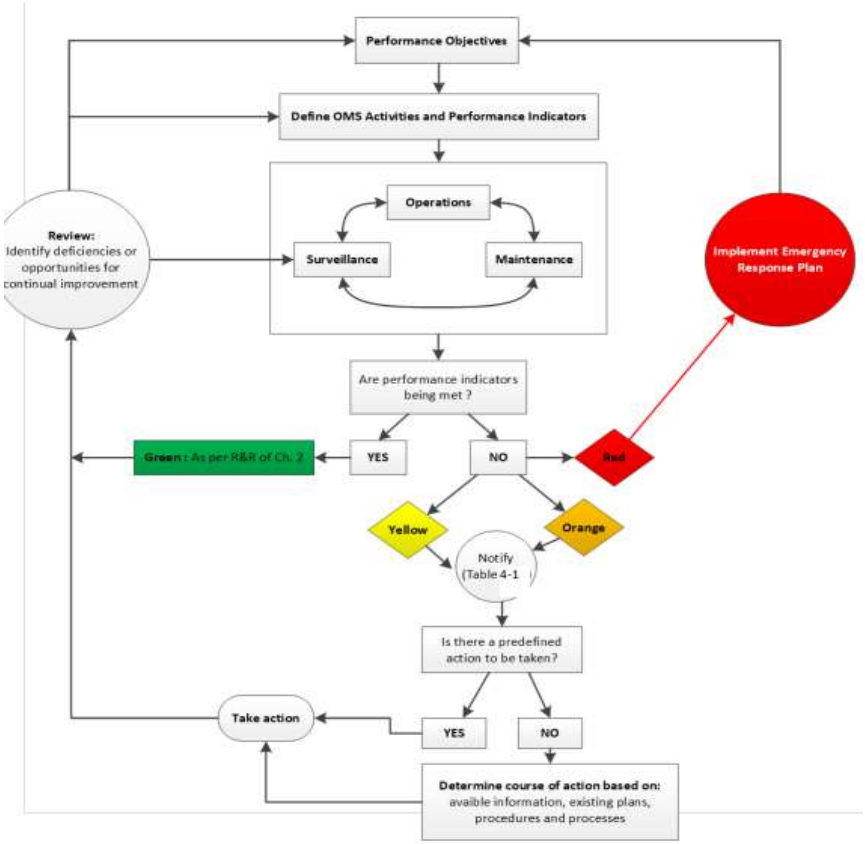
AGNICO EAGLE

TARP Notes:

- Red Level still doesn't signify immediate overtopping (at 35 masl, still have 2.5 m freeboard for wind and waves). But the conservatism is may be warranted, since there is no EOC.
- Yellow TARP level is set based on storing the PMF below 35 masl.
- Orange TARP is set based on storing ½ of the PMF below 35 masl.
- Yellow and Orange TARP Levels rounded down for conservatism and simplicity. See table.

This information was presented at the 2023 IRB meeting for review. Updated Water Elevation TARPs were finalized in 2023.

From TIA OMS



igure 4-1: Communication and Decision Process for Water Management Infrastructure TARP

Table 4-1 : Communication Procedure to Change TARP Level

Category	Notify	Timeline	Method of Communication
Green	On-Site team → Responsible person → • Independent Review Board • Designer • General Manager • EOR • AEO	The trigger are back to green for more than 2 weeks	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status Brief memo sent by e-mail to officialise TARP change
Yellow	On-Site team → Responsible person → • EOR	Within 24 hours of the TARP level condition being met	Phone Call and E-mail to inform on status change. RP and EOR must agree to change status. If RP can't be joined the on-site team will try to contact these people in this order : Water & Tailings GS, EOR, AEO
	Responsible person → • Independent Review Board • Designer • General Manager • EOR • Process Plant Superintendent	Within 72 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation if required
	EOR → • AEO	Within 1 week of TARP level change	Left to the EOR discretion
Orange	On-Site team → Responsible person → • EOR	Immediately upon discovering TARP level triggers change	Phone Call, E-mail and meeting to inform on status change. If RP can't be joined the on-site team will try to contact these people in this order : Water & Tailings GS, EOR, AEO
	Responsible person → • Independent Review Board • Designer • General Manager • EOR • AEO • Health & Safety Superintendent • Process Plant Superintendent	Within 24 hours of the TARP level change	Brief memo sent by e-mail to officialise TARP change Meeting to be set to explain situation
RED	On-Site team → Emergencies Response Team Once an emergency is declared refer to the ERP. Emergency response is out of scope of this document	Immediately when the emergency is discovered. If there is currently a risk to Env or Health and Safety	Emergency – Emergency Emergency and road channel Or at Emergencies 911
		Immediately when the emergency is discovered. If there is imminent risk to Env or Health and Safety	Phone call to ERT coordinator (103) & Health and Safety Superintendent

Appendix H: Standard Operating Procedures (SOPs)

Hope Bay Project, South Dam Monitoring: Standard Operating Procedures – Revision 1

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.064
August 2020

Hope Bay Project, South Dam Monitoring: Standard Operating Procedures – Revision 1

August 2020

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File Name:
Hope_Bay_South_Dam_Monitoring_SOP_Rev1_20200813_1CT022.064_PL.docx

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1 Introduction

1.1 Revision Summary

Table 1 provides a summary of the revision history for the South Dam Monitoring Standard Operating Procedures (SOP).

Table 1: Revision History for the South Dam Monitoring SOP

Revision	Status	Date	Major Changes
0	DRAFT - Issued for Review	June 2020	-
1	Issued for Use	August 2020	-

1.2 Background

The South Dam is one of three dams that will be constructed as part of the ultimate Doris tailings impoundment area (TIA). Phase 1 tailings deposition requires the use of two out of the three structures; namely the North Dam and Phase 1 of the South Dam. Future Phase 2 tailings deposition will require the South Dam to be raised with downstream methods to its ultimate crest elevation (46.0m). During Phase 2, as the tailings elevation continues above the containment provided by natural topography around Phase 1 TIA, a third containment structure, the West Dam, will be required.

The South Dam was designed to have tailings deposited off the upstream face to create a beach. Its successful performance is dependent on maintaining the integrity of the frozen foundation through preservation of permafrost underlying the dam. Because of complex foundation conditions, differential settlement longitudinally and transversely across the dam is expected. To track whether foundation conditions and deformations are within the design limits for the dam, a rigorous monitoring program has been established.

Table 2 lists the South Dam monitoring components.

Table 2: South Dam Monitoring Components

Component	Instrument	Quantity
Thermal	Horizontal ground temperature cables	9
	Vertical ground temperature cables	12
	Key trench toe alignment temperature cables	1
	D505 Dataloggers	8
Deformation	Deep Settlement Points (DSP)	3
	Surficial Survey Points (SSP), located on the crest and downstream face	19
	Crest Survey Monitoring Points (SMP), located along the upstream crest	6
	Crest survey monitoring points, located along the downstream crest	6
Water level	Pressure transducer installed in Reclaim pond	1
Seepage	No defined instrumentation	n/a
Visual	No defined instrumentation	n/a

1.3 Objectives

Responsibility for implementing the South Dam monitoring program rests with TMAC, and the data must be reviewed annually by the Engineer of Record (EOR) as part of an annual geotechnical inspection. This document provides Standard Operating Procedures (SOP) for carrying out the required monitoring.

2 Monitoring Overview

2.1 Thermal Monitoring

2.1.1 Ground Temperature Cables

The foundation of the Phase 1 South Dam has been designed to remain frozen for the life of the structure. The upstream edge of the key trench base is expected to remain at a temperature of at least -2°C, while the underlying foundation soils remain colder. Twelve functioning vertical GTCs are installed to monitor the foundation temperature, to an approximate depth of 15 m below the base of the key trench or original ground dependent on the cables installed location. Four functioning horizontal GTCs are installed directly above the lower GCL liner to monitor foundation temperatures within the key trench and five functioning horizontal GTCs are installed along the upper GCL liner to monitor temperatures within the above ground dam fill. A single longer horizontal GTC is installed directly above the liner overlap flap, between approximately stations 2+45 and 4+25 to monitor temperature near the interface with the original ground. At the time of writing, six of the installed GTCs are inactive due to irreparable damage or malfunction.

Eight dataloggers were installed at the South Dam. These D505 data loggers are manufactured by BeadedStream and are powered by an internal battery that is charged from solar panels on each unit. Appendix A1, A4 and A5 provides additional details on the D505 data loggers, and Appendix B1 provides additional data logger specifications. Data is stored internally and currently transmitting every 12hrs via satellite telemetry through a two-way satellite transceiver and Iridium antenna. These dataloggers have an operating range of -40°C to +85°C. The SOP for monitoring downloading data from this instrumentation is presented in Section 4.

2.2 Deformation Monitoring

2.2.1 Survey Point Monitoring

The Phase 1 South Dam is expected to undergo deformation because of creep over its design life, which includes differential longitudinal and transverse settlement. A total of 34 survey monitoring points were installed within the structure to track these deformations such that it can be confirmed that they are within the specified design limits.

The installed monitoring points are illustrated on Figures 1 and 2, and include the following:

- **Deep Settlement Points (DSP):** Three deep settlement points are located on the downstream slope of the dam. The deep settlement points are intended to track deformation of the foundation soils directly below the dam. The Deep Settlement Points are constructed of rods attached to plates buried at the foundation of the dam. The rods are contained within a casing that allows free movement of the rod, independent of the dam fill
- **Crest (Fixed) Survey Monitoring Points (SMP):** Twelve crest survey monitoring points are located along the crest of the dam, six of which are intended to monitor deformation below the upstream crest near the upper GCL liner contact and six intended to monitor deformation below the downstream crest under 2 meters of transition material.

- **Surficial Survey Points (SSP):** Nineteen surficial survey points are located at select locations on the crests and downstream shell of the dam. The surficial survey points are intended to track deformation of the dam shell or the foundation soils dependent on their installation location.

The SOP for completing these manual surveys, are included in Section 5.

2.3 Water Balance Monitoring

The Phase 1 South Dam is not designed to retain water. Water level measurements in the Reclaim Pond are monitored with a pressure transducer and data logger. An elevation constant is used to convert the water level to an elevation. This should continue to be used as the primary source of water level data. See the SRK North Dam SOP for additional details (SRK 2020a). Ponded water should never encroach closer than 100 m from the upstream Phase 1 South Dam Crest. As communicated in a number of reports, including the Annual Geotechnical Report (SRK 2020b) and the deposition plan (SRK 2020b, Appendix N). Visual markers approximately 100 m from the Phase 1 upstream dam crest have been placed on each shoreline to assist in visual checks (Figure 1 and 2).

2.4 Visual Monitoring

Visual inspections are critical to the safe operations of the TIA as infrequent or specific instrumentation data alone does not complete the full performance picture. It is expected that the tailings deposition operations are monitored daily by qualified site staff at the dam. These inspections undocumented and are intended to be checks of dam conditions with a focus on atypical conditions or obvious geotechnical concerns at the dam or surrounding infrastructure. A weekly visual inspection must be carried out to thoroughly inspect the dam and formally document any issues observed. More details on the visual monitoring requirements are provided in Section 7.

A comprehensive visual inspection must be carried out as part of the AGI while a Dam Safety Review (DSR) must be completed in accordance with the CDA guidelines, at a frequency dependent on the dam hazard classification and the Canadian Dam Association (CDA) guidelines. It is suggested that the next South Dam DSR be completed in 2021 at the same time as the next North Dam DSR. While this is earlier than the stated CDA guideline minimum frequency requires, this will allow a more comprehensive review of the TIA as a system, rather than just the dam in isolation. A DSR is intended to re-assess the containment facility to validate the safety margin established for day-to-day operation, engineering practices, and legal and/or regulatory requirements. DSRs are completed by an independent review engineer that is not influenced by his or her prior participation in the design, construction, operation, maintenance, or inspection of the dams under review.

2.5 Seepage Monitoring

Dam seepage is not expected, however, if seepage is observed at the toe of the South Dam, monitoring is required in accordance with the SOP provided in Section 8. Ponded water was present in ice-wedge troughs prior to construction of the South Dam. Baseline water quality

monitoring of ponded water on the downstream side of the dam is also required in accordance with Section 8 to establish a record of baseline water chemistry.

2.6 Tailings Deposition

Performance of the Phase 1 South Dam is directly dependent on adherence to the tailings deposition plan (SRK 2020b, Appendix N) to specifically establish an adequate tailings beaches upstream of the structure and limit ponding of supernatant water. Annual topographic surveys of the tailings beach above water and bathymetric surveys should be completed to confirm that deposition is consistent with the current plan. The deposition plan can be modified as necessary based on the annual data.

3 Monitoring Protocols

3.1 Monitoring Frequency/Responsibility

A summary of the monitoring requirements and associated responsibility is listed in Table 3. These monitoring requirements can be revised at any time under the direction of the South Dam Engineer-of-Record, or the qualified Licensed Geotechnical Engineer carrying out the AGI.

Table 3: Summary of Monitoring Requirements

Element	Item	Method	Responsibility	Minimum Frequency
Thermal	Ground Temperature Cables	Data Loggers	TMAC	Daily[1]
Deformation	Deep Settlement	Manual	TMAC	Monthly (from May to November)
	Shallow Settlement	Manual	TMAC	Monthly (from May to November)
	Surficial Settlement	Manual	TMAC	Monthly (from May to November)
Water Balance	Water Level	Data Logger	TMAC	Daily[2]
	Seepage Monitoring and Sampling	Manual	TMAC	Weekly when observed
	Downstream Ponded Water	Manual	TMAC	Monthly when observed
Tailings Deposition	Ground and Bathymetric Surveys	Manual	TMAC	Annually
Visual	Walkover Survey	Informal (not documented)	TMAC	Daily
		Formal (documented)	TMAC	Weekly
	Annual Geotechnical Inspection	Manual	Independent Qualified Licensed Geotechnical Engineer	Annually

Element	Item	Method	Responsibility	Minimum Frequency
	Dam Safety Review	Manual	Independent Qualified Licensed Geotechnical Engineer	In accordance with CDA Guidelines

Notes:

1. Currently thermal data is collected and transmitted every 12 hours.
2. Currently water level data is collected every 6 hours and transmitted every 5 days.

3.2 Monitoring Data Management Protocols

All monitoring data collected must be stored electronically. Manual notes must be scanned, and the raw data saved together with any transposed or processed data. All data must be reviewed by appropriate qualified staff immediately following collection to confirm integrity of the instrumentation, as well as to ensure that dam performance is consistent with expectations. If staff is not qualified to draw such conclusions, the EOR must be contacted to perform these duties.

Reporting requirements are specified in each section typically via email, however where appropriate, agreed upon shared drives can be used for file transfer, but a notification email should be sent once the inspection is uploaded. Currently a South Dam monitoring shared folder is stored here:

https://van.files.srk.com/nextcloud/index.php/s/EERtAo85KZLocdy?path=%2FTIA%20Monitoring

4 BeadedStream GTC and Datalogger Standard Operating Procedure

Ground Temperature Cables (GTCs) and Dataloggers at the South Dam are manufactured by BeadedStream. Each of the eight dataloggers installed are powered by an internal battery that is charged by integrated solar panels on each unit (Figure 3). Appendix A and Appendix B1 provides additional details on the D505 BeadedStream data loggers that were installed on site.

These data loggers record the data internally and are currently transmitting data (every 12hrs) to an online portal via satellite telemetry. The BeadedStream online portal can be accessed at the website below, using the login name provided or by creating an account that is created by contacting BeadedStream.

https://app.beadedstream.com

Username: enviro@tmacresources.com

Password: TmacResources1

To access the GTC data, navigate to Projects> Hope Bay South Dam> Sites > Select the GTC name. This data is treated as the 'raw data'.

SRK has developed a centralized Hope Bay 'Data Management System' portal and parallel database for the TIA and more broadly the Hope Bay project overall. The 'raw data' from the BeadedStream portal is automatically loaded into the database daily and displayed on the DMS portal. The login details for the portal are provided below:

https://maps.srk.com/hopebay/

Username: enviro@tmacresources.com

Password: HopeBay1!

To create a new account, select "Register as a new user".

The instrumentation layout (Figure 1 and 2) shows the location of the data logger and GTCs IDs at each monitoring node.

The Operator's manuals and app based manual download procedures are provided in Appendix A. The cable configurations and calibration sheets for the GTCs are presented in Appendix B.

No regular data collection is currently required for the South Dam GTCs. Data transmitted to the web portal is monitored by the monitoring team at SRK and the EOR, if conditions of concern arise, the EOR will notify site and take appropriate measures. TMAC personnel responsible for the monitoring and safe operation of the TIA should familiar with the portal and review the GTC data regularly (Suggestion: Monthly).

4.1 Overall Procedure

The South Dam dataloggers transmit data automatically, and do not normally require manual downloads. The following provides monthly monitoring requirements under automated and manual conditions:

1. **Field Data Collection**

   (a) Automated data collection and transmission of data: No action required, however regular reviews of the data are conducted by SRK and may require input or review from TMAC personnel.

   (b) Manual Option 1: Downloading via "Capture by Beaded Stream (Capture app)" (iOS only app) using Bluetooth communication

   (c) Manual Option 2: Downloading via Laptop and Realterm

2. **Inspection.** Dataloggers must be inspected for damage as part of the weekly visual monitoring (Section 7)

3. **Maintenance**. This procedure defines basic maintenance necessary for the ongoing operation of the dataloggers (Section 4.3).

4.2 Field Data Collection

4.2.1 Automated Data Collection and Transmission

Currently the ground temperature is collected and transmitted automatically. No action is regularly required on site to complete the downloads. The Sections 4.2.2 are provided as reference.

4.2.2 Manual Data Download Methods

Downloading via the *Capture* by Beaded Stream app (iOS app) using Bluetooth communication

Attached is the manufacturer instruction for use of the Capture app with the D505 datalogger titled "D505 & Torpedo 2 | Capture App Guide" (Attachment A1). The attached document is the main reference from which a summary is provided below for quick reference:

1) Download the "Capture by BeadedStream" app from the Apple App Store and install. Prior to heading to the field ensure the App is working and that the iOS device has a full battery. https://apps.apple.com/us/app/capture-by-beadedstream/id1329058755

2) Configure the Settings, including Units (°C, Meters), Lat/Long (Degrees Decimal) and an email for data export (This must be an active email in the Apple "Mail" app).

3) A magnet is required to activate the datalogger Bluetooth in the field. Small silver magnets are provided with the datalogger, as shown in the picture below. Other small magnets

available on-site should also work.

4) Once at the datalogger is in the field, swipe the magnet over the left panel near the blinking light. Swiping the magnet will activate a Red flashing light, indicating the datalogger and Bluetooth have been activated. At this point, the datalogger should be indicated as a "Loggers In Range" in the app.

   Note: do not hold the magnet near the magnet switch for extended periods unless intending to force a reading or otherwise reboot the datalogger (See Appendix A1 for more detail)

5) In the app, click New Capture, select the logger, then download logger data on the next screen. When process completes an email draft should appear, ensure a log of the Datalogger ID is contained within the email text or csv and send this email draft to the pre-defined email address (Typically enviro@tmacresources.com).
   Note: Downloading 300-500 readings can take 5-10 minutes

6) On the opposite side of the logger there is a widow with a green and blue LED.

   a) The Blue LED will be activated during Bluetooth connection or activity.

   b) The Green LED indicates processor activity and will blink every 7 seconds if the datalogger is idle but operational, and solid during a reading or transmission.

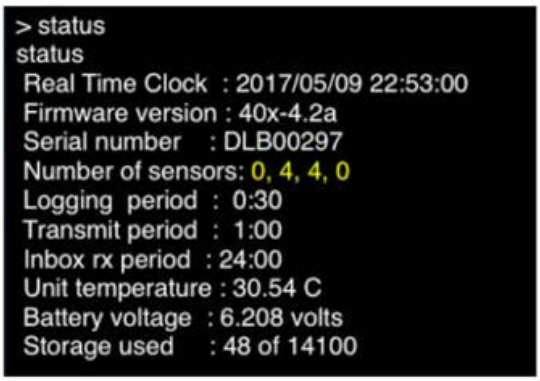
   Note: Details on all logger states and the associated status lights are provided in Appendix A1)

7) Once all data collection is complete, access the emailed files in the office, compile these and send in one email to hopebaymonitoring@srk.com.

Data logger status via the Capture by BeadedStream App

Open the app, navigate to Settings > Terminal Emulator then select the logger. Attachment A1 details all the commands, below are the minimum necessary commands to download the data:

a) Status: This will output a number of records relevant to the status of the datalogger and a quick check for the connected GTC's.



Note the GTC position in the datalogger in “number of sensors”. The GTC is the non zero port. i.e. Number of sensors: 0, 0, 13, 0 would indicate that the GTC is connected to Port 3.

b) Temps: This command will read the current temperatures of the GTC, with the output values displayed on the emulator screen. These can be recorded in a field notebook or a screen capture can be saved.

Forced spot readings and other commands may be required at times. Refer to Appendix A1 for more detail.

Regardless of the method, the green LED should remain on to verify transfer has not stopped or failed.

Downloading via Laptop and Realterm

Communication with the datalogger via Realterm should be used as an alternative method for downloading data from the datalogger. The section below outlines the basic instructions and detailed instruction is provided in the Attachment A5, “D400 Series Data Logger”.
Caution: This guideline should be used for Realterm instructions only, the data logger referenced (D400) is not installed on site.

Realterm software must be installed on a laptop computer.

http://sourceforge.net/projects/realterm/files/Realterm/

A MiniUSB cable will be needed to connect between the laptop computer and the datalogger. In order to connect via USB, a driver is also required that may not be automatically installed on the computer. The proper driver for the laptop operating system is available at:

http://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx

Select the correct driver that corresponds to your operating system for installation.

Follow the setup instructions in Attachment A3 page 3 and 4 to setup Realterm. The most important section is the PORT settings and Baud rate. Your computer needs information regarding the nature and location of devices to communicate with the logger. This is designated

by assigning ports. At this point, using the miniUSB connector cable, connect the Data Logger to the USB interface on your computer.

To determine what port is being used, access the 'Device Manager', when using a Windows platform. To access the Device Manager, navigate to 'Device Manager' on the computer (under Windows 'Home', 'My PC' or the search bar. Locate the Universal Double-clicking on 'Ports (COM & LPT)' or 'Universal Serial Bus controllers' will reveal which USB Serial Port is being used (i.e. Port_#0005 or COM5 would mean that your computer assigned Port 5 arbitrarily to this device). Return to Realterm.

In Realterm, change the baud rate to 115200, enter the port number and click 'Open'. Open initiates communication between the computer and the data logger, click 'Change' in order for communication prompts to be actualized. At this point, the data logger is synced to the computer and active communication can begin.

To test that this has been set up correctly, while connected to the datalogger via USB, type STATUS into the Realterm interface. This command will prompt the current status of the datalogger and a number of sensors connected. The number of sensors should be output as "Number of sensors: 0, 0, 13, 0", this would indicate that the GTC is connected to Port 3. The GTC could also be connected to Port 1 through 4, if needed.

For each command, the user must hit enter after each request to send the command to the datalogger.

Read X: Read X will output the current temperature at the GTC beads connected to a specific port, where that Port number is X. The temperatures and GTC details will be output on the screen and record a reading into the datalogger. This is only used if necessary.

Temps: Temps will display the temperatures, but not record the measurements.

Data: Typing Data will output all current readings from the day the datalogger was initiated.

To complete the data download, type the following:

Status (Enter)

Data (Enter)

The output the file in a CSV format on the Realterm screen. To capture the data, the user manual states:

In Realterm select the third tab called, 'capture' to save logger data to your computer using the following steps:

1. Next to 'File', select the desired output location of the file that will hold your captured data. Name this something that reflects the data that you are capturing.

2. Uncheck the box that selects ‘Direct Capture’. This will allow you to see the commands that you are typing while they are being captured.

3. If starting a new capture, select ‘Start Overwrite’. If appending data to an existing capture file, select ‘Start Append’. Upon selecting one of these options, the interface will turn RED. This is good and indicates that capturing is imminent.

4. Now you will type commands into the command window. Information typed into this window during a capture will be stored in the output file.

5. Type ‘status’, and then ‘data’. When all data has been captured, simply select, ‘Stop Capture’.

6. All data is now available in the capture output file designated in Step 1.

If this capture method does not work, the text can also be copied into a typical text file in Notepad.

4.3 Maintenance Procedure

The BeadedStream data loggers are designed to be reliable and require minimal recurring maintenance. Below is the key parameters for monitoring the health of the datalogger and the GTC system, and some additional notes on maintenance that may be required.

- Battery Voltage: Maintain above 6.15 Volts.
- Solar panel and housing orientation:
  - Maintain the solar panel orientation in a true south direction with the solar panel facing the horizon, and the cable ports facing down (i.e. 0° vertical tilt).
  - The panel and housing should be kept snow and ice free.
- Moisture: Inspect for condensation on the inside of the housing (inspect the clear portions of the housing, DO NOT OPEN for this purpose).
- GTC Cables: Ensure the GTCs remain securely connected to the datalogger, this can be checked by lightly tugging on the cable.
- A typical BeadedStream datalogger installation on the South Dam is shown in Figure 4.

4.3.1 Battery Maintenance

The D505 Dataloggers should not require recharge due to their low power requirements and solar panel recharging. Annual voltage checks are completed as part of the AGI to confirm the required voltage is maintained. The battery voltage can be monitored via the BeadedStream web portal listed above. The voltage must remain above 6.0 Volts to maintain data logging and transmission function. The battery thresholds are listed below:

- Full battery: 6.6 Volts or more

- Report low battery to EOR or BeadedStream: 6.15 Volts
- Transmission minimum: 6.0 Volts
- Datalogging minimum: 5.5 Volts

Additional steps of irregular battery maintenance (ie an on-site battery change) are listed in Appendix A2.

4.3.2 Desiccant Pack Maintenance

Each D505 Datalogger contains a desiccant pack. These packs absorb condensation moisture inside the housings to protect the internal electronics. If moisture or condensation is noted within the datalogger housing, notify the EOR for further instructions. Desiccant packs must be replaced or oven dried (standard vented oven at 93^{o}C) when moisture inside the datalogger housing is visible. However, replacement of the desiccant packs should only be carried out by someone qualified to do so.

4.4 Reporting Procedures

Any manually downloaded data should be provided in an Excel, *.csv or similar format. Any additional observations (such as noted damage or issues with the datalogger or cables) that may assist with data interpretations should be recorded and sent along with the compiled data downloads or the Visual Monitoring reports (Section 7). All data should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

5 Ground Survey Standard Operating Procedure

5.1 Objective

Ground surveys of the South Dam control points, monitoring points and the South Dam downstream toe are required to monitor for any deformation that may adversely impact the performance of the dam. The monitoring components include:

- Four Control Points surrounding the South Dam, these are rock bolts installed in bedrock outcrops and are used for survey control during construction and monitoring.
- The three Deep Settlement Points (DSP) are located on the downstream slope of the dam. The three deep settlement points are intended to track deformation of the foundation soils directly below the dam. These consist of rods attached to plates buried at the foundation of the dam. The rods are contained within a casing that allows free movement of the rod, independent of the dam fill.
- The twelve Crest (Fixed) Settlement Monitoring Points (SMP) are located along the crest of the dam. Six of which are intended to monitor deformation below the upstream crest near the upper GCL liner contact and six intended to monitor deformation below the downstream crest under 2m of transition material. These are similar to the DSPs in setup and function.
- The nineteen Surficial Settlement Points (SSP) are located at select locations on the crests and downstream shell of the dam. The surficial survey points are intended to track deformation of the dam shell and/or the foundation soils dependent on their installation location. These are boulders placed at the surface of the dam shell with rock bolts installed near the highest point on their surface. These allow a more dispersed network of surface settlement monitoring across the dam.
- The South Dam downstream toe interface between the ROQ rock fill and the native tundra (vegetation or bedrock)

Figure 1 shows a general arrangement, along with primary survey control points. Figure 2 presents a plan view of the instrumentation layout, including location names and UTM coordinates. Figure 5 shows typical details for the installed deformation monitoring instrumentation, deep settlement points, and surficial survey points.

5.2 Survey Procedures

The ground surveys for deformation monitoring are typically completed with Total Station survey instruments that have high degree of accuracy (typically ± 2mm). Due to control point locations and survey logistics, monitoring is currently completed by a mix of surveying with a Total Station for the Deep Settlement Points and a RTK GPS for the Crest Survey Monitoring Points and the Surficial Survey Monitoring Points. While the horizontal and vertical accuracy for the RTK GPS is ± 10 mm horizontal and ± 15 mm vertical, over time this is expected to provide an adequate indication of displacement trends, and balances accuracy with reduced base station moves in the field. If significant variability in readings is observed, obscuring any potential displacement trends, the EOR may require the monitoring procedure to return to a Total Station only approach, similar

to the North Dam deformation monitoring. Surveys must be completed by a qualified TMAC surveyor or subcontractor.

The following outlines the procedure for surveying the deformation monitoring points (adapted from input provide by Sub-arctic Surveyors and previous site guidance):

5.2.1 Deep Settlement Points (DSP) and Crest Survey Monitoring Points (SMP) using a Total Station:

1) Setup at the SD2 Control Point. (Rock bolt in bedrock)
2) Use the SD1 Control Point as a back-sight. (Rock bolt in bedrock)
3) Use SD3 as a check measurement

For each of the 3 DSP:

4) Remove the top cap from the orange steel casing
5) Survey the exact center at the top of the inner pipe (within the casing) and replace the top cap.
6) Move on to the next location.

For each of the 13 SMP (shorter than the DSPs):

7) Open the hinged top-plate
8) Survey the exact center of the internal rebar (within the casing) and close the top-plate

A flashlight may be needed to see inside and centralize the prism on the DSP or SMP rod.

Any accumulated dirt or ice around these protective caps or plates should be removed. Before placing the cap back on the monument after the monthly ground survey, all caps should be cleaned. If the caps are moist, it is suggested that the insides of the caps be dried prior to being placed back over the monitoring points to avoid jamming or freezing.

5.2.2 Surficial Survey Point (SSP) with the RTK GPS.

1) Set up the GPS base station over the SD1 Control Point (Rock bolt in bedrock)
2) Using an epoch count of 5, make a check measurement at SD2 Control Point. This is also a rock bolt in bed rock that was used as a check/secondary base point for the South Dam construction. The results of this check measurement should be within 10mm in northing and easting, and 15mm in elevation.
3) Using the same 5 epoch count, all SSP on the South Dam can be surveyed and the results recorded.

5.2.3 South Dam Downstream Toe with the RTK GPS

1) Walk the South Dam toe and complete a survey pick-up of the interface between the ROQ fill and the tundra where snow-free.

2) Survey shots should be collected every 5m or as appropriate to capture the variability in the alignment.

3) When the dam toe is not completely free of snow or ponded water, survey the interface between the ROQ and snow or water, noting this in each of the survey point names

5.2.4 Additional Details

An additional reference on "Suggested guidelines of surveying at the North Dam", with a Total Station, is presented in Appendix D (from Cornelissen 2013). While initially written for monitoring the North Dam, it is expected that this document may be generally applicable to the setup and potential sources of error at the South Dam. Specifically, these guidelines discuss:

- Expected manpower and time allocation;
- Equipment and accessories;
- Metadata/control points;
- Station set-ups; and
- General surveying and survey error reduction.

Any damage noted to any of the survey monitoring locations (DSP, SMP, SSP) should be recorded and submitted with the survey data.

In addition to the monitoring points and the downstream toe, one surveyed elevation of the water level in the TIA Reclaim Pond should be collected on the upstream face of the North Dam. While this is required under the North Dam SOP (SRK 2020a), a survey point taken by GPS is acceptable and may be done while set up at the SD-1 Control Point. This survey point must be collected at least once annually during open water season in the Reclaim Pond (typically completed in August). Additional water level shots during the monthly survey events may be recorded opportunistically, when conditions allow. The water elevation of this point is used to confirm the elevation constant used to convert the TIA-2 water level data collected from the pressure transducer to an elevation above sea level. Refer to the North Dam SOP (2020) for more detail.

5.3 Reporting Procedures

The survey data is expected to be supplied in Excel or *.csv format. For expedient monitoring, please indicate the correct point type and number in the point name to be easily recognizable (e.g. SSP04 or the full SD-SSP-04). Any additional observations (such as noted damage) that may assist with data interpretations should be recorded and sent along with the compiled survey data to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

6 Water Level Monitoring Standard Operating Procedure

6.1 Objective

The South Dam is designed and constructed as a tailings retaining dam with a minimum required tailings beach length, and not a water retaining structure. The minimum beach length of 100 m from the upstream Phase 1 South Dam crest to any open water in the TIA must be maintained (either the Reclaim Pond or other large isolated ponds on the tailings beach), and shoreline markers have been placed to help visually check this. The current beach slope of the tailings is between 0.5% and 1% and therefore this criterion can be approximated by ensuring the water level is at least 0.5 m to 1.0 m (respectively) lower than the minimum beach elevation at the South Dam.

As of August 2019 (previous open water season), the minimum beach elevation was 33 masl, therefore the water level must currently be maintained below 32 masl. The value will be rechecked annually as part of the TIA Annual Geotechnical Inspection.

Water level is a critical monitoring parameter and is currently recorded and transmitted to the online portal every five days.

6.2 Measurement Procedures

The water level is monitored at TIA-2 in the northeast end of the TIA, near Reclaim Barge. Details on the measurement procedures are provided in the North Dam SOP (SRK 2020a)

A visual estimate of the beach length with relation to the water level is required as part of the Visual Monitoring (Section 7).

6.3 Reporting Procedures

No additional reporting is required, however if any observations relating to the water level made (such as ponding water near the dam), please record the relevant information and send to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

7 Visual Monitoring Standard Operating Procedure

7.1 Objective

Formal visual (walk over) inspections of the South Dam, and immediate surrounding area, is required to act as an early notification for potential issues in areas not directly monitored by the installed instrumentation or other monitoring activities. Two levels of inspection are proposed:

1) Daily monitoring to identify issues or observations that may adversely impact the dam.

2) Full weekly visual (walk over) inspections.

7.2 Daily Visual Inspection

It is expected that the tailings deposition operations are monitored daily by qualified site staff at the TIA. The daily inspections are not intended to be an intensive exercise, rather it should include a walking or driving from one end of the dam to the other inspecting for major changes that have the potential to compromise its performance between weekly inspections. These inspections should include:

1. Settlement, depressions, sinkholes, cracking or signs of movement along the crest, the downstream or upstream face of the dam;

2. Significant changes in the observed seepage conditions compared to the prior weekly inspection;

3. Rapidly changing erosion conditions at the interface of the dam and the tundra;

4. The minimum beach length of 100 m from the upstream Phase 1 South Dam crest to any open water in the TIA, either the Reclaim Pond or other large isolated ponds on the tailings beach. Shoreline markers have been placed to help visually check this;

5. Leaks or unplanned discharges from the tailings discharge or reclaim pipeline

6. Any other atypical conditions observed that are concerning or have the potential to compromise the dam performance.

There is no reporting requirement for the daily visual inspections.

7.3 Weekly Visual (Walk Over) Inspection and Reporting

The upstream and downstream slopes, crest and downstream toe of the dam should be the focus during the walk over visual inspections. Specifically, the following should be noted:

1. Erosion

   (a) Any erosion of the dam fill or immediately surrounding tundra over 5 cm in depth should be noted. Erosion locations should be recorded (using a handheld GPS or survey) and photographed.

   (b) If erosion is notable then it should be monitored carefully to ensure that conditions do not worsen (i.e., getting larger, deeper, to greater extent).

   (c) If erosion can be safely measured, then simple visual estimates or measurements with a tape measure should be completed on the larger erosional features.

2. Settlements / Depressions / Sinkholes.

   (a) If observed, the location(s) should be recorded (using a handheld GPS or survey), photographed, and the dimension / extents estimated.

3. Cracks/ Movements

(a) If signs of cracking or movement are observed the locations should be recorded (using a handheld GPS or survey), photographed and the approximate crack dimensions should be measured.

4. Debris and Vegetation

   (a) Any debris or vegetation growing on the upstream and downstream slopes of the dam should be noted.

   (b) Materials should not be stockpiled on or against the dam surface. Any debris on the dam should be removed to assist with better performing visual inspections over these areas.

   (c) Snow can affect thermal performance of the dam. Natural snow drifting over 1.0 m should be noted, along with and snow should not be piled against the dam surface during snow clearing operations.

5. Seepage or Ponding

   (a) Seepage is defined as water flowing from the South Dam. Walk the full length of the downstream dam toe to identify any currently flowing seepage locations or location that appear to have evidence of past seepage (which can be monitored going forward).

   (b) If seepage water is found, note the location (by dam chainage/station or GPS), photograph and provide a preliminary estimate the seepage rate if possible.

   (c) Ponded water exists at the downstream toe of the dam. If new ponded areas are observed or the existing ponds appear to be expanding, note the location and approximate extent on the inspection form and photograph.

   (d) Notify the on-site environmental coordinator to conduct water quality sampling monitoring (Section 8).

6. Tailings Beach Development

   (a) Inspect the upstream side of the dam. The minimum length of 100 m from the upstream crest of the Phase 1 South Dam to any open water in the TIA must be maintained (either the Reclaim Pond or other large isolated ponds on the tailings beach), and shoreline markers have been placed to help visually check this. Figure 2 provides the 100 m buffer in plan view for reference.

7. Instrumentation

   (a) Look for visual damage to instrumentation (i.e., does all instrumentation appear to be intact or has it been damaged by equipment, animals or personnel?).

   (b) Inspect the dataloggers and confirm that:

      - The GTC cables are properly connected at the base of the data logger (they should not be disconnected or loose);

      - No moisture has condensed on the inside of the solar panel; or

- The solar panel faces the southern aspect (downstream side of the dam) and hoar frost or ice has not accumulated on the panel

(c) If damage or other issues are noted, then photographs and notes / observations should be collected to assist with determining if repair of the instrumentation is possible.

The South Dam Walkover Report is presented in Appendix D. This inspection form, along with any photos or notes from the inspection should be formally recorded and submitted to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

The EOR should be notified immediately after any inspection where notable changes to any of the areas / items listed above are observed. The EOR will work with TMAC to provide further guidance on monitoring or sampling requirements and to determine if mitigation measures are required.

8 Seepage and Ponded Water Monitoring Standard Operating Procedure

8.1 Objective

Seepage or contact water flowing from the toe of the South Dam must be monitored to confirm that the source of seepage is not seepage from the TIA (or if it is the TIA to better monitor seepage rates and to track flow paths). Additional monitoring of the water ponded (no apparent flow) on the tundra, downstream of the dam is also required (tundra pond water) to establish a record of baseline water chemistry in the former location of the ice wedge.

8.2 Procedure

Seepage is defined as water flowing from the South Dam (SDSEEP). Ponded water is defined as water near the dam without a notable flow rate and is present as shown in Figure 6 between Station 2+60 and 3+60. The primary sampling locations (SDPOND) for ponded water are (435650 m E, 7555910 m N) and (435630 m E, 7555907 m N) (UTM NAD83, Zone 13).

Monitoring and sample collection at the South Dam are to be performed by on-site environmental personnel trained in seepage identification and sample collection methods. The seepage and ponded water monitoring procedure at the South Dam toe is described as follows:

1. Complete a walk over survey on foot. This will consist of walking the full length of the downstream dam toe to identify any locations of currently flowing seepage, areas that appear to have evidence of past seepage (which can be monitored for seepage going forward) or areas of ponded water.
2. At each seepage location, collect water samples for the parameters listed in the laboratory analytical suite (LAS) in this SOP and record the following field data:

- Pre-determine a Sample ID following the naming convention (SDSEEP-YYMMDD-SN)
  - SN is a sample number. This should be assigned an unique two digit number for that date, for example the first would be SDSEEP-200602-01.
- GPS coordinates,
- Photograph (upstream and downstream look directions include the sample location),
- Volumetric flow rate estimates
  - For samples collected at the toe of the dam, flow volume and velocity can be estimated by taking a container of a known volume and recording the time it takes for the seepage to fill the known volume. Alternatively, estimate the cross-sectional area of the flow and the velocity of the water. To ensure accuracy of the measurement, at least three iterations of the estimate should be completed. Revisit subsection 2.2, bullet number 2 for additional details.
- Field measurements: temperature, pH, electrical conductivity (EC), chloride, and oxidation reduction potential (ORP),
- Date and time,
- Name of sampler, and
- The sampling frequency is **once per week** while seepage is occurring or at the discretion of the EOR.

3. At the primary pond locations (435650 m E, 7555910 m N) and (435630 m E, 7555907 m N) (UTM NAD83 Zone 13), and where any other independent large continuous ponds of water are observed at or near the downstream toe (typically between Station 2+80 and 3+40) (Figure 6), collect water samples from near the toe of the dam for the parameters listed in the laboratory analytical suite (LAS) in this SOP and record the following field data:
   - Pre-determine a Sample ID following the naming convention (SDPOND-YYMMDD-SN)
     - SN is a sample number. This should be assigned a two digit number for that date, for example the first would be SDPOND-200602-01.
   - GPS coordinates,
   - Photograph (upstream and downstream shots (include the sample location)),
   - Ponded area, and depth estimate,
     - A simple estimate of the pond size and visible depth will help quantify the scale. There is no need to physically measure the pond dimensions at this point.
   - Identify any of the known seeps that are actively flowing into the pond from the rock fill or the downstream toe. Provide a sketch or identification of the active seeps flowing into the ponded water.

- Field measurements: temperature, pH, electrical conductivity (EC), chloride, and oxidation reduction potential (ORP),
- Date and time,
- Name of sampler, and
- The sampling frequency is **once per year** while the primary ponds are accessible under open water conditions or at the discretion of the EOR. Typically, there should be no ponding directly against the downstream toe of the South Dam, however if this condition does exist then this water should be sampled to help assess seepage potential.

4. Check upstream side of the South Dam for water. If water is observed near or against the upstream side of the dam, the following actions are to be taken:
   - Ensure the EOR jkurylo@srk.com and hopebaymonitoring@srk.com has been notified if the Reclaim Pond is within 100 m of the upstream crest of the Phase 1 South Dam, or any large isolated pond has formed on the tailings beach.
   - Where ponding is observed against the dam, collect water samples for lab parameters listed below (LAS) provided samples can be safely collected while standing on the dam.
   - Record field measurements (temperature, pH, EC, chloride, ORP), and
   - Record field notes as outlined above, e.g. GPS coordinates, photographs, etc.
5. Once per month, collect the following QA/QC samples to validate the geochemical data set:
   - One field duplicate, one travel blank and one field blank for lab parameters listed below (LAS).
   - For the field duplicates only, field measurements (temperature, pH, EC, chloride, ORP).
6. Once per month during routine sampling of SNP station TL-5 (tailings supernatant discharge from the mill), conduct the following for TL-5:
   - Record field measurements (temperature, pH, EC, chloride, ORP), and
   - Collect water samples for lab parameters listed below (LAS).
   - This monthly sampling of TL-5 is a monitoring requirement of the South Dam however is also outlined in Section 9.2 of the North Dam Monitoring SOP (SRK 2020a). Separate samples for each dam monitoring program are not required.

8.3 Laboratory Analytical Suite (LAS)

The laboratory analytical suite (LAS) for the South Dam Seepage Monitoring SOP is as follows:

- Lab pH and EC
- SO_4, Cl
- Alkalinity

- Ammonia, NO_3, NO_2, Total N
- Total CN, Free CN, SCN, CNO
- Total metals (including sulphur and mercury)
- Dissolved metals (including sulphur and mercury)

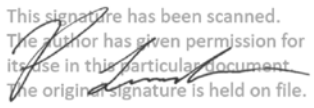
8.4 Sample Shipment and Reporting Procedure

Water samples are to be shipped to ALS Environmental. When samples are shipped, send the appropriate Chain of Custody (COC) form and field data to SRK, and notify the Engineer of Record (EOR) that samples have been collected and shipped. Upon receipt of the lab results, these should also be sent to SRK. All documentation and results should be sent to Lbarazzuol@srk.com (Lisa Barazzuol), rcocuaco@srk.com (Rosie Cocuaco), mting@srk.com (Maritess Ting) and Hopebaymonitoring@srk.com (SRK Hope Bay monitoring account).

9 Tailings Deposition Monitoring Standard Operating Procedure

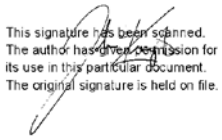
Performance of the Phase 1 South Dam is directly dependent on adherence to the tailings deposition plan (SRK 2020b, as per main text and Appendix N) and specifically establishment of adequate tailings beaches from the structure. Annual topographic surveys of the tailings beach above water and bathymetric surveys should be completed to confirm that deposition is consistent with the current plan. The deposition plan can be modified as necessary based on the annual data. To compliment these surveys monthly checks using satellite data (ex. Sentinel-2) should also be done to help track tailings beach development and tailings spigot movements. TMAC site staff should be familiar with the tailings deposition plan and work with SRK to ensure the plan is implemented as specified, any deviations from the plan must be discussed with and approved by the EOR.

This report, “Hope Bay Project, South Dam Monitoring: Standard Operating Procedures – Revision 1”, was prepared by SRK Consulting (Canada) Inc.



Peter Luedke, EIT
Consultant

and reviewed by:



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All data used as source material plus the text, tables, figures, and appendices of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

10 References

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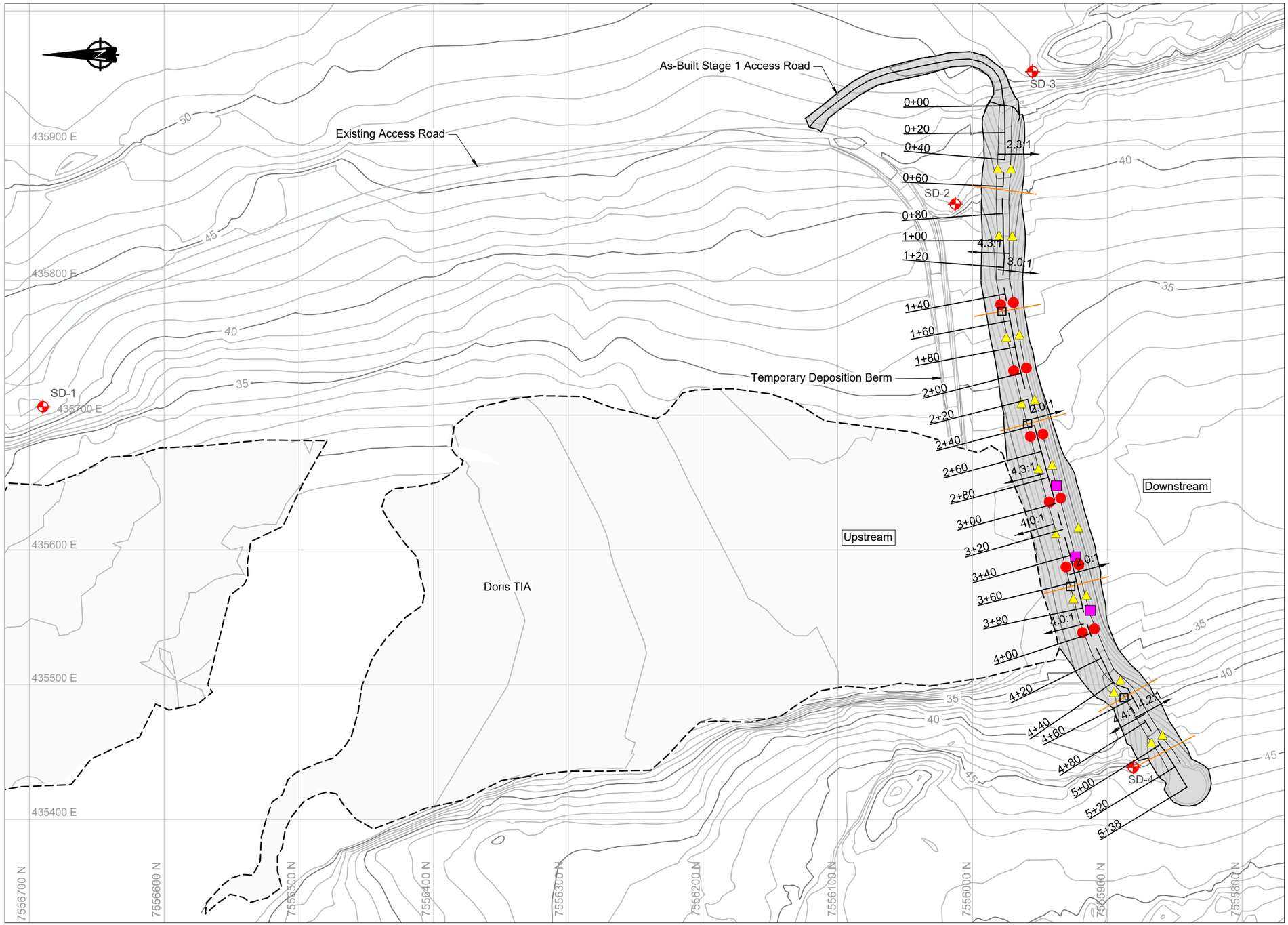
Figures



LEGEND

- Crest Survey Monitoring Point (SMP)
- Surficial Survey Point (SSP)
- Deep Settlement Point (DSP)
- Datalogger Location
- Control Point
- 2019 Sub-aerial Tailings Extent (approx.)

NOTES

1. Topographic and As-built data was provided by the Client
2. Contours shown at 1.0m interval.
3. All units shown are in meters unless otherwise stated.

REFERENCES

NAD83 UTM Zone 13.

PRIMARY CONTROL POINTS STAKE OUT TABLE

ID	Northing	Easting	Elev. (m)
SD-1	7556689.91	435706.20	43.34
SD-2	7556012.82	435856.58	43.16
SD-3	7555955.49	435954.91	52.20
SD-4	7555880.67	435438.74	46.28

srk consulting

SRK JOB NO.: 1CT022.064

FILE NAME: 1CT022.064 - SD Instrumentation Plan.dwg

TMAC RESOURCES

Doris TIA

South Dam Monitoring SOP

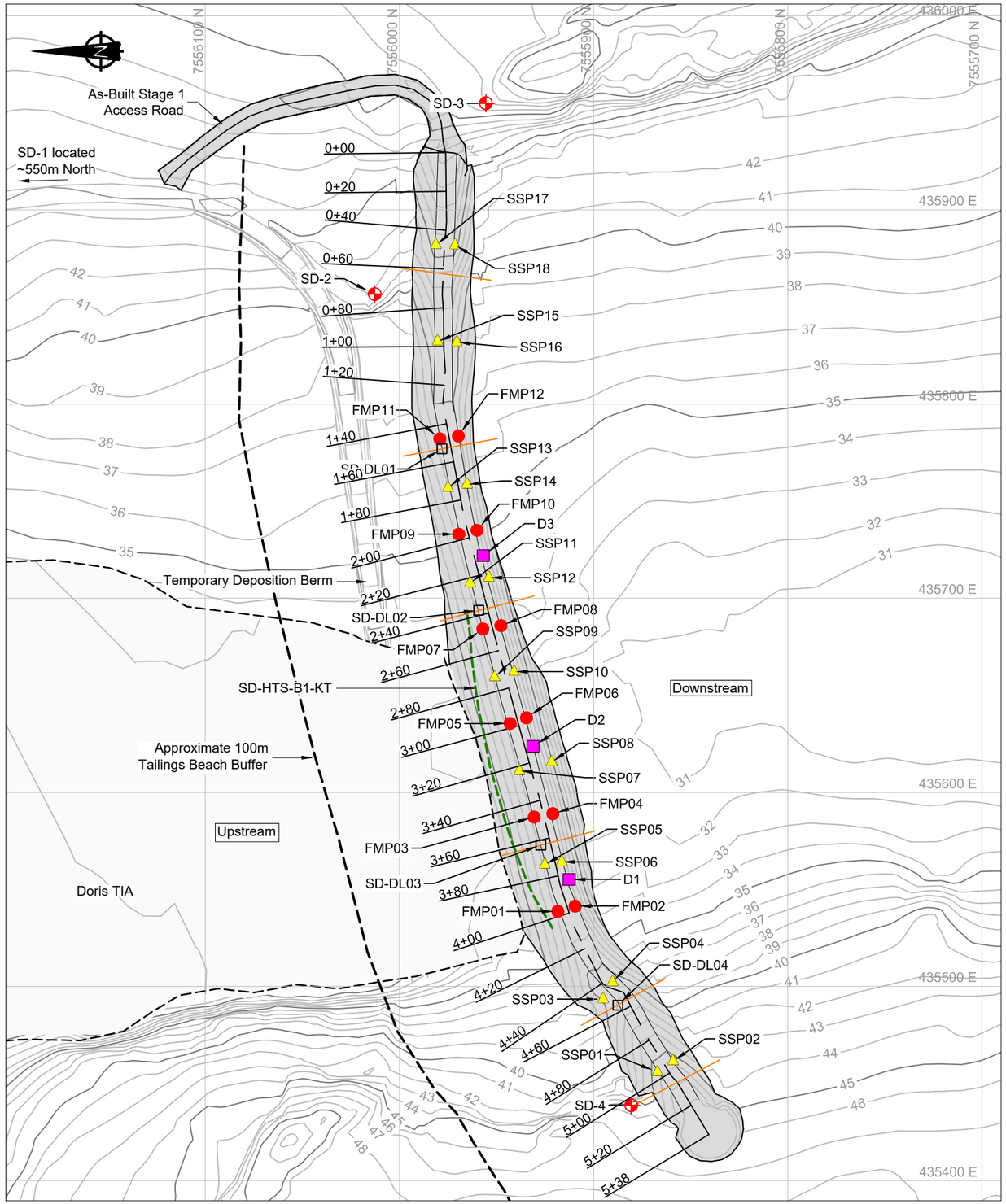
South Dam General Arrangement and Instrumentation

DATE: June 2020

APPROVED: PL

FIGURE: 1

P:\Projects\01_SITES\Hope Bay\ACAD\2019 Drawings\South Dam SOP\1CT022.064 - SD Instrumentation Plan.dwg



LEGEND

- As-Built Survey Monitoring Point
- Design Surface Monitoring Point
- Design Deep Settlement Point
- Datalogger Location
- Control Point
- 2019 Sub-Aerial Tailings Extent (Approx.)

NOTES

1. Topographic and As-built data was provided by the Client
2. Contours shown at 1.0m interval.
3. All units shown are in meters unless otherwise stated.

REFERENCES

NAD83 UTM Zone 13.

Node (2 Dataloggers)	GTC Name
SD-DL01	SD-VTS-065-KT
	SD-HTS-065-US
	SD-VTS-155-KTC
	SD-HTS-155-US
	SD-VTS-155-US
	SD-VTS-155-DS
	SD-VTS-155-KT*
SD-DL02	SD-HTC-240-KT
	SD-VTS-240-KT
	SD-HTS-240-US
	SD-VTS-240-US
	SD-VTS-240-DS
SD-DL03	SD-HST-365-KT*
	SD-VTS-365-KT
	SD-HTS-365-US
	SD-VTS-365-US
	SD-VTS-365-DS
	SD-VTS-US1
	SD-VTS-US2
SD-DL04	SD-VTS-460-KT
	SD-HST-460-KT
	SD-HTS-460-US*
	SD-VTS-460-US
	SD-VTS-460-DS
	SD-VTS-510-KT
	SD-HTS-510-US
	SD-HST-B1-KT

* denotes Not Connected

AS-BUILT SURFICIAL SURVEY POINT (SSP) STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
SD-SSP-01	7555867.82	435455.96	45.67
SD-SSP-02	7555858.65	435461.87	45.57
SD-SSP-03	7555891.61	435492.14	40.94
SD-SSP-04	7555888.48	435503.97	40.64
SD-SSP-05	7555923.75	435557.73	38.34
SD-SSP-06	7555914.52	435560.18	38.41
SD-SSP-07	7555936.52	435608.87	38.31
SD-SSP-08	7555927.20	435611.16	38.52
SD-SSP-09	7555950.16	435660.61	38.53
SD-SSP-10	7555941.74	435663.52	38.47
SD-SSP-11	7555963.07	435707.16	38.40
SD-SSP-12	7555954.46	435711.00	38.43
SD-SSP-13	7555974.12	435755.06	38.97
SD-SSP-14	7555964.83	435756.80	39.06
SD-SSP-15	7555981.95	435832.00	41.12
SD-SSP-16	7555971.80	435831.60	41.06
SD-SSP-17	7555982.30	435882.00	45.82
SD-SSP-18	7555971.81	435881.78	45.72
SD-SSP-19	7555869.96	435462.38	45.10

AS-BUILT SURVEY MONITORING POINT (SMP) STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
SD-SMP-01	7555918.41	435538.69	38.67
SD-SMP-02	7555909.54	435541.41	38.72
SD-SMP-03	7555930.58	435587.27	38.60
SD-SMP-04	7555920.99	435588.99	38.59
SD-SMP-05	7555943.00	435635.52	38.66
SD-SMP-06	7555934.56	435638.37	38.65
SD-SMP-07	7555957.03	435684.15	38.75
SD-SMP-08	7555947.77	435685.90	38.79
SD-SMP-09	7555969.45	435732.95	38.63
SD-SMP-10	7555960.05	435734.99	38.84
SD-SMP-12	7555969.66	435783.53	40.02
SD-SMP-13	7555979.11	435782.09	39.94

AS-BUILT DEEP SETTLEMENT POINT (D) STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
SD-DSP-01	7555914.31	435557.90	39.56
SD-DSP-02	7555924.06	435595.90	38.86
SD-DSP-03	7555937.19	435644.95	39.45

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SRK JOB NO.: 1CT022.064

FILE NAME: 1CT022.064 - SD Instrumentation Layout.dwg

TMAC RESOURCES

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South Dam Monitoring SOP

South Dam Instrumentation Layout

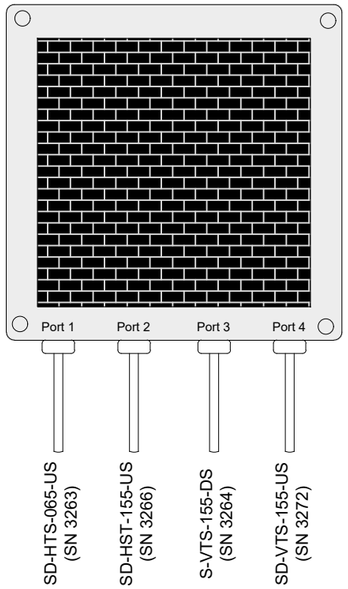
DATE: June 2020 | APPROVED: PL | FIGURE: 2

P:\Projects\01_SITES\Hope Bay\ACAD\2019 Drawings\South Dam SOP\1CT022.064 - SD Instrumentation Layout.dwg

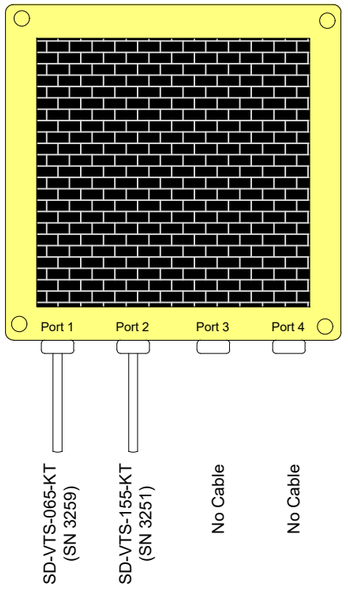
Node SD-DL01

Sta. 1+55

SD-DL01A
(SN-D505058)



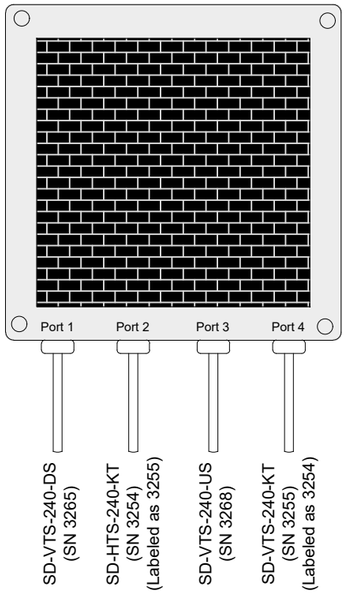
SD-DL01B
(SN-D5050081)



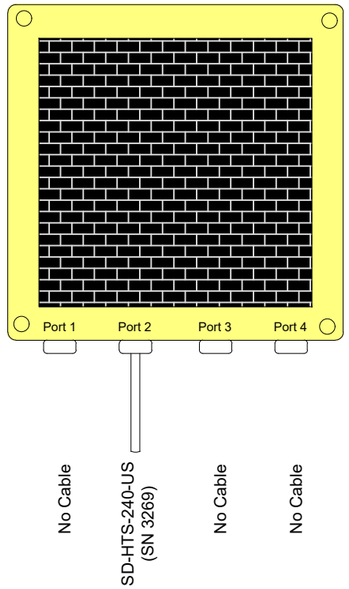
Node SD-DL02

Sta. 2+40

SD-DL02A
(SN-D5050035)



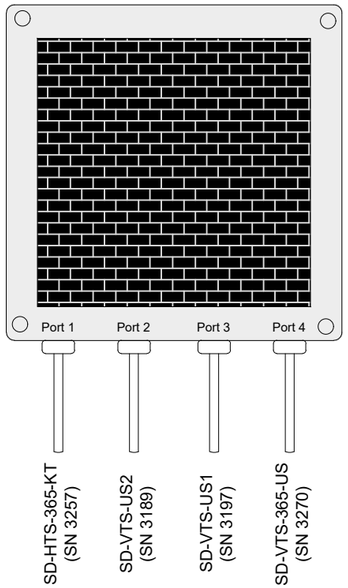
SD-DL02B
(SN-D5050106)



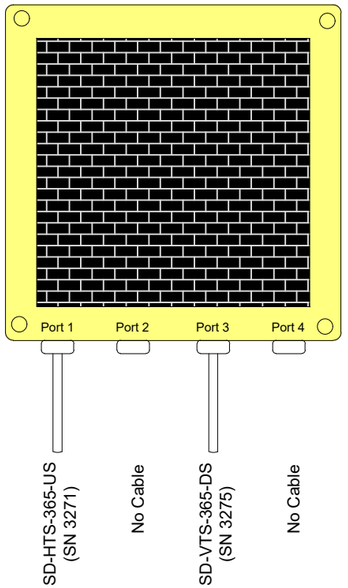
Node SD-DL03

Sta. 3+65

SD-DL03A
(SN-D5050071)



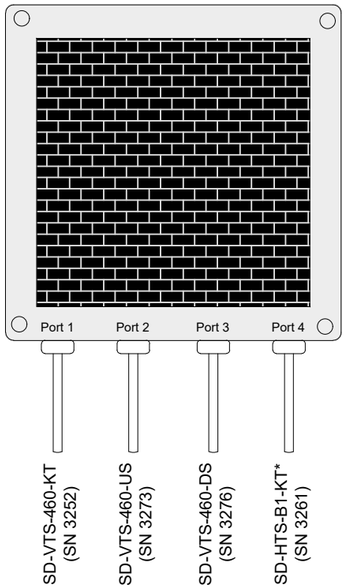
SD-DL03B
(SN-D5050014)



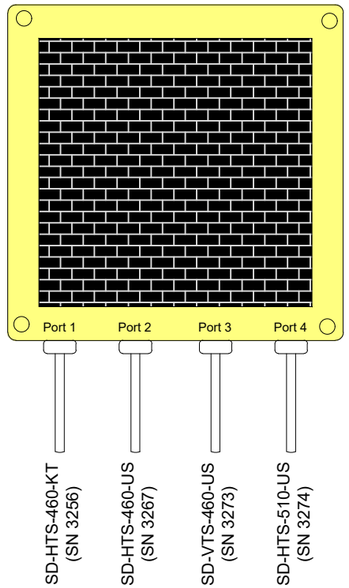
Node SD-DL04

Sta. 4+60

SD-DL04A
(SN-D5050038)



SD-DL04B
(SN-D5050034)



Datalogger Node	Datalogger ID	Nominal GTC station	ID	Serial Number	Number of Beads
SD-DL01	SD-DL01A	0+65	SD-HTS-065-US	3263	5
	SD-DL01B	0+65	SD-VTS-065-KT	3259	11
	SD-DL01A	1+55	SD-HTS-155-US	3266	5
	SD-DL01A	1+55	SD-VTS-155-US	3272	11
	SD-DL01A	1+55	SD-VTS-155-DS	3264	11
	SD-DL01B	1+55	SD-VTS-155-KT	3251	11
	Not connected	1+55	SD-HTS-155-KT	0	0
SD-DL02	SD-DL02A	2+40	SD-HTS-240-KT	3254	11
	SD-DL02A	2+40	SD-VTS-240-KT	3255	11
	SD-DL02A	2+40	SD-VTS-240-US	3268	11
	SD-DL02A	2+40	SD-VTS-240-DS	3265	11
	SD-DL02B	2+40	SD-HTS-240-US	3269	7
SD-DL03	SD-DL03A	3+30	SD-VTS-US1	3197	13
	SD-DL03A	3+30	SD-VTS-US2	3189	15
	SD-DL03A	3+65	SD-HTS-365-KT	3257	11
	SD-DL03A	3+65	SD-VTS-365-US	3270	11
	SD-DL03B	3+65	SD-HTS-365-US	3271	11
	SD-DL03B	3+65	SD-VTS-365-DS	3275	11
	Not connected	3+65	SD-VTS-365-KT	0	0
SD-DL04	SD-DL04A	4+60	SD-VTS-460-KT	3252	11
	SD-DL04A	4+60	SD-VTS-460-US	3273	11
	SD-DL04A	4+60	SD-VTS-460-DS	3276	11
	SD-DL04B	4+60	SD-HTS-460-KT	3256	11
	SD-DL04B	4+60	SD-HTS-460-US	3267	0
	Not connected	4+60	SD-VTS-460-US	3273	11
	SD-DL04B	5+10	SD-VTS-510-KT	3260	11
	SD-DL04B	5+10	SD-HTS-510-US	3274	5
	SD-DL04A	N/A	SD-HTS-B1-KT*	3261	20

Note:
*Located parallel to key trench

Datalogger ID	Color	Serial Number (SN)
SD-DL01A	Grey	D5050058
SD-DL01B	Yellow	D5050081
SD-DL02A	Grey	D5050035
SD-DL02B	Yellow	D5050106
SD-DL03A	Grey	D5050071
SD-DL03B	Yellow	D5050014
SD-DL04A	Grey	D5050038
SD-DL04B	Yellow	D5050034

LEGEND

3-watt solar panel with temperature compensated charge control circuit.

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SRK JOB NO.: 1CT022.064
FILE NAME: 1CT022.064 - South Dam Monitoring.dwg

MAC RESOURCES

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South Dam Monitoring SOP

GTC Data Logger Nodes

DATE: July 2020
APPROVED: PL
FIGURE: 3

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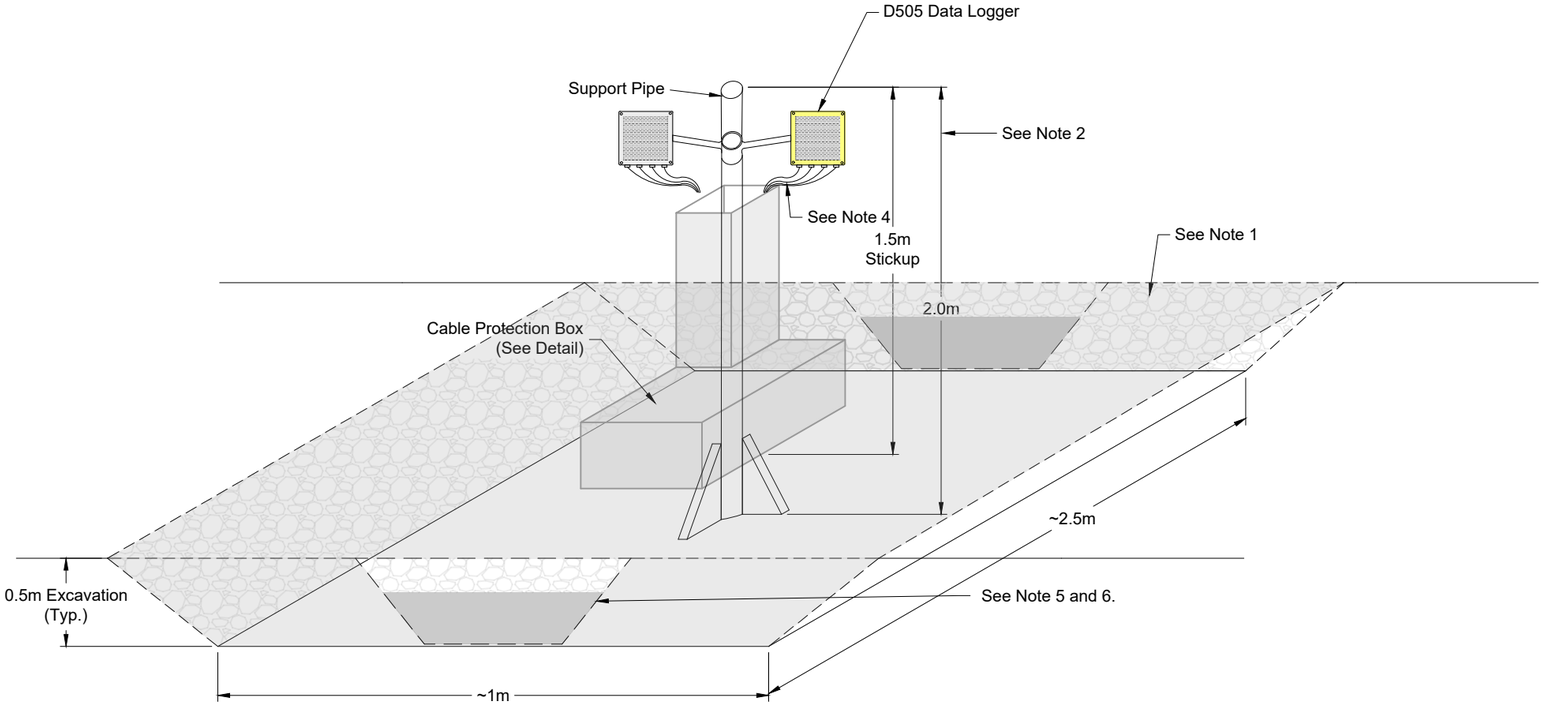
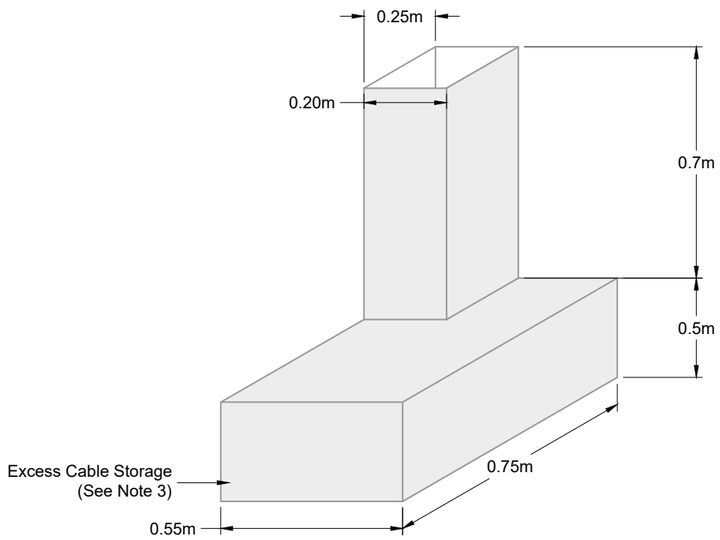


Typical Installation Detail of Data Loggers SD-DL01 through SD-DL04

Not To Scale



Wood Cable Protection Box

Not To Scale

Installation at Node SD-DL03

NOTES

1. Following installation of the support pipe, the excavation was backfilled with ROQ material prior to installation of the cable protection box.
2. All dimensions are approximate.
3. Additional lead cable stored for protection from wildlife and the outdoor elements in Cable Protection Box.
4. Limited lead cable exposed between the Cable Protection Box and the Data Logger for protection from wildlife and the outdoor elements.
5. Ground temperature cables enter the Cable Protection Box through shallow trenches located near the upstream dam crest.
6. Crushed rock placed under and around ground temperature cables then backfilled with select ROQ.

srk consulting	TMAC RESOURCES	South Dam Monitoring SOP
SRK JOB NO.: 1CT022.064		Typical Data Logger and GTC Install Details
FILE NAME: 1CT022.064 - South Dam Monitoring.dwg	Doris TIA	DATE: June 2020 / APPROVED: PL / FIGURE: 4

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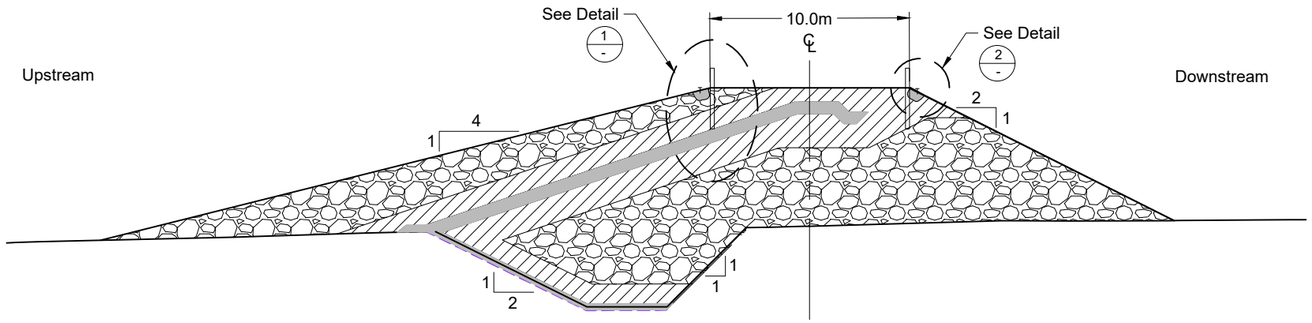
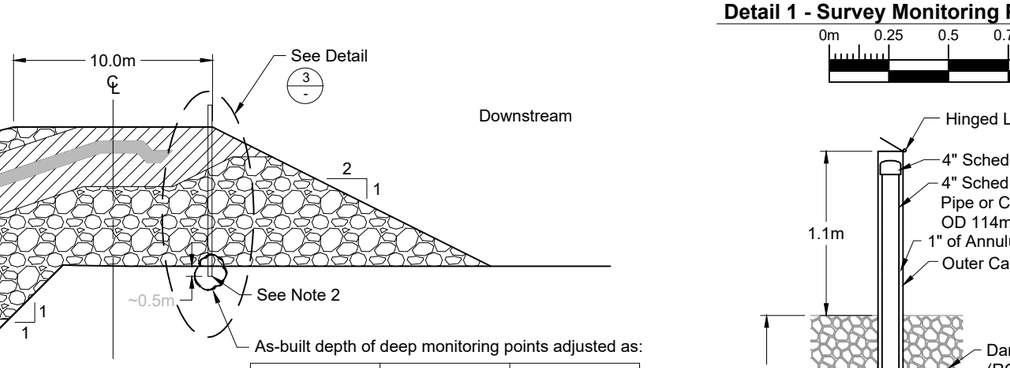


Near-surface Survey Monitoring Points (SSP and SMP) (Sta. 3+00 and 3+20)

0m 3 6 9 12

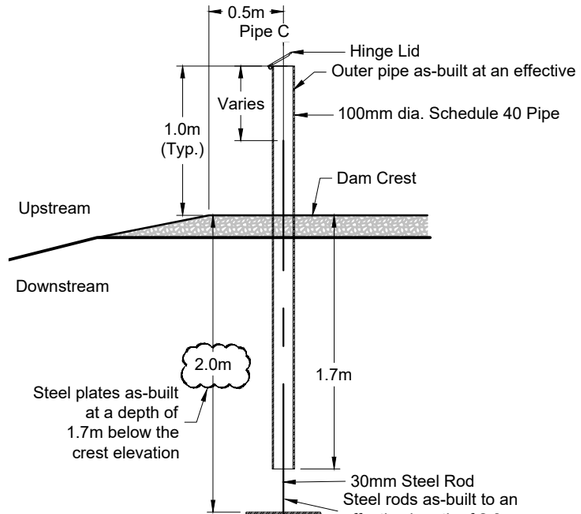


As-built depth of deep monitoring points adjusted as:

Monitoring Point ID	Depth below Dam Crest (m)	Approximate Elevation (m)
D1 = 3+80	6.2	31.8
D2 = 3+40	8	30
D3 = 2+90	5.4	32.6

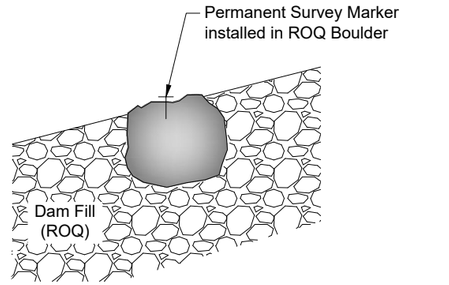
Deep Settlement Points (Sta. 3+50)

0m 3 6 9 12



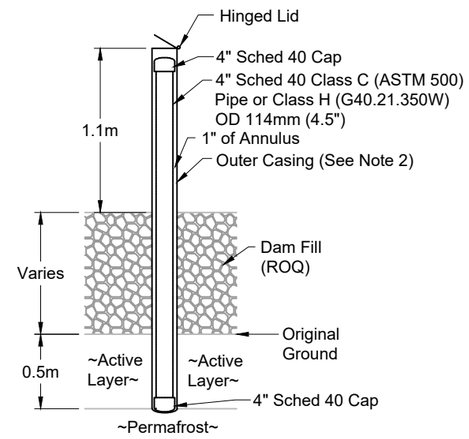
Detail 1 - Survey Monitoring Point Installation

0m 0.25 0.5 0.75 1.0



Detail 2 - Surficial Survey Point Installation

0m 0.25 0.5 0.75 1.0



Detail 3 - Deep Settlement Point Installation

0m 0.25 0.5 0.75 1.0

LEGEND

- Lower GCL Liner
- Upper GCL Liner
- Bedding Material
- Transition Material
- Run of Quarry Backfill

NOTES

1. All units shown are in meters unless otherwise stated.
2. D1 and D3 as-built using steel pipe, OD 102mm.
   D2 as-built using HDPE pipe OD 51mm.

P:\Projects\01_SITES\Hope Bay\ACAD\2019 Drawings\South Dam SOP\1CT0022.064 - InstrumentationXS.dwg

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SRK JOB NO.: 1CT022.064

FILE NAME: 1CT0022.064 - InstrumentationXS.dwg

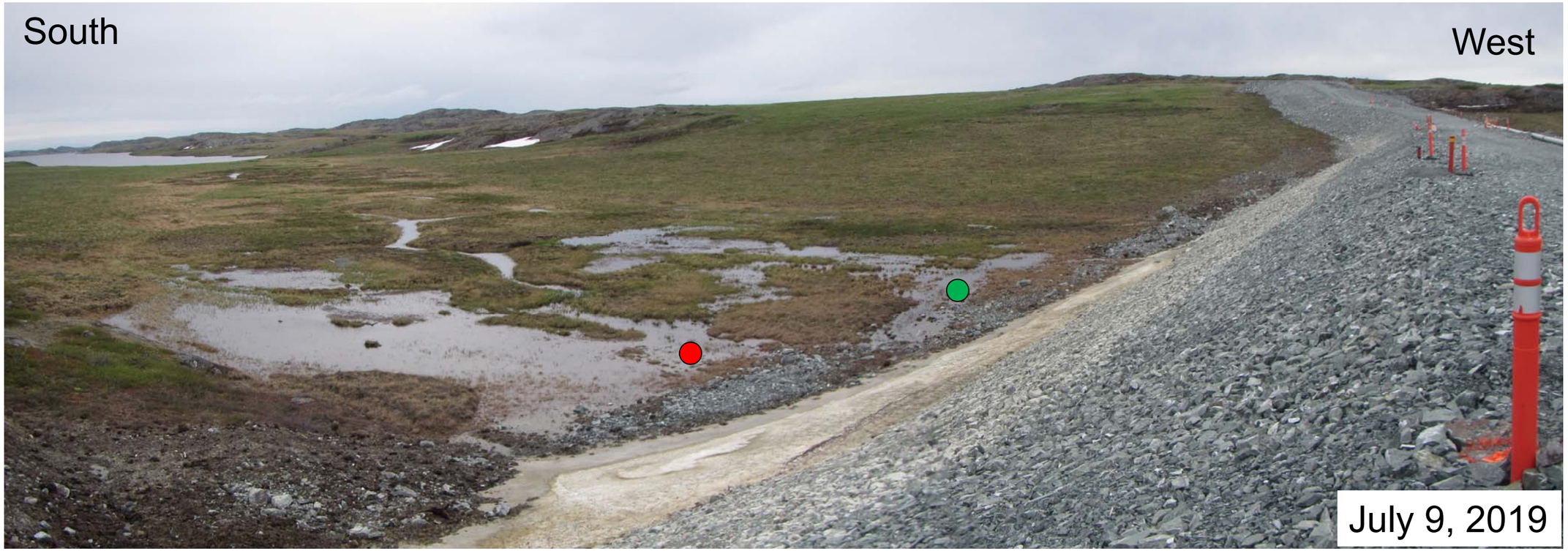
TMAC RESOURCES

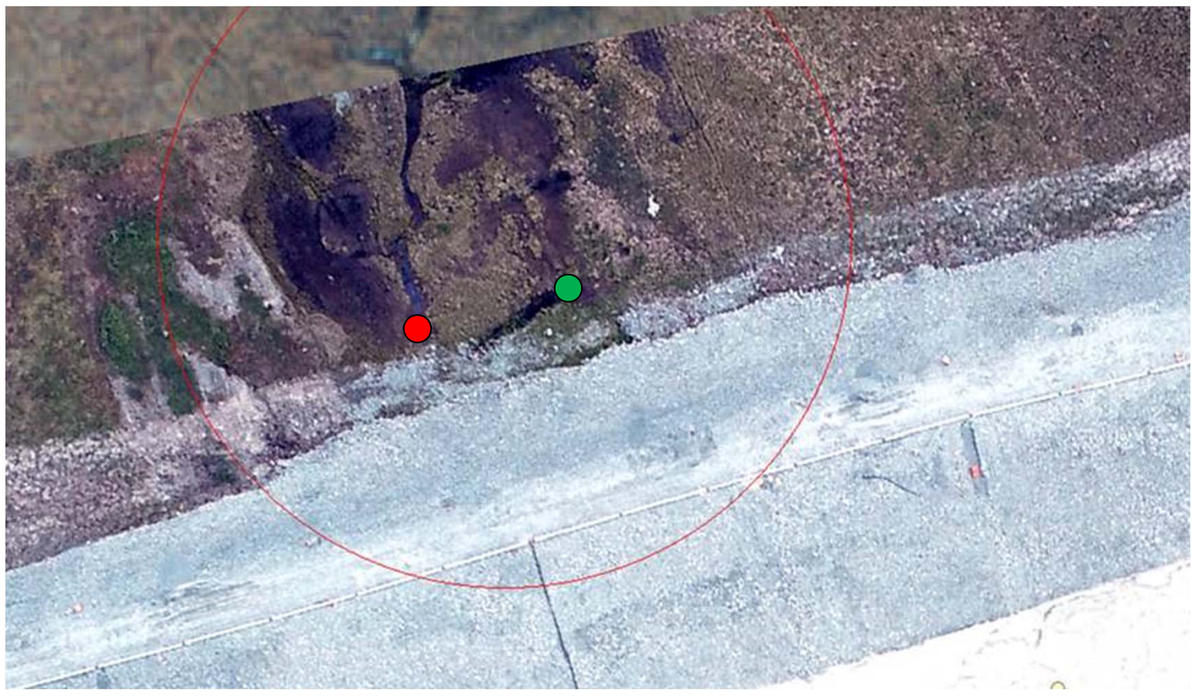
Doris TIA

South Dam Monitoring SOP

Typical Deformation Monitoring Point Details

DATE:	APPROVED:	FIGURE:
June 2020	PL	5





Legend

- Ponded water sampling location (SDPOND01)
- Ponded water sampling location (SDPOND02)

srk consulting	TMAC RESOURCES	South Dam Monitoring SOP
		South Dam Ponded Water Sample Locations
Job No: 1CT022.064 Filename: Figure_SDSOP_1CT022.064_20200604.pptx	Doris TIA	Date: June 2020 / Approved: PL / Figure: 6

Appendix A - Operator’s Manuals

Appendix A1 - D505 Series Data ‘Capture App’ Guide

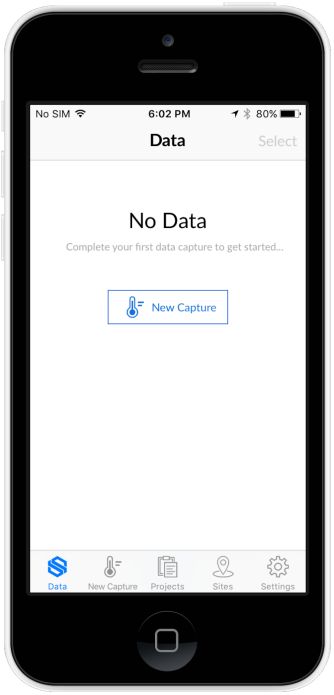
beadedstream

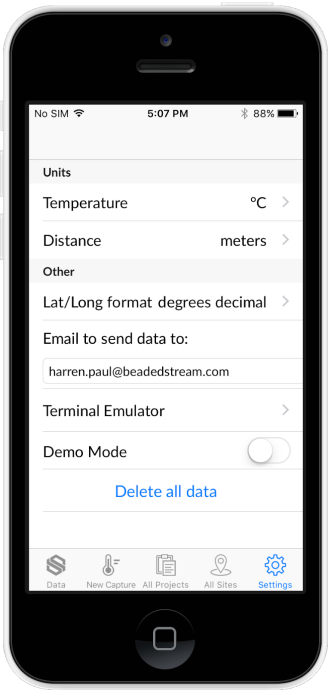
D505 & Torpedo 2 | *Capture* App Guide

"Capture by BeadedStream" is available free on the iOS App Store. The app connects via Bluetooth to D5XX loggers: the D505 (*satellite*) and the "Torpedo 2" (*portable*).

Getting started

On first launch of the app, the **Data** screen will show (*below, left).*



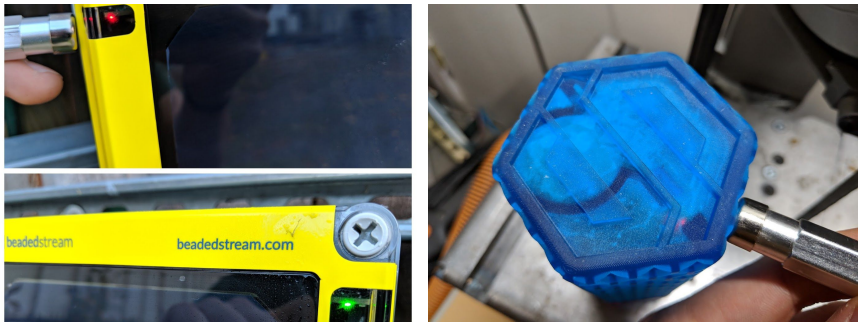


Settings should be configured (*above, right*):

- **Units:** "Distance" will affect sensor positions that display alongside temperature.
- **Lat/long format:** Stored with a [Site]. A "site" is any place instrumented with a temporary/dedicated cable.
- **Email:** The recipient for data export.
    - **Note:** *requires a functioning email account in Apple's "Mail" app.*

Wake the logger before connection

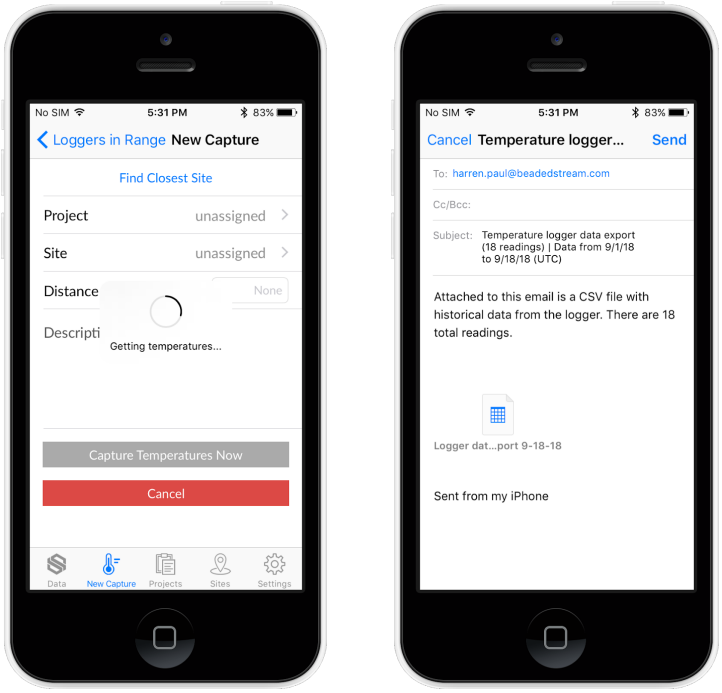
Required: Just before data capture/logger connection, blink the red LED with a magnet swipe:



***Swipe locations**: (Left) Left decal cutout for the D505 (Right) Bottom of the Torpedo 2 shell*

Download logger data

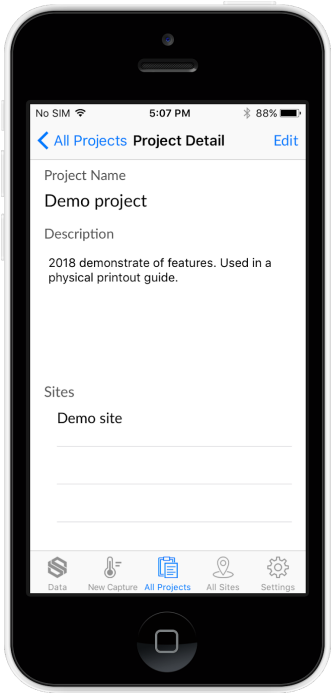
Starting at New Capture, select the logger, then [Download logger data] on the next screen. When process completes, hit [Send] on the email draft (*data is attached*):

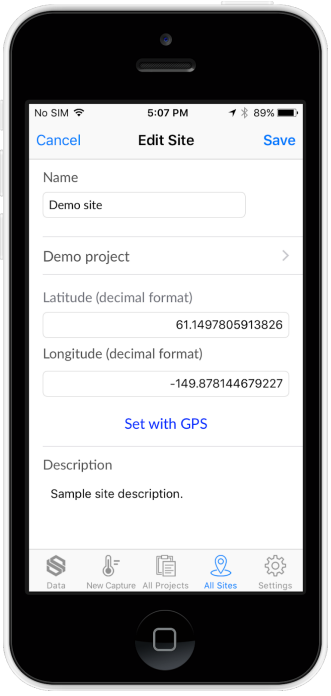


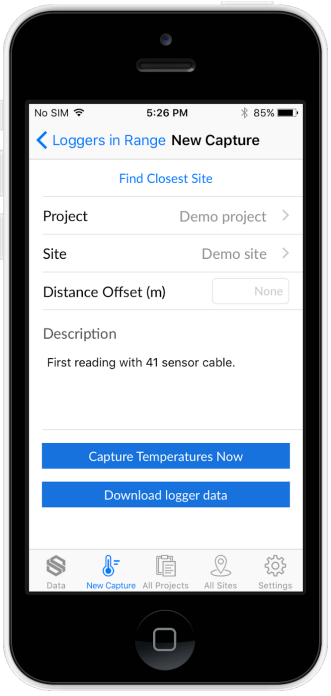
Spot capture

"Spot" capture is a manual temperature reading taken with a connected cable. Data will store on the iOS device, *not* the logger. To perform:

1. **Create a Project**: Give it a name and a description.
2. **Create Site(s)**: One for each location a cable will measure.
    - **Note:** Make sure sites are saved **in** a project
    - *Optional:* Lat/long can be added manually or [Set with GPS]
3. **Prepare and capture:** Starting at New Capture, select the logger, then choose a [Project] and [Site] then [Capture Temperatures Now]. Extra options:
    - **Find Closest Site**: Phone location is compared with lat/long configured in any sites, and the closest is auto-filled.
    - **Distance Offset:** *Positive value* means the top sensor is above a ground reference.
4. **Export data:** Go to Data, hit [Select], then select readings, days, or [Select all]. Hit [Send]. Hit [Send] on the email draft (*data is attached*)



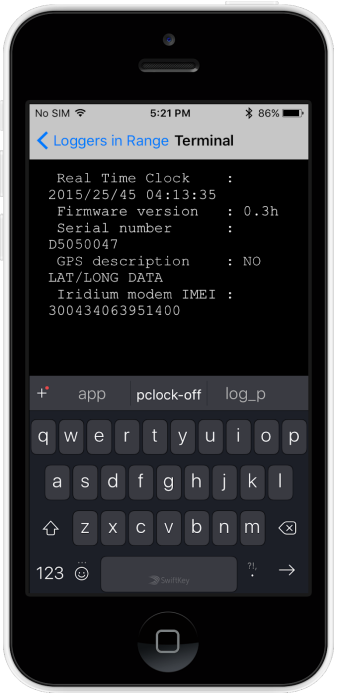




Deploying a logger in the field

Achieving a “terminal” connection with the data logger will allow verification of logger status and sensor function. Complete the BeadedStream Logger Installation Checklist before this step.

Starting in Settings, select [Terminal Emulator], then the logger. Upon connection, the **status** command will run and finish within 15 seconds. See Appendix B for details on commands.



The following command should be run and will **complete deployment**:

```
> deploy
```

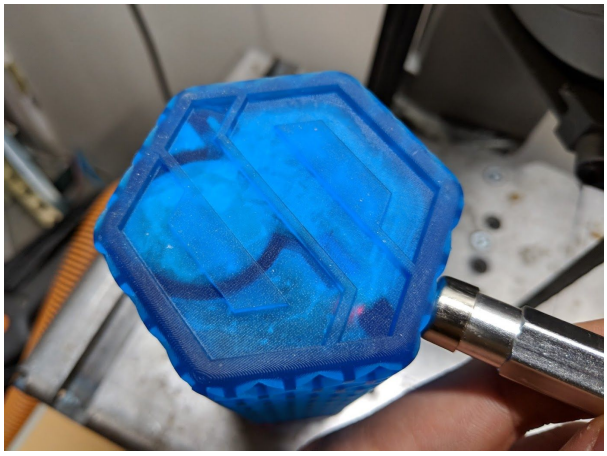
The command will automate a flow of final settings configuration and sensor checks. The last step will transmit logger configuration to Iridium.

- **Note:** If the final step *fails*, see the bottom of Appendix B (*see also for command detail*).

Appendix A | LED detail, logger states, magnet actions

D5XX data loggers share the same circuit board and the same three LEDs:

- **Red** (*below*): Lights when sensing a magnet. Blinks *every second* with constant hold.
- **Green** (*below, left*): Lights during processor activity.
- **Blue** (*unpictured, next to green*): Lights during Bluetooth connection/activity.



Unpictured: *Green and blue LEDs for the Torpedo 2 - located opposite the red along the long edge of the enclosure.*

Data logger states are indicated by LED status:

- **On, idling**: Green blink every 7 seconds.
- **On, nap mode:** Green double blink every 7 seconds. See Nap Mode Notice for more.
- **On, processor awake**. *No LED indication*. Lasts a few minutes after boot up or after a magnet swipe. Scheduled readings/transmissions wake the processor.
- **On, busy**. Solid green. The logger is reading, transmitting, or moving data (Bluetooth).
- **On, active Bluetooth connection**. Solid blue while connected to an iOS device.
- **Rebooting**. All LEDs quickly flash after battery connection or a magnet-reboot.
- **Off - Unplugged/dead battery**. *No LED activity*. The battery molex connection can be checked through the blue/green LED decal cutout (*D505*).

Actions can be triggered with a magnet:

- **Wake the logger:** Swipe magnet for a red LED blink.
- **Force a reading/transmission:** Hold for—2 red LED blinks—and release.
- **Engage nap mode for 60 days:** Hold for—4 red LED blinks—and release.
- **Trigger a reboot:** Hold until the red LED goes *out* and all LEDs flash (*about 8s*).

Appendix B | Useful terminal commands

Below lists useful terminal commands. **BOLD** indicates an input placeholder:

```
> ?
> status
> temps
> log_p H
> log_p HH:MM
> transmit_p H
> send
> lock
> deploy
```

Command detail:

?	Displays all commands. Many commands should be ignored.
status	Displays logger configuration. "Inbox rx period" is the satellite check interval (*hard coded to 24 hours*). **Note:** 6.6V+ is a full battery. Transmissions will fail at 6V (*dead battery*), but logging functions down to 5.5V.
temps	Queries all sensors and displays results
log_p **H**	Sets the logging interval in hours. Starts at (UTC) midnight.
log_p **HH:MM**	Finer control of logging. Allows sub-hour values (*e.g. 0:15 for 15 mins*)
transmit_p **H**	Sets the transmit interval. Transmits ONLY current reading, no batching.
send	Queries all sensors and transmits to Iridium.
lock	Acquires logger configuration and transmits to Iridium.
deploy	*Batches* these commands: status, log_p, transmit_p, temps, lock

Note: A satellite transmit session can commonly send data successfully but **not** receive a confirmation response. This will show as a FAIL TO SEND in the app. Retry a few times till success and/or contact BeadedStream for full confirmation.

Appendix A2 - Quick Reference for the D405/505 Battery

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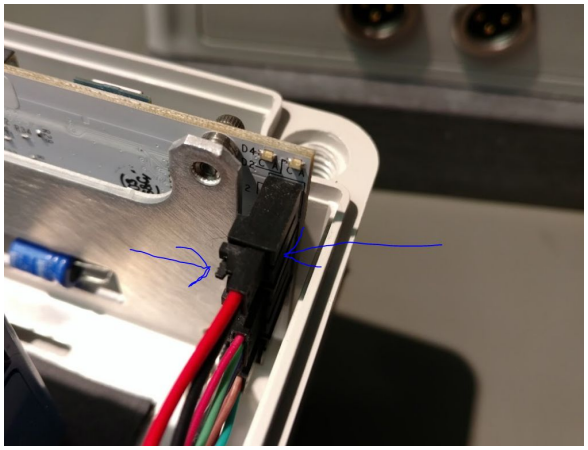
Quick Reference for the D405/505 Battery

- When preparing to change or connect/disconnect the D405/505 battery, first make sure the logger has spent about 30 minutes acclimating to a warm and dry environment.

If the above is not possible, be extra careful with the torque on the screws or they can snap in the cold!

- Start by removing the plastic Vynckier screws, seen below in the first image.

Take care when removing the lid- there will be a small wire connecting the solar panel in the lid to the circuit board in the body of the enclosure.



- With the lid off, follow the red and black wire pair from the battery to the two-pin molex connector. The second image above shows the connection.
- **Simultaneously**, lightly support the female molex receptacle while squeezing the tab on the male connector and pull to release the battery connection. When reconnecting, look/listen for the click of the small locking tab.

When re-attaching the lid...

- Make sure that no wires are caught in the seal or the edges.
- Make sure **not to overtorque** the screws, they only need to be turned to the limit of a light screwdriver grip (fingertip) and then a final 180° turn to complete. The black seal between the lid and base should visibly compress as the screws receive the final twist - *this is a good indicator of enough torque.*

If the battery is being changed...

- Use a 5/16” hex bit to loosen the hose clamp. Alternatively a flathead screwdriver can be used.
- Grip and twist the old battery initially to break the contact adhesion with the rubber pad below.

Questions? Email us at contact@beadedstream.com or call 844-488-4880

Appendix A3 - D400 Series Data Logger
(Alternative Resource NOT THE MODEL INSTALLED)

D400 SERIES DATA LOGGER

The D401 and D405 Data Loggers are extremely low-powered, programmable units used to log and/or transmit temperature data from BeadedStream TACs. The D401 has been engineered to be easily deployed and log data locally for site visits and manual downloads, while the D405 transmits data in real-time, through the Iridium Satellite Network, to the Internet.

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Manually connecting to the D400 series loggers and other useful information

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Direct Communication with D400 Series Loggers

D400 Loggers are shipped ready to be deployed in the field (unless specifically stated otherwise). *However, in the event that the Iridium Link is not used, a manual connection is necessary to configure the logger and download data*.

Terminal Emulator Instructions for Windows

For direct communication with BeadedStream Data Loggers, we use command line software called *RealTerm*. Realterm is a terminal emulator specially designed for capturing, controlling and debugging binary and other difficult data streams. By using Realterm, BeadedStream users will be able to configure data loggers and download temperature data.

Downloading Realterm

Realterm is free command line software that can be downloaded from:

http://sourceforge.net/projects/realterm/files/Realterm/ if not provided directly by BeadedStream.

By downloading the latest version of Realterm, an executable (.exe) file will be placed in your default downloads location. Double-clicking on this executable will initiate installation of Realterm. Follow the installation prompts and accept default settings. Realterm should install on your PC in just a few moments. You may need to restart your computer; otherwise a desktop icon should be available for immediate access to Realterm.

Connecting to your BeadedStream D400 Series Data Logger

To connect to your data logger you will need:

1. A laptop or desktop computer with Realterm installed
2. A standard USB to mini-USB connector cable
3. A data logger

Locate the mini USB connector port within the logger enclosure and firmly plug in the mini-USB. Plug the other end of the cable into your computer.

NOTE: If your USB connection is not working, there are a few potential reasons.

1. *Please check settings on your PC with regards to being able to automatically download USB drivers from the internet.*

2. *The logger can hold a communication connection even if not powered with a battery. In the event that a battery is dead or not connected and a connection is needed, the logger can be powered through the USB connection.* ***In the event that USB power is needed – attach the USB and wait at least 5 minutes – this will allow time for capacitors on the logger to charge and function.***
3. *D400 Loggers require a unique driver that may or may not install automatically on your computer. You can obtain the proper driver by visiting this website >* http://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx < Select the correct driver that corresponds to your operating system.

Open Realterm in your computer by double clicking on the Realterm icon on your desktop. Realterm has many advanced applications; however, here we will explain only the steps necessary to interface with your BeadedStream Data Logger.

The Realterm command prompt is characterized by a black window; this is where commands are typed. Below this window there are 10 tabs. **We will only be concerned with the first three (Display, Port and Capture).**

DISPLAY

To begin, we will set some parameters under the display tab. We accept most of the default settings, however under 'Rows' change the default from 16 to 30. This will make the command window larger. The number of rows can be set to any desired number. Additionally check the box for 'Scroll back'. This will allow for the ability to scroll to previous command entries and returns.

PORT

Your computer needs information regarding the nature and location of devices in order to communicate. This is designated by assigning ports. At this point, using your USB connector cable, connect your Data Logger to the USB interface on your computer. To determine what port is being used, you'll need to access the '**Device Manager',** when using a Windows platform. To access the Device Manager, you can type 'Device Manager' in the search bar or right click on '**My Computer'**. This will prompt a menu, where you'll want to select '**Manage'**. This will further prompt the '**Computer Management'** dialog box. Select '**Device Manager'**. Double-clicking on '**Ports (COM & LPT**)' will reveal which USB Serial Port is being used (i.e. COM5 would mean that your computer assigned Port 5 arbitrarily to this device).

Back in Realterm, *change the baud rate to 115200*, enter the port number and click '**Open**'. Open initiates communication between your computer and the data logger, however you must also click '**Change'** in order for communication prompts to be actualized.

At this point, the data logger is synced to your computer and active communication can begin.

Terminal Emulator Instructions for MAC

For direct communication with BeadedStream Data Loggers using a Mac, most new Macs come stocked with a terminal emulator called 'CoolTerm'

Connecting to your BeadedStream D400 Series Data Logger

To connect to your data logger you will need:

1. A laptop or desktop computer with Cool Term installed
2. A standard USB to mini-USB connector cable
3. A data logger

Locate the mini USB connector port on the bottom of the logger enclosure and firmly plug in the mini-USB. Plug the other end of the cable into your computer.

NOTE: If your USB connection is not working, there are a few potential reasons.

1. *Please check settings on your PC with regards to being able to automatically download USB drivers from the internet.*
2. *The logger can hold a communication connection even if not powered with a battery. In the event that a battery is dead or not connected and a connection is needed, the logger can be powered through the USB connection.* ***In the event that USB power is needed – attach the USB and wait at least 5 minutes – this will allow time for capacitors on the logger to charge and function.***
3. *D400 Loggers require a unique driver that may or may not install automatically on your computer. You can obtain the proper driver by visiting this website >* http://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx < Select the correct driver that corresponds to your operating system.

Open CoolTerm from your Mac Desktop.

- Select 'Options'
- In the Serial Port menu, 'Re-Scan Serial Ports'
- In Port, select 'SLAB_USBtoUART'.
- Set the BaudRate to 115200
- Click 'OK'
- Choose 'Connect' amongst the menu icons.

At this point, the data logger is synced to your computer and active communication can begin.

BLE Dongle Instructions

D400 Loggers have a BlueTooth Low Energy (BLE) Radio that can be used instead of a USB cable to establish a connection with either a MAC or PC. The dongle does not come standard with BeadedStream equipment, but can be useful if a wireless connection is necessary using a laptop. The instructions below describe how to use the dongle.

Connect to the Logger via Bluetooth

1. Plugging the BLE dongle into a USB port will prompt your PC to find and download necessary drivers automatically. In your Bluetooth Radios tab under 'Device Manager' – you should now have 'Broadcom 20702 Bluetooth 4.0 Adapter' – or something similar.

2. Your logger will need to be powered (Battery or USB) in addition to having a BLE connection. Plug the logger to your PC via USB and also have the BLE dongle plugged in. You should have one COM port connection at this point. On my computer, the logger has been assigned to COM5 via Bluetooth. *Ignore the COM50 connection specified here.*

3. Back in RealTerm – in the below example, I set a Baud of 115200 and set the port to COM5. I then click 'open' and then 'change'. ***My Bluetooth connection has not been made yet*** – there are a few commands to enter.

4. To conserve power on the logger, the Bluetooth Radio is turned off of unless prompted by magnet swipe over a hall effect sensor (labeled MAG on the outside of your logger enclosure). To initiate Bluetooth pairing between the logger and Dongle Radio, you'll need to swipe a magnet over this switch. This will activate the logger for **60 seconds –** to which you will need to go through the sequence below …. Really just a couple of commands

5. Click in the terminal window and type the following command (don't forget you've only got 60 seconds once you've tripped the switch with your magnet) – you may not receive an echo in the terminal, but once you hit carriage return, it should work.

    a. *Type :* atdile (with carriage return)
    b. *Receive:*
    OK

    DISCOVERY,2, **ECFE7E10557C**,0,-070,4,020106-020A04-051208001000-1107796022A0BEAFC0BDDE487962F1842BDA

DISCOVERY,6, **ECFE7E10557C**,0,-070,2,05FF85000000-1109426C7565526164696F73313035333330

DONE,1,1

c. *NOTE: this shows that the Bluetooth Dongle Radio 'sees' the Logger radio. If no 'Discovery' has been made, you may not have triggered the mag swtich. Try again, the connection should be immediate within the 60 second window.*

6. Next you need to type another command – notice the x's below need to be substituted with the bold scratchpad material above:
   a. Type: atdmle, **xxxxxxxxxxxx,** 1
   b. *Type or copy and paste:* atdmle, **ECFE7E10557C,** 1 (with carriage return)
   c. *Receive:*
      OK

      CONNECT,0,1,0,ECFE7E105330

      BRSP,0,1
   d. Note: there will be a couple of error messages – just ignore those. **YOU SHOULD NOW BE CONNECTED TO THE LOGGER VIA BLUETOOTH!!**

Communicating with your BeadedStream D400 Series Data Logger

Click in the black, command prompt box and follow some example syntax below. Commands that you would type are presented in **bold** *italics.* Returns are presented in normal *Italics*.

Help Menu

To set basic parameters in your data logger, start by typing the following commands and pressing ENTER:

help

HELP # show monitor commands
VERSION # show firmware version
DATE [yy/mm/dd] # set/get the current year/month/day
TIME [hh:mm] # set/get the current hours:minutes
SITE [site description] # set/get the site description
SERIAL [serial number] # set/get the unit serial number
DEPLOY [yy/mm/dd] # set/get the deployment date
GPS [lat, long] # set/get the latitude and longitude
LOG_P [hh:mm] # set/get the logging period
TRANSMIT_P [hh:mm] # set/get the satellite TX period (hours)
BAT_V # read battery voltage
TEMPS # read current temperatures
CLEAR # erase the log
DATA [NEW] # get all or only NEW logged temperature data
SEND # take a reading and transmit it via satellite
STATUS # show unit status

Date and Time

Setting Date and Time Manually

To set the time, it is necessary to find an accurate time source, such as www.time.gov . At BeadedStream we generally set the time to Zulu, however, the time can be set to any time zone.

Example Syntax:

date 13/12/31

2013/12/31 22:12:29

time 1:13

2013/12/31 01:13:00

Setting Date and Time with Iridium

If the logger is in contact with Iridium, the time and date will update automatically.

Setting Date and Time using the GPS radio

Similarly, if the logger does not have an Iridium link, the time can be set using the GPS radio by typing the following command while a having a clear view of the sky (likely outside). Entering a time (in seconds) after the command will prompt the GPS radio to attempt connection for that duration. The default time value is 60 seconds

Example Syntax:

rtc-set-from-gps

waiting max 60 seconds for gps update…

61 11.357380 N, 149 59.332136 W

2013/11/11 22:18:35

RTC UPDATED

Status Command

Similar steps are used to set site, deployment date, GPS coordinates, and the logging interval. Once these parameters are set, they can all be easily checked simultaneously by typing:

Status

Real Time Clock : 2013/11/11 22:23:37
Site description : SITE - NOT SET
Serial number : DLB00056
Site deployment : DEPLOYED - NOT SET
GPS description : GPS - NOT SET
Number of sensors: 8
Logging period : 12:00
Transmit period : 12:00
Inbox rx period : 24:00
Unit temperature : 17.37 C
Battery voltage : 6.574 volts
Storage used : 24 of 14600

Using Status is an easy way to get all necessary information regarding your logger in one swoop. Both date and time are presented as well as site description, serial number, site deployment, GPS points, and the number of sensors on your cable (this quickly shows that your logger is in fact reading a Temperature Acquisition Cable (TAC). In addition, the logging period shows that the logger logs cable

temperatures every 12 hours, and also transmits them every 12 hours. There is current battery voltage, low battery threshold flag, and storage used. The logger 'know's whether or not it is Iridium enabled (D405). In the case that it is not (D401), only the logging interval is available to set.

Logging and Transmitting Intervals

The logging and transmission intervals, 'log_p' and 'transmit_p', can only be set to factors of a 24 hour day with a minimum of 5 minutes. NOTE: if using a D401, only the logging interval is settable. If using a D405, the logging and transmitting intervals are both settable. The logging interval is displayed in 'status', however, it can also be accessed by typing:

log_p

4:00

To change the logging period to 2 hours, type:

log_p 02:00

To make sure the change has been made, type:

log_p

2:00

Reading Temperature Data

To obtain temperature readings from your logger outside of the normal logging interval, simply type:

Temps

If not connected to a TAC, the logger will return:

Temperature sensors:
0 sensors found
FAULTS: 1

When connected to a TAC, the logger will read and return sensor serial numbers, and temperatures for each sensor.

Temperature sensors: 4 sensors found
1) 02000002CBC8CC28 temp = 19.93 C
2) 15000002CBC02C28 temp = 20.06 C
3) 06000002CBC02228 temp = 20.06 C
4) 0C000002CBD1ED28 temp = 20.00 C

Here, the logger is connected to a 4 – sensor TAC, where ambient air temperatures are at room temperature.

To access all recorded data on your logger simply type:

Data

According to the 'status' readout above, there are 24 entries out of 14600. In addition, headers are not included, but they are shown below to identify what data is returned with the 'data' command. There is date, time, snow depth (In the event that your logger has a depth sensor) and battery voltage. Panel Temp is the onboard temperature reading, while T1 – T4 are the four sensors on the attached cable. Sensor ID uniquely identifies the TAC by the serial number of the first sensor. If more than one TAC is attached to the logger (maximum of 4 TACs), the temperature data from each TAC will be preceded by the sensor ID of the first sensor of each TAC.

Data Flag, Date, Time, Panel Temp, Battery Voltage, Sensor ID (TAC 1), byte flag, T1, T2, T3, T4, Sensor ID (TAC 2), byte flag, T1, T2, T3, T4

02, 11/11/2013, 22:22:55, 17.37, 6.570, 00 00 04 29 c9 fc, 05, 16.63, 14.69, 15.75, 16.81, 00 00 04 29 b9 d4, 06, 16.81, 15.13, 14.76, 15.26
02, 11/11/2013, 22:23:16, 17.31, 6.574, 00 00 04 29 c9 fc, 05, 16.56, 14.63, 15.69, 16.75, 00 00 04 29 b9 d4, 06, 16.81, 15.01, 14.63, 15.07

Verifying Iridium Functionality

In the field, to verify that a D405 logger is working properly, we can use the 'Send' command to have the logger show us that 1. It is reading the TACs correctly, and 2. It is able to successfully send a transmission through Iridium. In this example, there are two, four-sensor TACs connected. In the terminal, we first see what data is going to be transmitted, and secondly, we see if that transmission was successful or not. The 'Faults' can be ignored.

Send

02, 11/11/2013, 22:22:20, 17.49, 6.578, 00 00 04 29 c9 fc, 05, 16.88, 14.88, 15.94, 17.00, 00 00 04 29 b9 d4, 06, 17.00, 15.32, 15.07, 15.63
transmitting ... please wait
SUCCEEDED, 241 tx attempt(s) since last successful tx
FAULTS: 1

Recording Temperature Data from the Logger

Capture Function in Windows

To save logger data onto your computer, we will do what is called a 'capture'. In Realterm select the third tab called, 'capture' and follow these steps:

1. Next to 'File', select the desired output location of the file that will hold your captured data. Name this something that reflects the data that you are capturing.

2. Uncheck the box that selects 'Direct Capture'. This will allow you to see the commands that you are typing while they are being captured.
3. If starting a new capture, select 'Start Overwrite'. If appending data to an existing capture file, select 'Start Append'. Upon selecting one of these options, the interface will turn RED. This is good and indicates that capturing is imminent.
4. Now you will type commands into the command window. Anything that is typed into this window during a capture will be captured in the output file.
5. Some suggestions would be to type **'status'**, and then **'data'.**
6. When all data has been captured, simply select, 'Stop Capture'.
7. All data is now available in the capture output file designated in Step 1.

Capture Function for Mac

1. Select the 'Connection' tab from the main CoolTerm Menu bar
2. Select 'Capture To Textfile'
3. Use options to 'Start | Pause | Stop'

Logger LEDs

Windows in the lid decal of the logger give visual access to LED indicator lights. There are three different LED colors with combined behavior that indicates elements of logger status. In the right hand window you will see activity from a BLUE and GREEN LED, while in the left, a RED LED.

1. GREEN
    a. With regular logging, **between** logging intervals, the logger will blink GREEN about every 8 seconds. This serves as a 'heartbeat' indicating that the logger is functioning normally.
    b. With regular logging, **during** logging intervals, the logger will turn solid GREEN indicating that it is communicating with the TAC to obtain, store and transmit temperature readings.
    c. A flashing BLUE LED coupled with flashing GREEN LED for ~ 30 seconds indicates a logger reset.
2. RED
    a. When the magnet is used to reset the logger, the RED LED will go solid.
    b. When the magnet is used to issue an automatic log and/or transmission, the RED LED will flash briefly
3. BLUE
    a. A solid BLUE LED indicates a Bluetooth connection
    b. A flashing BLUE LED coupled with flashing GREEN LED for ~ 30 seconds indicates a logger reset.

Hall Effect Switch

D400 Data Loggers are built with an externally accessible hall effect sensor that varies its voltage output in response to a magnetic field. Holding a magnet over the left side of the logger (as indicated in Figure 2) will prompt the logger to do either 1) a one-time temperature reading and transmit outside of the set logging interval. In addition this will allow the BLE radio to advertise for a five minute duration, or 2) reboot the logger.

1) Perform a one-time temperature transmit (and advertise BLE):
    a. Hold the magnet in the vicinity of the sensor. When the sensor is tripped the RED LED will shine solid – quickly remove the magnet. Upon removing the magnet, the GREEN LED will shine solid GREEN, indicating that temperatures are being recorded. Once the LED turns GREEN start counting the seconds that it stays GREEN. Most transmissions will take on the order of 10 -25 seconds. In the event that the light stays GREEN for more than 90 seconds, assume the transmission was unsuccessful and try again. The LED will turn off automatically when finished.

2) Reboot the logger:

    a. Hold the magnet in position, wait until the LED shines RED, hold the magnet in place until the RED light turns off (about 7 or 8 seconds).
    b. Next you'll get some flashing of the BLUE and GREEN LEDs.
    c. Then, you'll get some solid GREEN – the logger is searching for a USB connection.
    d. Flashing BLUE – the logger is searching for a Bluetooth connection
    e. In the end, what you really want to see is the logger returning to the Idle mode (above) → GREEN LED blinks every 8 seconds.

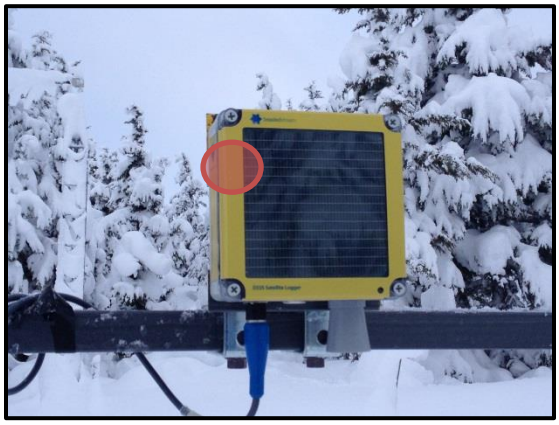

Figure 2: Photo of the D405. The circle demonstrates where the magnet needs to be placed on the outside of the logger enclosure to trip the magnetic switch.

Charging the Battery

D405 and D401 Loggers with Solar Recharge (Lead – Acid)

Each unit is solar rechargeable, thus if the logger is installed properly with the solar panel facing a southerly aspect, the logger should stay charged. Each logger ships with a full battery – ready to deploy. However, the units are always running. If you anticipate not using the logger for an extended period, it is recommended that you either open up the lid and unplug the battery, **OR EVEN BETTER** – just change the logging interval to something infrequent, like once every 24 hours. If the logger has been dormant for a while and you're about to deploy it, either open up the lid and put the battery on a 6V trickle charger (be sure to unplug the power leads from the logger board), **OR EVEN BETTER** – stick the logger out in the sun for a couple days.

D401 Loggers without Solar Recharge (Lithium Ion)

These batteries are a 7.2 V Tadiran Li-Ion, NON-RECHARGEABLE battery. Do not attempt a recharge, these batteries are made custom for BeadedStream – contact us if you need a replacement.

Two-way Communication through Iridium

D405 Loggers have the unique characteristic of being able to receive and process certain commands remotely. Essentially a text message can be emailed to Iridium that will ultimately find its way to the specified D405 Logger. This allows BeadedStream to remotely perform the following actions

- Change logging and transmitting intervals
- Update the RTC
- Determine which TACs are attached to the logger

This has been proven useful to confirm TACs being used, and change intervals either to save power through a long winter or obtain finer temporal resolution during thermal monitoring.

TAC XLR Connector

Each D400 Logger comes standard with 2 ports. These are male-ended XLR connectors. Matching female-ended XLR connectors can be found on the TAC itself. These XLR connectors are pretty darn strong. A couple points to be made here:

1. We recommend a conductive paste when coupling the XLR connectors in harsh, humid environments to prevent corrosion.
2. Make sure you hear a 'click' when plugging the connectors into the logger. Then do a 'tug test ' – they should not come out without needing to press the release tab!

Appendix A4 - BeadedStream Logger Installation Checklist

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BeadedStream Logger Installation Checklist

Logger:
- ❏ Oriented to true south (*northern hemisphere*)
- ❏ Minimal vertical tilt** *Photo left shows large but acceptable tilt.*

Sonic sensor:
- ❏ Mounted well above minimum reading distance of 30 cm (~1 foot)
- ❏ Clear path to the ground
- ❏ Flat target on the ground *Brush cleared/plywood set down*

Air temperature sensor:
- ❏ Secured in radiation shield gland shield.

Cables:
- ❏ Connector face coated with **small** amount of "Stuf" paste
- ❏ Connector locked into bulkhead receptacle (*push hard, light tug test, repeat until success*)

System status:
- ❏ Checked out with the Capture app.

Tilt **will DRASTICALLY REDUCE satellite antenna performance. **No tilt** means logger bottom ports point straight down. In locations with snow, no tilt is a good balance of direct sun and energy reflected from the snow.

*See **Buoy Installation Instructions** for marine environment logger deployments.*

Questions? Email us at contact@beadedstream.com or call 844-488-4880

Appendix A5 - Understanding the health of a deployed D505 satellite and sensor system

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Understanding the health of a deployed D505 satellite and sensor system

A D505 transmits a few types of data (*alongside connected sensor data*) that contribute to understanding the system's health. This data is accessible in the **Legend** on any data site page on the BeadedStream web application.

Data site page | Core logger metrics

Below is a snapshot of transmitted data. Additional information below in the table and notes:

Data type	Axis	Operating range/detail
Battery	R	**6.6V+** (full charge) | **6.3V** (half) | **6.15V** (*very low*) | **6V** dead *See Note 1*
Comm. Status	R	Number of attempts to transmit data. **0-5** (normal) **6-15** *See Note 2*
Panel Temp	L	Internal temperature of the logger. *See Note 3*

Note 1: The logger does not protect itself at a "dead" voltage of 6V - it will continue programmed routines unless remotely commanded to slow or stop. Draining below 6V will permanently harm battery capacity. Transmission will not function reliably. Logging will function down to <5.5V. The **6.15-6.25V** range is a good time to check in with BeadedStream.

Note 2: If the logger begins to or consistently takes many attempts to transmit each data set, battery life and endurance will be impacted. More on this below.

Note 3: Internal temperature is not a reliable air temperature because of the "oven baking" effect: UV radiation penetrates the enclosure, generated infrared heat stays trapped inside.

Changes and trends in cable or logger data

A deployed data logger can experience many undesirable events that have an adverse affect on transmit performance and battery levels. Examples include:

- **Snow stackup on logger:** Reduced transmit performance.
    - *Dry is better, but wet on the antenna (water content) harshly reduces performance.*
- **Logger articulation disturbed:** Reduced solar recharge and transmit performance.
- **Solar panel frosted:** Reduced solar recharge.
- **Temporary/permanent obstruction:** Reduced solar recharge and transmit performance.
    - *The logger antenna functions best with an unobstructed hemisphere above the unit. Metal specifically has a negative effect but is sometimes unavoidable, see the thermosiphon mount below:*

Events can be indirectly identified by analysis of one or more of the following:

- **Battery voltage:** latest/recent. Sharper decline is a concern.
- **Transmit attempts:** (*comm. status*) latest/recent. Spikes and increases are a concern.
- **Unit temperature:** latest/recent. Extreme cold will co-indicate reduced charging and increase battery load during function.
- **Loss of all data from a data site/cable:** can indicate disconnected/damaged cable at or near the logger, or cable damage anywhere between the connector and first sensor.
- **Sharp shift in value of one or more temperatures:** cable may have been pulled out of the ground and some/all sensors are tracking closely with the air temperature.

    Note: Partial cable/sensor loss on one or more cables can also occur. If this problem occurs, reach out to pm@beadedstream.com for help.

Appendix B - GTC Specifications and Calibration Certificates

Appendix B1 - D505 Data Logger Specifications

beadedstream

35140-01

D505 | Our latest satellite data logger.

Log your data without logging the miles. The BeadedStream D505 Data Logger is purpose built for remote deployments and reliable performance in extreme conditions. Now with enhanced solar and Bluetooth performance.

Specifications

Hardware / Firmware	• Ultra low-power, high performance industrial microcontroller. • Multi-threaded custom embedded OS. Free firmware updates.
Storage	• Capacity for over 1 million temperature readings. • Non-volatile flash memory survives even if battery dies.
Real Time Clock	• ± 5 minutes per year (temperature compensated). • Periodically synchronizes with GPS network.
Communication	• Bluetooth 4.2 wireless interface. • Compatible with *Capture*, our all new iOS app.
Connections	• Up to 4 DTC ports, up to 2 additional ports for other sensors, power, etc. • 5V driver available to power DTC sensors if needed.
Ultra Low Power	• 6 to 10 VDC (max) input. • Sleep mode: 90 µA typical. Active mode: 70 mA typical.
Battery	• Rechargeable 6V 5.5 Ah sealed lead-acid battery. • 2 months typical w/o solar recharge (Transmitting hourly).
GPS	• Embedded 40-channel dedicated GPS processing module. • 34-second time to first fix (typical). Integrated 1575.42 MHz antenna.
Worldwide Telemetry	• Embedded two-way satellite transceiver and Iridium antenna. • Uses Iridium's mesh network, 66 satellites, 100% pole to pole coverage.
Operating Range	• -40° C to +85° C (-40° F to +185° F). NEMA Type 4X/IP68.
Weight and Dimensions	• 2.3 kg (5.1 lbs) (*without mount*). 7.1" x 7.1"x 3.1" (18 cm x 18 cm x 7.9 cm).
Mounting	• Multi-function pivoting arm mount comes standard.

beadedstream

35140-01

Specifications (continued)

Integrated Solar	• 3 Watt nominal solar panel with temperature compensated charge control circuit to protect and prolong battery life.
Contactless Switch	• Built-in magnetic switch is immune to dust, dirt, mud and water. • Triggers through the case for spot readings and Bluetooth wake.
Optional Rangefinder	• Small, lightweight, rugged. An ultrasonic outdoor sensor for snow and water level measurement. IP67 rated. • Long narrow detection zone with a 1 cm resolution, minimum detection range of 50 cm, 1 meter maximum. • Filtering algorithms yield excellent noise tolerance and clutter rejection.

Appendix B2 - GTC (DTC) Cable Product Specifications

beadedstream

35110-04

Digital Temperature Cable (DTC)

Standard High Visibility Yellow

It all starts with BeadedStream's all-digital temperature cables. DTCs increase the speed and ease of obtaining temperature data and deliver accurate, highly resolved measurements in digital form.

Specifications

Application	• Multi-use industrial temperature monitoring
Length	• Customizable; user specified • Standard maximum length of 450 m (1500 ft)
Diameter	• Cable is 7.0 mm ± 0.1 mm • Straight sensor housing is 11 mm ± 0.5 mm
Maximum Operating Temperature Range	• -55° C to 125° C (-67° F to 257° F)
Field Conditions	• Wet / Dry / Frozen
Colors	• High-visibility yellow; gray (reinforced cable); white • Black or white heat shrink available for sensor sections
Outer Jacket	• BeadedStream S724EX polyurethane jacket formulated for low temperature durability and flex with reduced diameter and weight • Gray option with reinforced shielding for added protection from wildlife and improved crush resistance • UV stabilized • Cut and abrasion resistant • Flexing minimum temperature -40° C/F
Central Strength Member	• Built-in Aramid fibers increase strength in tension and minimize cable stretch
Conductors	• Stranded tinned copper; 22 AWG; Number: 3
Maximum # of Sensors	• 110
Sensor Accuracy	• ± 0.1° C from -10° C to 30° C (14° F to 86° F)

beadedstream 35110-04

DTC Specifications (continued)

Sensor Spacing	• Customizable; user specified • Variable spacing available upon request • Minimum standard spacing: 10 cm • Closer spacing available – please inquire
Additional Sensor Features	• Requires only one signal line for bidirectional communication • Each sensor has a unique ID for individual communication • Operates using input voltage between 3.0 V and 5.5 V • Converts temperatures in 750 ms (max)

Appendix B3 - GTC Order Sheets

beadedstream

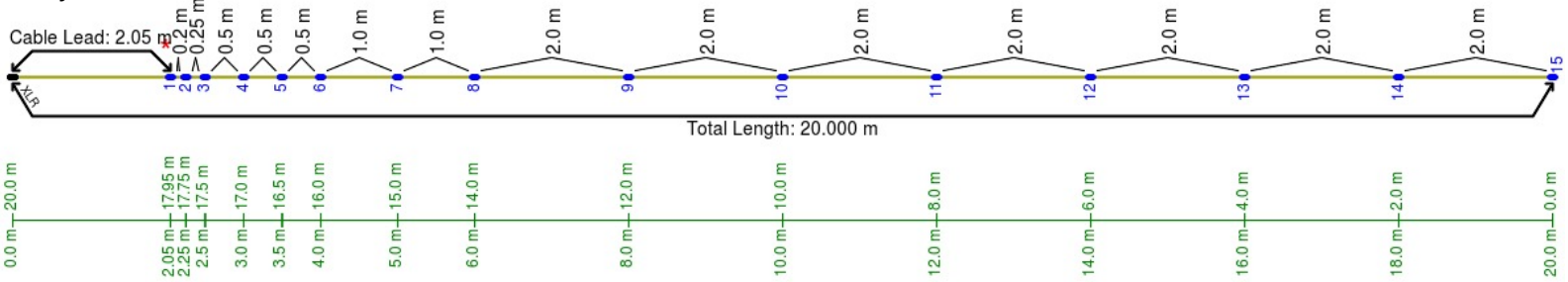
DTC Order Sheet

Customer: SRK Consulting
Project Name: 2018 - Point Hope Phase 1
Order Date:

DTC Name: 15 sensor profiler for the following locations: SRK17-STH-DH-02, SRK17-STH-DH-03, Spare #1
Serial Number: 2839
Units: meters

Object	Mold	Cable	Distance
XLRConnector	XLR Mold	Yellow	2.05m
Protection/Sensor 1	Straight	Yellow	0.2m
Sensor 2	Straight	Yellow	0.25m
Sensor 3	Straight	Yellow	0.5m
Sensor 4	Straight	Yellow	0.5m
Sensor 5	Straight	Yellow	0.5m
Sensor 6	Straight	Yellow	1.0m
Sensor 7	Straight	Yellow	1.0m
Sensor 8	Straight	Yellow	2.0m
Sensor 9	Straight	Yellow	2.0m
Sensor 10	Straight	Yellow	2.0m
Sensor 11	Straight	Yellow	2.0m
Sensor 12	Straight	Yellow	2.0m
Sensor 13	Straight	Yellow	2.0m
Sensor 14	Straight	Yellow	2.0m
Sensor 15	End	N/A	N/A

Comments: Quantity 3 *** Use NO hole sensor boards *** OK to cut Kevlar



* indicates that this sensor contains a protection unit

Return signed order sheet to BeadedStream at
e-mail: contact@beadedstream.com
call: 844-488-4880 for support

Approved _____ Date _____

beadedstream

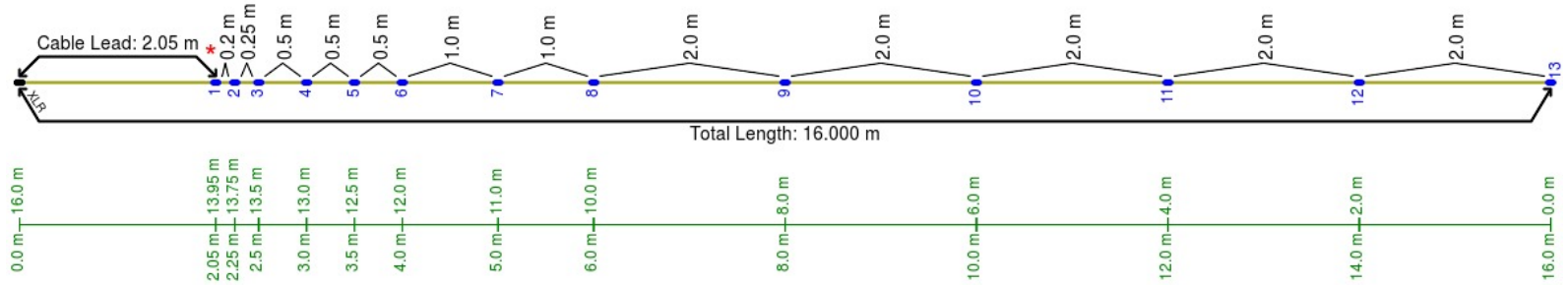
DTC Order Sheet

Customer: SRK Consulting
Project Name: 2018 - Point Hope Phase 1
Order Date:

DTC Name: 13 sensor profiler for: SRK17-BWRP-DH-01, Spare #2
Serial Number: 2841
Units: meters

Object	Mold	Cable	Distance
XLRConnector	XLR Mold	Yellow	2.05m
Protection/Sensor 1	Straight	Yellow	0.2m
Sensor 2	Straight	Yellow	0.25m
Sensor 3	Straight	Yellow	0.5m
Sensor 4	Straight	Yellow	0.5m
Sensor 5	Straight	Yellow	0.5m
Sensor 6	Straight	Yellow	1.0m
Sensor 7	Straight	Yellow	1.0m
Sensor 8	Straight	Yellow	2.0m
Sensor 9	Straight	Yellow	2.0m
Sensor 10	Straight	Yellow	2.0m
Sensor 11	Straight	Yellow	2.0m
Sensor 12	Straight	Yellow	2.0m
Sensor 13	End	N/A	N/A

Comments: Quantity 2 *** Use NO hole sensor boards *** OK to cut Kevlar



* indicates that this sensor contains a protection unit

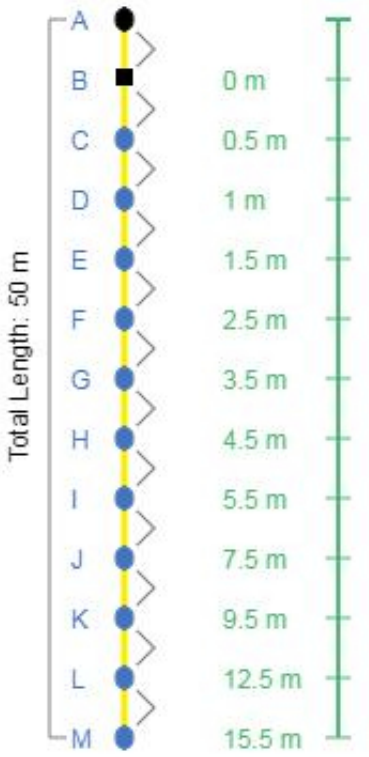
Return signed order sheet to BeadedStream at
e-mail: contact@beadedstream.com
call: 844-488-4880 for support

Approved _____ Date _____

Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-155-KTC and SD-VTS-460-KTC
Quantity: 2	Serial Number(s): 3251, 3252

Client Notes:
Priority 1

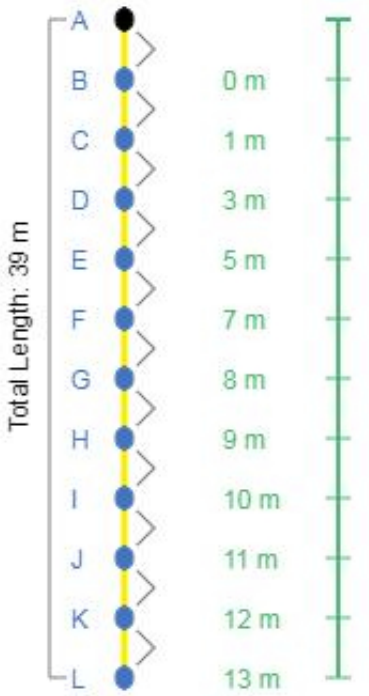
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	34.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-HTS-155-KT and SD-HTS-460-KT
Quantity: 2	Serial Number(s): 3253, 3254

Client Notes:
Priority 2

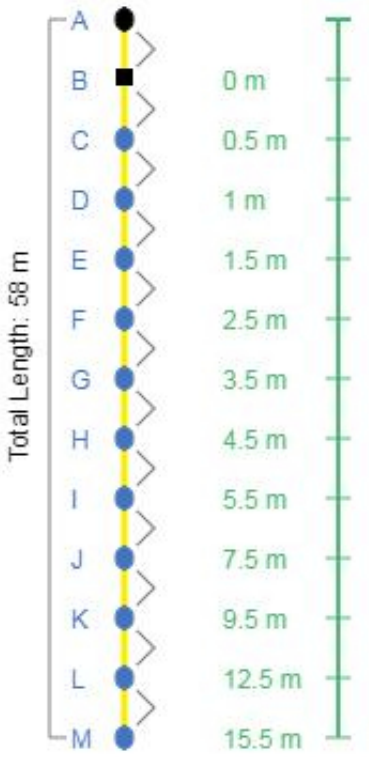
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	26 m	yellow
Protection/Sensor 1	Straight	0 m	1 m	yellow
Sensor 2	Straight	1 m	2 m	yellow
Sensor 3	Straight	3 m	2 m	yellow
Sensor 4	Straight	5 m	2 m	yellow
Sensor 5	Straight	7 m	1 m	yellow
Sensor 6	Straight	8 m	1 m	yellow
Sensor 7	Straight	9 m	1 m	yellow
Sensor 8	Straight	10 m	1 m	yellow
Sensor 9	Straight	11 m	1 m	yellow
Sensor 10	Straight	12 m	1 m	yellow
Sensor 11	End Mold	13 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-240-KTC
Quantity: 1	Serial Number(s): 3255

Client Notes:
Priority 1

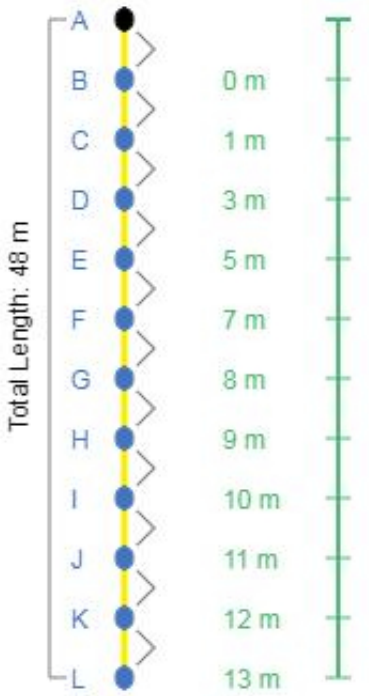
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	42.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-240-KT
Quantity: 1	Serial Number(s): 3256

Client Notes:
Priority 2

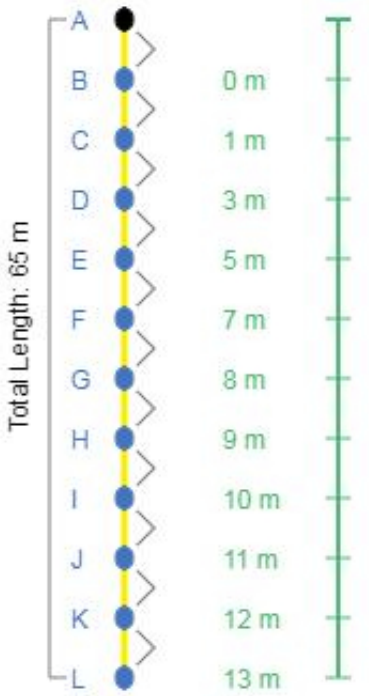
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	35 m	yellow
Protection/Sensor 1	Straight	0 m	1 m	yellow
Sensor 2	Straight	1 m	2 m	yellow
Sensor 3	Straight	3 m	2 m	yellow
Sensor 4	Straight	5 m	2 m	yellow
Sensor 5	Straight	7 m	1 m	yellow
Sensor 6	Straight	8 m	1 m	yellow
Sensor 7	Straight	9 m	1 m	yellow
Sensor 8	Straight	10 m	1 m	yellow
Sensor 9	Straight	11 m	1 m	yellow
Sensor 10	Straight	12 m	1 m	yellow
Sensor 11	End Mold	13 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-HTS-365-KT
Quantity: 1	Serial Number(s): 3257

Client Notes:
Priority 2

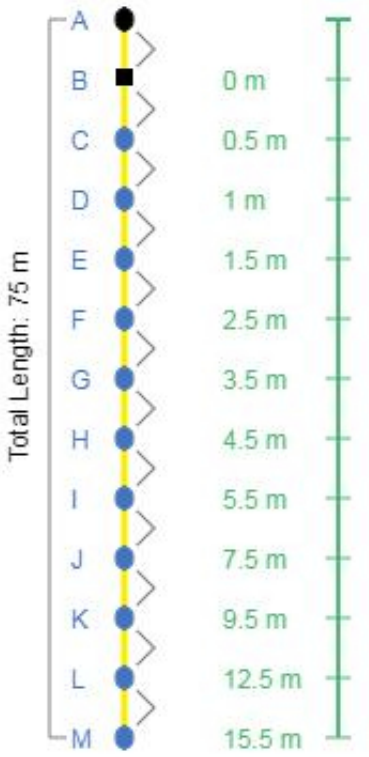
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	52 m	yellow
Protection/Sensor 1	Straight	0 m	1 m	yellow
Sensor 2	Straight	1 m	2 m	yellow
Sensor 3	Straight	3 m	2 m	yellow
Sensor 4	Straight	5 m	2 m	yellow
Sensor 5	Straight	7 m	1 m	yellow
Sensor 6	Straight	8 m	1 m	yellow
Sensor 7	Straight	9 m	1 m	yellow
Sensor 8	Straight	10 m	1 m	yellow
Sensor 9	Straight	11 m	1 m	yellow
Sensor 10	Straight	12 m	1 m	yellow
Sensor 11	End Mold	13 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-365-KTC
Quantity: 1	Serial Number(s): 3258

Client Notes:
Priority 1

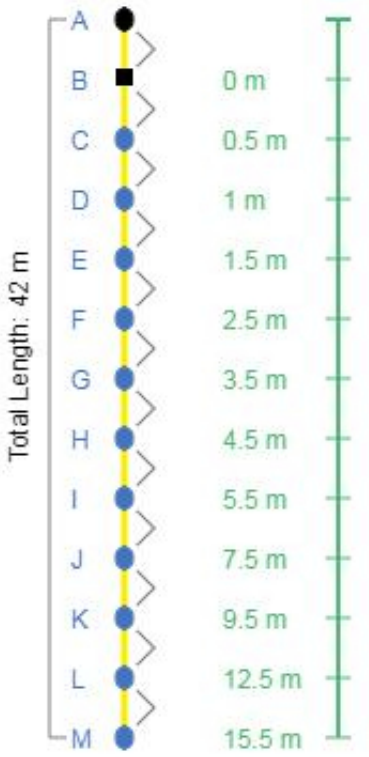
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	59.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-065-KTC
Quantity: 1	Serial Number(s): 3259

Client Notes:
Priority 1

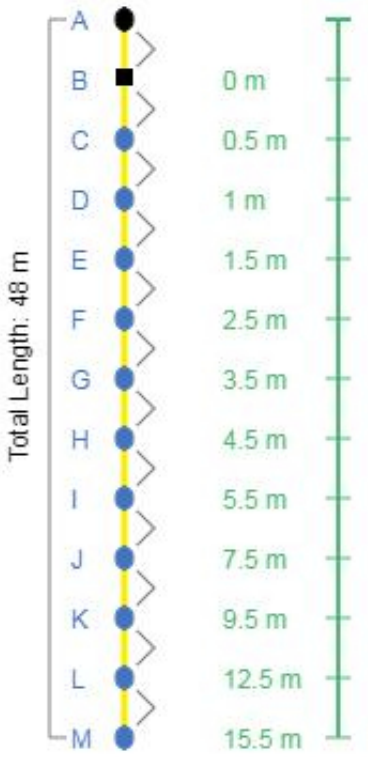
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	26.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-VTS-510-KTC
Quantity: 1	Serial Number(s): 3260

Client Notes:
Priority 1

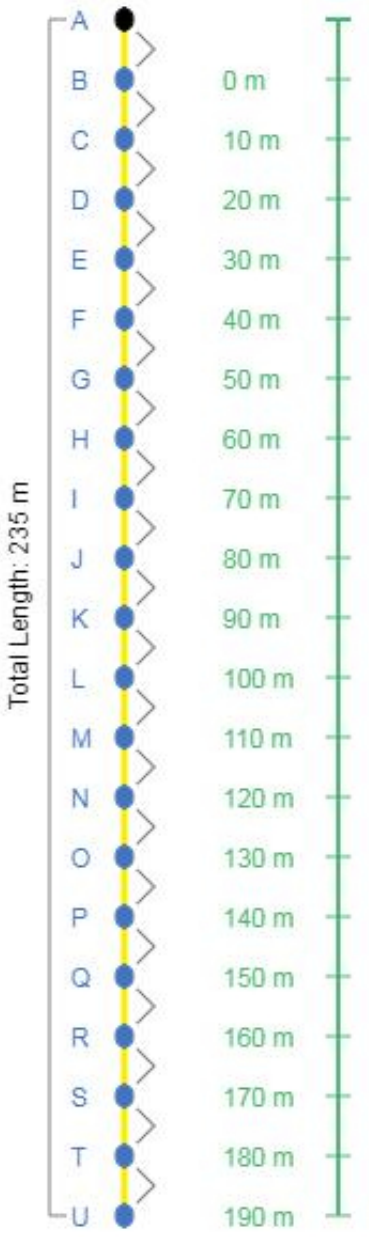
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	32.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 02-20-2018
Project: Hope Bay - South Dam	DTC Name: SD-HST-B1-KT
Quantity: 1	Serial Number(s): 3261

Client Notes:
Priority 3

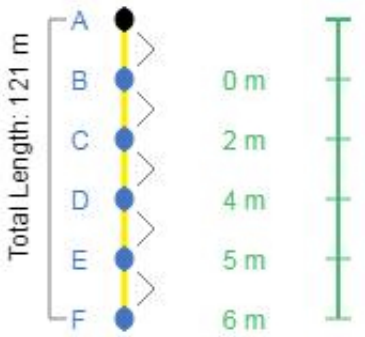
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	45 m	yellow
Protection/Sensor 1	Straight	0 m	10 m	yellow
Sensor 2	Straight	10 m	10 m	yellow
Sensor 3	Straight	20 m	10 m	yellow
Sensor 4	Straight	30 m	10 m	yellow
Sensor 5	Straight	40 m	10 m	yellow
Sensor 6	Straight	50 m	10 m	yellow
Sensor 7	Straight	60 m	10 m	yellow
Sensor 8	Straight	70 m	10 m	yellow
Sensor 9	Straight	80 m	10 m	yellow
Sensor 10	Straight	90 m	10 m	yellow
Sensor 11	Straight	100 m	10 m	yellow
Sensor 12	Straight	110 m	10 m	yellow
Sensor 13	Straight	120 m	10 m	yellow
Sensor 14	Straight	130 m	10 m	yellow
Sensor 15	Straight	140 m	10 m	yellow
Sensor 16	Straight	150 m	10 m	yellow
Sensor 17	Straight	160 m	10 m	yellow
Sensor 18	Straight	170 m	10 m	yellow
Sensor 19	Straight	180 m	10 m	yellow
Sensor 20	End Mold	190 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-HTS-065-US
Quantity: 1	Serial Number(s): 3263

Client Notes:
Priority 1

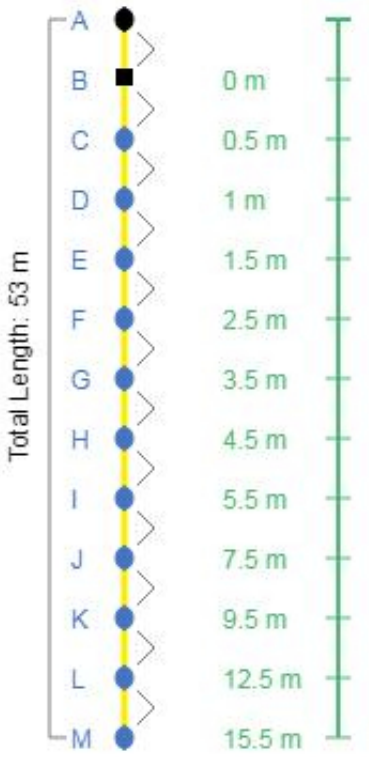
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	115 m	yellow
Protection/Sensor 1	Straight	0 m	2 m	yellow
Sensor 2	Straight	2 m	2 m	yellow
Sensor 3	Straight	4 m	1 m	yellow
Sensor 4	Straight	5 m	1 m	yellow
Sensor 5	End Mold	6 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-VTS-155-DST and SD-VTS-240-DST
Quantity: 2	Serial Number(s): 3264, 3265

Client Notes:
Priority 3

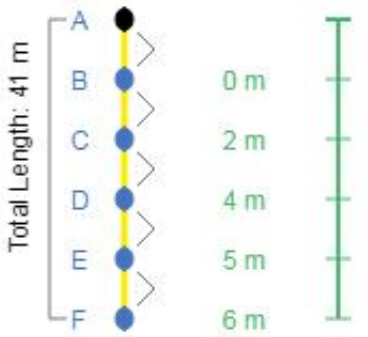
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	37.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-HTS-155-US and SD-HTS-460-US
Quantity: 2	Serial Number(s): 3266, 3267

Client Notes:
Priority 1

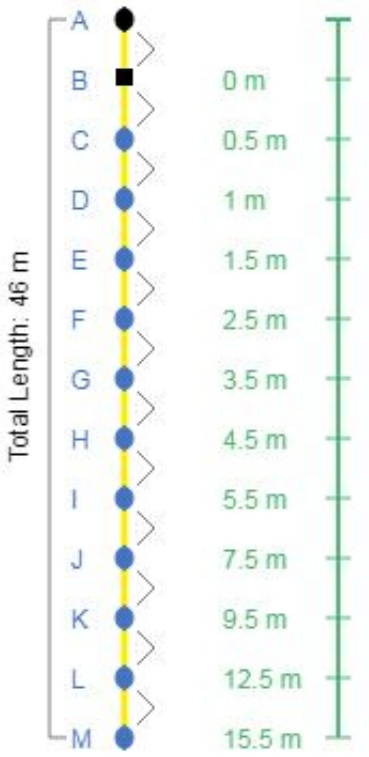
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	35 m	yellow
Protection/Sensor 1	Straight	0 m	2 m	yellow
Sensor 2	Straight	2 m	2 m	yellow
Sensor 3	Straight	4 m	1 m	yellow
Sensor 4	Straight	5 m	1 m	yellow
Sensor 5	End Mold	6 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-VTS-240-UST
Quantity: 1	Serial Number(s): 3268

Client Notes:
Priority 2

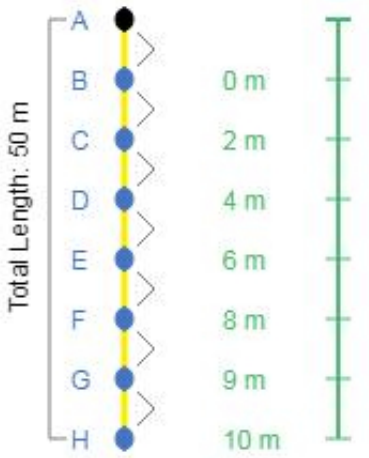
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	30.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-HTS-240-US
Quantity: 1	Serial Number(s): 3269

Client Notes:
Priority 1

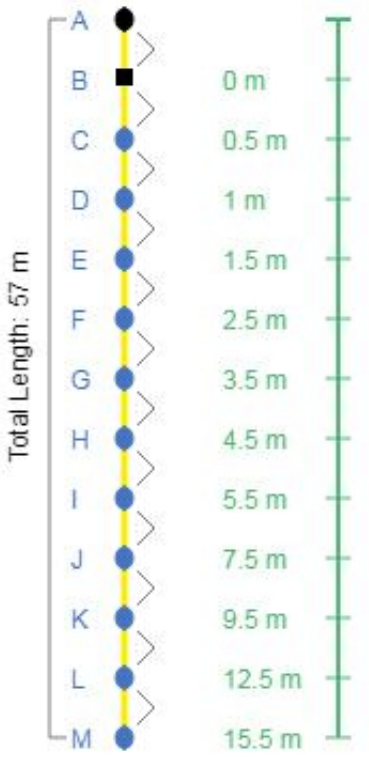
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	40 m	yellow
Protection/Sensor 1	Straight	0 m	2 m	yellow
Sensor 2	Straight	2 m	2 m	yellow
Sensor 3	Straight	4 m	2 m	yellow
Sensor 4	Straight	6 m	2 m	yellow
Sensor 5	Straight	8 m	1 m	yellow
Sensor 6	Straight	9 m	1 m	yellow
Sensor 7	End Mold	10 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-VTS-365-UST
Quantity: 1	Serial Number(s): 3270

Client Notes:
Priority 2

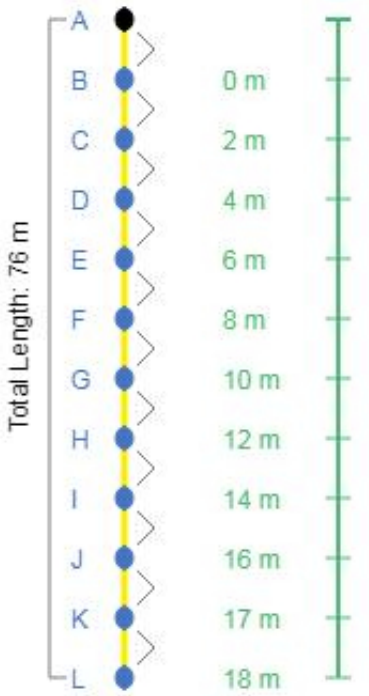
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	41.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-HTS-365-US
Quantity: 1	Serial Number(s): 3271

Client Notes:
Priority 1

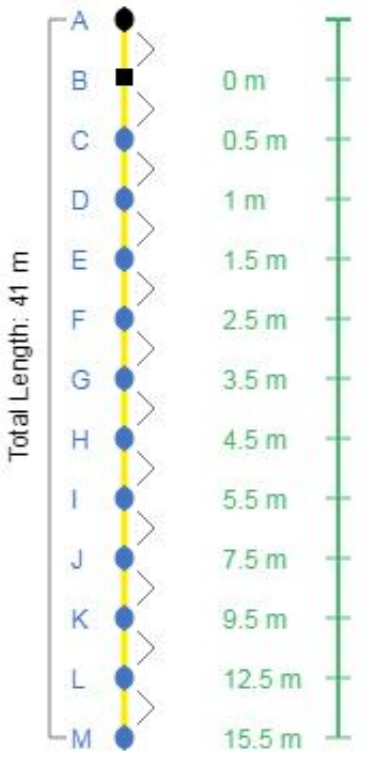
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	58 m	yellow
Protection/Sensor 1	Straight	0 m	2 m	yellow
Sensor 2	Straight	2 m	2 m	yellow
Sensor 3	Straight	4 m	2 m	yellow
Sensor 4	Straight	6 m	2 m	yellow
Sensor 5	Straight	8 m	2 m	yellow
Sensor 6	Straight	10 m	2 m	yellow
Sensor 7	Straight	12 m	2 m	yellow
Sensor 8	Straight	14 m	2 m	yellow
Sensor 9	Straight	16 m	1 m	yellow
Sensor 10	Straight	17 m	1 m	yellow
Sensor 11	End Mold	18 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-VTS-155-UST, SD-VTS-460-UST
Quantity: 2	Serial Number(s): 3272, 3273

Client Notes:
Priority 2

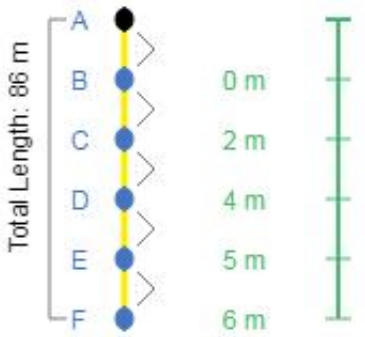
Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	25.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-14-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-HTS-510-US
Quantity: 1	Serial Number(s): 3274

Client Notes:
Priority 1

Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	80 m	yellow
Protection/Sensor 1	Straight	0 m	2 m	yellow
Sensor 2	Straight	2 m	2 m	yellow
Sensor 3	Straight	4 m	1 m	yellow
Sensor 4	Straight	5 m	1 m	yellow
Sensor 5	End Mold	6 m	- m	-



Customer: SRK Consulting (Alaska)	Date Generated: 03-16-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: Extensions for SD-VTS-065-KTC, 510-KTC
Quantity: 2	Serial Number(s): 3277, 3278

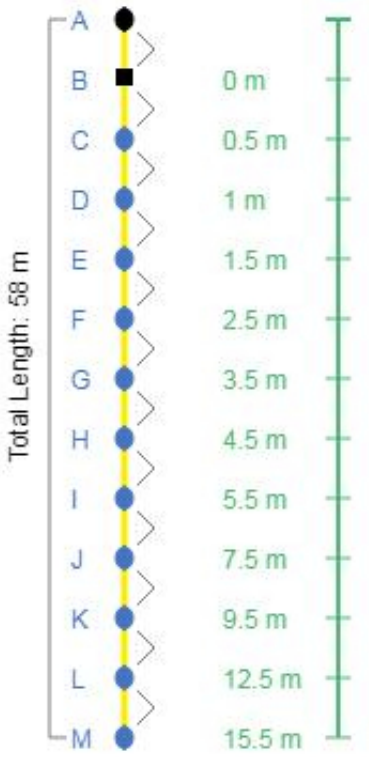
Client Notes:
The "zero marker" on the end of this extension represents the opposite gender XLR connector.

Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	90 m	yellow
Zero Marker	None	0 m	- m	-

Customer: SRK Consulting (Alaska)	Date Generated: 03-16-2018
Project: Hope Bay - South Dam - Order 2	DTC Name: SD-VTS-365-DST, SD-VTS-460-DST
Quantity: 2	Serial Number(s): 3275, 3276

Client Notes:
Priority 3

Component	Mold	Position	Section	Cable
XLR	XLR Mold	-	42.5 m	yellow
Zero Marker	None	0 m	0.5 m	yellow
Protection/Sensor 1	Straight	0.5 m	0.5 m	yellow
Sensor 2	Straight	1 m	0.5 m	yellow
Sensor 3	Straight	1.5 m	1 m	yellow
Sensor 4	Straight	2.5 m	1 m	yellow
Sensor 5	Straight	3.5 m	1 m	yellow
Sensor 6	Straight	4.5 m	1 m	yellow
Sensor 7	Straight	5.5 m	2 m	yellow
Sensor 8	Straight	7.5 m	2 m	yellow
Sensor 9	Straight	9.5 m	3 m	yellow
Sensor 10	Straight	12.5 m	3 m	yellow
Sensor 11	End Mold	15.5 m	- m	-



Appendix B4 – GTC Calibration Certificates

DTC Calibration Certificate
SRK - Hope Bay Phase 1

This certificate verifies and displays the results of calibration for the digital temperature cables with serial numbers **3187 to 3201**. **3188** had repair work started but was then superseded by replacement cable **3201**. The values are shown in the tables below.

Offset values are a result of BeadedStream's rigorous calibration process where each offset is determined with measurement in a **0.000 °C ice bath** confirmed with our NIST traceable secondary reference platinum RTD (Resistance temperature detector).

When temperature readings are taken with a D405 Datalogger or NetGate (Ethernet Bridge), the offset values are first subtracted from the raw temperature and then are driven to **+/- 0.1 °C accuracy** using BeadedStream's proprietary characteristic error curve correction algorithm.

Sensor	Sensor ID	Offset
	Serial 3187	
1	E6 00 00 07 12 68 2F 28	0.250
2	BC 00 00 08 40 A4 88 28	1.000
3	94 00 00 08 40 4C 14 28	0.438
4	2B 00 00 08 40 EA 8C 28	0.375
5	A3 00 00 08 40 A4 EC 28	0.875
6	66 00 00 08 40 B6 02 28	0.938
7	2F 00 00 08 41 31 A2 28	0.438
8	65 00 00 08 41 06 62 28	0.250
9	37 00 00 08 40 C5 F2 28	0.438
10	29 00 00 08 41 4C B6 28	0.375
11	78 00 00 08 41 30 C1 28	0.375
12	2C 00 00 08 41 06 F9 28	0.375
13	45 00 00 08 40 9D 55 28	1.000
14	DE 00 00 08 40 6B 5D 28	0.438
15	15 00 00 08 41 36 03 28	0.375
	Serial 3189	
1	29 00 00 07 12 09 21 28	0.375
2	B2 00 00 08 40 4C 08 28	0.500

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **January 24th 2018***
*Cable 3201 calibrated and added and certificate completed by **Paul Harren** (Project Manager) on **February 1st 2018***

3	F1 00 00 08 40 6B 88 28	0.438
4	EE 00 00 08 40 5D 38 28	1.000
5	D1 00 00 08 40 8F F4 28	0.375
6	52 00 00 08 41 22 0C 28	0.438
7	98 00 00 08 41 38 D6 28	0.438
8	C0 00 00 08 3F F1 41 28	0.563
9	BD 00 00 08 41 49 D1 28	0.313
10	E0 00 00 08 40 A5 31 28	1.000
11	87 00 00 08 40 64 D9 28	0.750
12	05 00 00 08 41 30 CD 28	0.438
13	3A 00 00 08 40 64 23 28	0.813
14	EE 00 00 08 40 64 6B 28	1.000
15	EF 00 00 08 41 36 1B 28	0.313
	Serial 3190	
1	65 00 00 07 12 67 9A 28	0.188
2	A5 00 00 08 40 5D B0 28	0.938
3	38 00 00 08 41 22 28 28	0.250
4	DB 00 00 08 40 19 58 28	0.875
5	CA 00 00 08 40 64 64 28	0.938
6	D5 00 00 08 3F CD 54 28	0.313
7	76 00 00 08 40 11 F2 28	0.563
8	55 00 00 08 40 92 4A 28	0.500
9	59 00 00 08 40 64 CE 28	1.000
10	F4 00 00 08 40 8F 7E 28	0.125
11	65 00 00 08 41 22 0D 28	0.375
12	3B 00 00 08 3F B0 D3 28	0.875
	Serial 3191	
1	A0 00 00 07 12 7A F3 28	0.250
2	70 00 00 08 41 49 C8 28	0.625
3	D5 00 00 08 41 22 18 28	0.313
4	E4 00 00 08 40 64 34 28	0.875
5	6E 00 00 08 40 38 FC 28	0.750
6	AC 00 00 08 3F FD FC 28	0.313
7	C6 00 00 08 3F B1 62 28	1.125

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **January 24th 2018***
*Cable 3201 calibrated and added and certificate completed by **Paul Harren** (Project Manager) on **February 1st 2018***

11	CE 00 00 08 40 19 63 28	1.000
12	B0 00 00 08 41 38 B3 28	0.500
	Serial 3197	
1	B0 00 00 07 12 08 CD 28	0.438
2	2E 00 00 08 3F D1 EC 28	0.375
3	57 00 00 08 40 EB 1C 28	0.438
4	4B 00 00 08 40 59 72 28	0.250
5	53 00 00 08 40 7A 86 28	1.125
6	F7 00 00 08 3F B1 56 28	0.938
7	3A 00 00 08 40 EA 91 28	0.438
8	03 00 00 08 40 8F 89 28	0.500
9	F6 00 00 08 40 A4 85 28	0.938
10	25 00 00 08 40 8F 95 28	0.375
11	41 00 00 08 40 11 F3 28	0.438
12	89 00 00 08 41 38 CB 28	0.375
13	79 00 00 08 40 90 3B 28	0.063
	Serial 3198	
1	2F 00 00 07 12 09 14 28	0.250
2	66 00 00 08 40 D9 98 28	0.375
3	32 00 00 08 40 7A 78 28	0.875
4	47 00 00 08 40 A5 0C 28	1.000
5	3E 00 00 08 40 9D 6C 28	0.813
6	E7 00 00 08 40 A5 81 28	1.000
7	2C 00 00 08 40 72 51 28	0.250
8	72 00 00 08 3F CD 69 28	0.500
9	4A 00 00 08 40 57 69 28	0.438
10	97 00 00 08 41 22 59 28	0.375
11	AC 00 00 08 40 FE 75 28	0.563
12	53 00 00 08 40 D6 0D 28	0.375
13	2C 00 00 08 40 D1 5D 28	0.938
	Serial 3199	
1	29 00 00 07 12 AF 50 28	0.188
2	9C 00 00 08 40 D9 80 28	0.188
3	43 00 00 08 40 9D 60 28	0.938

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **January 24th 2018***
*Cable 3201 calibrated and added and certificate completed by **Paul Harren** (Project Manager) on **February 1st 2018***

DTC Calibration Certificate
SRK - Hope Bay South Dam

This certificate verifies and displays the results of calibration for the digital temperature cables with serial numbers **3251 to 3261**. The values are shown in the tables below.

Offset values are a result of BeadedStream's rigorous calibration process where each offset is determined with measurement in a **0.000 °C ice bath** confirmed with our NIST traceable secondary reference platinum RTD (Resistance temperature detector).

When temperature readings are taken with a D405 Datalogger, NetGate, or Recite, the offset values are first subtracted from the raw temperature and then are driven to **+/- 0.1 °C accuracy** using BeadedStream's proprietary characteristic error curve correction algorithm.

Sensor	Sensor ID	Offset
	Serial 3251	
1	B2 00 00 07 11 F6 10 28	0.250
2	EA 00 00 07 12 11 00 28	0.188
3	C3 00 00 07 12 46 30 28	0.375
4	21 00 00 07 12 42 98 28	0.250
5	37 00 00 07 12 46 51 28	0.125
6	43 00 00 07 12 60 C9 28	0.250
7	A7 00 00 07 12 27 69 28	0.250
8	CF 00 00 07 12 24 75 28	0.375
9	35 00 00 07 12 7B 75 28	0.250
10	88 00 00 07 12 9E C3 28	0.188
11	73 00 00 07 12 51 E3 28	0.250
	Serial 3252	
1	54 00 00 07 12 09 2D 28	0.313
2	C5 00 00 07 12 1C 60 28	0.250
3	C8 00 00 07 12 AD 38 28	0.125
4	7D 00 00 07 12 19 44 28	0.250
5	84 00 00 07 12 9D 82 28	0.188
6	D3 00 00 07 12 6F 72 28	0.250
7	23 00 00 07 12 01 B6 28	0.250

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **March 2nd 2018***

8	2A 00 00 07 12 2B 8E 28	0.250
9	DD 00 00 07 12 9A CE 28	0.313
10	6D 00 00 07 11 FD 61 28	0.188
11	22 00 00 07 12 77 F1 28	0.250
	Serial 3253	
1	60 00 00 07 12 A0 4C 28	0.313
2	1C 00 00 07 11 E3 10 28	0.313
3	46 00 00 07 12 49 B0 28	0.063
4	8F 00 00 07 12 A3 44 28	0.313
5	C8 00 00 07 11 F8 32 28	0.250
6	16 00 00 07 11 F3 C6 28	0.313
7	52 00 00 07 12 3D FE 28	0.375
8	B0 00 00 07 12 42 21 28	0.250
9	B1 00 00 07 12 01 99 28	0.313
10	91 00 00 07 12 42 8D 28	0.188
11	8C 00 00 07 12 96 2D 28	0.188
	Serial 3254	
1	20 00 00 07 12 A1 07 28	0.313
2	26 00 00 07 12 78 50 28	0.250
3	4B 00 00 07 11 FC 64 28	0.250
4	9E 00 00 07 12 64 2C 28	0.188
5	35 00 00 07 12 74 F2 28	0.125
6	5C 00 00 07 12 5E B1 28	0.313
7	5B 00 00 07 12 10 89 28	0.188
8	18 00 00 07 12 49 03 28	0.063
9	D3 00 00 07 12 AC 63 28	0.188
10	DE 00 00 07 12 78 5B 28	0.188
11	07 00 00 07 12 2C 07 28	0.188
	Serial 3255	
1	41 00 00 07 12 6A 20 28	0.250
2	17 00 00 07 12 4E B0 28	0.250
3	6A 00 00 07 12 78 68 28	0.125
4	36 00 00 07 11 F0 C4 28	0.250
5	1B 00 00 07 12 48 8C 28	0.188

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **March 2nd 2018***

6	53 00 00 07 12 2D F2 28	0.313
7	81 00 00 07 12 45 5A 28	0.313
8	34 00 00 07 12 2A 76 28	0.375
9	CC 00 00 07 12 60 91 28	0.188
10	4A 00 00 07 12 19 45 28	0.250
11	96 00 00 07 12 27 5D 28	0.125
	Serial 3256	
1	94 00 00 07 12 93 84 28	0.250
2	55 00 00 07 11 EC 0C 28	0.188
3	61 00 00 07 11 E3 1C 28	0.188
4	C8 00 00 07 12 A7 C2 28	0.125
5	35 00 00 07 12 42 26 28	0.250
6	92 00 00 07 12 33 96 28	0.250
7	A2 00 00 07 12 00 8E 28	0.125
8	D5 00 00 07 12 8C 5D 28	0.125
9	56 00 00 07 12 0C 43 28	0.125
10	03 00 00 07 12 5A E3 28	0.188
11	0F 00 00 07 12 50 73 28	0.188
	Serial 3257	
1	B4 00 00 07 12 91 9F 28	0.063
2	E8 00 00 07 12 AC 08 28	0.125
3	11 00 00 07 12 90 A8 28	0.188
4	C6 00 00 07 12 AC 58 28	0.250
5	37 00 00 07 12 14 FC 28	0.313
6	78 00 00 07 12 A2 AA 28	0.313
7	82 00 00 07 11 E8 B6 28	0.313
8	19 00 00 07 12 A7 29 28	0.250
9	2F 00 00 07 12 78 99 28	0.250
10	24 00 00 07 11 F8 87 28	0.313
11	95 00 00 07 12 08 47 28	0.188
	Serial 3258	
1	27 00 00 07 12 7A E7 28	0.313
2	F3 00 00 07 11 F9 40 28	0.188
3	25 00 00 07 12 38 D0 28	0.000

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **March 2nd 2018***

4	05 00 00 07 12 77 68 28	0.313
5	94 00 00 07 12 2B E2 28	0.313
6	0D 00 00 07 11 F1 B6 28	0.313
7	3D 00 00 07 12 00 4E 28	0.438
8	5D 00 00 07 12 15 C1 28	0.313
9	78 00 00 07 12 0A 45 28	0.250
10	62 00 00 07 11 EC 0D 28	0.313
11	E9 00 00 07 12 33 AF 28	0.250
	Serial 3259	
1	20 00 00 07 11 E9 31 28	0.313
2	64 00 00 07 12 98 20 28	0.250
3	28 00 00 07 12 2A 84 28	0.188
4	70 00 00 07 12 9A AC 28	0.250
5	2A 00 00 07 12 36 B2 28	0.313
6	E0 00 00 07 12 0D 7A 28	0.313
7	42 00 00 07 12 16 8E 28	0.250
8	03 00 00 07 12 08 4E 28	0.250
9	AD 00 00 07 12 3E 6E 28	0.313
10	27 00 00 07 12 00 89 28	0.188
11	B9 00 00 07 12 A8 23 28	0.313
	Serial 3260	
1	BB 00 00 07 12 9D CF 28	0.313
2	DB 00 00 07 11 FC 58 28	0.250
3	86 00 00 07 12 45 EA 28	0.250
4	57 00 00 07 11 ED 06 28	0.188
5	58 00 00 07 11 F0 C6 28	0.250
6	85 00 00 07 12 01 0E 28	0.250
7	8A 00 00 07 12 97 01 28	0.375
8	5A 00 00 07 11 F0 D5 28	0.313
9	04 00 00 07 12 4B C3 28	0.563
10	8B 00 00 07 12 01 77 28	0.250
11	94 00 00 07 11 FD EF 28	0.438
	Serial 3261	
1	A6 00 00 07 12 39 FB 28	0.250

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **March 2nd 2018***

2	27 00 00 07 12 01 90 28	0.313
3	FD 00 00 07 12 A7 D0 28	0.563
4	22 00 00 07 12 55 C8 28	0.563
5	7B 00 00 07 12 2A D8 28	0.500
6	53 00 00 07 11 E9 44 28	0.375
7	63 00 00 07 11 F1 B4 28	0.563
8	F7 00 00 07 12 2E 72 28	0.688
9	F3 00 00 07 11 FB 72 28	0.500
10	51 00 00 07 12 4B AA 28	0.563
11	AA 00 00 07 12 A7 AA 28	0.250
12	94 00 00 07 12 42 2E 28	0.375
13	68 00 00 07 12 10 AE 28	0.313
14	B7 00 00 07 12 45 DE 28	0.438
15	6F 00 00 07 12 17 51 28	0.438
16	36 00 00 07 12 79 D1 28	0.125
17	26 00 00 07 12 01 15 28	0.313
18	12 00 00 07 12 08 53 28	0.375
19	1D 00 00 07 11 ED 0B 28	0.375
20	BF 00 00 07 12 44 8B 28	0.375

*Calibrations performed by **Lindsey Bohnert** (Tech Ops Associate) on **March 2nd 2018***

DTC Calibration Certificate
SRK - Hope Bay South Dam Order 2

This certificate verifies and displays the results of calibration for the digital temperature cables with serial numbers **3263 to 3276**. The values are shown in the tables below.

Offset values are a result of BeadedStream's rigorous calibration process where each offset is determined with measurement in a **0.000 °C ice bath** confirmed with our NIST traceable secondary reference platinum RTD (Resistance temperature detector).

When temperature readings are taken with a D405 Datalogger, NetGate, or Recite, the offset values are first subtracted from the raw temperature and then are driven to **+/- 0.1 °C accuracy** using BeadedStream's proprietary characteristic error curve correction algorithm.

Sensor	Sensor ID	Offset
	Serial 3263	
1	9D 00 00 07 12 7F D0 28	0.188
2	92 00 00 07 11 F3 44 28	0.375
3	E7 00 00 07 12 39 2C 28	0.125
4	04 00 00 07 12 29 EC 28	0.188
5	DE 00 00 07 11 F6 01 28	0.250
	Serial 3264	
1	5D 00 00 07 11 E9 3D 28	0.188
2	36 00 00 07 11 F8 0C 28	0.313
3	CF 00 00 07 11 F8 82 28	0.313
4	D8 00 00 07 12 AF 92 28	0.313
5	B4 00 00 07 12 2A D2 28	0.188
6	23 00 00 07 12 5A CA 28	0.250
7	1F 00 00 07 11 EC 01 28	0.063
8	4C 00 00 07 12 87 4B 28	0.188
9	00 00 00 07 11 F3 6B 28	0.188
10	AD 00 00 07 12 0D C7 28	0.250
11	2E 00 00 07 12 7B 37 28	0.188
	Serial 3265	

*Calibrations performed by **Lindsey Bohnert and Trevor Sprague** (Tech Ops Associates) on **April 7th 2018***

1	0B 00 00 07 12 32 7A 28	0.063
2	38 00 00 07 12 9C E4 28	0.250
3	37 00 00 07 11 F5 3C 28	0.313
4	C7 00 00 07 12 61 52 28	-0.063
5	42 00 00 07 12 87 32 28	0.125
6	F3 00 00 07 11 F3 BA 28	0.375
7	C9 00 00 07 12 2A DE 28	-0.063
8	4C 00 00 07 12 10 A1 28	0.125
9	6F 00 00 07 12 0E 09 28	0.125
10	AE 00 00 07 12 A8 0B 28	0.250
11	AD 00 00 07 12 8D EB 28	0.250
	Serial 3266	
1	7B 00 00 07 12 7F 3A 28	0.313
2	8E 00 00 07 12 4B 38 28	0.188
3	0F 00 00 07 12 75 05 28	0.188
4	39 00 00 07 12 14 85 28	0.125
5	5D 00 00 07 12 46 75 28	0.125
	Serial 3267	
1	CB 00 00 07 11 E9 34 28	0.250
2	46 00 00 07 12 3D 40 28	0.125
3	DB 00 00 07 12 91 18 28	0.438
4	2A 00 00 07 12 2D D8 28	0.125
5	DC 00 00 07 12 02 26 28	0.250
	Serial 3268	
1	87 00 00 07 12 08 CC 28	0.313
2	19 00 00 07 12 64 38 28	0.188
3	FF 00 00 07 12 A8 44 28	0.125
4	9A 00 00 07 12 64 0A 28	0.313
5	C5 00 00 07 12 87 26 28	0.063
6	17 00 00 07 11 F6 3E 28	0.188
7	95 00 00 07 12 3C A1 28	0.438
8	E5 00 00 07 11 EC 19 28	0.250
9	65 00 00 07 11 F5 E5 28	0.125
10	6A 00 00 07 12 33 9D 28	0.125

*Calibrations performed by **Lindsey Bohnert and Trevor Sprague** (Tech Ops Associates) on **April 7th 2018***

11	C6 00 00 07 12 32 63 28	0.125
	Serial 3269	
1	6E 00 00 07 12 93 9C 28	0.188
2	F5 00 00 07 11 FC 08 28	0.250
3	09 00 00 07 12 3B B8 28	0.188
4	4B 00 00 07 11 F4 AC 28	0.313
5	EA 00 00 07 12 17 56 28	0.125
6	5F 00 00 07 12 AC AD 28	0.000
7	CE 00 00 07 11 FC 63 28	0.188
	Serial 3270	
1	18 00 00 07 12 09 15 28	0.313
2	8C 00 00 07 12 2D 60 28	0.438
3	10 00 00 07 12 4A 64 28	0.250
4	44 00 00 07 12 2B 8C 28	0.063
5	3F 00 00 07 12 A6 2C 28	0.250
6	2B 00 00 07 12 75 0A 28	0.188
7	24 00 00 07 12 10 96 28	0.188
8	BD 00 00 07 12 04 8E 28	0.188
9	55 00 00 07 12 74 89 28	0.250
10	BB 00 00 07 12 A5 85 28	0.250
11	DF 00 00 07 12 85 D3 28	0.125
	Serial 3271	
1	2B 00 00 07 12 AF 43 28	0.375
2	52 00 00 07 12 01 D0 28	0.438
3	FC 00 00 07 12 81 08 28	0.313
4	16 00 00 07 12 5A D8 28	0.125
5	86 00 00 07 12 5A E4 28	0.125
6	3F 00 00 07 12 7B 2A 28	0.125
7	7E 00 00 07 11 ED E6 28	0.375
8	2D 00 00 07 11 F8 4E 28	0.125
9	71 00 00 07 12 3D 41 28	0.250
10	4B 00 00 07 12 2A 69 28	0.250
11	7C 00 00 07 12 91 25 28	0.063
	Serial 3272	

*Calibrations performed by **Lindsey Bohnert and Trevor Sprague** (Tech Ops Associates) on **April 7th 2018***

1	ED 00 00 07 11 F0 70 28	0.125
2	98 00 00 07 12 9D 70 28	0.125
3	22 00 00 07 12 02 18 28	0.250
4	ED 00 00 07 11 F8 B8 28	0.375
5	56 00 00 07 12 AC 64 28	0.313
6	4D 00 00 07 12 01 B4 28	0.125
7	5B 00 00 07 12 1B 6A 28	0.313
8	4C 00 00 07 12 02 1A 28	0.188
9	BA 00 00 07 12 99 2E 28	0.313
10	5C 00 00 07 12 01 A9 28	0.125
11	F7 00 00 07 12 6F 7D 28	0.125
	Serial 3273	
1	98 00 00 07 12 AF C0 28	0.188
2	BF 00 00 07 12 9C F0 28	0.250
3	B1 00 00 07 11 F8 18 28	0.250
4	AB 00 00 07 12 16 98 28	0.125
5	D6 00 00 07 12 2C EC 28	0.250
6	54 00 00 07 12 A1 C2 28	0.188
7	CE 00 00 07 12 85 CE 28	0.250
8	B8 00 00 07 12 95 91 28	0.188
9	54 00 00 07 12 2E 69 28	0.125
10	D5 00 00 07 11 F4 E9 28	0.250
11	26 00 00 07 12 2E 99 28	0.250
	Serial 3274	
1	7B 00 00 07 12 90 8C 28	0.250
2	EA 00 00 07 12 4A 7C 28	0.125
3	0F 00 00 07 12 59 A2 28	0.188
4	4B 00 00 07 12 5D B2 28	0.000
5	B6 00 00 07 11 F6 36 28	0.188
	Serial 3275	
1	41 00 00 07 11 E8 D6 28	0.250
2	FB 00 00 07 12 60 90 28	0.188
3	AA 00 00 07 12 6F 58 28	0.125
4	9F 00 00 07 12 04 B4 28	0.313

*Calibrations performed by **Lindsey Bohnert and Trevor Sprague** (Tech Ops Associates) on **April 7th 2018***

5	E6 00 00 07 12 23 DA 28	0.250
6	49 00 00 07 12 A2 9E 28	0.188
7	92 00 00 07 12 02 0D 28	0.250
8	54 00 00 07 12 18 BD 28	0.250
9	31 00 00 07 11 FF F3 28	0.375
10	6C 00 00 07 12 1B 6B 28	0.063
11	AD 00 00 07 11 FD 97 28	0.313
	Serial 3276	
1	54 00 00 07 12 8B 33 28	0.125
2	09 00 00 07 12 75 30 28	0.188
3	CC 00 00 07 11 FC 70 28	0.438
4	12 00 00 07 12 9A C4 28	0.188
5	D5 00 00 07 12 01 C4 28	0.250
6	CD 00 00 07 12 2E 9C 28	0.250
7	23 00 00 07 11 EC DA 28	0.313
8	E4 00 00 07 12 00 E9 28	0.125
9	75 00 00 07 11 EC 25 28	0.250
10	30 00 00 07 11 EB 9B 28	0.188
11	69 00 00 07 12 52 0F 28	0.188

*Calibrations performed by **Lindsey Bohnert and Trevor Sprague** (Tech Ops Associates) on **April 7th 2018***

Appendix C - Suggested Guidelines for Surveying at the North Dam

NOTE: Example procuderes provided for the North Dam.

If control points are set-up specifically at the South Dam then a description of those control points should be added to these guidelines. Suggest that specific control points be set-up at the South Dam in 2020.

Suggested guidelines for surveying at the North Dam

Introduction

In the upcoming years, it is expected that at regular interval, monitoring surveys will take place at the North Dam. Various surveyors may be called up to do the work. Following those suggested guidelines will provide consistency in the data acquisition process.

Manpower & Time allocation

If the surveyor is flying to the mine site for the work, three days should be allocated for this work.

- Day one: Fly to site, orientation, equipment testing and calibration.
- Day two: Surveying, data processing.
- Day three: Final data preparation, packing of equipment and fly out.

Equipment and accessories

- Robotic total station and accessories, including barometer and thermometer.
- Back sight kit.
- Extensions for the mini prism for the surveying of the crest monitoring points.
- A source of light to shine into the casing for the surveying of the crest monitoring points.
- A transparent template with circles at 5mm increment to pin point exactly the center of the deep settlement points.

Metadata

There are five control points: ND1, ND2, ND3, ND4 and ND5. Each control point consists of 1 inch Hilti bolt with an approximate height of 15 centimeters (~ 6 inch) from ground. The control points at the North Dam were originally surveyed by GNSS method. Closed leveling loops were performed in 2012 (ND3-ND2) and 2013 (ND3-ND2-ND1). ND5 appears to be weak, being located on a large flat boulder, 2013 survey indicates that it could have shifted.

The data is grid. Scale factor at DN1 is 0.99965099.

Station set-up

For consistency from one survey to the next, the total station should set-up at control point ND1. From this station, all points to be surveyed are visible. Back sight point is ND4. Once the station set-up is

completed, it is suggested to transfer the elevation to the total station from ND3. Most total stations have this capability (whether called elevation transfer, remote benchmark, etc). This method helps in reducing the error that could have been introduced in measuring the height of the station with a tape. Once the station is set-up is in orientation and elevation, a check shot on ND2 should be carried before commencing the monitoring surveys.

Surveying - general

As a minimum, each surveyed point should have face 1 and 2 observations. Taking measurements with both faces eliminate the following systematic errors of the total station:

- HZ collimation error
- Tilting axis error
- Compensator index error
- vertical index error

Once all points have been surveyed, if time allows, additional data should be obtained to confirm the observations. Should multiple prisms be used, it is recommended to use prisms that have the same prism constant. By doing so, the chances of introducing a prism constant error are reduced.

Conclusion

This document was simply prepared to help out the surveyor who will do the work. By following the same method in the station set-up as well as using the right coordinate system will help in providing reliable data to the engineering team.

Those guidelines were prepared for the scenario of having only one (1) surveyor allocated to the work. Should there be additional manpower, some of the work should also include traditional leveling method.

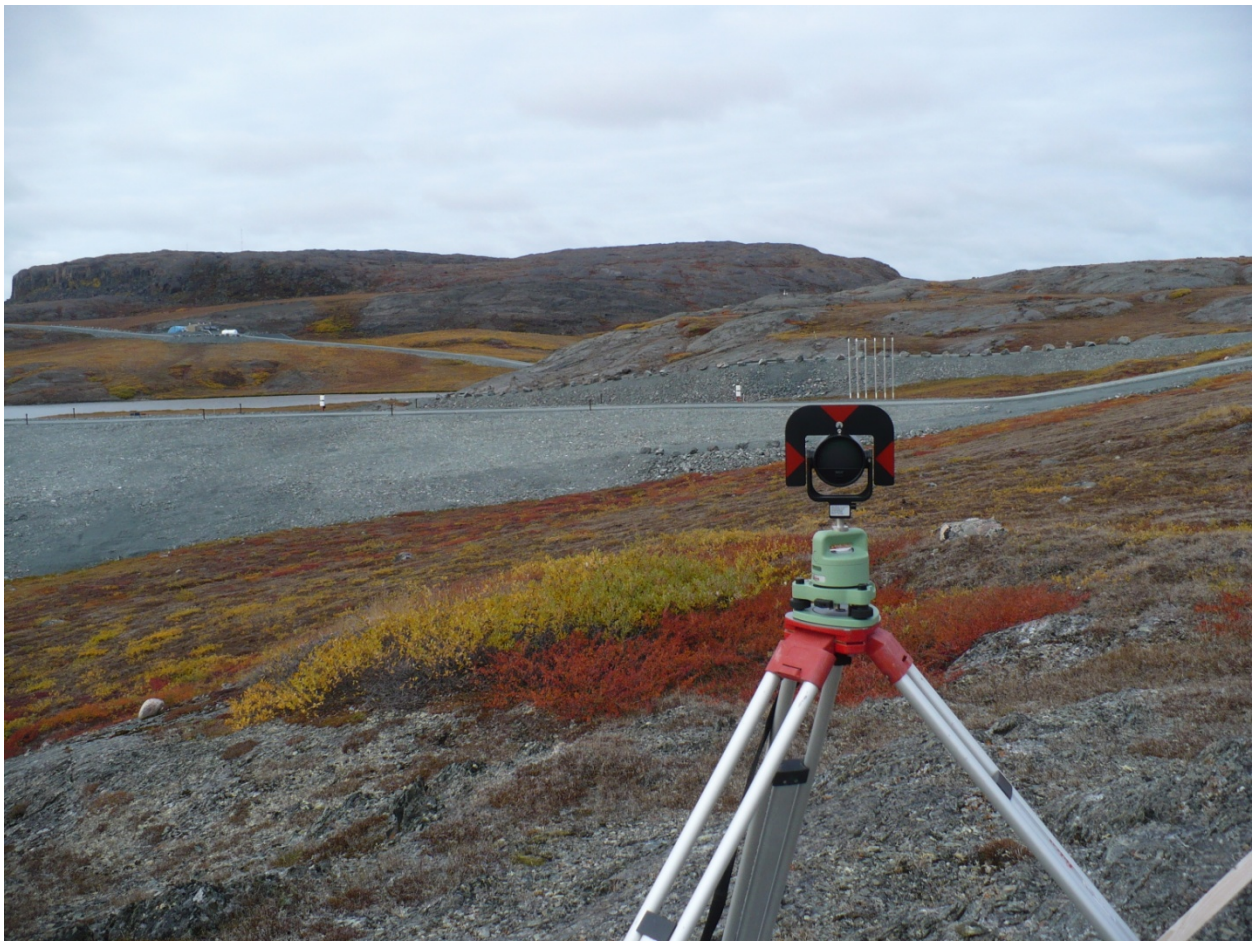
In the following pages are pictures and supplementary information for this work.

Prepared by:

Georges Cornelissen, C.E.T.
E-mail: gc@yk.com
Hopebay, Nunavut
September 10, 2013

A robotic total station kit

Station at ND1



Back sight at ND4

Control Point ND5

Note: Could be weak, not recommended to use for set-up.

Mini-prisms

Note: some points require greater than 40 cm height.

Consistent prism constants

Deep settlement point

Note: Placing a transparent template with circles at 5mm Increment (example) would help to pin point exactly the center of the deep settlement points.

View inside the casing of a crest monitoring point

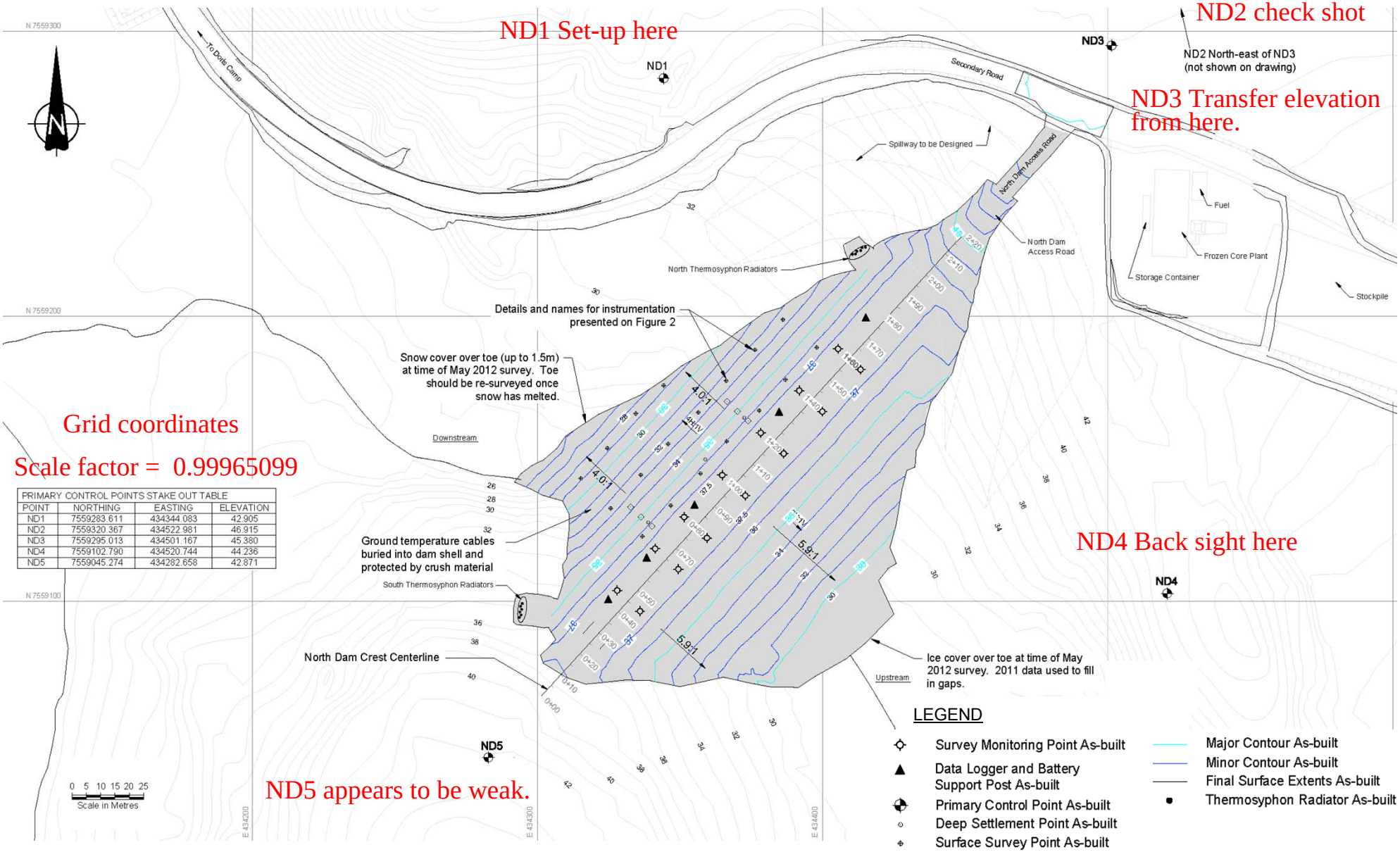
The surface survey points are constructed with same material as control points.

Please remember

The data is grid.

Scale factor at ND1 is 0.99965099.

J:\01_SITES\Hope.Bay\!ACAD\2013 Drawings\North Dam



PRIMARY CONTROL POINTS STAKE OUT TABLE

POINT	NORTHING	EASTING	ELEVATION
ND1	7559283.611	434344.083	42.905
ND2	7559320.367	434522.981	46.915
ND3	7559295.013	434501.167	45.380
ND4	7559102.790	434520.744	44.236
ND5	7559045.274	434282.658	42.871

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TMAC RESOURCES

Job No: 1CT022.000

Filename: HopeBay_NorthDamMonitoringSOP_NodeFIGS_1CT022.000_im_jbk_20130709.pptx

Hope Bay

North Dam Monitoring SOP

North Dam General Arrangement and Primary Control Points

Date:	Approved:	Figure:
July 2013	IM / JBK	1

Appendix D - South Dam Visual Inspection / Checklist Form

South Dam
Walkover Report

Frequency: Weekly or as specified by EOR

Date:	
Inspected By:	
Conditions:	(ie. snow on ground, clear)

Visual Inspection:

This weekly walkover survey report is a means to track the condition on the **South Dam**, please provide details on changes that have developed since the previous inspection and/or any observations of particular concern. All photos are appreciated. Please send the completed form (scans are fine) and any photos to hopebaymonitoring@srk.com and pluedke@srk.com

Upstream Side of Dam (Overall)		
Any visible concerns? (cracks, depressions, erosion, etc.)	Yes	No
Downstream Side of Dam (Overall)		
Any visible concerns? (cracks, depressions, erosion, seepage, etc.)	Yes	No
Crest of Dam (Overall)		
Any visible concerns? (cracks, depressions, erosion, etc.)	Yes	No
Tailings Beach on the Upstream Side		
Is the beach within the operating limits? (Beach length of 100 meters, no water ponding or pooling near the dam etc.) * Use shoreline markers indicating 100 meters from the crest for visual reference*	Yes	No
Active Tailings Discharge Spigot		
Indicate the active discharge spigot location (Spigot number or (S) on the figure provided)		
Settlement Instrumentation (on crest and downstream side)		
Any visible concerns? (significantly rusted or otherwise damaged, etc.)	Yes	No
Thermistors and Dataloggers		
Any visible concerns? (cables frayed, disconnected or damaged, boxes cracked, etc.)	Yes	No
Water at the Toe of the Downstream Side of the Dam		
Is water visible on the downstream side of the dam?	Yes	No
Is the water visibly flowing?	Yes	No
Walk over inspection of the downstream toe complete? (May to November)		
Inspector should walk the length of the downstream toe inspecting for seepage or slumping once most of the snow has melted (May to November)	Yes	No

If you answered yes to any of the questions above, or made other observations, please provide details and photos. Observations can be sketched on the figure provided below.

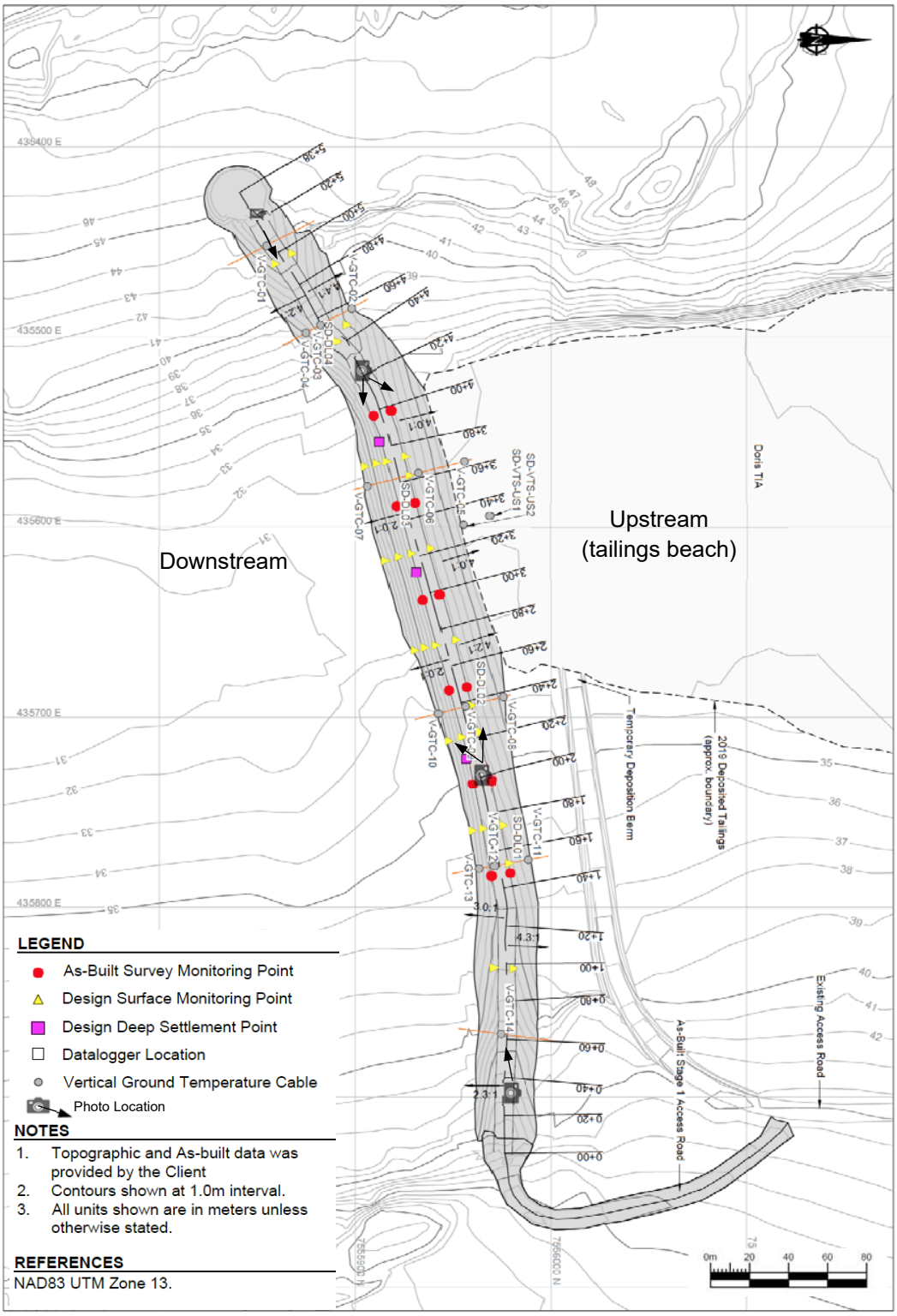
NOTES:

If seepage has been noted estimate the flow (high/medium/low) and report to TMAC Environmental Superintendent:

Photos:

Please collect the following photos:

- Photo from the crest looking W along the dam crest (Station 0+30) ☐
- Photo from the crest looking SW over the downstream toe along the dam (Station 2+00) ☐
- Photo from the crest looking W over the tailings beach (Station 2+00) ☐
- Photo from the crest looking NE over the tailings beach (Station 4+20) ☐
- Photo from the crest looking E over the downstream toe along the dam (Station 4+20) ☐
- Photo from west end looking E along the dam crest (Station 5+20) ☐



Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.064
August 2020

Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3

August 2020

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File Name: Hope_Bay_North_Dam_Monitoring_SOP_R03_20200813_1CT022.064_PL.docx

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1 Introduction

1.1 Revision Summary

Table 1 provides a summary of the revision history for the North Dam Monitoring Standard Operating Procedures (SOP).

Table 1: Revision History for the North Dam Monitoring SOP

Revision	Status	Date	Major Changes
0	Issued for Use	July 2013	-
1	Issued for Use	September 2013	Updates to Section 6 and 7
2	Issued for Use	August 2017	Monitoring frequency requirements (Section 3.1), data download procedures (Section 4), ground survey monitoring (Section 5), water level monitoring via permanent datalogger (Section 7), addition of more detail on seepage monitoring (Section 9), Primary contact email (throughout) from Hopebay@srk.com to hopebaymonitoring@srk.com
3	Issued for Use	August 2020	Water level monitoring transmission frequency (Section 5), Seepage monitoring (Section 9) adding location TL-5 and the development of a Quality Assurance / Quality Control (QA/QC) program Minor updates to align with the South Dam SOP

1.1 Background

The North Dam at Hope Bay has been designed as a water retaining structure. Its successful performance is dependent on maintaining the integrity of the frozen core through preservation of permafrost in the dam foundation (SRK 2007). Because of complex foundation conditions, differential settlement longitudinally and transversely across the dam is expected. To track whether deformations are within the design limits for the dam, a rigorous monitoring program has been established (SRK 2012).

Table 2 lists the North Dam monitoring components and Figure 1 presents a general arrangement of the North Dam.

Table 2: North Dam Monitoring Components

Component	Instrument	Quantity
Thermal	Horizontal ground temperature cables	13
	Vertical ground temperature cables	11
	Thermosyphon monitoring temperature cables	12
Deformation	Deep settlement points	3
	Surficial survey points, located on the downstream shell of the dam	18
	Crest monitoring points, located along the crest of the dam	14
	Inclinometers installed downstream slope of the dam	6
Water level	Pressure transducer installed in Reclaim pond	1
Seepage	No defined instrumentation	n/a
Visual	No defined instrumentation	n/a

1.2 Objectives

Responsibility for implementing the North Dam monitoring program rests with TMAC, and the data will be reviewed annually by the Engineer of Record (EOR) as part of the annual geotechnical inspection. This document provides comprehensive Standard Operating Procedures (SOP) for carrying out the required monitoring.

1.3 Layout

Section 2 of this document provides a summary of the instrumentation that has been installed (SRK 2012). The required monitoring frequency and responsibility matrix is provided in Section 3. Sections 4 to 9 contain the specific SOPs.

2 Monitoring Overview

2.1 Thermal Monitoring

2.1.1 Ground Temperature Cables

The frozen core and the underlying foundation have been designed to remain frozen for the life of the structure. The core should at all times be a temperature of at least -2°C, while the underlying foundation soils must be a temperature of at least -8°C (SRK 2007). Thirteen horizontal ground temperature cables have been installed to monitor the core temperature, and eleven vertical ground temperature cables have been installed to monitor the foundation temperature (Figure 1 and 2). One of the horizontal ground temperature cable (ND-HTS-085-33.5) was damaged beyond repair during construction and a replacement could not be installed. Additionally, one vertical ground temperature cable (ND-VTS-060-US) was irreparably damaged prior to datalogger installation. Therefore, these cables are not included in the monitoring program.

All working ground temperature cables are connected to two automated dataloggers via a series of multiplexers, which allow data collection at any pre-programmed frequency. The location of these dataloggers and associated multiplexers are indicated on Figure 2. The SOP for downloading data from these dataloggers is presented in Section 4.

2.1.2 Thermosyphon Monitoring

Horizontal sloped passive thermosyphons are installed in the base of the key trench. These have been designed to promote freezing conditions in the foundation soils. The thermosyphons are sealed pressure vessels and do not have moving parts that require service or maintenance. A thorough physical inspection for signs of corrosion is however required on the exposed portions of the thermosyphon system as part of routine visual inspections.

Each thermosyphon is monitored by a cable connected to one thermistor bead. These are referred to as Thermosyphon Status Thermistors (TSTs) are attached to the riser of each thermosyphon radiator. These TSTs allow monitoring of the thermosyphon operation during the active cooling season. Monitoring is done by measuring the temperature of the radiator pipe where it exits in the ground (this is equivalent to measuring the temperature of the cooling agent in the thermosyphon) and comparing it to the ambient air temperature at the panel. During the active cooling season the cooling agent within the thermosyphon, where it exits in the ground, is expected to be a minimum of 5°C warmer than the air temperature.

The TSTs were attached to the thermosyphon radiators using epoxy resin adhesive. The TST attachments were made as close to the riser elbow as possible and were insulated using spray foam. In total 12 TSTs were installed (one for each radiator). Photos of the installation and a simplified schematic of the thermosyphon radiator layout are shown in Figure 9.

At the north radiator cluster the TST lead cables were connected into Multiplexer #9 in Node E. The leads from the south radiator cluster were routed to Node A and from there fed through the pre-installed metal conduits along the crest of the dam and connected into Multiplexer #9 in Node E (Figures 3 and 4).

2.2 Deformation Monitoring

2.2.1 Survey Point Monitoring

The North Dam is expected to undergo deformation because of creep over its design life; this includes differential longitudinal and transverse settlement. These settlements are expected to result in strains of less than 2% in the frozen core of the dam (SRK 2007). A total of 35 survey monitoring points was installed within the dam to track these deformations such that it can be confirmed that they are within the specified design limits.

The installed monitoring points are illustrated on Figures 1 and 3, and include the following:

- **Primary Survey Control Points:** five permanent survey control points were established on exposed bedrock locations outside of the North Dam peripheral.
- **Deep Settlement Points:** three deep settlement points are located on the downstream slope of the dam. The deep settlement points are intended to track deformation of the foundation soils near the shell. Deep settlement points are located along the downstream face of the dam approximately 7 m from the downstream crest of the dam, and were installed to a depth of 0.5 m below the original ground surface. They consist of 102 mm (4-inch) steel pipes protected by a 152 mm (6-inch) diameter outer steel casing. The top of the steel casing is protected by a fabricated steel cap.
- **Surficial Survey Points:** 18 surficial survey points are located on the downstream shell of the dam. The surficial survey points are intended to track deformation of foundation soils at the location of maximum expected deformation. The surficial survey points were installed by embedding 1 m diameter boulders in a grid pattern into the run-of-quarry material of the dam shell. Once these boulders were seated into the dam shell, holes were drilled and expansion bolts were installed into each boulder.
- **Crest Monitoring Points:** 14 crest monitoring points are located along the crest of the dam. These monitoring points are intended to monitor differential settlement and deformation of the upper portion of the frozen core. The crest monitoring monuments were manufactured on site and are comprised of steel rods attached to base plates. 102 mm (4-inch) steel pipe housing protects the rods, and a steel cap protects the top of each monitoring point housing.

The SOP for completing these manual surveys, are included in Section 5.

2.2.2 Inclinometer Monitoring

Six inclinometers were installed on the downstream slope of the dam. These inclinometers were installed along the zone of the dam expected to undergo the maximum amount of deformation, and thus subject to the maximum strain. The locations of the installed inclinometers are shown on Figure 3. The SOP for taking these readings are included in Section 6.

2.3 Water Level Monitoring

Reclaim pond water level monitoring recorded automatically using a datalogger and georeferenced by monthly survey monitoring during the open water season as described in Section 7.

Between July 2015 and June 2017, a pressure transducer datalogger was used to monitor the depth of water during open water season. This was installed at a depth of approximately 5 m below the Reclaim pond water level of 29.08 masl. The data was downloaded manually and provided to the EOR on an as-requested basis. In June 2017, a new temporary pressure transducer was connected to a Datagarrison data transmitter installed on the shore of the Reclaim pond. The data logger collects a reading every 15 minutes and the data is transmitted to the online portal every 5 days. This pressure transducer was permanently installed for year-round monitoring on September 28, 2017.

The pressure transducer records water level in the Reclaim pond as meters of water (head) above the datalogger and require a known elevation of the datalogger for accurate translation to elevations. Therefore, as part of the monthly survey data collection (Section 5) a survey of the Reclaim pond water level is required to calibrate the pressure transducer readings. The full monitoring SOP is provided in Section 7.

2.4 Visual Monitoring

Visual inspection must be carried out for the North Dam and all its components, looking for obvious signs of distress.

During the initial years of dam operations several depressions were identified on the shell of the dam. These depressions are likely due to settlement of shell material after construction; however, the known depressions and any future depressions must be monitored to ensure that they are not signs of larger issues or instability. Monitoring will continue until stability of the depression can be confirmed.

Additional details on the primary focus areas for the visual monitoring is presented in Section 8.

2.5 Seepage Monitoring

Previously water has been noted at the toe of the dam. When noted, additional monitoring is required. The SOP for seepage monitoring is provided in Section 9.

3 Monitoring Protocols

3.1 Monitoring Frequency/Responsibility

A summary of the monitoring requirements and associated responsibility is listed in Table 3. These monitoring requirements can be revised at any time under the direction of the North Dam EOR, or the qualified Licensed Geotechnical Engineer carrying out the annual geotechnical inspection after consultation with the North Dam EOR.

Table 3: Summary of Monitoring Requirements

Element	Item	Method	Responsibility	Frequency
Thermal	Ground Temperature Cables	Dataloggers	TMAC	Daily readings, monthly downloads
	Thermosyphons	Dataloggers	TMAC	Daily readings, monthly downloads
Deformation	Downstream Deep Settlement	Manual	TMAC	Monthly, May to November(1)
	Downstream Surface Settlement	Manual	TMAC	
	Crest Settlement	Manual	TMAC	
	Depression	Manual	TMAC	
	Inclinometers	Manual	TMAC	Monthly
Water Balance	Water Level	Datalogger	TMAC	Daily readings (online portal)
	Water Level	Manual	TMAC	Monthly, when Reclaim pond is not frozen
	Seepage Monitoring	Per Section 9	TMAC	Weekly when seepage is observed
	TL-5 Geochemical Sampling	Manual	TMAC	Monthly
	Geochemical QA/QC	Manual	TMAC	Monthly (in conjunction with other sampling)
Visual	Visual Walk over Inspection and Reporting	Manual	TMAC	Weekly (below FSL(2)) Daily (at or above FSL)
	Geotechnical Inspection	Manual	Independent Qualified Licensed Geotechnical Engineer	Annually
Maintenance	Datalogger Primary Batteries	Manually recharge	TMAC	Annually
	Datalogger Backup Batteries	Manually replace	TMAC	5-year cycle
	Datalogger Recalibration	Manual	TMAC	5-year cycle
	Desiccant Packs Replace	Manual	TMAC	As required

Note(s)

(1) Deformation monitoring is not required during the winter months when the ground is frozen, if thermal data from the ground temperature cables does not indicate any cause for concern.

(2) FSL: Full Service Level

3.2 Monitoring Data Management Protocols

All monitoring data collected must be stored electronically. Manual notes must be scanned and the raw data saved together with any transposed or processed data. All data must be reviewed by appropriate qualified staff immediately following collection to confirm integrity of the instrumentation, as well as to ensure that dam performance is consistent with expectations. If staff is not qualified to draw such conclusions, the EOR must be contacted to perform these duties.

Reporting requirements are specified in each section typically via email, however where appropriate, agreed upon shared drives can be used for file transfer, but a notification email should be sent once the inspection is uploaded. Currently a South Dam monitoring shared folder is stored here:

https://van.files.srk.com/nextcloud/index.php/s/EERtAo85KZLocdy?path=%2FTIA%20Monitoring

4 Datalogger Standard Operating Procedures

For the thermal monitoring instrumentation, SOPs have been developed for the datalogger downloads. The dataloggers are connected to the ground temperature cables and permanent TSTs.

Figure 2 shows the location of the ground temperature cables and TSTs while Figures 4 and 5 show the general layout of the data acquisition system and associated monitoring nodes.

The Operator's manuals for the dataloggers (CR1000) and associated Compact Flash Module (CFM100) are provided in Appendix A1, and A2. The wiring diagrams for the dataloggers, multiplexers and ground temperature cables are presented in Appendix B, and for completeness Appendix C presents an overview of the CR1000 datalogger programming.

4.1 Objective

The datalogger SOP has been developed to provide TMAC staff with clear instructions on how to maintain and operate the two North Dam dataloggers. These dataloggers are used to record ground temperature and thermosyphon radiator performance data.

4.2 Overall Procedure

The datalogger SOP can be summarized by the following procedures:

1. **Field Data Extraction.** Data collection requires that the data either be downloaded directly from the datalogger or the exchange of the flash card with a blank flash card. Complete details of this field procedure are described in Section 4.3.
2. **Data Download and Processing.** Complete details on these office procedures are described in Sections 4.4 and 4.4.3. This task involves extraction of data from the memory flash cards and subsequent forwarding of this data to the EOR.
3. **Maintenance**. This field procedure defines basic maintenance procedures necessary for the ongoing successful operation of the dataloggers (Section 4.5).

4.3 Field Data Extraction (Direct Download or Card Exchange Procedure)

4.3.1 Direct Download

This is the preferred download procedure as over time it has led to fewer card errors and download issues. This procedure uses the PC200W software. Prior to any download the particular datalogger has to be initialized in the software. The current field computer is set up for this, however should the datalogger be renamed after recalibration or PC200W be reinstalled, communication to each datalogger will need to be re-initialized on the computer (Appendix A1). Once installed and set up, the download procedure is as follows and screenshots are provided in Figure 7:

- **Step 1:** Connect the dedicated data transfer cable to the RS 232 port of the datalogger. Connect the cable to the field computer using either a serial port or a USB port through a Serial-USB adapter.
- **Step 2:** Open PC200W.
- **Step 3:** From the stations list on the left of the window select the appropriate datalogger. Ensure the selection the same datalogger being downloaded from, otherwise the file names will be misleading.
- **Step 4:** Click “Connect”. Once this is finished, select the “Download all data” button. This should start the download.
- **Step 5:** Switch to “Collect Data” tab.
- **Step 6:** Select “All data from datalogger (Overwrite data files)” option is selected; this enables the download of all data stored in the datalogger’s memory. Tick off all the files in the list of files for the complete download. Click “Collect”. Data collection may take 20 minutes or more if the datalogger is full. If the cables get disconnected for any reason, you have to restart the download.
- **Step 7:** Take note of the path to the downloaded files. The computer defaults to the main drive (C:\ drive for most computers) where it creates a “Campbellsci” folder. Once back to the office, these will be the files sent to SRK.
- **Step 8:** Click “disconnect”. **IMPORTANT,** If you close without disconnecting, next time you open PC200W it will be looking for the datalogger that was last connected, causing various problems with the laptop.
- **Step 9:** Disconnect the cables from the datalogger and from the field laptop.

4.3.2 Card Exchange (Alternative Method)

This should be completed as required, i.e., when the direct download method is not working. Steps 1 through 5 below explain the procedure for exchanging the memory flash cards for each of the two dataloggers:

- **Step 1:** Open each of the two weatherproof enclosures containing the dataloggers. Their physical locations, and key elements within the weatherproof enclosures are shown on Figure 6.
- **Step 2:** Push the removal button on the CFM100 Compact Flash Module, which is connected to the CR1000 datalogger. Wait for a green light. The removal button is located on the upper left corner of the unit, as illustrated in Figure 6. Note that it may take a few seconds for the green light to illuminate.
- **Step 3:** Once the solid green light is on, open the flash card cover hinged door (Figure 6). To do this, loosen the securing screw with manual finger effort (no need for hand tools).
- **Step 4:** Press the card release button and remove the flash card (Figure 6). The card release button is the small square button immediately above the flash card.

- **Step 5:** Place the exchange card into the flash card slot (it can only go in one way). Make sure that the correct card (marked as CR1000 #1 or CR1000 #2) is placed into the appropriate individual datalogger.
  - *Warning: Installing the wrong card will cause an error in the program which will prevent transfer of data to the card.*
- **Step 6:** Close and secure the hinged door by hand-tightening the securing screw (no need for any tools).

4.4 Data Download Procedure

4.4.1 Direct Download

For the direct download method, the steps above result in the files saved on the computer. Please ensure the file name generated by the datalogger. The naming convention includes

- File 1 – 8: NorthDamCR1000#n_m

Where: *n* = datalogger number (either CR1000 #1 or CR1000 #2)

m = file type (Daily_Samples, Public, StationStatus or Status)

Once back in the office, email all eight downloaded files to SRK as listed in Section 4.4.4 below.

4.4.2 Card Exchange (Alternative Method)

If the card exchange method is used in place of the Direct Download, follow the steps below to extract the data from the cards:

- **Step 1:** Insert the memory flash card into the appropriate slot of the Media Reader (Figure 8).
- **Step 2:** Connect the reader to a computer.
- **Step 3:** Copy the two files from each of the two cards and save to the hard drive.
- **Step 4:** Once copied, email all four files to SRK as listed in Section 4.4.4 below.

Please note that the two files from each card should automatically follow the following naming convention, and should not be altered:

- File #1: “HB_NorthDam_CR1000_#n.Daily_Samples_YYYY_MM_DD_HHmm.dat”
- File #2: “HB_NorthDam_CR1000_#n.StationStatus_YYYY_MM_DD_HHmm.dat”

Where: *n* = datalogger number (either CR1000 #1 or CR1000 #2)

YYYY = calendar year

MM = calendar month

DD = calendar date

HHmm = time

Note: the data and timestamp in the filename will correspond to the time and data that was first transferred onto the card, i.e., when the card was placed into the datalogger.

4.4.3 Data Pre-Processing Procedure

If the files collected during the card exchange procedure are too large to be sent by email, some pre-processing will be required. Typically, this will not be required unless files sizes exceed 10 megabytes (MB). Steps 1 through 5 below describe these data processing procedures:

- **Step 1**: Open the LoggerNet software and choose the "**Card Convert**" option from the "**Data**" menu.
- **Step 2:** Select the correct card drive by clicking on the "**Select Card Drive**" button and navigating to the appropriate computer drive. Select the files to be pre-processed.
  - *Note:* there will always be two files created at the same time (see Section 4.4.2). Select both files.
- **Step 3:** Select the output directory for the processed files. It is recommended that a folder directory be created and dedicated to the field data on the C:\ drive. That way the data can always be backed up by the download computer.
- **Step 4:** Click on the "**Destination Files Options**" button. From the pop-up window, select the "**ASCII Table Data (TOA5)**" format for the output file. Make sure to tick off the "**TimeDate Filenames**", "**Create New Filenames**", and "**Store Time Stamp**" options.
- **Step 5:** Email the *.TOA5 output files to SRK as listed in Section 4.4.4 below.

Figure 7 provides example software screenshots from the key steps above.

4.5 Maintenance Procedure

4.5.1 Battery Maintenance

The two 12-volt batteries (Node B and Node D as shown on Figures 3 to 5) powering the data acquisition system must be charged at least once every year. They can be charged with an automotive / car battery charger (typically in the range of 2 to 6 amps for 12-volt lead acid batteries). This should ideally be done in the fall, in preparation for winter operation.

When not connected to the 12-volt battery the datalogger has an internal battery to ensure that the internal clock/ time is maintained. The rest of the electronics are solid state so upon re-hooking up the 12-volt battery the data gathering will resume.

Twenty-four hours after the 12-volt batteries are recharged or replaced and reconnected to the data acquisition system, a data download (Section 4.4) is required. This check is required to ensure that the system is operational.

4.5.2 Datalogger Re-Calibration

Every five years the CR1000 dataloggers must be re-calibrated and the internal battery replaced. This work must be done by a qualified person approved by the EOR. Additional details on datalogger (CR1000) care and maintenance can be found in Appendix A1.

4.5.3 Desiccant Pack Maintenance

Desiccant packs have been placed in each datalogger and multiplexer housing (i.e., Nodes A to E as shown in Figures 3 to 5). These packs absorb condensation moisture inside the housings to protect the internal electronics. Desiccant packs must be replaced or oven dried (standard vented oven at 93^{o}C [200^{o}F]) when moisture inside the readout housing is visible, or when the desiccant status indicators are flagged (Figure 6). Damaged desiccant packs must be replaced.

4.6 Reporting Procedure

Any manually downloaded data should be provided in the required format as listed above. Any additional observations (such as noted damage or issues with the datalogger or cables) that may assist with data interpretations should be recorded and sent along with the compiled data downloads or the Visual Monitoring reports (Section 8). SRK should also be informed when battery recharges or other maintenance occurs.

All data or observations should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

5 Ground Survey Standard Operating Procedure

5.1 Objective

Ground surveys of the control points, deep settlement points, surficial survey points and crest settlement monitoring points are required. Figure 1 shows a general arrangement, along with primary survey control points, and Figure 3 presents a plan view of the instrumentation layout, including location names and UTM coordinates. Figure 10 shows a typical layout for the installed North Dam deformation monitoring instrumentation while Figure 11 shows additional details on the deep settlement points and surficial survey points.

5.2 Survey Procedures

The ground surveys/deformation monitoring should be completed with survey instruments that have accuracy in the range of ± 2 mm (horizontal and vertical). Likely these surveys will be completed by a Total Station survey; however, if the specified is maintained, other appropriate survey methods may be adopted by a qualified sub-contractor or TMAC surveyor. Additional details on “suggested guidelines of surveying at the North Dam”, with a Total Station, are presented in Appendix D (from Cornelissen 2013). Specifically, these guidelines discuss:

- Expected manpower and time allocation;
- Equipment and accessories;
- Metadata/control points;
- Station set-ups; and
- General surveying and survey error reduction.

For the deep settlement points and crest monitoring points a steel cap / top was fabricated to protect the monitoring points. Any accumulated dirt or ice around these protective caps should be removed and the caps removed to access the protected points. Before leaving the North Dam area, after the monthly ground survey, all caps should be cleaned. If the caps are moist, it is suggested that the insides of the caps be dried prior to being placed back over the monitoring points to avoid jamming or freezing. Any damage noted to any of the survey / monitoring points should be recorded and submitted with the survey data.

In addition to the monitoring points, the water level of the TIA reclaim pond should be surveyed to correlate the water level data (from the pressure transducer) with an elevation.

5.3 Reporting Procedures

The survey data is expected to be supplied in Excel or csv format. Any additional observations (such as noted damage) that may assist with data interpretations should be noted and sent along with the compiled survey data. All data should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

6 Slope Inclinometer Standard Operating Procedure

6.1 Objective

Six inclinometers were installed on the downstream slope of the dam, along the dam area that is expected to undergo the maximum amount of deformation. Procedures for taking, reading and transferring the collected inclinometer data using the dedicated software is outline below. Additional details and photographs of the inclinometer instrumentation are presented in Figures 12 to 14.

6.2 Procedure

6.2.1 Instrument Description

The inclinometer instrumentation (Figure 12) is comprised of the following parts:

- Inclinometer probe (manual provided in Appendix A3);
- Digitilt DataMate readout box (manual provided in Appendix A4);
- Control cable (on a spool); and
- Inclinometer casing (installed permanently on the dam).

The inclinometer probe is transported and stored in a plastic carry case (see Figure 12). The probe is a very sensitive instrument, and must be protected from shocks and vibrations as much as possible, i.e., transport it on the seat inside the cab, opposed to the cargo box or platform of the truck.

6.2.2 Measurement Procedure

The following steps should be followed when taking a measurement:

- **Step 1:** Connect the readout to the probe using the control cable. Avoid over-tightening the connector at the probe end, which would reduce the effectiveness of the O-ring seal.
- **Step 2:** Remove the steel cap off the inclinometer casing, exposing the top of the inner (blue) guide casing.
- **Step 3:** Turn the readout box ON. This will power up the servo-accelerometers inside the probe, making them less vulnerable to shocks.
  - *Note:* the switch lever must be pulled up slightly when turning the readout on or off.
- **Step 4:** Cup the wheels of the probe with one hand and lower the probe in the casing. Make sure the upper wheel is aligned with the groove facing upstream (southeast/towards the reclaim pond and approximately perpendicular to the dam centerline), as shown in Figure 13.
  - *Note:* To avoid the need for data corrections, care should be taken to ensure that for the first set of readings at each location, the orientation of the upper inclinometer wheel is positioned in the groove towards the upstream.

  - *Note:* After long periods between collecting inclinometer measurements (more than two months), the inclinometer holes should first be measured with a weighted tape measure to better determine an expected maximum reading depth. If water, soil or rock can make it within the plastic acrylonitrile butadiene styrene (ABS) casing, the maximum reading depth may be affected.

- **Step 5:** Lower the probe slowly to the bottom of the casing, making sure not to strike the bottom of the hole. The probe will therefore be about 15 cm past the deepest expected measurement marker on the control cable (expected depths provided in Table 4).
  - *Note:* To assist in estimating the total depth, the measurement beads on the inclinometer cable should be counted as they are lowered down hole. Total depth estimate in meters, can then determined by multiplying the counted number of beads by 0.5 m (or divide the number of beads lowered down the hole by two).
- **Step 6:** Wait ten minutes to allow the probe temperature to equilibrate with the temperature in the hole.
  - *Note:* If multiple holes/locations are being completed in one day, as long as the probe is not removed from the ambient air temperatures (i.e., moved or temporarily stored within a vehicle or heated container), then the temperature equilibration time can be reduced to five minutes for subsequent holes (i.e., 10 minutes equilibration on the first hole and then five minute equilibration on the remaining holes).
- **Step 7:** Once the probe has equilibrated, the arrows on the readout box should be used to move the cursor to select "**Read**" from the menu screen. Press "**Enter**" to complete the selection.
- **Step 8:** Next "**Record**" should be selected from the menu screen. Again "**Enter**" should be pushed for selection. From the installation list that comes up, select the station location that matches the location the current reading is being taken at. Press "**Enter**" to step past each parameter, as no edits should be needed. The complete list of locations is provided in Table 4.

Table 4: Inclinometer Installation and Measurement Details

Site Name	Installation	Minimum Reading Depth (m)	Maximum Expected Reading Depth* (m)	Reading Intervals (m)
N. Dam	070-1	0.5	14.5	0.5
N. Dam	070-2	0.5	14.0	0.5
N. Dam	070-3	0.5	12.5	0.5
N. Dam	120-1	0.5	12.0	0.5
N. Dam	120-2	0.5	11.0	0.5
N. Dam	120-3	0.5	4.5	0.5

*Based on initial set of readings completed / gather by SRK on September 8 and 9, 2012

- **Step 9:** The next screen will show the start depth (e.g., bottom reading for each hole, for example 14.5 for N.Dam:120-1) and the first readings for the A and B axis (A0 and B0 respectively). Figure 12 shows the designation of the A, B, A0 and B0 axes.
  - *Troubleshooting Note:* If there are discrepancies between what is pre-programmed into the readout box and what is measured in the field as the maximum reading depth, then one of the following options should be completed before proceeding to Step 10:
    1. Scroll up on the readout box until the measured maximum depth is reached; or
    2. Repeatedly press "**Enter**" on the readout box to input a 'dummy' or/stand-in value for the bottom intervals until the desired field measured maximum reading depth is reached. Notes should be taken to reflect which depths have 'dummy' numbers recorded in them.
- **Step 10:** Slowly raise the probe off the bottom of the inclinometer casing to the first measurement mark on the control cable. The range of measurement depths for each inclinometer station is provided in Table 4. Hold the top of the marker aligned with the top of the casing, as shown in Figures 13 and 14. The cable has yellow markers at 0.5 m intervals and red markers at 1 m intervals, i.e. alternating red and yellow markers.
- **Step 11:** Allow the readings to stabilize. A diamond will be displayed next to each number when the readings are stable. Press "**Enter**" to record the readings. The recorded readings will be marked with a star and shown on the bottom line of the display. The new depth will appear on the top line.
  - *Note:* every reading should be taken from the same point/location on the top of the inclinometer casing to limit measurement errors and discrepancies. These errors are often later apparent as large A & B checksum values when the data is downloaded, see Section 6.2.3. For best measurement repeatability, the location where measurements are being taken from should be marked on the top of the inclinometer casing with a permanent marker or tape.
- **Step 12:** If the readings do not seem to stabilize, record the average of the shown readings manually in your field book and then skip the level using the UP arrow. One average should be recorded for each A0 and B0 respectively.
- **Step 13:** Pull the cable up until the next measurement mark on the cable is aligned with the top of the inclinometer casing (at the same measurement location as used in Step 11). Record the reading when the numbers have stabilized.
  - *Note:* If any of the reading measurement markers are overshot then the probe should be lowered back to the previous level and then raised again to the exact marker depth. To ensure consistent measurements the probe must be drawn upward before each reading.
- **Step 14:** Repeat the process for each mark on the cable, until the probe is at the top of the casing (i.e., last reading will be at the 0.5 m mark on the cable).
- **Step 15:** After the last reading, the readout will display a menu screen. Select "**Continue**" from the menu options.

- **Step 16:** Carefully lift out the probe, cupping the wheel assemblies with your hand to prevent them from snapping open.
- **Step 17:** Holding the probe upright, slowly rotate it 180 degrees (do not flip), and re-insert the probe into the inner inclinometer casing. This time the upper wheel will be facing downstream (northwest/toward the camp or slightly west of the Doris Creek Bridge location).
  - Note: It is important that the probe is rotated 180 degrees and not into the inclinometer casing groves that are only 90 degrees from the initial groves. A full 180-degree rotation of the probe is required so that readings are taken both ways down the hole. This 180-degree rotation allows for a second set of measurements to be recorded which can then be later used to eliminate potential small errors in calibration. A reading should be taken from the same marked location at the top of the inclinometer casing, as outlined in Step 11.
- **Step 18:** Allow the probe to re-equilibrate for five minutes then repeat Steps 4 through 14. Parameters A and B will change to A180 and B180.
  - *Note:* These readings will be marked with the pi sign (π).
- **Step 19:** After the last reading select "**Done**" from the menu and move to the next station.
- **Step 20:** Make sure the blue protective cap for the inclinometer casing is placed back on and is secured. Before moving to the next inclinometer location, the steel cover should be re-placed back over the steel protective housing.

  Refer to the user manuals of the Digitilt Inclinometer (Appendix A3) and the Digitilt DataMate II (Appendix A4) for further details, if/as needed. Figure 2 shows the physical location of each inclinometer station.

6.2.3 Data Transfer

Once the data has been recorded, it is stored in the internal memory of the readout box. The data can be retrieved from the readout by connecting the readout box to a personal computer running a Windows operating system. Once connected, the Digitilt's DataMate Manager (DMM), DigiPro or DigiPro 2 program (all versions of the Durham Geo Slope Indicator software) can be used to complete the data transfer. A manual for the DMM for Windows, DigiPro and DigiPro 2 for Windows software is presented in Appendix A5, A6 and A7 respectively. The following steps should be followed to allow for a successful data transfer:

- **Step 1:** Download and install the DMM, DigiPro or DigiPro2 software (Slope Indicator software) from the Slope Indicator website (www.slopeindicator.com/downloads/dmm-download-page.html).
- **Step 2:** Start the Slope Indicator software program.
- **Step 3:** Power up the readout.
- **Step 4:** Connect the readout to the PC using the USB cable provided.
- **Step 5:** On the readout box, choose "**Comm**" from the main menu.

- **Step 6:** Open the Slope Indicator software. Go to "**File**" on the menu bar and then select "**New**" to create a new file or "**Open**" to navigate and open and existing database file.
  - Note: only once you have created or selected an existing database file will you be able to access the "DataMate" menu bar outlined in Step 7.
- **Step 7:** In the Slope Indicator software, select the "**DataMate**" drop-down menu.
- **Step 8:** Select the appropriate "**Comm Port**" (communication port) from the drop-down menu.
  - *Note:* each port (such as USB port) on your computer may have a different "Communication Port" number designation. Make sure you select the right Communication Port number for the installed cable driver. If the selected Communication Port is not responding, then you may need to try a different Communication Port number. If all ports do not work, you may need to download a new driver for the cable by connecting to the internet then connecting the port to your computer. Alternately drivers can be downloaded from www.slopeindicator.com.
- **Step 9:** From the main menu of the Slope Indicator software, select "DataMate" and then pick "Retrieve All" from the drop-down menu (Figure 14).
  - *Note:* different retrieved surveys may be dragged and dropped into a saved / compiled project database (i.e., a database with all the data for each round of measurements saved into it). Alternately you can go to "**File**" then "Import" on the drop-down menu to add in additional field data, if/as desired, to a compiled site inclinometer database.
- **Step 10:** From the main menu of the Slope Indicator software, select "**File**" and then pick "**Save As**" from the fly-down menu (for the older DMM or DigiPro software). Alternately if you are using DigiPro2 create a backup database by selecting "**File**" and then "**Backup Database**" from the fly-down menu (Figure 14).
  - *Note:* once the inclinometer survey / field data is received into the Slope Indicator software it can be viewed by clicking the drop-down sections / inclinometer location groupings on the left-hand side of the screen. Note that each of the individual field surveys can then be viewed by again clicking / expanding the file tree list below each inclinometer location / grouping.
    - When viewing the raw field data, the "**A_Checksum**" and "**B_Checksum**" columns can be used to check the quality of the survey data. Typically, these A and B checksum values (unit less) should be $\pm$ 50 or less, and with no more than two values for any given survey location being between 50 and 100; excluding the top 0.5 m depth rows / readings. Checks on the data quality will be done by the EOR however; the steps outlined above can proactively be completed by site personnel to limit the chance of re-surveys being asked for.
- **Step 11:** Save the data as a project database (or backup database) to the computer's desktop. The file can then be moved and stored for archiving after it has been e-mailed to the EOR.

The primary component of the file name is the date the data was collected on. The file names should be similar to the example "Copy of DataMate_*YYYY_MM_DD*.mdb" Where:

YYYY – calendar year

MM – calendar month

DD – calendar date

- **Step 12:** Close the software and turn off the readout.
- **Step 13:** Send the data to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.. Any additional field notes that outline details about how the inclinometer field survey was completed or about conditions at the time of this survey should be supplied with the updated database file.

6.3 Instrument Maintenance

6.3.1 General

When all measurements are complete, disconnect the control cable from the probe and the readout. Wipe the probe and the cable clean and replace the protective caps of the readout and the probe for transport.

Once back inside (e.g., office), open the probe carry case and remove all protective caps of the probe and the readout to allow the instruments and the connectors to dry for a few hours.

Before initially heading out to the field, the probe should be connected to the readout and tested in the office to ensure that a proper connection between the probe and DataMate is being made.

6.3.2 Battery Maintenance

The Digitilt DataMate battery should be charged overnight prior to collecting the survey data. The Digitilt DataMate has an AC main socket for the battery charger attachment or for external power if/as required. Battery levels can be checked by going to the '**Utilities**' menu, then by choosing '**Batt**'. A new, fully charged battery should show approximately 6.6 volts with a full charge. The battery should be recharged if below 6 volts. It is best to charge the battery overnight if possible.

6.3.3 Desiccant Pack Maintenance

The desiccant is located inside the Digitilt DataMate. To check the moisture level in the DataMate go to the '**Utilities**' menu and choose '**Temp**'. The DataMate displays humidity and temperature. Humidity levels from 20% to 60% are normal and if the humidity exceeds 75%, replace the desiccant (Appendix A4, page 16 of Digitilt DataMate manual).

7 Water Level Monitoring Standard Operating Procedure

7.1 Objective

Performance monitoring of the North Dam can only be properly done in conjunction with an accurate determination of the water level behind the dam. Water levels are recorded and transmitted to the online portal on regular basis.

7.2 Measurement Procedures

The water level measurements are recorded at TIA-2 using a permanent data logger (Instrumentation Northwest Inc.) paired with a HOBO Energy Pro Datalogger (Onset Computer Corp.). The data is then transmitted by a solar-powered iridium satellite transceiver where it can be accessed on the online portal. There is also a back-up datalogger installed but is not part of the regular monitoring SOP (Appendix F)

The data logger is configured to collect a reading every 15 minutes and the data is transmitted to an online portal on a regular basis (currently every 5 days). The login details are as follows:

https://datagarrison.com/
Username: 300234010417660
Password: hobo

Water level data will be monitored by SRK from the online portal. If modification to the datalogger-transmitter configuration are made, provide details to SRK at hopebaymonitoring@srk.com.

Water levels are measured as meters of water (head) above the data logger and require a known elevation of the datalogger or, more easily acquired, a surveyed water level for accurate translation to elevations for comparison to critical dam elevations. When initially installed by ERM (September 2017) a constant of 27.761 m was to be added for conversion to an elevation (Appendix F). As such, the only steps for active monitoring of the water level are as follows:

- **Step 1:** Regularly inspect the datalogger-transmitter setup at TIA-2 to confirm no damage or modification has occurred. Possible causes could be ice movement, human modification or animal interaction.
- **Step 2:** If damage or modification is noted, it must be reported with the time, date, detailed observations and at least one photo to SRK at hopebaymonitoring@srk.com.
- **Step 3:** As part of the monthly survey data collection (Section 5) a survey point of the water level must be collected.
- **Step 4:** In addition, ERM proposes to complete bi-annual water level surveys of the TIA reclaim pond to update the water level conversion constant, when received, these must also be provided to SRK to ensure agreement between surveys.

7.3 Reporting Procedures

Water level data recorded by the TIA-2 logger-transmitter system will be downloaded from the online portal discussed in this section. The water level survey data is expected to be supplied in Excel compatible format and would be sent along with the ground survey data (Section 5). Any observed changes to the TIA-2 configuration should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

8 Visual Monitoring Standard Operating Procedure

8.1 Objective

Formal visual (walk over) inspections of the South Dam, and immediate surrounding area, is required to act as an early notification for potential issues in areas not directly monitored by the installed instrumentation or other monitoring activities. Two levels of inspection are proposed:

1) Daily monitoring to identify issues or observations that may adversely impact the dam.

2) Full weekly visual (walk over) inspections.

8.2 Daily Visual Inspection

It is expected that the tailings deposition operations are monitored daily by qualified site staff at the TIA. The daily inspections are not intended to be an intensive exercise, rather it should include a walking or driving from one end of the dam to the other inspecting for major changes that have the potential to compromise its performance between weekly inspections. These inspections should include:

1. Settlement, depressions, sinkholes, cracking or signs of movement along the crest, the downstream or upstream face of the dam;

2. Significant changes in the observed seepage conditions compared to the prior weekly inspection;

3. Rapidly changing erosion conditions at the interface of the dam and the tundra;

4. Any other atypical conditions observed that are concerning or have the potential to compromise the dam performance.

There is no reporting requirement for the daily visual inspections and should be conducted as part of a daily ‘round’ at the TIA.

8.3 Weekly Visual (Walk Over) Inspection and Reporting

The upstream and downstream slopes and crests of the dams should be the focus during the walk over visual inspections. Specifically, the following should be noted:

1. Erosion

   (a) Any erosion over 5 cm in depth should be noted. Erosion locations should be recorded (using a handheld GPS or survey) and photographed.

   (b) If erosion is notable then it should be monitored carefully to ensure that conditions do not worsen (i.e., getting larger, deeper, to greater extent).

   (c) If erosion can be measured, then simple visual estimates or measurements with a tape measure should be completed on the larger erosional features.

2. Settlements / Depressions / Sinkholes.

   (a) If observed, then locations should be recorded (with GPS), photographed and the dimension / extents estimated.

3. Cracks/ Movements

   (a) If signs of cracking or movement are apparent then the crest on the upstream and downstream should be noted, photographed and the approximate crack dimension should be estimated or measured.

4. Debris and Vegetation

   (a) Any debris or vegetation growing on the upstream and downstream slopes of the dam should be noted.

   (b) Materials should not be stockpiled on the dam surface. Any debris on the dam should be removed to assist with better performing visual inspections over these areas.

   (c) Snow can affect thermal performance of the dam. Natural snow drifting over 1.0 m should be noted.

5. Ponding or Potential Seepage

   (a) Seepage is defined as water in contact with and flowing downstream of the dam. Walk the full length of the downstream dam toe to identify and currently flowing seepage locations or location that appear to have evidence of past seepage (which can be monitored going forward).

   (b) If seepage water is found, note the location (by dam chainage/station or GPS), photograph and provide a preliminary estimate the seepage rate if possible.

   (c) Ponded water exists only at the lowest point at the downstream toe of the dam. If new ponded areas are observed along the downstream toe, note the location and approximate extent on the inspection form and photograph.

   (d) Notify the on-site environmental coordinator to assess and conduct seepage monitoring (Section 9).

6. Instrumentation

   (a) Look for visual damage to instrumentation (i.e., does all instrumentation appear to be intact or has it been damaged by equipment, animals or personnel?).

   (b) If damage is noted, then photographs and notes / observations should be collected to assist with determining if repair of the instrumentation is possible.

7. Thermosyphon Radiators

   (a) Look for visual damage or corrosion to thermosyphon radiators (i.e., is any rust notable, is any physical damage notable, and is the thermosyphon radiators generally still upright).

(b) If damage is noted, then photographs and notes / observations should be collected.

A monitoring checklist is presented in Appendix E. This inspection form, along with any photos or notes from the inspection should be formally recorded and submitted to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

The EOR should be notified immediately after any inspection where notable changes to any of the areas / items listed above are observed. The EOR will work with TMAC to provide further guidance on monitoring or sampling requirements and to determine if mitigation measures are required.

9 Seepage Monitoring Standard Operating Procedure

9.1 Objective

Seepage or contact water flowing from the toe of the North Dam has been observed since dam construction. With deposition of tailings ongoing, seepage monitoring is required to confirm that the source is not seepage from the TIA.

This procedure must be conducted when potential seepage is identified during the Visual Monitoring (Section 8) or **weekly** once potential seepage has been identified.

9.2 Procedure

Seepage is defined as water flowing from the toe of the North Dam. Monitoring and sample collection are to be performed by on-site environmental personnel, who are trained in seepage identification and sample collection methods. Seepage monitoring of the North Dam toe specifically is described as follows:

1. Complete a walk over survey on foot. This will consist of walking the full length of the downstream dam toe to identify any currently flowing seepage locations or location that appear to have evidence of past seepage (which can be monitored going forward). Ponded water should be inspected for seepage feeding into the ponded water, if none, no sampling is required.
2. At each flowing seepage location, collect water samples for the parameters listed in the laboratory analytical suite (LAS) listed in this section and record the following field data:
    - GPS coordinates,
    - Photographs (upstream and downstream shots),
    (a) Volumetric flow rate
        1. Volumetric flow rates determined as follows:

        For samples collected at the v-notch weir:

        - The height of the water in the weir reservoir, relative to the bottom of the v-notch itself, should be measured. The level should not be measured in the v notch (this could be done as a check but should not be the primary measurement).
        - For calibration of the v-notch weir, a container of known volume should be filled from the flow passing through the v-notch. The time required to fill the entire container (of a know volume – e.g. 1L) should be recorded. This should be repeated three times per sampling event. This is most critical during the first sampling events of the year.
        - All seepage that reports the v-notch weir area should be directed through the weir. Where a large proportion of the seepage is flowing around the weir, the

percentage of total seepage flowing through the weir should be estimated and reported with the field notes.

For samples collected at the toe of the dam (not at the v-notch weir):

- Flow volume and velocity can be estimated by taking a container of a known volume and recording the time it takes for the seepage to fill the known volume. Alternatively, estimate the cross-sectional area of the flow and using a stop watch visually estimate the velocity of the water (time for identifiable debris to travel a known distance through the estimated cross-sectional area). To help improve accuracy of the estimate / measurement, at least three iterations of the estimate should be completed.

(b) Field measurements: temperature, pH, electrical conductivity (EC), chloride, and oxidation reduction potential (ORP),

(c) Date and time,

(d) Name of sampler, and

The seepage sampling frequency is **once per week** while seepage is occurring or at the discretion of the EOR.

3. For every seepage sampling event, collect additional samples at the following locations:

   (a) SNP station TL-1 (Reclaim Barge)

      1. Field measurements (temperature, pH, EC, chloride, ORP), and
      2. Water samples for lab parameters listed below (LAS).

   (b) Upstream side of the North Dam (reservoir touching the upstream slope)

      1. Field measurements (temperature, pH, EC, chloride, ORP), and
      2. Water samples are not required at this location.

4. **Once per month**, collect the following QA/QC samples to validate the geochemical data set:

   (a) One field duplicate, one travel blank and one field blank for lab parameters listed below (LAS); and

   (b) For the field duplicate only, field measurements (temperature, pH, EC, chloride, ORP).

5. **Once per month** during routine sampling of SNP station TL-5 (tailings supernatant discharge from the mill), collect samples for the analysis of:

   (a) Field measurements (temperature, pH, EC, chloride, ORP), and

   (b) Water samples for lab parameters listed below (LAS).

   (c) This monthly sampling of TL-5 satisfies the TL-5 monitoring requirements outlined in the South Dam SOP (SRK, 2020).

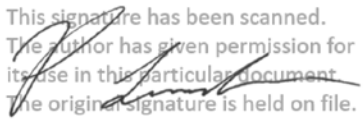
The laboratory analytical suite (LAS) for North Dam Seepage Monitoring Program is as follows:

- Lab pH and EC
- SO_4, Cl
- Alkalinity
- Ammonia, NO_3, NO_2, Total N
- Total CN, Free CN
- SCN, CNO
- Total metals (including sulphur and mercury)
- Dissolved metals (including sulphur and mercury)

9.3 Sample Shipment and Reporting Procedure

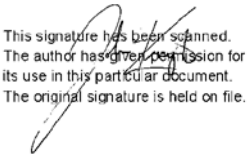
Water samples are to be shipped to ALS Environmental. When samples are shipped, the appropriate Chain of Custody (COC) form and the field data should be sent to SRK, and the Engineer of Record (EOR) should be notified that the sample have been collected and shipped. Upon receipt of the lab results, these should also be sent to SRK. All documentation and results should be sent to Lbarazzuol@srk.com (Lisa Barazzuol) rcocuaco@srk.com (Rosie Cocuaco), mting@srk.com (Maritess Ting) and Hopebaymonitoring@srk.com (SRK Hope Bay monitoring account).

This report, “Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3”, was prepared by SRK Consulting (Canada) Inc.

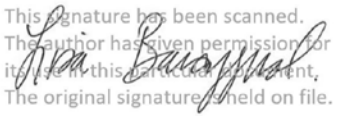


Peter Luedke, EIT
Consultant

and reviewed by:



John Kurylo, MEng PEng
Senior Consultant



Lisa Barazzuol, PGeo
Principal Consultant (Geochemistry)

All data used as source material plus the text, tables, figures, and appendices of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

10 References

Cornelissen, G. 2013. Suggested Guidelines for Surveying at the North Dam. PDF notes supplied by True North Geomatics Ltd. / Nuna Logistics to SRK Consulting (Canada) Inc. September.

National Oceanic and Atmospheric Administration (NOAA) / John Lipe. Accessed July 2013 online at: http://www.srh.noaa.gov/srh/dad/hydro/Doingasurvey.html.

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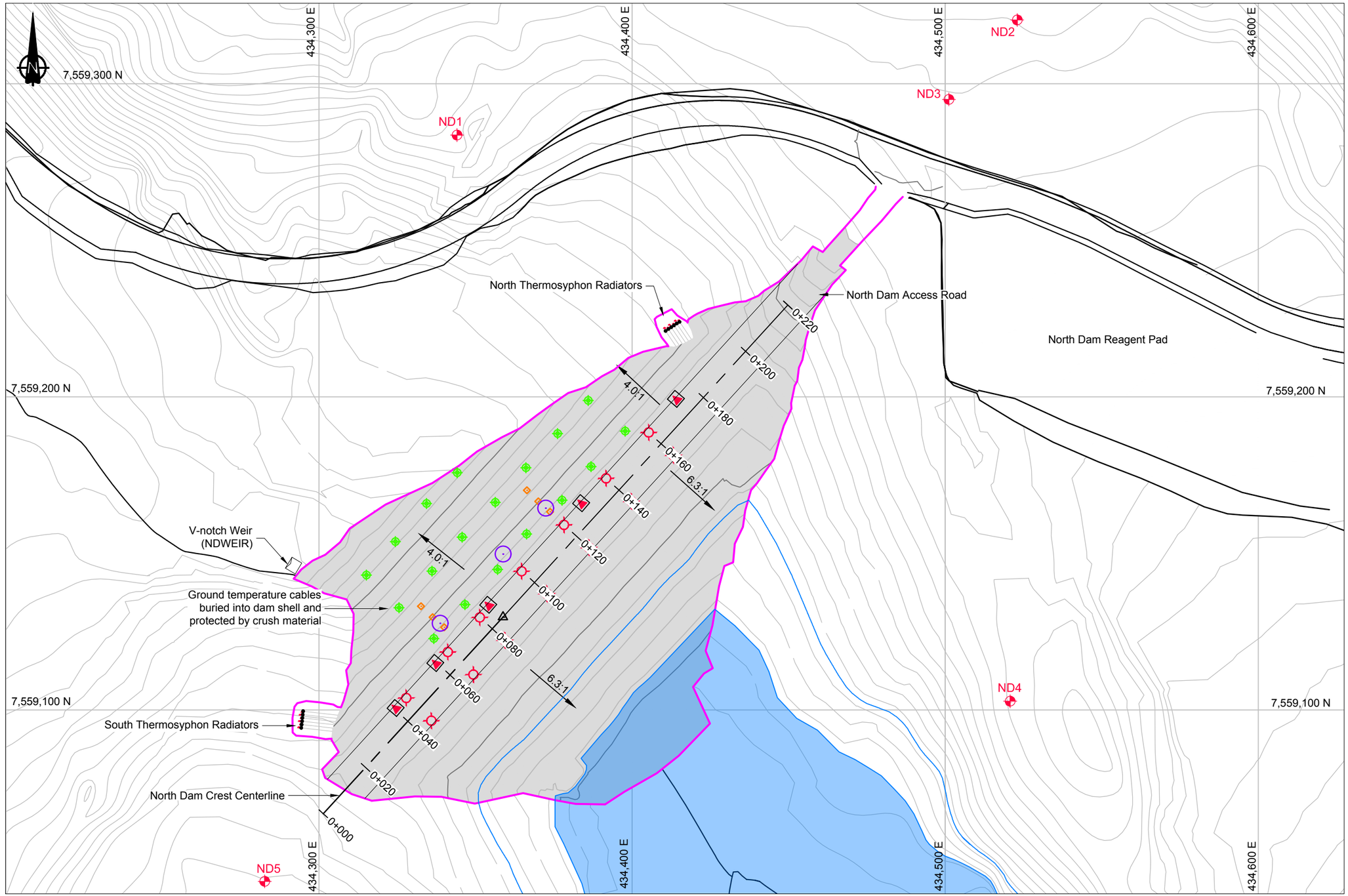
Figures



LEGEND

- Primary Control Point
- Survey Monitoring Point (Crest)
- Deep Settlement Point
- Surficial Survey Point
- Inclinometer Location
- Major Contour
- North Dam Extents
- Full Supply Level (Elev. 33.5m)
- Thermosyphon Radiator
- GTC Instrumentation Node

NOTES

1. Topographic contour data was provided by the Client. As-Built contour data for terrain model was provided by the Contractor.
2. Contours shown at 1.0m intervals.
3. Details and names for instrumentation presented on Figure 2.

REFERENCE

NAD83 UTM Zone 13.

PRIMARY CONTROL POINTS STAKE OUT TABLE

Point ID	Northing	Easting	Elev. (m)
ND1	7559283.611	434344.083	42.905
ND2	7559320.367	434522.981	46.915
ND3	7559295.013	434501.167	45.38
ND4	7559102.79	434520.744	44.236
ND5	7559045.274	434282.658	42.871

0m 10 20 30 40 50

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SRK JOB NO.: 1CT022.036.500

FILE NAME: 1CT022.036 - Monitoring SOP.dwg

TMAC RESOURCES

Hope Bay Project

North Dam SOP

North Dam General Arrangement and Primary Control Points

DATE: August 2019 | APPROVED: PL | FIGURE: 1

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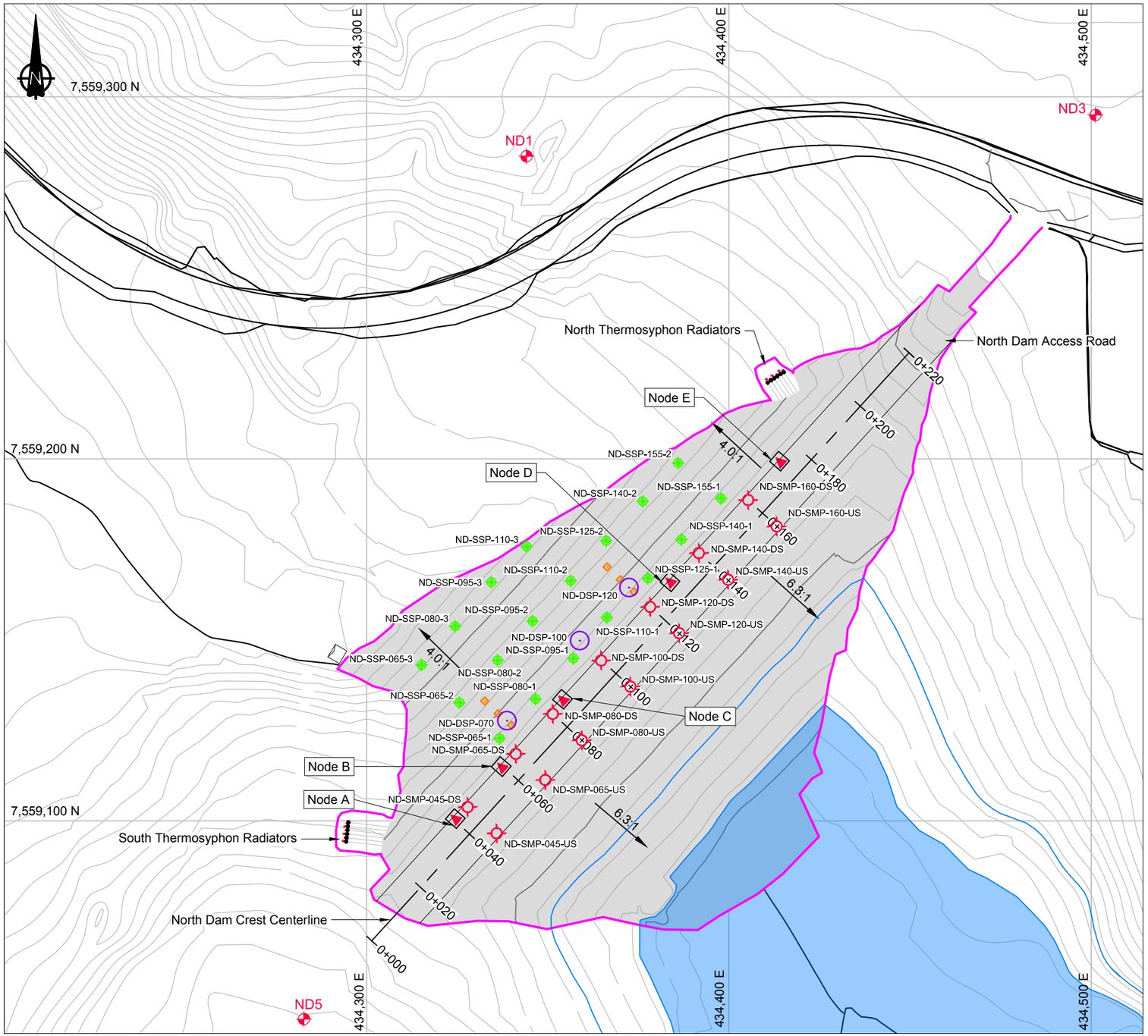

LEGEND

- Primary Control Point As-Built
- Survey Monitoring Point (Crest)
- Deep Settlement Point
- Surficial Survey Point
- Inclinometer Location
- Major Contour
- Final Surface Extents
- Full Supply Level (Elev. 33.5m)
- Thermosyphon Radiator
- GTC Instrumentation Node

NOTES

1. Topographic contour data was provided by the Client. As-Built contour data for terrain model was provided by the Contractor.
2. Contours shown at 1.0m intervals.
3. Nodes B and D are the two weatherproof enclosures which house the GTC instrumentation nodes

REFERENCE

NAD83 UTM Zone 13.

AS-BUILT DEEP SETTLEMENT POINTS STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
ND-DSP-070	7559127.69	434338.65	36.95
ND-DSP-100	7559149.78	434358.75	36.86
ND-DSP-120	7559164.46	434372.37	36.92

AS-BUILT SURFICIAL SURVEY POINTS STAKEOUT TABLE

ID	Northing	Easting	Elev.(m)
ND-SSP-065-1	7559122.80	434336.67	36.77
ND-SSP-065-2	7559132.67	434325.55	32.81
ND-SSP-065-3	7559143.10	434315.11	29.43
ND-SSP-080-1	7559133.65	434346.59	36.79
ND-SSP-080-2	7559144.37	434336.10	32.92
ND-SSP-080-3	7559153.75	434324.36	29.33
ND-SSP-095-1	7559144.90	434357.04	36.58
ND-SSP-095-2	7559155.21	434345.72	32.85
ND-SSP-095-3	7559165.92	434334.35	28.70
ND-SSP-110-1	7559156.20	434366.29	36.32
ND-SSP-110-2	7559166.31	434356.29	32.88
ND-SSP-110-3	7559175.79	434344.10	28.97
ND-SSP-125-1	7559166.97	434377.61	36.77
ND-SSP-125-2	7559177.37	434366.08	32.91
ND-SSP-140-1	7559177.75	434386.85	36.48
ND-SSP-140-2	7559188.28	434376.19	32.84
ND-SSP-155-1	7559189.07	434397.79	36.80
ND-SSP-155-2	7559198.85	434385.98	32.91

AS-BUILT SURVEY MONITORING POINTS STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
ND-SMP-065-DS	7559118.52	434341.14	38.46
ND-SMP-065-US	7559111.31	434349.30	38.36
ND-SMP-080-DS	7559129.57	434351.35	38.41
ND-SMP-080-US	7559122.27	434359.34	38.40
ND-SMP-100-DS	7559144.32	434364.71	38.39
ND-SMP-100-US	7559137.12	434372.77	38.46
ND-SMP-120-DS	7559159.12	434378.24	38.41
ND-SMP-120-US	7559151.88	434386.24	38.46
ND-SMP-140-DS	7559173.98	434391.69	38.39
ND-SMP-140-US	7559166.62	434399.77	38.42
ND-SMP-160-DS	7559188.64	434405.30	38.40
ND-SMP-160-US	7559181.37	434413.18	38.43

Node (Station)	GTC Name
Node A (0+040)	1.ND-VTS-040-KT
	12.ND-HTS-040-31.5
	13.ND-HTS-040-33.5
Node B (0+060)	2.ND-VTS-060-KT
	3.ND-VTS-060-US
	4.ND-VTS-060-DS
	14.ND-HTS-060-28.8
	15.ND-HTS-060-31.0
	16.ND-HTS-060-33.5
Node C (0+085)	5.ND-VTS-085-KT
	6.ND-VTS-085-US
	7.ND-VTS-085-DS
	17.ND-HTS-085-25.3
	18.ND-HTS-085-29.4
	19.ND-HTS-085-33.5
Node D (0+130)	8.ND-VTS-130-KT
	9.ND-VTS-130-US
	10.ND-VTS-DS
	20.ND-HTS-130-28.8
	21.ND-HTS-130-31.0
	22.ND-HTS-130-33.5
Node E (0+175)	11.ND-VTS-175-KT
	23.ND-HTS-175-32.5
	24.ND-HTS-175-33.5
	25.N Thermosyphons (x6)
	26.S Thermosyphons (x6)

AS-BUILT INCLINOMETER LOCATION STAKEOUT TABLE

ID	Northing	Easting	Elev. (m)
ND-IN-070-1	7559126.41	434340.00	37.44
ND-IN-070-2	7559129.63	434336.27	36.20
ND-IN-070-3	7559133.13	434332.57	34.85
ND-IN-120-1	7559163.31	434373.78	37.44
ND-IN-120-2	7559166.64	434370.03	36.05
ND-IN-120-3	7559170.15	434366.40	34.95

0m 10 20 30 40 50

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SRK JOB NO.: -

FILE NAME: 1CT022.036 - Instrumentation LO.dwg

TMAC RESOURCES

Hope Bay Project

North Dam SOP

North Dam Instrumentation Layout

DATE: August 2019

APPROVED: -

FIGURE: 2

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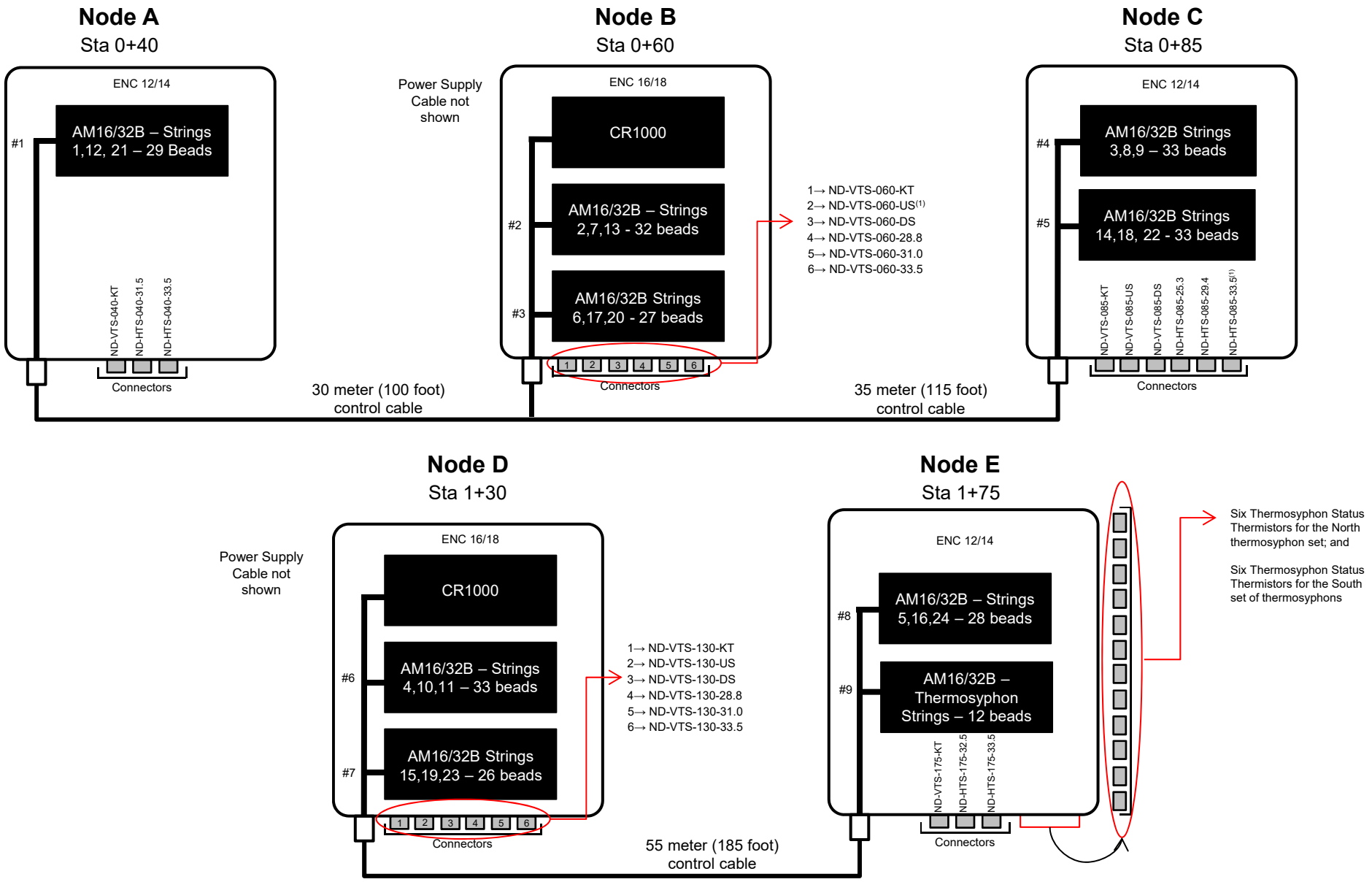
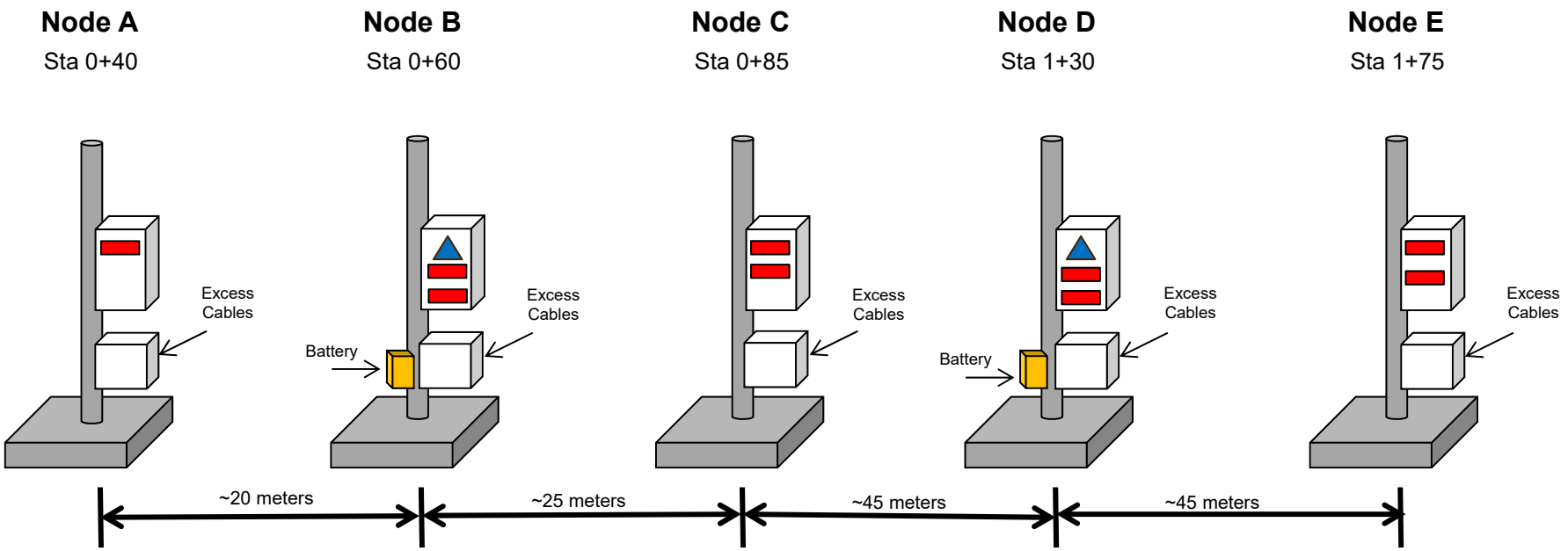


Notes:
Internal temperature of data logger housing is measured continuously.
(1) GTC irreparably damaged, no recorded data.

srk consulting	TMAC RESOURCES	North Dam Monitoring SOP (Revision 3)
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_Rev03_Landscape_1CT022.000_pl_Rev00	Doris Mine	**Monitoring Nodes A through E**
		Date: July 2020 / Approved: JBK/IM/PL / Figure: **3**



Legend

- AM 16/32 Multiplexer
- CR1000 Datalogger

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TMAC RESOURCES

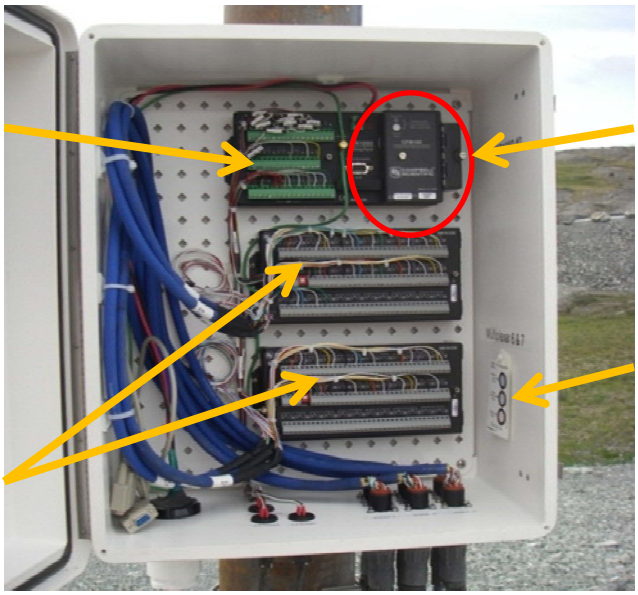
Job No: 1CT022.000
Filename: HopeBay_NorthDamMonitoringSOP_Rev03_Landscape_1CT022.000_pl_Rev00

Doris Mine

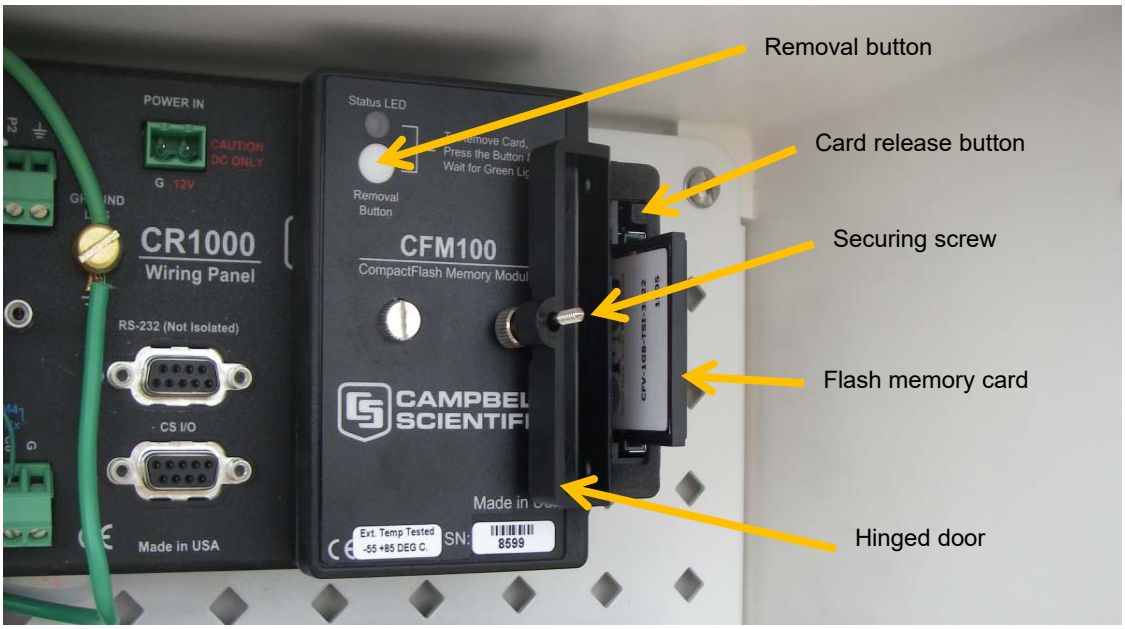
North Dam Monitoring SOP (Revision 3)

Layout of Data Acquisition System

Date:	Approved:	Figure:
July 2020	JBK/IM/PL	4



Key components inside the weatherproof enclosure



Close-up view of the CR1000 data logger and CFM 100 Compact Flash Module inside the weatherproof enclosure

srk consulting	MAC RESOURCES	North Dam Monitoring SOP (Revision 3)
		Weatherproof Enclosure and Datalogger Components
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_FIGURES	Doris Mine	Date: July 2020 / Approved: JBK/IM/PL / Figure: **5**

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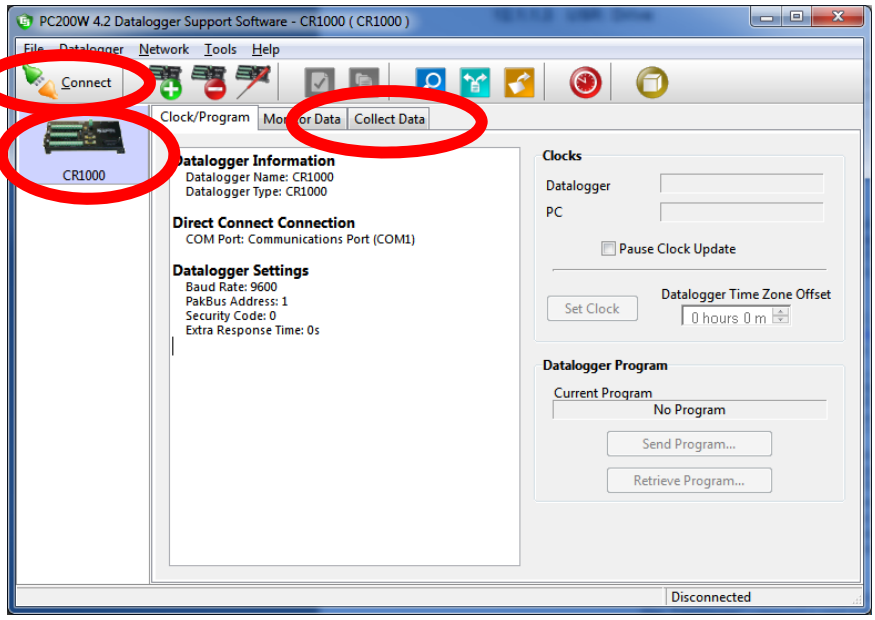
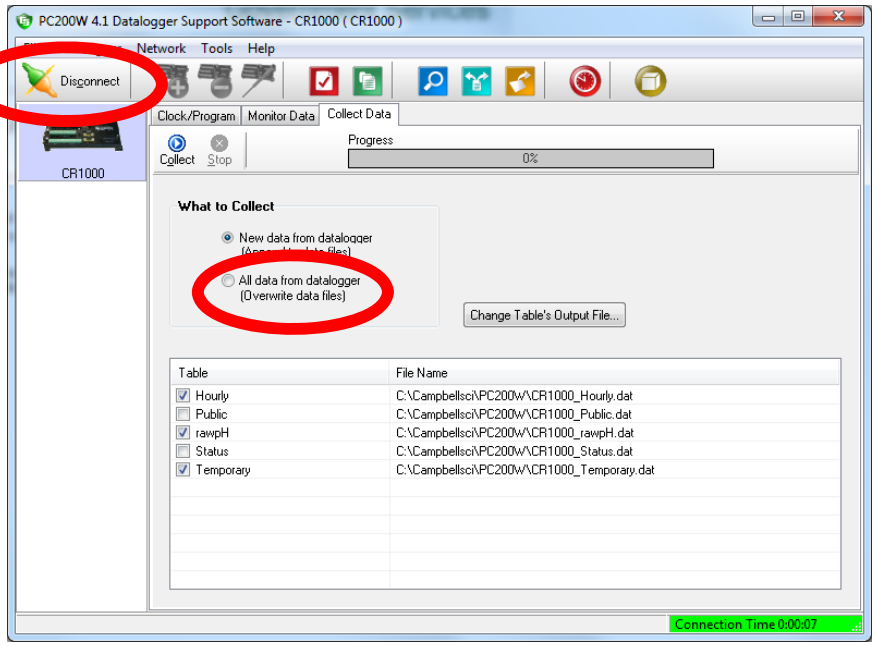
Step 1



PC200W Datalogger connection (Section 4.3.1)



PC200W 'Collect Data' tab (Section 4.3.1)

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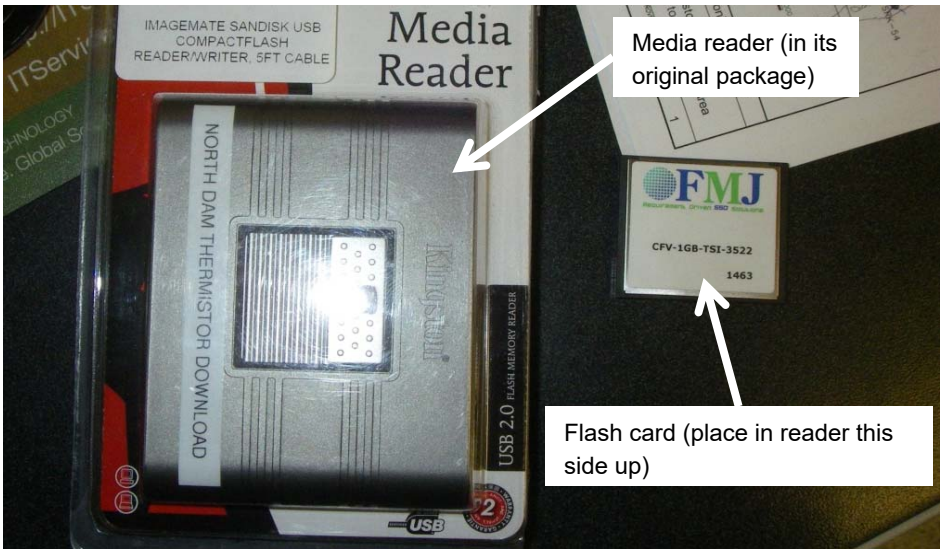
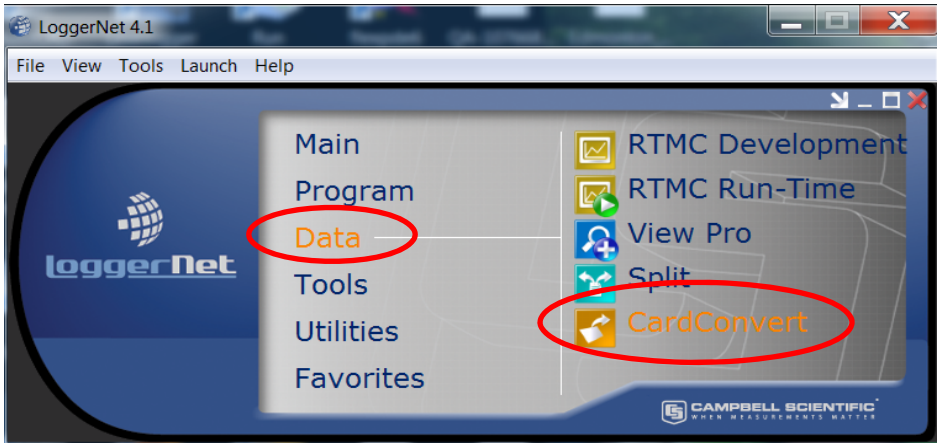
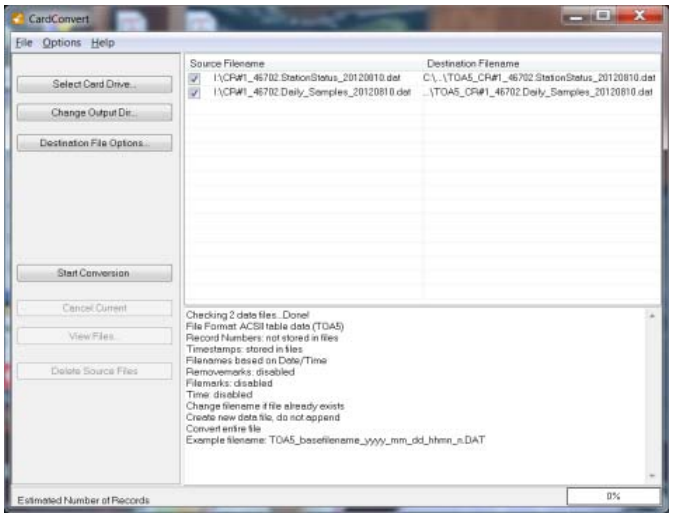


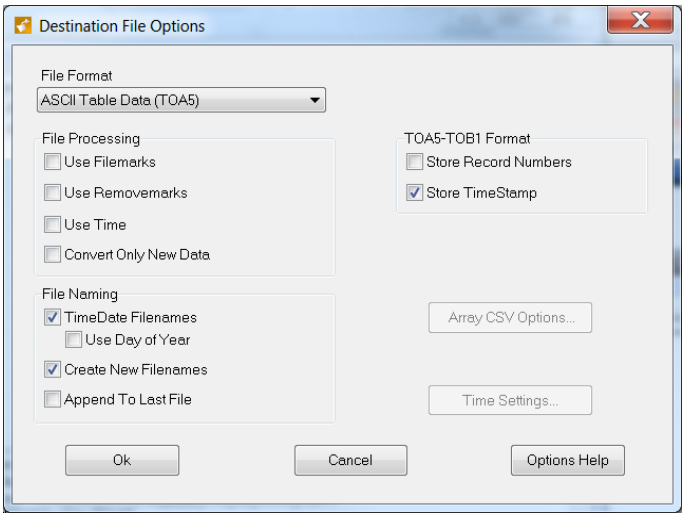
View of media card reader and flash memory card



Screenshot of LoggerNet starting menu (outlined in Section 4.5)



Screenshot of the file selection screen referred to in Step 2 (Section 4.5)



Screenshot of the "Destination File Options" referred to in Step 4 (Section 4.5)

srk consulting	TMAC RESOURCES	North Dam Monitoring SOP (Revision 3)
		Datalogger Flash Card Exchange Details / Screenshots
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_FIGURES	Doris Mine	Date: July 2020 / Approved: JBK/IM/PL / Figure: **7**

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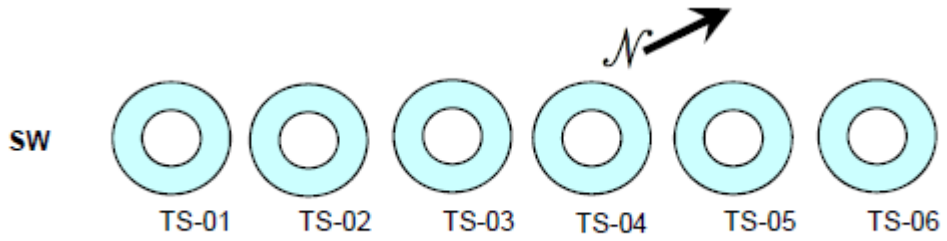
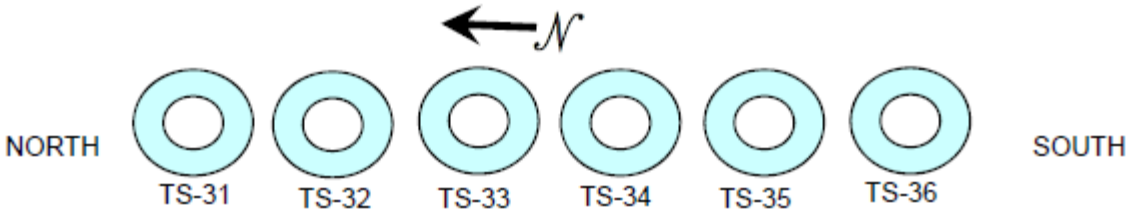


Simplified Plan Layout of North Thermosyphons



Simplified Plan Layout of South Thermosyphons

Thermosyphon status thermistors attached to thermosyphon risers using epoxy resin and zip-ties.

Thermosyphon status thermistors after being heat-insulated using expanding spray foam.

srk consulting	MAC RESOURCES	North Dam Monitoring SOP (Revision 3) **Thermosyphons Status Thermistor Details**
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_FIGURES	Doris Mine	Date: July 2020 | Approved: JBK/IM/PL | Figure: **8**

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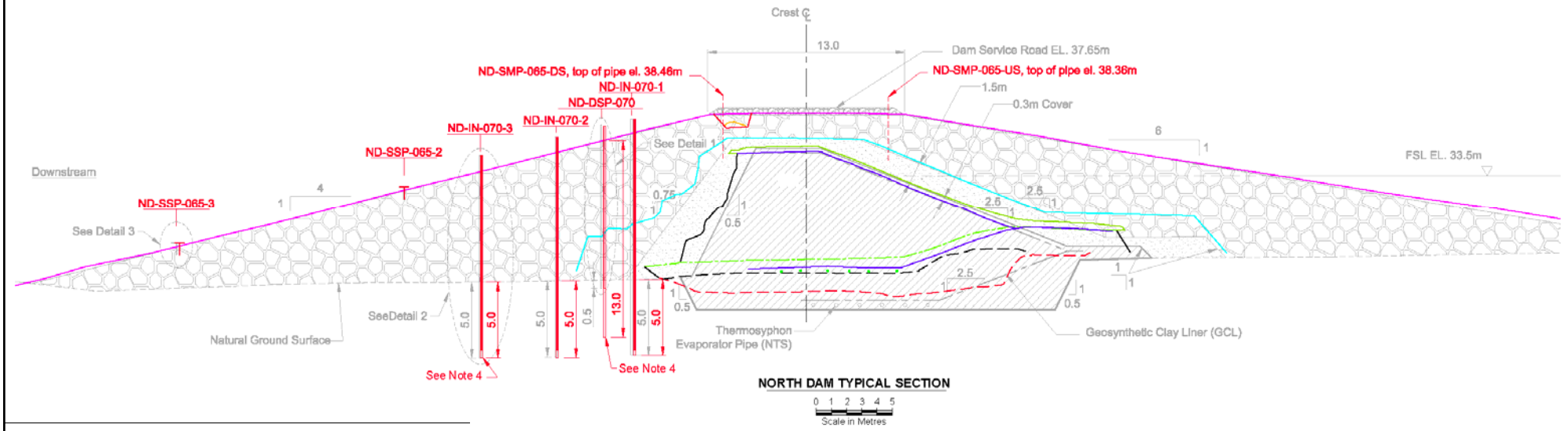
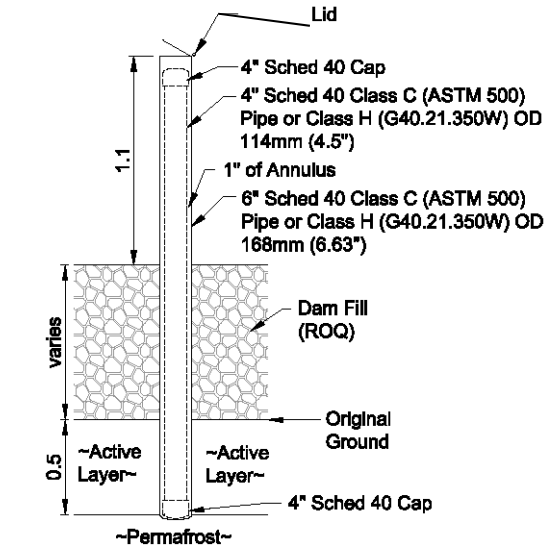


- Core Material
- Transition Material
- Run of Quarry (ROQ)
- Surfacing Material
- Bedrock
- Peat

- GCL As-built
- Core Material As-built
- Core Material (2011) As-built
- Levelling Course (Core Material) As-built
- Instrumentation Trench Cover As-built
- Key Trench / Instrumentation Trench As-built
- GCL Cover Material As-built
- Transition Material As-built
- ROQ Material As-built
- Thermosyphon Evaporator Pipes As-built

Example of as-built instrumentation installed on the downstream of dam.

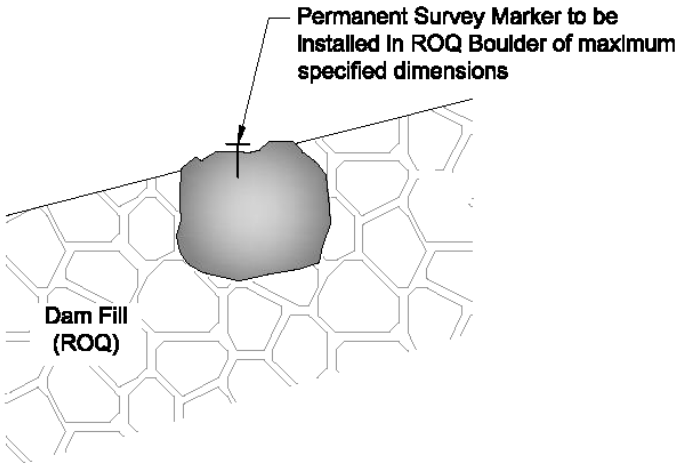
srk consulting	TMAC RESOURCES	North Dam Monitoring SOP (Revision 3)
		Deformation Monitoring Instrumentation Layout
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_Rev03_Landscape_1CT022.000_pl_Rev00	Doris Mine	Date: July 2020 / Approved: JBK/IM/PL / Figure: **9**



DETAIL
DEEP SETTLEMENT POINT INSTALLATION
Not to Scale

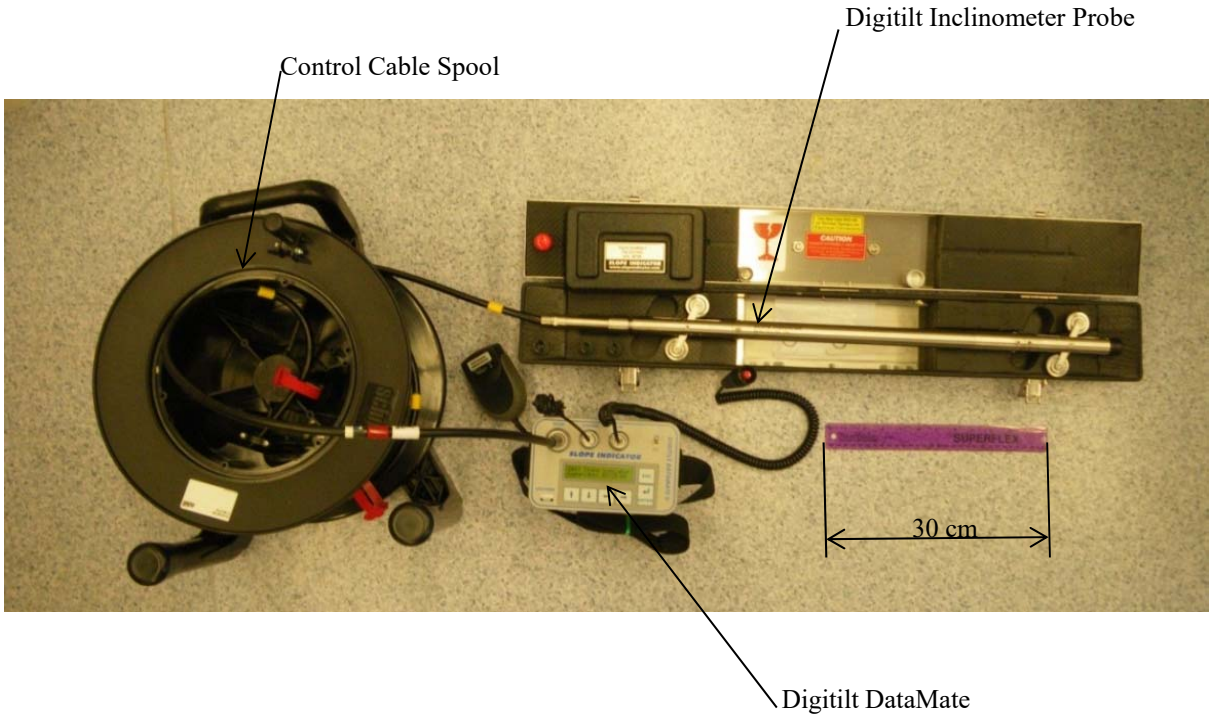
Examples of crest survey monument. Note the small rock bolt /anchor installed in the boulders seated into the dam shell.

Example of deep settlement points installed in the downstream of the dam.



DETAIL
SURFICIAL SURVEY POINT INSTALLATION
Not to Scale

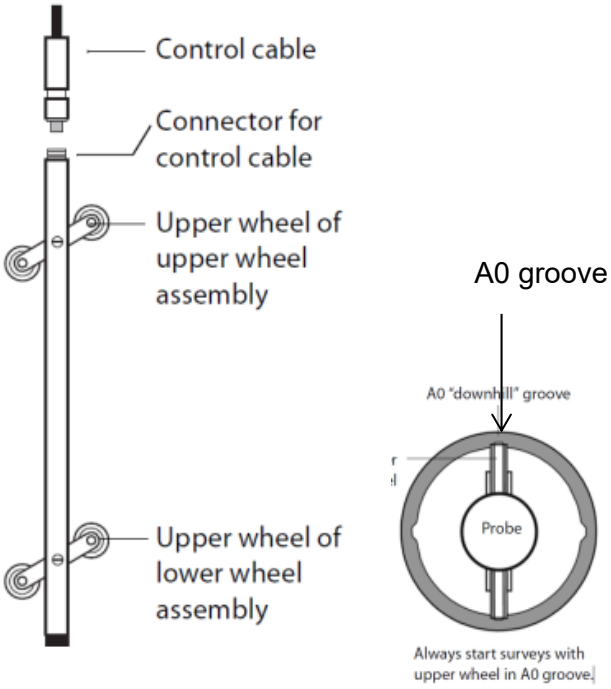
srk consulting	TMAC RESOURCES	North Dam Monitoring SOP (Revision 3)
Job No: 1CT022.000 Filename: HopeBay_NorthDamMonitoringSOP_Rev03_Landscape_1CT022.000_pl_Rev00	Doris Mine	**Deep Settlement Points and Surficial Survey Points Details** Date: July 2020 | Approved: JBK/IM/PL | Figure: **10**



Inclinometer probe with readout and control cable spool

Inclinometer instruments packages wrapped up for storage

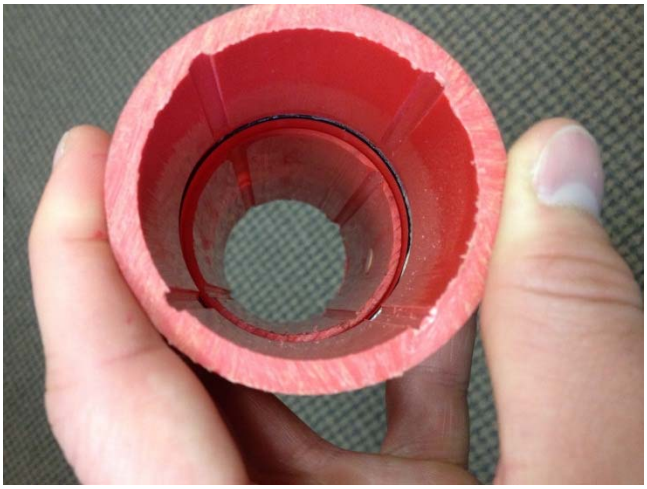
Example of Digitilt Inclinometer Set-Up



Schematic reproduced from www.slopeindicator.com

Schematic of Upper wheel and upstream marker from Slope Indicator manual (Appendix A)

Example of inclinometer protective casing, with and without top cap on.



Example of four inner groves spaced at ~90° angles. Note that only one set of grooves is used for the two sets of measurements (i.e. 180° rotation of instrument)

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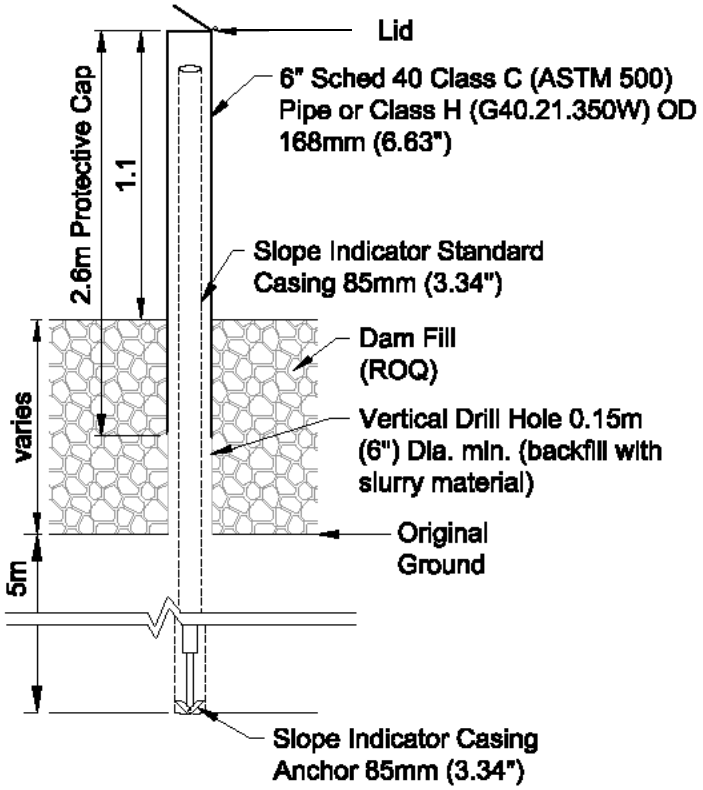
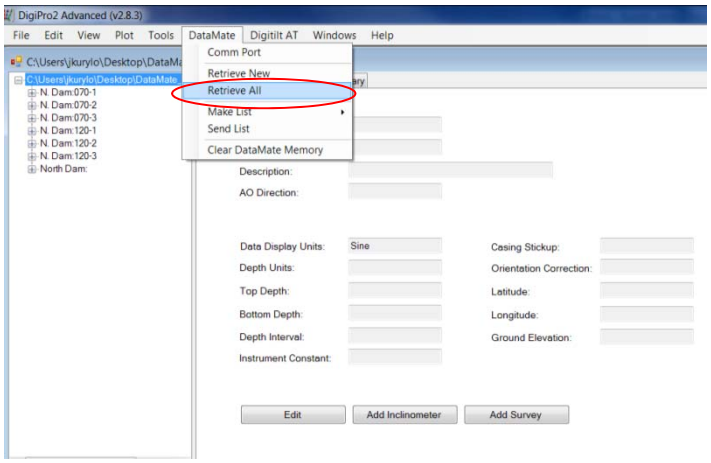
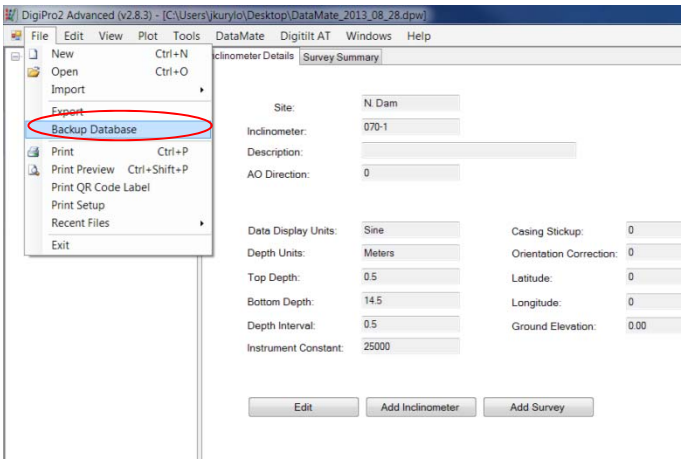


DETAIL
INCLINOMETER INSTALLATION
Not to Scale

Marker being correctly held and aligned with top of inclinometer casing



Main DataMate menu from DigiPro2 Inclinometer software



Backup menu from DigiPro2 Inclinometer software

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Appendix A - Operator’s Manuals

Appendix A1 - CR1000 Measurement and Control System

OPERATOR'S MANUAL

CR1000 Measurement and Control System

Revision: 7/11

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WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **thirty-six (36) months** from date of shipment unless specified otherwise. **** Batteries are not warranted.** ****** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

CAMPBELLSCIENTIFIC
CANADA CORP.
11564 - 149 street - edmonton - alberta - T5M 1W7
tel 780.454.2505 fax 780.454.2655
www.campbellsci.ca

PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

Select Sections extracted from CR100 Measurement and Control System (Revision: 7/11) Operator's Manual.

Full manual can be found online at: http://s.campbellsci.com/documents/us/manuals/cr1000.pdf

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Section 1. Introduction

Whether in extreme cold in Antarctica, scorching heat in Death Valley, salt spray from the Pacific, micro-gravity in space, or the harsh environment of your office, Campbell Scientific dataloggers support research and operations all over the world. Our customers work a broad spectrum of applications, from those more complex than any of us imagined, to those simpler than any of us thought practical. The limits of the CR1000 are defined by our customers. Our intent with the CR1000 manual is to guide you to the tools you need to explore the limits of your application.

You can take advantage of the CR1000's powerful analog and digital measurement features by spending a few minutes working through the *Quickstart Tutorial* (p. 3) and the *Overview* (p. 27). For more demanding applications, the remainder of the manual and other Campbell Scientific publications are available. If you are programming with CRBASIC, you will need the extensive Help available with the CRBASIC Editor software. Formal CR1000 training is also available from Campbell Scientific.

This manual is organized to take you progressively deeper into the complexity of CR1000 functions. You may not find it necessary to progress beyond the *Quickstart Tutorial* (p. 3) or *Overview* (p. 27) sections. *Quickstart Tutorial* (p. 3) gives a cursory view of CR1000 data acquisition and walks you through a first attempt at data acquisition. *Overview* (p. 27) reviews salient topics, which are covered in-depth in subsequent sections and appendices.

More in-depth study requires other Campbell Scientific publications, most of which are available on-line at *www.campbellsci.com*. Generally, if a particular feature of the CR1000 requires a peripheral hardware device, more information is available in the manual written for that device. Manuals for Campbell Scientific products are available at *www.campbellsci.com*.

If you are unable to find the information you need, please contact us at 435-753-2342 to speak with an applications engineer. Or, you can email us at *support@campbellsci.com*.

Section 2. Quickstart Tutorial

This tutorial gives a cursory look at CR1000 data acquisition.

2.1 Primer - CR1000 Data Acquisition

Data acquisition with the CR1000 is the result of a step wise procedure involving the use of electronic sensor technology, the CR1000, a telecommunications link, and *datalogger support software* (p. 439, p. 490).

2.1.1 Components of a Data Acquisition System

A typical data acquisition system is conceptualized in *FIGURE. Data Acquisition System Components* (p. 4). A CR1000 is only one part of a data acquisition system. To acquire good data, suitable sensors and a reliable data retrieval method are required. A failure in any part of the system can lead to "bad" data or no data.

2.1.1.1 Sensors

Suitable sensors accurately and precisely transduce environmental change into measurable electrical properties by outputting a voltage, changing resistance, outputting pulses, or changing states.

Read More! *APPENDIX. Accuracy, Precision, and Resolution* (p. 454)

2.1.1.2 Datalogger

CR1000s can measure almost any sensor with an electrical response. CR1000s measure electrical signals and convert the measurement to engineering units, perform calculations and reduce data to statistical values. Every measurement does not need to be stored. The CR1000 will store data in memory awaiting transfer to the PC via external storage devices or telecommunications.

2.1.1.3 Data Retrieval

The products of interest from a data acquisition system are data in data files, usually stored on and accessible by a PC.

Data are copied, not moved, from the CR1000 to the PC. Multiple users may have access to the same CR1000 without compromising data or coordinating data collection activities.

RS-232 and CS I/O ports are integrated with the CR1000 wiring panel to facilitate data collection.

On-site serial communications are preferred if the datalogger is near the PC, and the PC can dedicate a serial (COM) port for the datalogger. On-site methods such as direct serial connection or infrared link are also used when the user visits a remote site with a laptop or PDA.

In contrast, telecommunications provide remote access and the ability to discover problems early with minimum data loss. A variety of devices, and combinations of devices, such as telephone modems, radios, satellite transceivers, and TCP/IP network modems are available for the most demanding applications.

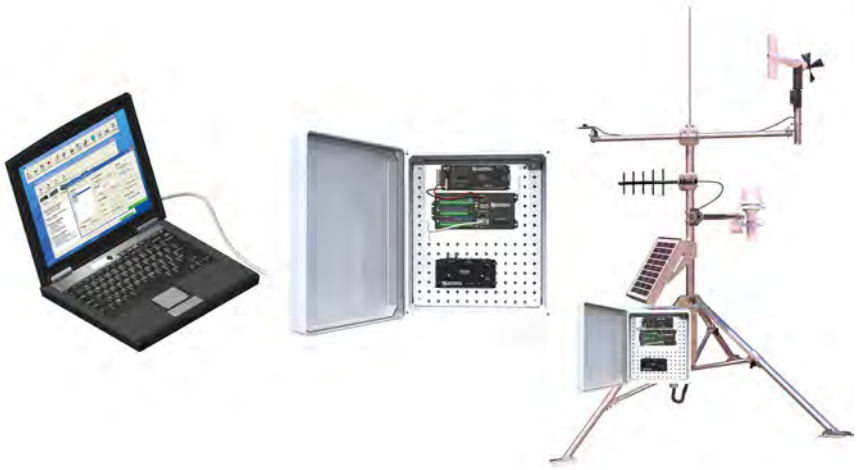


FIGURE 1. Data Acquisition System Components

2.1.2 CR1000 Module and Power Supply

The CR1000 module integrates electronics within a sealed stainless steel clamshell, making it economical, small, and very rugged.

2.1.2.1 Wiring Panel

The CR1000 module connects to the wiring panel. As shown in *FIGURE. CR1000 Wiring Panel* (p. 5), the wiring panel provides terminals for connecting sensors, power and communications devices. Internal surge protection is incorporated with the input channels.

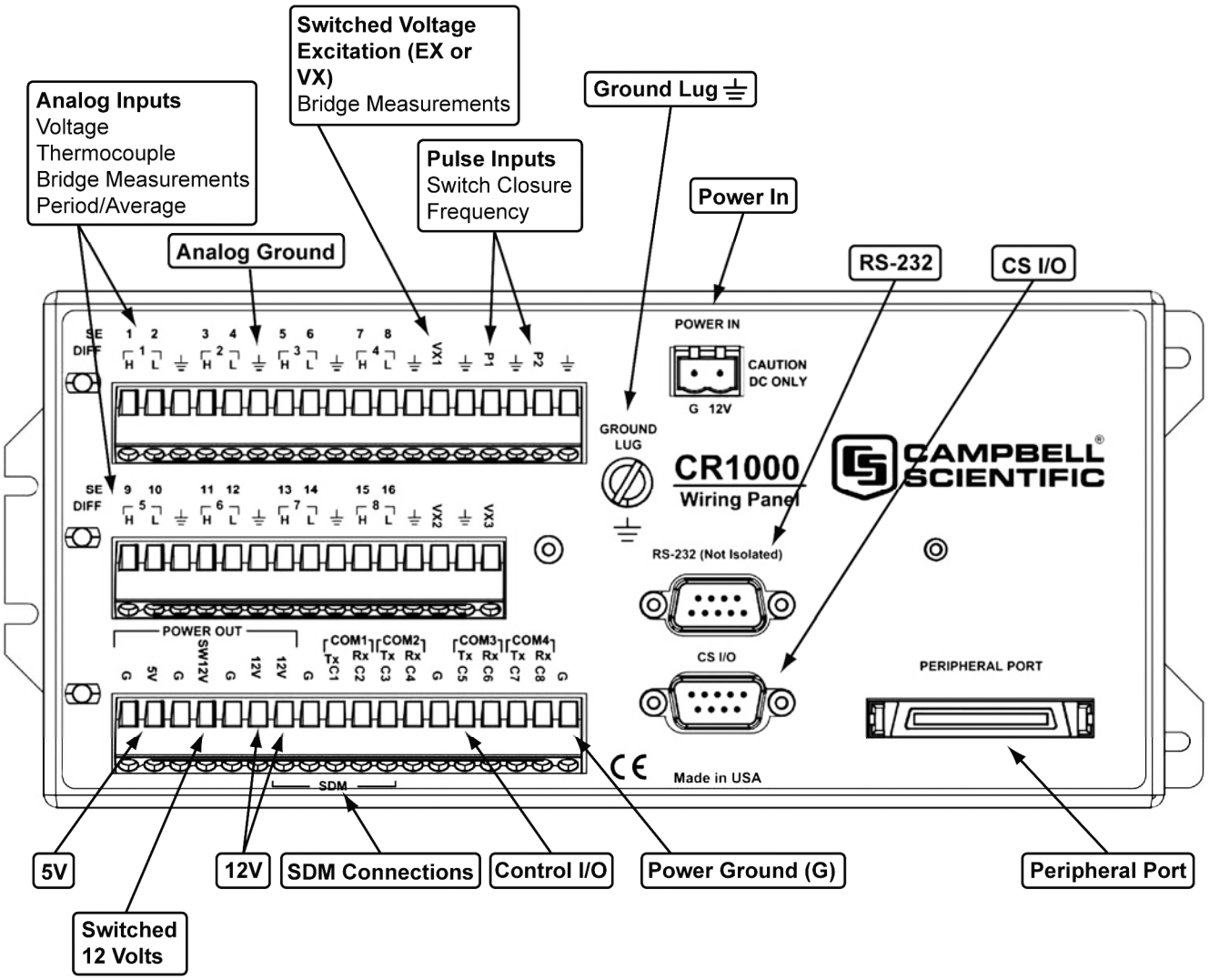


FIGURE 2. Wiring Panel

2.1.2.2 Power Supply

The CR1000 is powered by a nominal 12 Vdc source. Acceptable power range is 9.6 to 16 Vdc.

External power connects through the green "POWER IN" on the face of the CR1000. The "POWER IN" connection is internally reverse polarity protected.

2.1.2.3 Backup Battery

A lithium battery backs up the CR1000 clock, program, and memory in case of power loss. See *SECTION. Internal Battery* (p. 41)

2.1.3 Sensors

Most electronic sensors, whether or not manufactured or sold by Campbell Scientific, can be interfaced to the CR1000. Check for on-line content concerning interfacing sensors at *www.campbellsci.com*, or contact a Campbell Scientific applications engineer for assistance.

2.1.3.1 Analog Sensors

Analog sensors output continuous voltages that vary with the phenomena measured. Analog sensors connect to analog terminals. Analog terminals are configured as single-ended, wherein sensor outputs are measured with respect to ground (*FIGURE. Analog Sensor Wired to Single-Ended Channel #1* (p. 6)) or configured as differential, wherein high sensor outputs are measured with respect to the low output (*FIGURE. Analog Sensor Wired to Differential Channel #1* (p. 6)). *TABLE. Single-ended and Differential Input Channels* (p. 6) lists channel assignments.

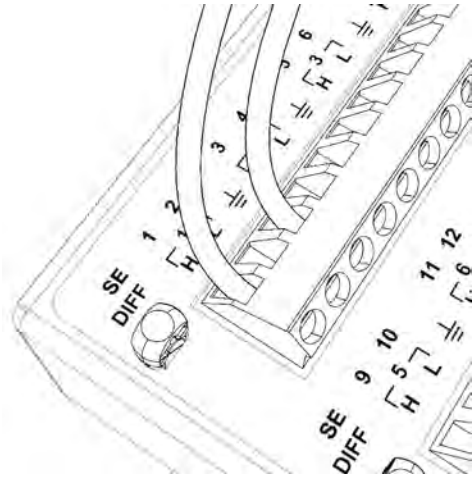


FIGURE 3. Analog Sensor Wired to Single-Ended Channel #1

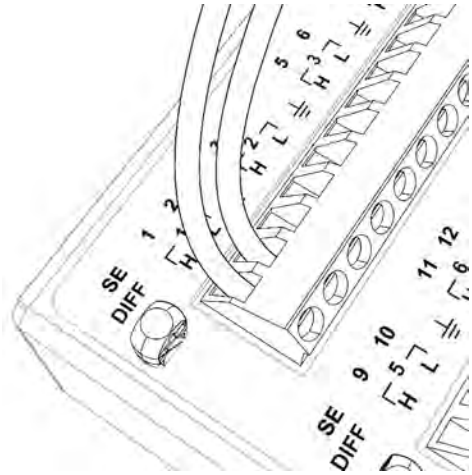


FIGURE 4. Analog Sensor Wired to Differential Channel #1

TABLE 1. Single-ended and Differential Input Channels	
Differential Channel	***Single-Ended Channel***
1H	1
1L	2
2H	3
2L	4
3H	5
3L	6
4H	7
4L	8
5H	9
5L	10
6H	11
6L	12
7H	13
7L	14
8H	15
8L	16

2.1.3.2 Bridge Sensors

Many sensors use a resistive bridge to measure phenomena. Pressure sensors and position sensors commonly use a resistive bridge. For example, a specific resistance in a pressure transducer strain gage correlates to a specific water pressure. A change in resistance in a wind vane potentiometer correlates to a change in wind direction.

2.1.3.2.1 Voltage Excitation

Bridge resistance can be determined by measuring the difference between a known voltage applied to a bridge and the measured return voltage. The CR1000 supplies a precise scalable voltage excitation via excitation terminals. Return voltage is measured on analog terminals. Examples of bridge sensor wiring using voltage excitation are illustrated in *FIGURE. Half Bridge Wiring -- Wind Vane Potentiometer* (p. 8) and *FIGURE. Full Bridge Wiring -- Pressure Transducer* (p. 8).

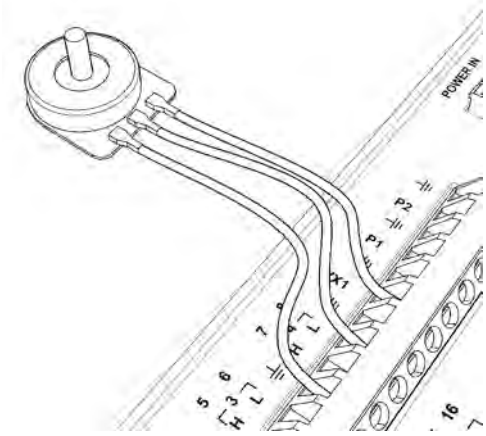


FIGURE 5. Half Bridge Wiring -- Wind Vane Potentiometer

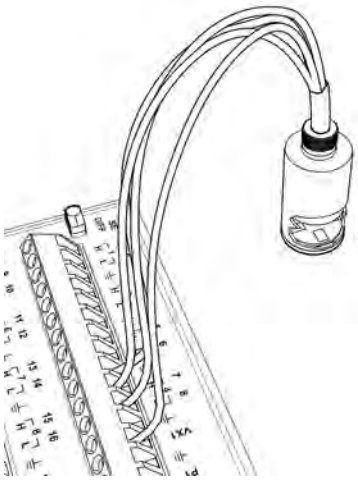


FIGURE 6. Full Bridge Wiring -- Pressure Transducer

2.1.3.3 Pulse Sensors

Pulse sensors are measured on CR1000 pulse measurement channels. The output signal generated by a pulse sensor is a series of voltage waves. The sensor couples its output signal to the measured phenomenon by modulating wave frequency. The CR1000 detects each wave as the wave transitions between voltage extremes (high to low or low to high). This is termed "state transition". Measurements are processed and presented as counts, frequency, or timing data.

Note Period averaging sensors, while technically frequency output sensors, are typically connected to single-ended analog channels and measured with the PeriodAverage() instruction.

2.1.3.3.1 Pulses Measured

FIGURE. Pulse Sensor Output Signal Types (p. 9) illustrates three pulse sensor output signal types.

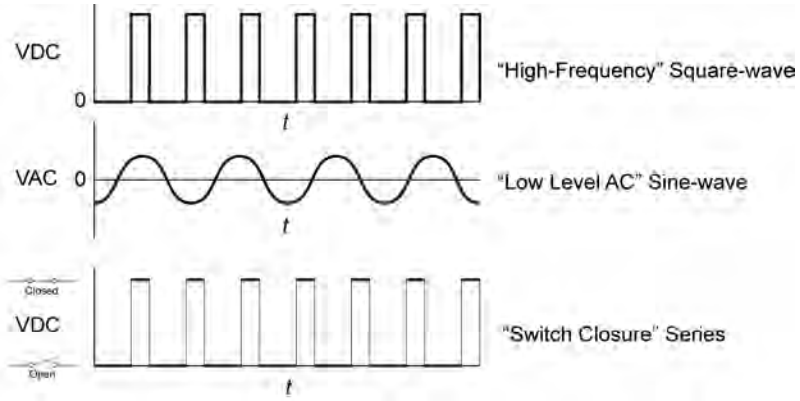


FIGURE 7. Pulse Sensor Output Signal Types

2.1.3.3.2 Pulse Input Channels

TABLE. Pulse Input Channels and Measurements (p. 9) lists devices, channels and options for measuring pulse signals.

TABLE 2. Pulse Input Channels and Measurements

Channels Available for Pulse Input	*Input Types*	*Data Option*	*CRBASIC Instruction*
P1, P2	High Frequency Low-Level ac Switch Closure	Counts Frequency Run Avg of Freq	PulseCount ()
C1, C2, C3, C4, C5, C6, C7, C8	High Frequency Switch Closure Low-Level ac (with LLAC4 Low-Level AC Conversion Module)	Counts Frequency Run Avg of Freq Interval Period State	PulseCount () TimerIO ()

2.1.3.3.3 Pulse Sensor Wiring

Wiring a pulse sensor to a CR1000 is straight forward, as shown in *FIGURE. Pulse Input Wiring -- Anemometer Switch* (p. 10). Pulse sensors have two active wires, one of which is always ground. Connect the ground wire to a ⏚ channel. Connect the other wire to a pulse channel. Sometimes the sensor will require power from the CR1000, so there will be two more wires – one of which

is always ground. Connect power ground to a G channel. Do not confuse the pulse wire with the positive power wire, or damage to the sensor or CR1000 may result. Some switch closure sensors may require a pull-up resistor. Consult *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86) for information on use of pull-up resistors.

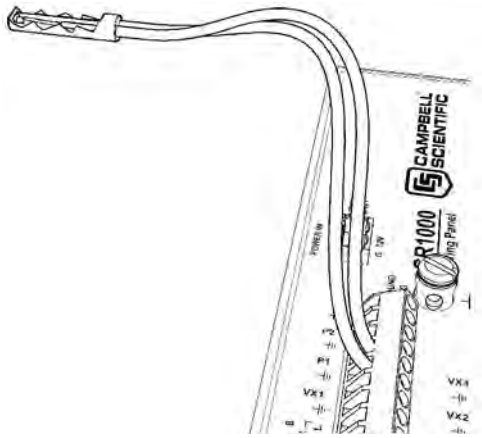


FIGURE 8. Pulse Input Wiring -- Anemometer Switch

2.1.3.4 RS-232 Sensors

The CR1000 has 6 ports available for RS-232 input as shown in *FIGURE. Location of RS-232 Ports* (p. 10). As indicated in *FIGURE. Use of RS-232 and Digital I/O when Reading RS-232 Devices* (p. 10), RS-232 sensors can be connected to the RS-232 port or to digital I/O port pairs. Ports can be set up with various baud rates, parity options, stop bit options, and so forth as defined in CRBASIC Help.

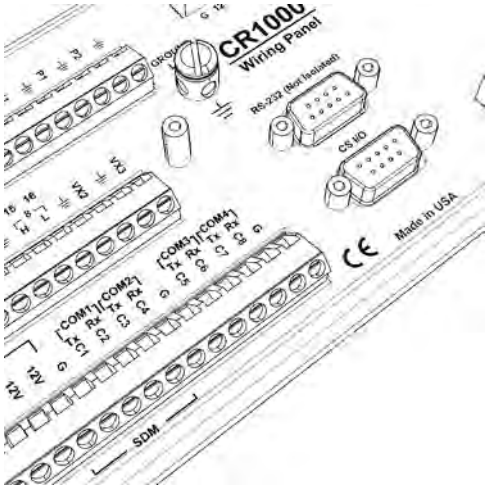


FIGURE 9. Location of RS-232 Ports

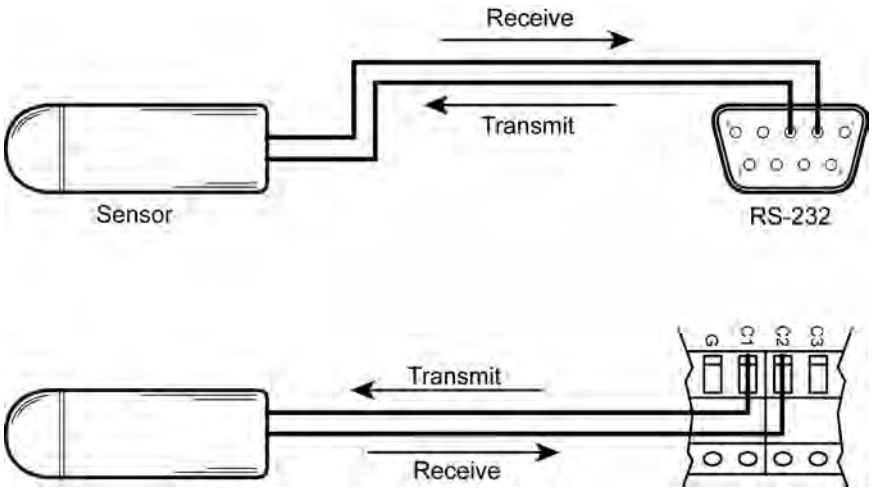


FIGURE 10. Use of RS-232 and Digital I/O when Reading RS-232 Devices

2.1.4 Digital I/O Ports

The CR1000 has 8 digital I/O ports selectable as binary inputs or control outputs. These are multi-function ports. Edge timing, switch closure, and high frequency pulse functions are introduced in *SECTION. Pulse Sensors* (p. 8) and discussed at length in *SECTION. Pulse Measurements* (p. 81). Other functions include device driven interrupts, asynchronous communications and SDI-12 communications. *FIGURE. Control and Monitoring with Digital I/O* (p. 12), illustrates a simple application wherein digital I/O ports are used to control a device and monitor the state (whether on or off) of the device.

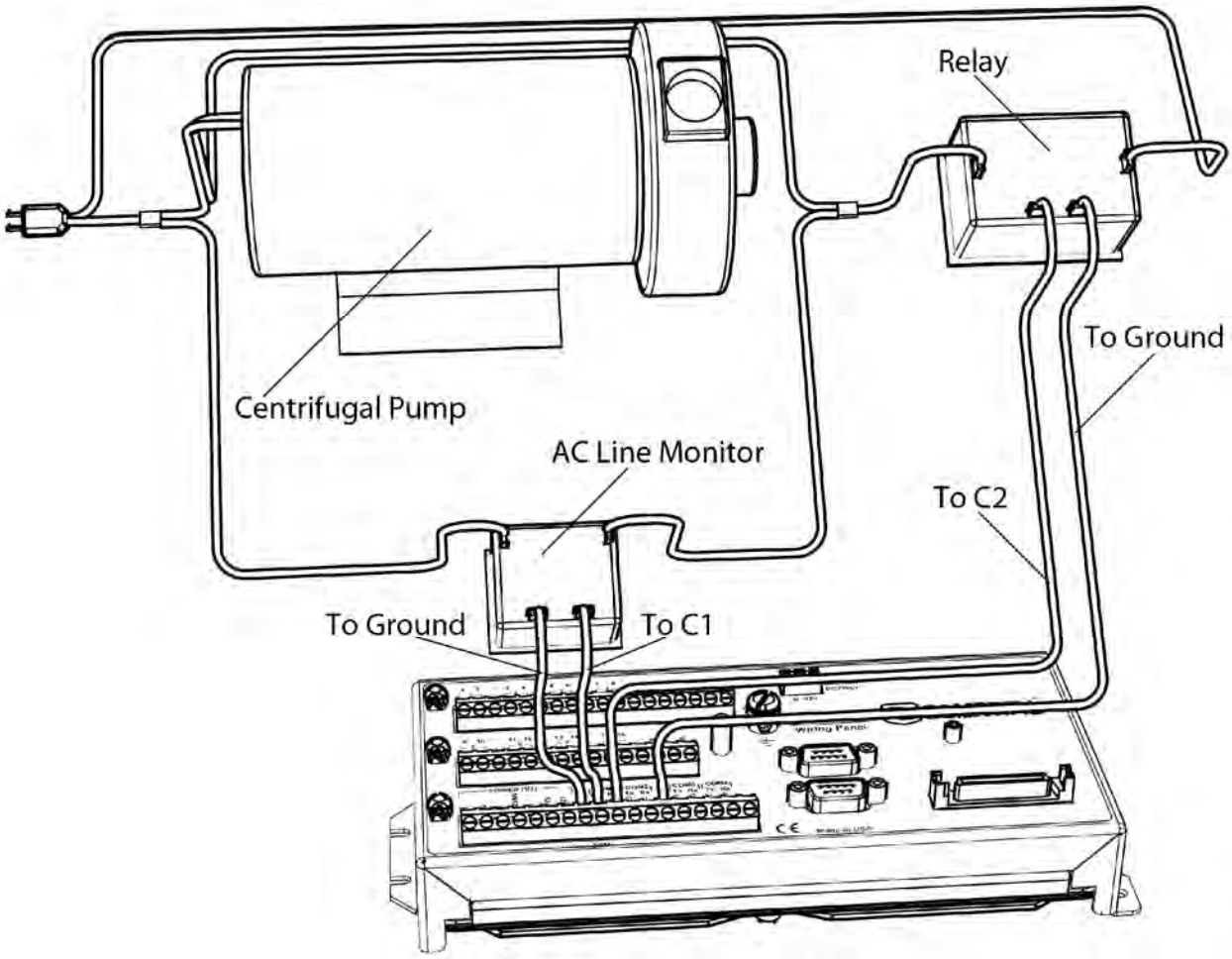


FIGURE 11. Control and Monitoring with Digital I/O

2.1.4.1 SDM Channels

SDM devices and a brief description of the their uses can be found in *APPENDIX. Sensors and Peripherals* (p. 495).

Digital I/O ports C1, C2 and C3 are used for SDM (Serial Device for Measurement) communications.

2.1.5 Input Expansion Modules

Modules are available from Campbell Scientific to expand the number of input and digital I/O ports on the CR1000. *APPENDIX. Digital I/O Expansion* (p. 498) lists available modules.

2.2 Exercise - Measuring a Thermocouple

This tutorial is designed to illustrate the function of the CR1000. During the exercise, the following items will be described.

- Attaching a thermocouple to analog differential terminals
- Creating a program for the CR1000
- Making a simple thermocouple measurement
- Sending data from the CR1000 to a PC
- Viewing the data from the CR1000

2.2.1 What You Will Need

The following items are needed to complete this exercise.

- Campbell Scientific CR1000 datalogger
- Campbell Scientific PS100 12 Vdc power supply (or other compatible power supply) with RED and BLACK wire leads.
- Thermocouple (included with the CR1000)
- Personal Computer (PC) with an available RS-232 serial port. A USB to RS-232 cable may be used if an RS-232 port is not available.
- RS-232 cable (included with the CR1000).

Note If the PC is to be connected to the RS-232 port for an extended period, use Campbell Scientific's SC32B interface to provide optical isolation. This protects low level analog measurements from outside interference.

- PC200W software. This software is available on the Campbell Scientific Resource CD or at www.campbellsci.com.

2.2.2 Hardware Set-Up

Note The thermocouple is attached to the CR1000 later

2.2.2.1 External Power Supply

With reference to *FIGURE. Power and RS-232 Connections* (p. 14),

1. Remove the green power connector from the CR1000.
2. Verify the RED wire on the PS100 is attached to a PS100 12V terminal, and the BLACK wire is attached to a PS100 G terminal.

3. Verify the On/Off switch on the PS100 is in the Off position.

4. Attach the RED wire from the PS100 to the terminal labeled 12V on the green connector.

5. Attach the BLACK wire from the PS100 to the terminal labeled G on the green connector.

6. After confirming the correct polarity on the wire connections, insert the green power connector into its receptacle on the CR1000.

7. Connect the RS-232 cable between the RS-232 port on the CR1000 and the RS-232 port on the PC (or to the USB to RS-232 cable).

8. Move the On/Off switch on the PS100 to the On position.

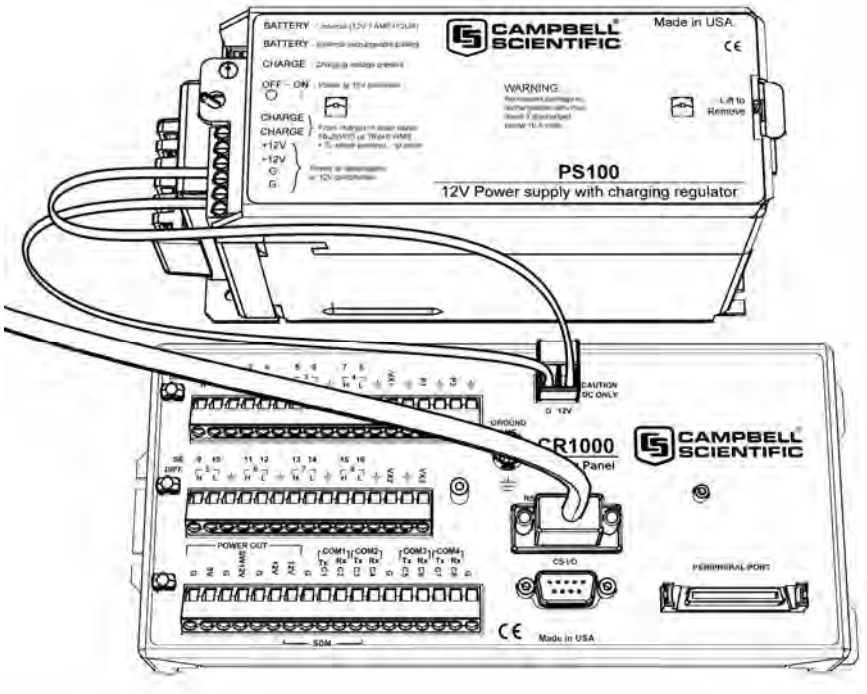


FIGURE 12. Power and RS-232 Connections

2.2.3 PC200W Software Setup

1. Install the PC200W software onto a PC. Follow the on-screen prompts during the installation process for the Program Folder and Destination Location.

2. Open the PC200W software (*FIGURE. PC200W Main Window* (p. 15)). When the software is first run, the EZSetup Wizard will be run automatically in a new window. This will configure the software to communicate with the CR1000. *TABLE. PC200W EZSetup Wizard Example Selections* (p. 15) indicates what information needs to be entered

on each screen. Click on Next at the bottom of the screen to advance to the next screen.

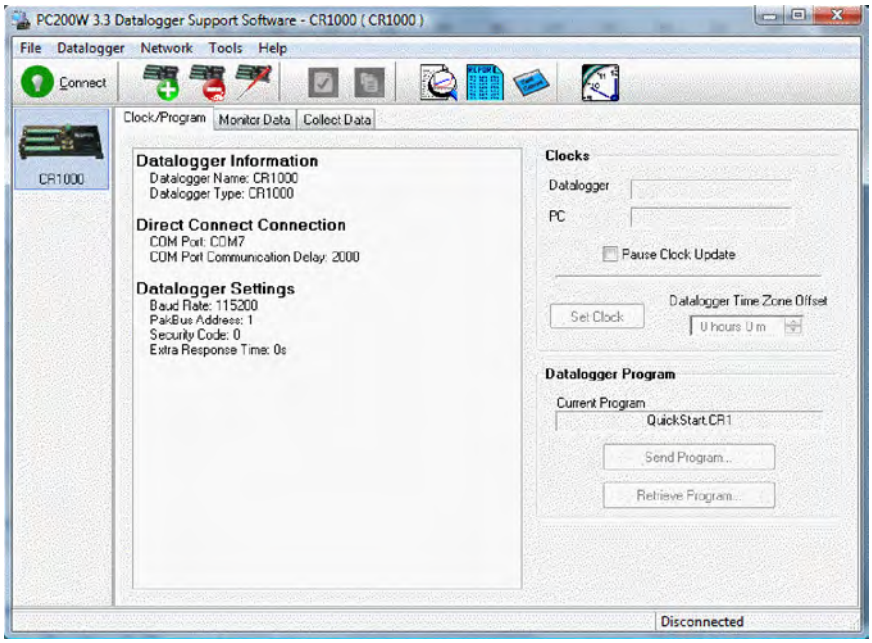


FIGURE 13. PC200W Main Window

TABLE 3. PC200W EZSetup Wizard Example Selections.	
Start the wizard to follow table entries	
Screen Name	***Information Needed***
Introduction	Provides and introduction to the EZSetup Wizard along with instructions on how to navigate through the wizard.
Datalogger Type and Name	Select the CR1000 from the scroll window. Accept the default name of "CR1000."
COM Port Selection	Select the correct COM port for RS-232 connection. Typically, this will be COM1. Other COM numbers are possible, especially when using a USB to serial cable. Leave the COM Port Communication Delay at "00 seconds." Note: When using a USB to serial cable, the COM number may change if the cable is moved to a different USB port. This will prevent data transfer between the software and CR1000. Should this occur, simply move the USB cable back to the original port. If this is not possible, it will be necessary to close the PC200W software and open it a second time to refresh the available COM ports. Click on "Edit Datalogger Setup" and change the COM port to the new port number.
Datalogger Settings	Used to configure how the CR1000 communicates through the COM port. For this tutorial, accept the default settings.

TABLE 3. PC200W EZSetup Wizard Example Selections.	
Start the wizard to follow table entries	
Screen Name	***Information Needed***
Communication Setup Summary	Provides a summary of the settings made in previous screens.
Communications Test	A communications test between the CR1000 and PC can be performed in this screen. For this tutorial, the test is not required. Press Finish to exit the Wizard.

After exiting the wizard, the main PC200W window becomes visible. The window has several tabs available. By Default, the Clock/Program tab is visible. This tab displays information on the currently selected datalogger along with clock and program functions. The Monitor Data or Collect Data tabs may be selected at any time.

A number of icons are available across the top of the window. These access additional functions available to the user.

2.2.4 Write Program with Short Cut

Short Cut Programming Objectives:

This portion of the tutorial will use Short Cut to create a program that measures the CR1000 power supply voltage, wiring panel temperature, and ambient air temperature. The CR1000 will take samples once per second and store averages of these values at one minute intervals.

2.2.4.1 Procedure: (Short Cut Steps 1-6)

1. Click on the Short Cut icon in the upper-right corner of the PC200W window. The icon resembles a clock face.

2. A new window will appear showing the option to create a new program or open an existing program. Select **New Program**.

3. A drop-down list will appear showing different dataloggers. Select the CR1000.

4. The program will now ask for the scan interval. Set the interval to 1 second and click on okay.

Note The first time Short Cut is run, a prompt will appear asking for a choice of "ac Noise Rejection." Select "60 Hz" for the United States and other countries using 60 Hz ac voltage. Select "50 Hz" for Europe and other countries operating on 50 Hz ac voltage.

5. A second prompt will ask for a choice of "Sensor Support." Select "Campbell Scientific, Inc."

6. Under Available Sensors, expand the "Sensors" folder by clicking on the "+" symbol. This shows several sub-folders. Expand the "Temperature" folder to view the available sensors.

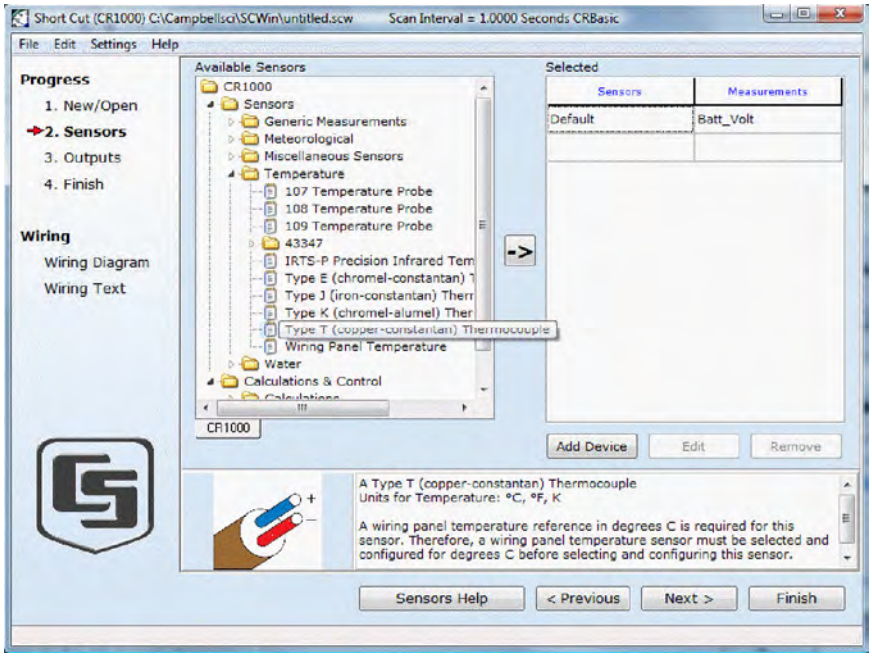


FIGURE 14. Short Cut Temperature Sensor Folder

2.2.4.2 Procedure: (Short Cut Steps 7-9)

7. Double-click the Wiring Panel Temperature sensor to add it to the Selected category. Alternatively, highlight the Wiring Panel Temperature sensor by clicking on it once, and then click on the arrow between Available Sensors and Selected to add it to the Selected sensors.

8. Double-click the Type T Thermocouple to add it to the Selected category. A prompt will appear asking for the number of sensors. Change this value to "1." A second prompt screen will appear. Set the Reference Temperature Measurement to "Ptemp_C," and then click OK to close the prompt.

9. Click on the Wiring Diagram link to view the sensor wiring diagram. Attach the Type T Thermocouple to the CR1000 as shown in the diagram.

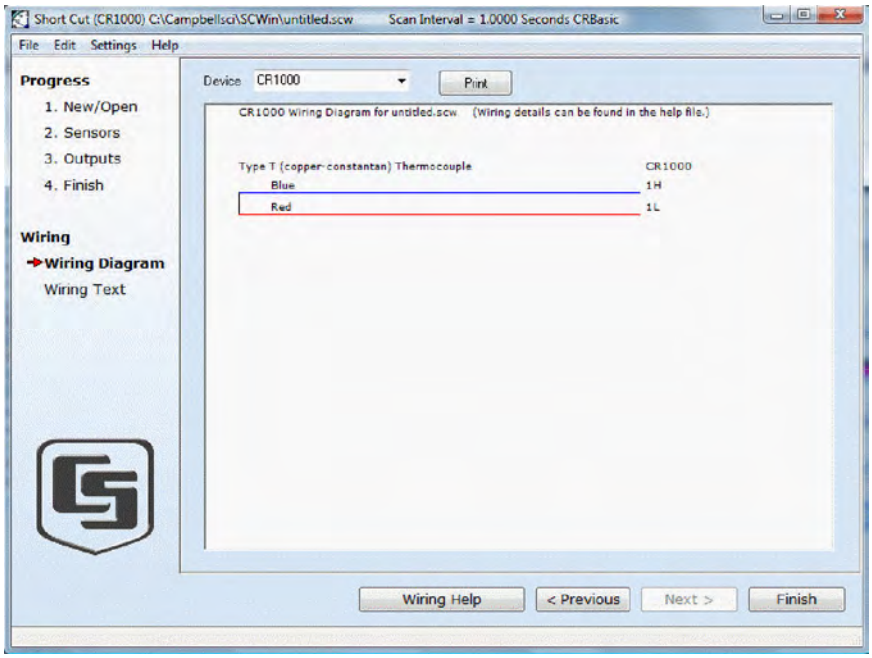


FIGURE 15. Short Cut Thermocouple Wiring

2.2.4.3 Procedure: (Short Cut Steps 10-11)

Historical Note In the space race era, a field thermocouple measurement was a complicated and cumbersome process incorporating a thermocouple wire with three junctions, a micro-voltmeter, a vacuum flask filled with an ice slurry, and a thick reference book. One thermocouple junction was connected to the micro-voltmeter. Another sat in the vacuum flask. The third was inserted into the location of the temperature of interest. When the temperature settled out, the micro-voltmeter was read. This value was then looked up on the appropriate table in the reference book to determine the temperature.

Then along came Eric and Evan Campbell. Campbell Scientific designed the first CR7 datalogger to make thermocouple measurements without the need of vacuum flasks, third junctions, or reference books. Now, there's an idea!

Nowadays, a thermocouple consists of two wires of dissimilar metals, such as copper and constantan, joined at one end. The joined end is the measurement junction; the junction that is created when the thermocouple is wired to the CR1000 is the reference junction.

When the two junctions are at different temperatures, a voltage proportional to the temperature difference is induced into the wires. The thermocouple measurement requires the reference junction temperature to calculate the measurement junction temperature using proprietary algorithms in the CR1000 operating system.

10. Click on Outputs to advance to the next step.

11. The Outputs window displays a list of selected sensors on the left, and data storage Tables on the right.

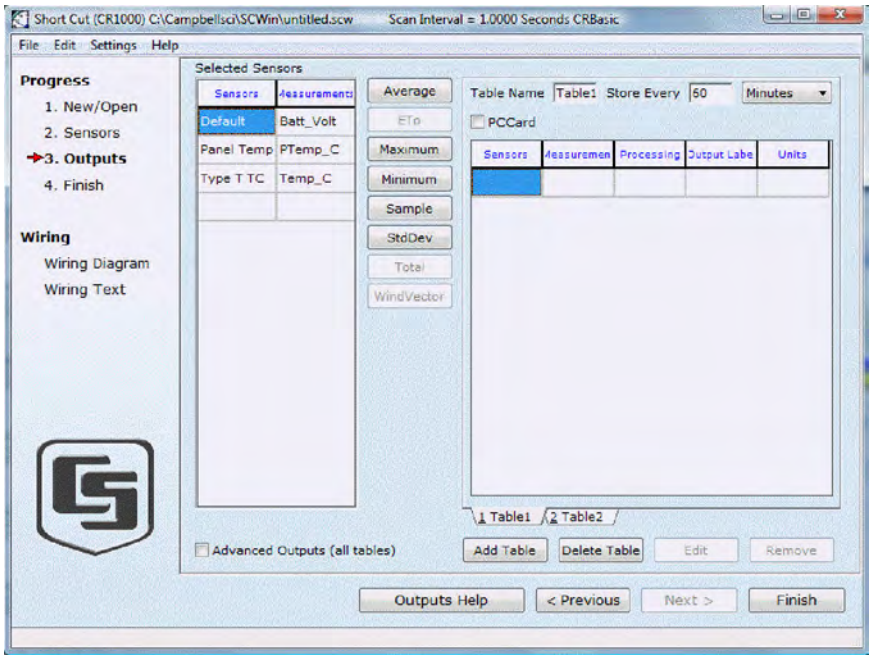


FIGURE 16. Short Cut Outputs Tab

2.2.4.4 Procedure: (Short Cut Steps 12-16)

12. By default, there are two Tables initially available. Both Tables have a Store Every field along with a drop-down box to select the time units. These are used to set the time interval when data is stored.

13. Only one Table is needed for this tutorial, so Table 2 can be removed. Select Table 2 by clicking on its tab, and then click on Delete Table.

14. Change the Table Name to OneMin, and then change the interval to 1 minute (Store Every 1 Minutes).

15. Adding a measurement to the table is done by selecting the measurement under Selected Sensors, and then clicking on one of the processing buttons in the center of the window.

16. Apply the Average function to the Batt_Volt, PTemp_C, and Temp_C measurements.

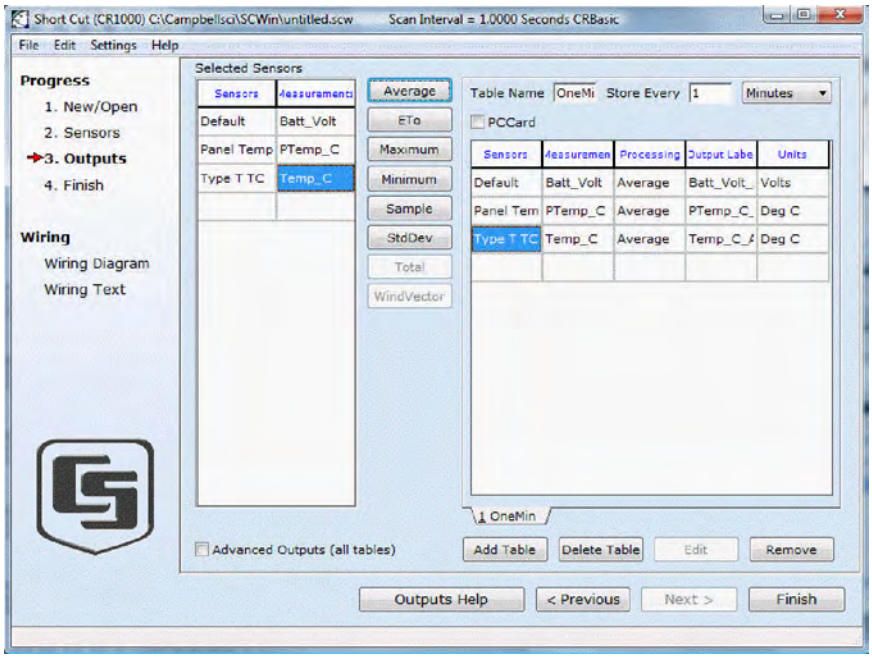


FIGURE 17. Short Cut Output Table Definition

2.2.4.5 Procedure: (Short Cut Steps 17-18)

17. Click on **Finish** to compile the program. Give the program the name "QuickStart." A summary screen will appear showing the compiler results. Any errors during compiling will also be displayed.

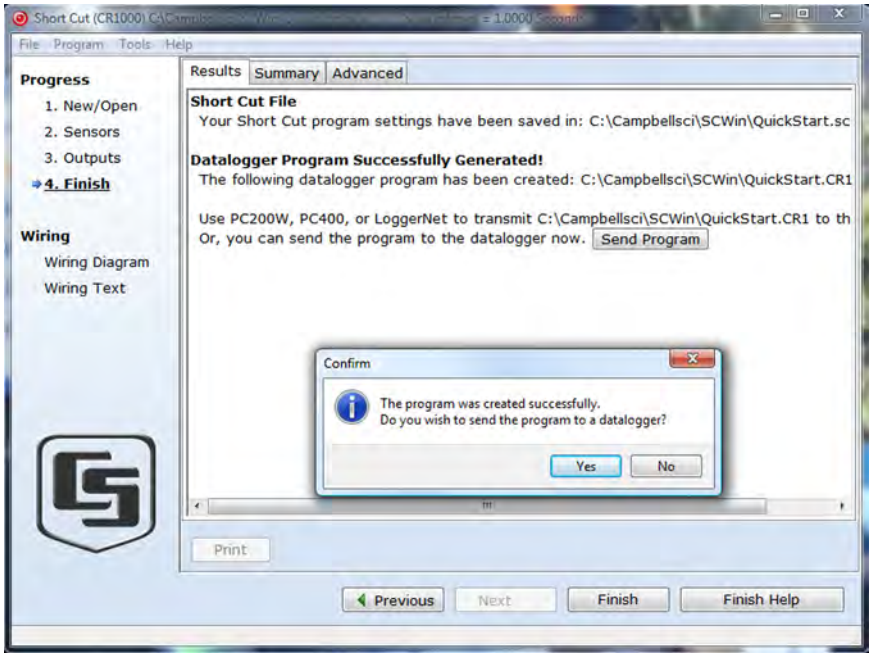


FIGURE 18. Short Cut Compile Confirmation

18. Close this window by clicking on the "X" in the upper right corner.

2.2.5 Send Program and Collect Data with PC200W

PC200W Support Software Objectives:

This portion of the tutorial will use PC200W to send the program to the CR1000, collect data from the CR1000, and store the data to the PC

2.2.5.1 Procedure: (PC200W Step 1)

1. From the PC200W Clock/Program tab, click on the *Connect* button to establish communications with the CR1000. When communications have been established, the text on the button will change to Disconnect.

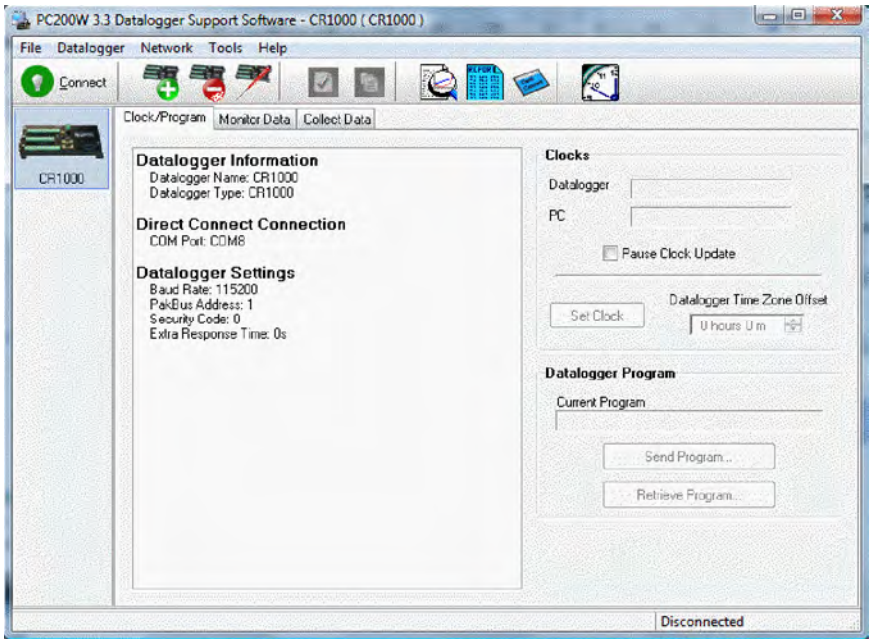


FIGURE 19. PC200W Connect Button

2.2.5.2 Procedure: (PC200W Steps 2-4)

2. Click the Set Clock button to synchronize the datalogger's clock with the computer's clock.

3. Click on the Send Program button. A window will appear warning that data on the datalogger will be erased. Answer "yes" to the prompt. Another window will open. Browse to the C:\CampbellSci\SCWin folder, select the QuickStart.CR1 file, and then click the Open button. A status bar will appear while the program is sent to the CR1000 followed by a confirmation that the transfer was successful. Click OK to close this window.

4. After sending a program to the CR1000, a good practice is to monitor the measurements to ensure they are reasonable. Select the Monitor Data tab. The window now displays data found in the Public Table coming from the CR1000. To view the OneMin table, select an empty cell in the display area, and then click on the Add button.

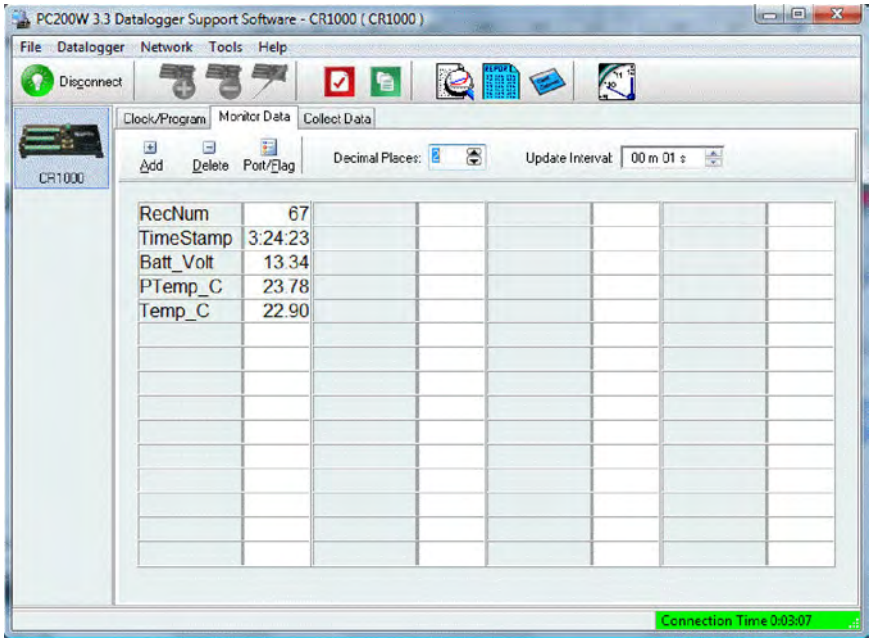


FIGURE 20. PC200W Monitor Data Tab - Public Table

2.2.5.3 Procedure: (PC200W Step 5)

5. In the Add Selection window, click on the OneMin table, and then click Paste. The OneMin table is now displayed in the main display.

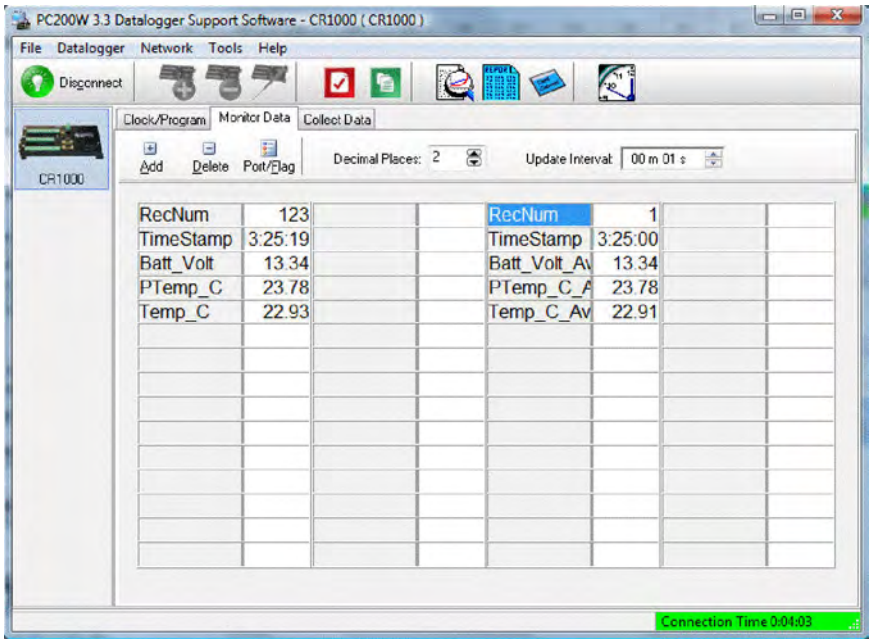


FIGURE 21. PC200W Monitor Data Tab - Public and OneMin Tables

2.2.5.4 Procedure: (PC200W Step 6)

6. Click on the Collect Data tab. From this window, data is chosen to be collected as well as the location where the collected data will be stored.

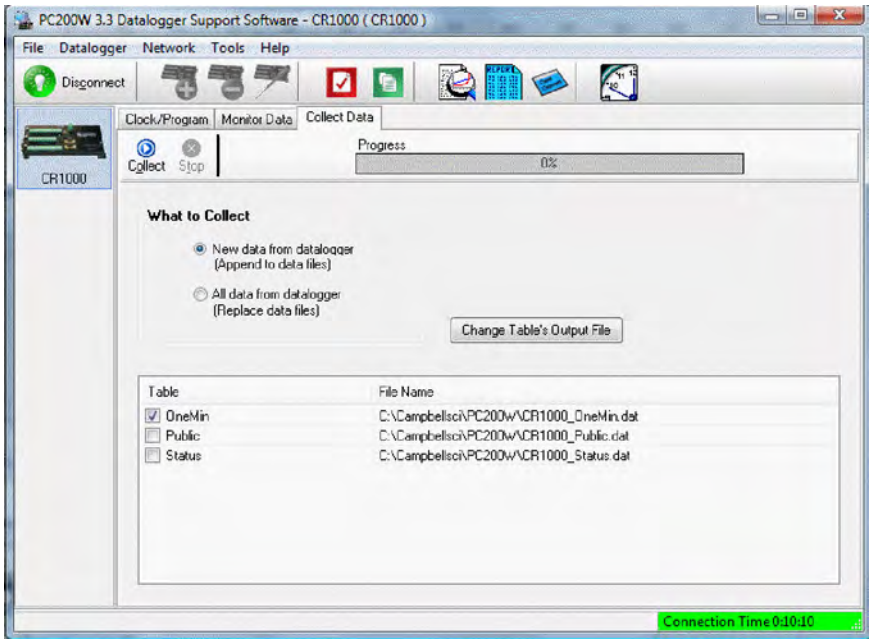


FIGURE 22. PC200W Collect Data Tab

2.2.5.5 Procedure: (PC200W Steps 7-9)

7. Click the OneMin box so a check mark appears in the box. Under the "What to Collect" heading, select "New data from datalogger." This selects which data will be collected.

8. Click on the Collect button. A requester box will appear, prompting for a filename. Click on Save to accept the default filename of "CR1000_OneMin.dat." A progress bar will appear as the data is collected, followed by the message, "Collection Complete." Click OK to continue.

9. To view the data, click on the View icon at the top of the window. This opens a new window.

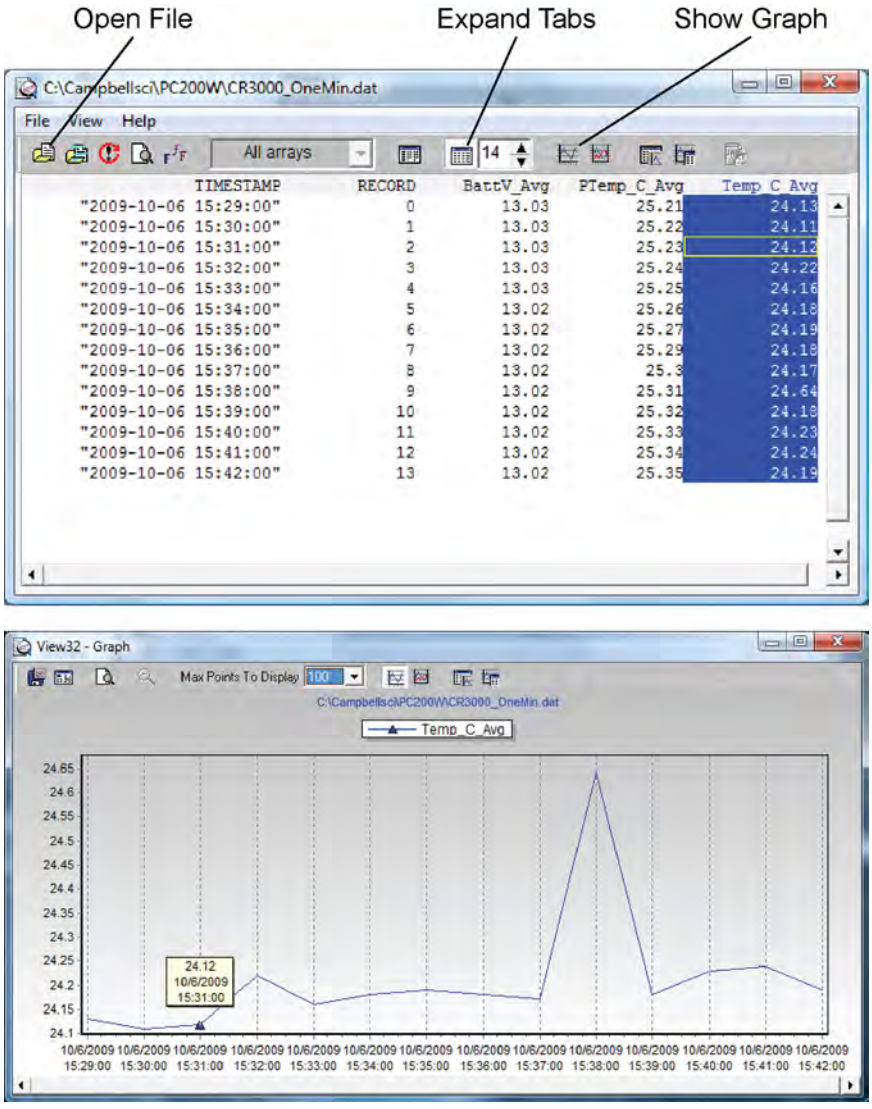


FIGURE 23. PC200W View Data Utility

2.2.5.6 Procedure: (PC200W Steps 10-11)

10. Click on the Open File icon to open a file for viewing. Select the "CR1000_OneMin.dat" file and click on Open. The collected data is now shown.

11. Click on Expand Tabs to display the data in columns with column headings.

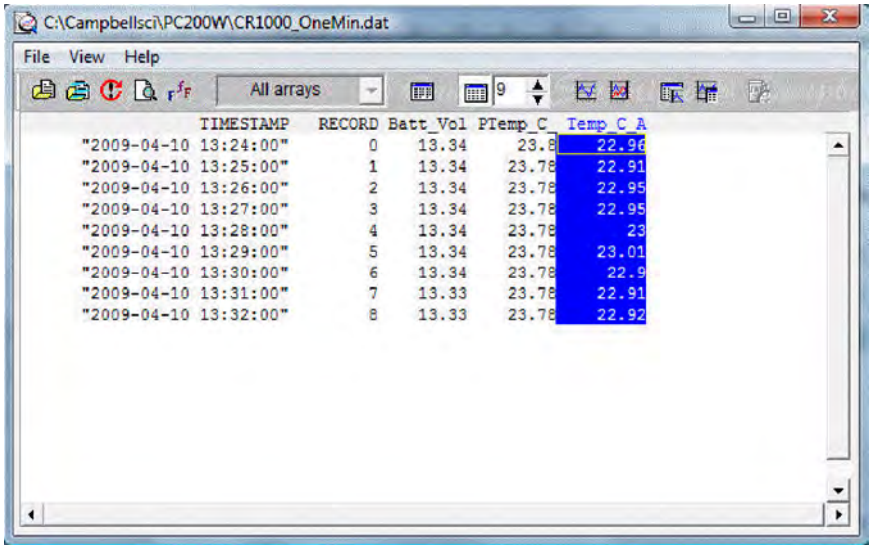


FIGURE 24. PC200W View Data Table

2.2.5.7 Procedure: (PC200W Steps 12-13)

12. Select any data column by clicking on it. To display the data in graphical form, click on one of the Show Graph buttons. A graph with one Y-axis or two Y-axes will be generated.

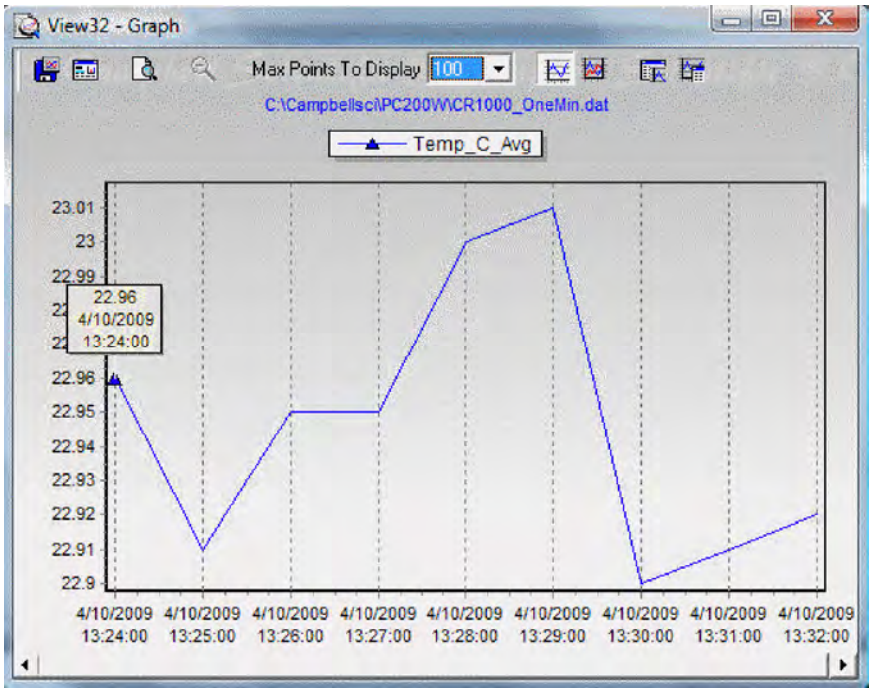


FIGURE 25. PC200W View Data Graph

13. Close the Graph and View windows, and then close the PC200W program.

Section 3. System Overview

A data acquisition system consists of hardware, user entered programs, and datalogger support software. *FIGURE. Features of a Data Acquisition System* (p. 27) illustrates a common CR1000-based data acquisition system.

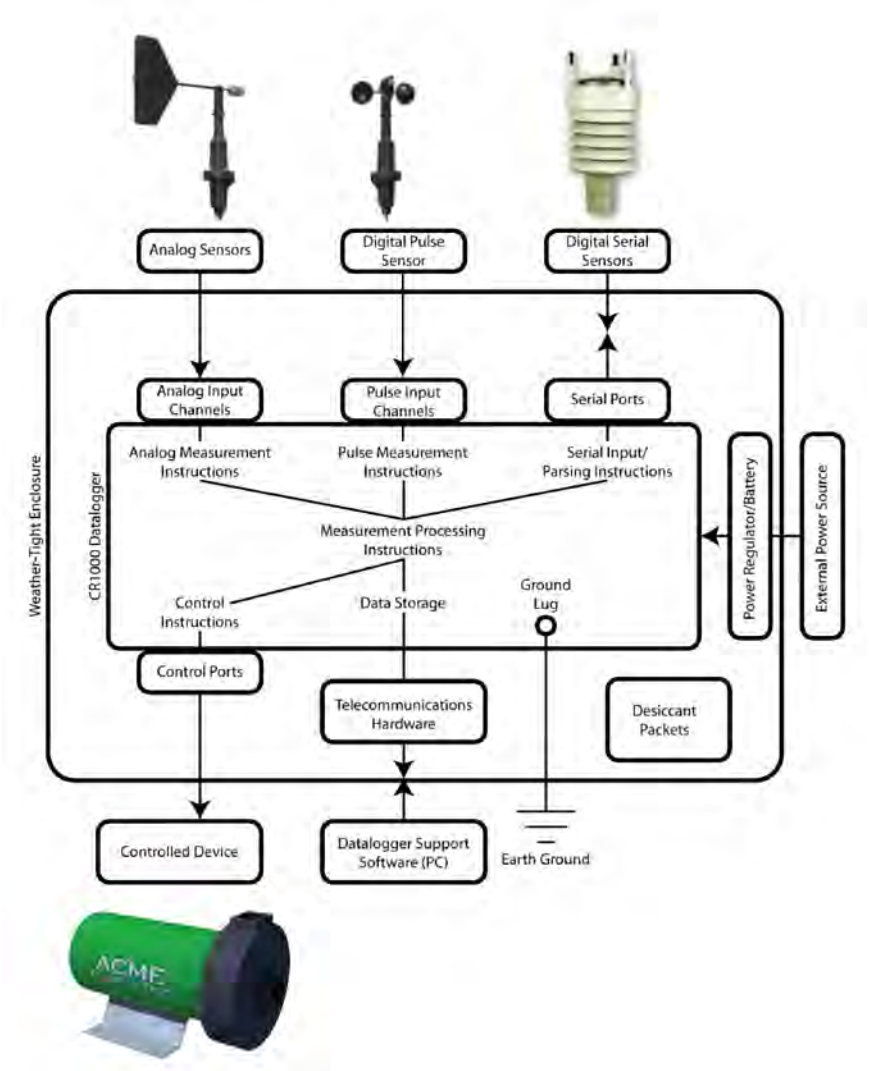


FIGURE 26. Features of a Data Acquisition System

3.1 CR1000 Datalogger

The CR1000 Datalogger is a precision instrument designed for demanding low-power measurement applications. CPU, analog and digital inputs, analog and digital outputs, and memory are controlled by the operating system in conjunction with the user program. The user program is written in CRBASIC, a

programming language that includes data processing and analysis routines and a standard BASIC instruction set. Campbell Scientific's datalogger support software facilitates program generation, editing, data retrieval, and real-time data monitoring (see *SECTION. Support Software* (p. 395)).

The CR1000 is a multimeter with memory and timekeeping. It is one part of a data acquisition system. To acquire quality data, suitable sensors and reliable telecommunications devices are also required.

Sensors transduce phenomena into measurable electrical forms, outputting voltage, current, resistance, pulses, or state changes. The CR1000, sometimes with the assistance of various peripheral devices, can measure nearly all electronic sensors.

The CR1000 measures analog voltage and pulse signals, representing the magnitudes numerically. Numeric values are scaled to the unit of measure such as milliVolts and pulses, or in user specified engineering units such as wind direction and wind speed. Measurements can be processed through calculations or statistical operations and stored in memory awaiting transfer to a PC via external storage or telecommunications.

The CR1000 has the option of evaluating programmed instructions sequentially, or in pipeline mode, wherein the CR1000 decides the order of instruction execution.

3.1.1 Sensor Support

Read More! See *SECTION. Sensor Support* (p. 43).

The following sensor types are supported by the CR1000 datalogger. Refer to *APPENDIX. Sensors* (p. 495) for information on sensors available from Campbell Scientific.

- Analog voltage
- Analog current (with a shunt resistor)
- Thermocouples
- Resistive bridges
- Pulse output
- Period output
- Frequency output
- Serial smart sensors
- SDI-12 sensors

A library of sensor manuals and application notes are available at *www.campbellsci.com* to assist in measuring many sensor types. Consult with a Campbell Scientific applications engineer for assistance in measuring unfamiliar sensors.

3.1.2 CR1000 Wiring Panel

The wiring panel of the CR1000 is the interface to all CR1000 functions. Most CR1000 functions are best introduced by reviewing features of the CR1000 wiring panel. *FIGURE. CR1000 Wiring Panel* (p. 5) illustrates the wiring panel and some CR1000 functions accessed through it.

Read More! Expansion accessories increase the input / output capabilities of the wiring panel. Read *SECTION. Measurement and Control Peripherals* (p. 95) for more information.

3.1.2.1 Measurement Inputs

Measurements require a physical connection with a sensor at an input channel and CRBASIC programming to instruct the CR1000 how to make, process, and store the measurement. The CR1000 wiring panel has the following input channels:

Analog Voltage: 16 channels (Diff 1 - 8 / SE 1 - 16) configurable as 8 differential or 16 single-ended inputs.

- Input voltage range: -5000 mV to +5000 mV.
- Measurement resolution: 0.67 µV to 1333 µV

Period Average: 16 channels (SE 1 -16)

- Input voltage range: -2500 mV to +2500 mV.
- Maximum frequency: 200 kHz
- Resolution: 136 ns

Note Both pulse count and period average measurements are used to measure frequency output sensors. Yet pulse count and period average measurement methods are different. Pulse count measurements use dedicated hardware -- pulse count accumulators, which are always monitoring the input signal, even when the CR1000 is between program scans. In contrast, period average measurement instructions only monitor the input signal during a program scan. Consequently, pulse count scans can usually be much less frequent than period average scans. Pulse counters may be more susceptible to low frequency noise because they are always "listening", whereas period averaging may filter the noise by reason of being "asleep" most of the time. Pulse count measurements are not appropriate for sensors that are powered off between scans, whereas period average measurements work well since they can be placed in the scan to execute only when the sensor is powered and transmitting a correct signal.

Period average measurements utilize a high-frequency digital clock to measure time differences between signal transitions, whereas pulse count measurements simply accumulate the number of counts. As a result, period average measurements offer much better frequency resolution per measurement interval, as compared to pulse count measurements. The frequency resolution of pulse count measurements can be improved by extending the measurement interval by increasing the scan interval and by averaging.

Pulse: 2 channels (P1 - P2) configurable for counts or frequency of the following signal types:

- High level 5V square waves
- Switch closures
- Low-level A/C sine waves

Digital I/O: 8 channels (C1 - C8) configurable for serial input, SDM, SDI-12, state, frequency, pulses, edge counting and edge timing.

- C1 - C8: state, frequency, pulse, edge counting and edge timing measurements.
- Edge Timing Resolution: 540 ns
- C1, C2 and C3: Synchronous Devices for Measurement (SDM) input / output.
- C1, C3, C5, C7: SDI-12 input / output.
- C1 & C2, C3 & C4, C5 & C6, C7 & C8: serial communication input / output.

9-Pin RS-232: 1 port (Computer RS-232) configurable for serial input.

Refer to *APPENDIX. Digital I/O Expansion* (p. 498), *APPENDIX. Pulse / Frequency Input Expansion Modules* (p. 498), and *APPENDIX. Serial Input / Output Peripherals* (p. 499) for information on available input expansion modules.

3.1.2.2 Voltage Outputs

The CR1000 has several terminals capable of supplying switched voltage and current to peripherals, sensors, or control devices.

Read More! See *SECTION. Control Output* (p. 95).

- **Switched Analog Output (Excitation)**: three channels (VX1 - VX3) for precise voltage excitation ranging from -2500 mV to +2500 mV. These channels are regularly used with resistive bridge measurements. Each channel will source up to 25 mA.
- **Digital I/O**: 8 channels (C1 - C8) configurable for on / off and pulse output duration.
- **Switched 12 Volts dc (SW-12)**: One terminal controls (switch on / off) primary voltage under program control for control of external devices requiring 12 Vdc, such as humidity sensors. SW-12 can source up to 900 mA. See *TABLE. Current Sourcing Limits* (p. 102).
- **Continuous Analog Output**: available by adding a peripheral analog output device available from Campbell Scientific. Refer to *APPENDIX. CAO Modules* (p. 498) for information on available output expansion modules.

3.1.2.3 Grounding Terminals

Read More! See *SECTION. Grounding* (p. 105).

Proper grounding will lend stability and protection to a data acquisition system. It is the easiest and least expensive insurance against data loss-and the most neglected. The following terminals are provided for connection of sensor and datalogger grounding:

- **Signal Grounds**: 12 ground terminals (⏚) used as reference for single-ended analog inputs, pulse inputs, excitation returns, and as a ground for sensor shield wires. Signal returns for pulse inputs should use ⏚ terminals located next to pulse inputs.
- **Power Grounds**: 6 terminals (G) used as returns for 5V, SW-12, 12V, and C1-C8 outputs. Use of G grounds for these outputs minimizes potentially large current flow through the analog voltage measurement section of the wiring panel, which can cause single-ended voltage measurement errors.
- **Ground Lug**: 1 terminal (⏚), the large ground lug is used to connect a heavy gage wire to earth ground. A good earth connection is necessary to secure the ground potential of the datalogger and shunt transients away from electronics. Minimum 14 AWG wire is recommended.

3.1.2.4 Power Terminals

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

Power In

Note: Refer to *APPENDIX. Power Supplies* (p. 495) for information on available power supplies.

- **External Power Supply**: One green plug (POWER IN): for connecting power from an external power source to the CR1000. This is the only terminal used to input power; other 12V terminals and the SW-12 terminal are output only terminals for supplying power to other devices. Review power requirements and power supply options in *SECTION. CR1000 Power Supply* (p. 99) before connecting power.

Power Out

- See *SECTION. Powering Sensors* (p. 100)
- **Peripheral 12 Vdc Power Source**: 2 terminals (12V) and associated grounds (G) supply power to sensors and peripheral devices requiring nominal 12 Vdc. This supply may drop as low as 9.6 Vdc before datalogger operation stops. Precautions should be taken to minimize the occurrence of data from underpowered sensors.
- **Peripheral 5 Vdc Power Source**: 1 terminal (5V) and associated ground (G) supply power to sensors and peripheral devices requiring regulated 5 Vdc.

3.1.2.5 Communications Ports

Read More! See *SECTION. RS-232 and TTL Recording* (p. 91), *SECTION. Telecommunications and Data Retrieval* (p. 369) and *SECTION. PakBus Overview* (p. 373).

The CR1000 is equipped with 6 communications ports. Communication ports allow the CR1000 to communicate with other computing devices, such as a PC, or with other Campbell Scientific dataloggers.

Note RS-232 communications normally operate well up to a transmission cable capacitance of 2500 picofarads, or approximately 50 feet of commonly available serial cable.

- **9-pin RS-232**: 1 DCE port for communicating with a PC through the supplied serial cable, serial sensors, or through 3rd party serial telecommunications devices. Acts as a DTE device with a null-modem cable.

Read More! See *APPENDIX. Serial Port Pin Outs* (p. 479).

Note The 9-pin RS-232 port is not electrically isolated. "Isolation" means isolated, by means of optical isolation components, from the communications node at the other end of the connection. Optical isolation prevents some electrical problems such as ground looping, which can cause significant errors in single-ended analog measurements. Campbell Scientific offers a peripheral optically isolated RS-232 to CS I/O interface as a CR1000 accessory. Refer to *APPENDIX. Serial Input / Output Peripherals* (p. 499) for model information.

- **9-pin CS I/O port**: 1 port for communicating through Campbell Scientific telecommunications peripherals. Approved CS I/O telecommunication interfaces are listed in *APPENDIX. Serial Input / Output Peripherals* (p. 499).

- **2-pin RS-232**: 4 ports configurable from Control I/O ports for communication with serial sensors or other Campbell Scientific dataloggers.

- **Peripheral**: 1 port for use with some Campbell Scientific CF memory card modules and IP network link hardware. See *SECTION. Data Table Declarations* (p. 177) for CF card precautions.

3.1.3 Power Requirements

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

The CR1000 operates from a dc power supply with voltage ranging from 9.6 to 16 V, and is internally protected against accidental polarity reversal. The CR1000 has modest input power requirements. In low power applications, it can operate for several months on non-rechargeable batteries. Power systems for

longer-term remote applications typically consist of a charging source, a charge controller, and a rechargeable battery. When ac line power is available, an ac/ac or ac/dc wall adapter, a charge controller, and a rechargeable battery can be used to construct a UPS (uninterruptible power supply). Contact a Campbell Scientific applications engineer for assistance in acquiring the items necessary to construct a UPS.

Applications requiring higher current requirements, such as satellite or cellular phone communications, should be evaluated by means of a power budget with a knowledge of the factors required by a robust power system. Contact a Campbell Scientific applications engineer if assistance is required in evaluating power supply requirements.

Common power devices are:

- Batteries
  - Alkaline D-cell - 1.5 Vdc / cell
  - Rechargeable Lead-Acid battery
- Charge Sources
  - Solar Panels
  - Wind Generators
  - ac/ac or ac/dc wall adapters

Refer to *APPENDIX. Power Supplies* (p. 495) for specific model numbers of approved power supplies.

3.1.4 Programming

The CR1000 is a highly programmable instrument, adaptable to the most demanding measurement and telecommunications requirements.

3.1.4.1 Firmware: OS and Settings

Read More! See *SECTION. CR1000 Configuration* (p. 111).

Firmware consists of the operating system (OS) and durable configuration settings. OS and settings remain intact when power is cycled.

Note The CR1000 is shipped factory ready with all settings and firmware necessary to communicate with a PC via RS-232 and to accept and execute user application programs. OS upgrades are occasionally made available at *www.campbellsci.com*.

For more complex applications, some settings may need adjustment. Adjustments are accomplished with DevConfig Software (*DevConfig* (p. 111)), the optional keyboard display (see *SECTION. Using the Keyboard Display* (p.

395)), or through datalogger support software (see *APPENDIX. Software* (p. 489)).

OS files are sent to the CR1000 with DevConfig or through the program Send button in datalogger support software. When the OS is sent via DevConfig, most settings are cleared, whereas, when sent via datalogger support software, most settings are retained.

OS files can also be sent to the CR1000 with a CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).

Read More! See *SECTION. Programming* (p. 129) and *SECTION. CRBASIC Programming Instructions* (p. 175) and CRBASIC help for more programming assistance.

A CRBASIC program directs the CR1000 how and when sensors are to be measured, calculations made, and data stored. A program is created on a PC and sent to the CR1000. The CR1000 can store a number of programs in memory, but only one program is active at a given time. Three Campbell Scientific software applications, Short Cut, CRBASIC Editor, and Transformer Utility create CR1000 programs.

- Short Cut creates a datalogger program and wiring diagram in four easy steps. It supports most sensors sold by Campbell Scientific and is recommended for creating simple programs to measure sensors and store data.
- Programs generated by Short Cut are easily imported into CRBASIC Editor for additional editing. For complex applications, experienced programmers often create essential measurement and data storage code with Short Cut, then edit the code with CRBASIC Editor. Note that once a Short Cut generated program has been edited with CRBASIC Editor, it can no longer be modified with Short Cut.

3.1.5 Memory and Data Storage

Read More! See *SECTION. Memory and Data Storage* (p. 349).

CR1000 memory size is posted in the Status Table (*APPENDIX. Status Table and Settings* (p. 457)).

The CR1000 stores these data:

- Operating system. Held in up to 2 Mbytes Flash EEPROM.
- Settings. Held in 512 K Flash.
- Programs, system data, and measurement data. Held in 4 Mbytes SRAM.

Note -- Maximum memory allowed for program storage is 490 kbytes.

Programs are stored as files on the automatically partitioned CPU: drive. Photographic images and measurement data files are stored on the USR: drive, which is partitioned by the user from data storage memory (See *APPENDIX. Cameras* (p. 504)). TableFile() instruction output files are usually stored on USR:. TableFile() also stores files on a USB: drive (*APPENDIX. Mass Storage Devices* (p. 504)). Data formats available for storage by TableFile() include TOA5, TOB1, CSIXML, CSIJSON.

Note CR1000s with serial numbers smaller than 11832 were usually supplied with only 2 Mbytes of SRAM.

Additional final data storage is available by using the optional CompactFlash® card with a CompactFlash® module listed in *APPENDIX. Card Storage Modules* (p. 503), or with a mass storage device (*APPENDIX. Mass Storage Devices* (p. 504)).

3.1.6 Data Retrieval

Data tables are transferred to PC files through a telecommunications link (*SECTION. Telecommunications and Data Retrieval* (p. 369)) or by transporting a CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) to the PC.

3.1.6.1 Via Telecommunications

Data are usually transferred through a telecommunications link to an ASCII file on the supporting PC using Campbell Scientific datalogger support software (*APPENDIX. Software* (p. 489)). See also the manual and Help for the software package being used.

3.1.6.2 Via Mass Storage Device

Caution When removing a CS mass storage device (thumb drive) from the CR1000, do so only when the LED is not lit or flashing. Removing a CS mass storage device from the CR1000 while the device is active can cause data corruption.

Data stored on CS mass storage devices are retrieved through a telecommunication link to the CR1000 or by removing the device, connecting it to a PC, and copying / moving files using Windows Explorer.

3.1.6.3 Via CF Card

Caution When installing a CF card module, first turn off the CR1000 power.

Before removing a CF card module from the datalogger, disable the card by pressing the "removal button" (NOT the eject button), wait for the green LED, then turn CR1000 power off.

Removing a card or card module from the CR1000 while the CF card is active can cause garbled data and can damage the card.

Sending a program to the CR1000 may erase all SRAM and CF card data. To prevent losing data, collect data from the CF card before sending a program to the datalogger.

The CR1000 manages data on a CF card as final storage table data, accessing the card as needed to fill data collection requests initiated with the Collect button in *datalogger support software* (p. 439, p. 490). If desired, binary data can be collected using the File Control utility in *datalogger support software* (p. 439, p. 490). Before collecting data this way, stop the CR1000 program to ensure data are not written to CF while data are retrieved, other wise, data corruption and confusion will result.

Data stored on CF cards are retrieved through a telecommunication link to the CR1000 or by removing the card, carrying it to a computer, and retrieving the data via a third party CF adaptor. Retrieving data, especially large files, is much faster through a CF adaptors than via telecommunications.

The format of data files collected via a CF adaptor is different than the format created by *datalogger support software* (p. 489). Data files read from the CF card via a CF adaptor can be converted to a Campbell Scientific format using CardConvert. CardConvert is included with mid- and top-level *datalogger support software* (p. 489). Consult the software manual for more CardConvert information.

3.1.6.4 Data File Formats in CR1000 Memory

Routine CR1000 operations store data in binary data tables. However, when the TableFile() instruction is used, data are also stored in one of several formats in discrete text files in internal or external memeory. See *SECTION. Data Storage* (p. 352) for more information on the use of the TableFile() instruction.

3.1.6.5 Data Format on Computer

CR1000 data stored on a PC via support software is formatted as either ASCII or Binary depending on the file type selected in the support software. Consult the software manual for details on the various available data file formats.

3.1.7 Communications

Read More! See *SECTION. Telecommunications and Data Retrieval* (p. 369).

The CR1000 communicates with external devices to receive programs, send data, or act in concert with a network. The primary communication protocol is PakBus. Modbus and DNP3 communication protocols are also supported. Refer to *APPENDIX. Telecommunications Hardware* (p. 501) for information on available communications devices.

3.1.7.1 PakBus

Read More! See *SECTION. PakBus Overview* (p. 373).

The CR1000 communicates with Campbell Scientific support software, telecommunication peripherals, and other dataloggers via PakBus, a proprietary network communications protocol. PakBus is a protocol similar in concept to IP (Internet protocol). By using signatured data packets, PakBus increases the number of communications and networking options available to the CR1000. Communication can occur via RS-232, CS I/O, or digital I/O ports.

Advantages of PakBus:

- Simultaneous communication between the CR1000 and other devices.
- Peer-to-peer communication-no PC required.
- Other PakBus dataloggers can be used as "sensors" to consolidate all data into one CR1000.
- Routing - the CR1000 can act as a router, passing on messages intended for another logger. PakBus supports automatic route detection and selection.
- Short distance networks with no extra hardware-A CR1000 can talk to another CR1000 over distances up to 30 feet by connecting transmit, receive and ground wires between the dataloggers. PC communications with a PakBus datalogger via the CS I/O port, over phone modem or radio, can be routed to other PakBus dataloggers.
- Datalogger to datalogger communications-special CRBASIC instructions simplify transferring data between dataloggers for distributed decision making or control.
- In a PakBus network, each datalogger is set to a unique address before being installed in the network. Default PakBus address is 1. To communicate with the CR1000, the datalogger support software (see *SECTION. Telecommunications and Data Retrieval* (p. 369)) must know the CR1000's PakBus address. The PakBus address is changed using the optional keyboard display, DevConfig software, CR1000 status table, or PakBus Graph software.

3.1.7.2 Modbus

Read More! See *SECTION. Modbus* (p. 388).

The CR1000 supports Modbus Master and Modbus Slave communication for inclusion in Modbus SCADA networks.

3.1.7.3 DNP3 Communication

Read More! See *SECTION. DNP3* (p. 385).

The CR1000 supports DNP3 Slave communication for inclusion in DNP3 SCADA networks.

3.1.7.4 Keyboard Display

Read More! See *SECTION. Using the Keyboard Display* (p. 395).

The optional keyboard display is a powerful tool for field use. It allows complete access to most datalogger tables and function, allowing the user to monitor, make modifications, and troubleshoot a datalogger installation conveniently and in most weather conditions.

3.1.7.4.1 Custom Menus

Read More! To implement custom menus, see CRBASIC Help for the DisplayMenu() instruction.

CRBASIC programming in the CR1000 facilitates creation of custom menus for the optional keyboard display.

FIGURE. Custom Menu Example (p. 39) shows windows from a simple custom menu named "DataView". "DataView" appears as the main menu on the keyboard display. DataView has menu item, "Counter", and submenus "PanelTemps", "TCTemps", and "System Menu". "Counter" allows selection of 1 of 4 values. Each submenu displays two values from CR1000 memory. PanelTemps shows the CR1000 wiring panel temperature at each scan, and the one minute sample of panel temperature. TCTemps displays two thermocouple temperatures.

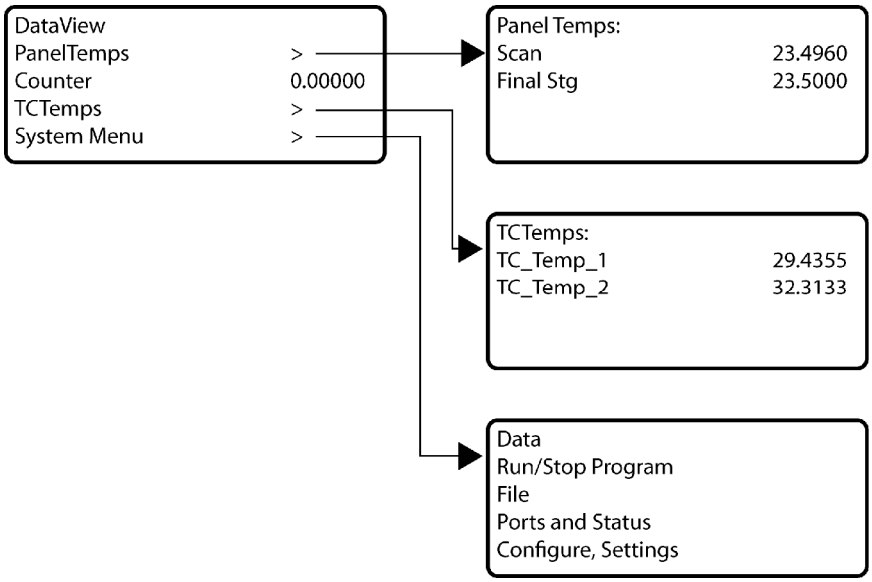


FIGURE 27. Custom Menu Example

3.1.8 Security

CR1000 applications may include collection of sensitive data, operation of critical systems, or networks accessible by many individuals. CR1000 security provides means by which partial or complete lock-out can be accomplished in the CRBASIC program code.

Up to three levels of security can be set in the datalogger. Level 1 must be set before Level 2. Level 2 must be set before Level 3. If a level is set to 0, any level greater than it will also be set to 0 (e.g., if Level 2 is 0, Level 3 is 0). Valid security codes are 1 through 65535 (0 is no security). Each level must have a unique code. If security is set to a negative code in the CR1000, a positive code must be entered to unlock the CR1000. That positive code = 65536 + (negative security code). For example, a security code of -1111 must be entered as 64425 to unlock the CR1000.

Security can be enabled using DevConfig, the optional keyboard display, Status Table, or the SetSecurity () instruction.

Note -- If SetSecurity () is used in the CRBASIC program, the security settings persist if a new program that has no SetSecurity () instruction is sent to the CR1000.

Functions affected by each level of security are:

- **Level 1**: collecting data, setting the clock, and setting variables in the Public table are unrestricted. Enter level 1 password to change or retrieve the datalogger program or set variables in the Status table.

- **Level 2**: collecting data are unrestricted. Enter level 2 password to set the clock or change variables in the public table. Enter level 1 password to change the datalogger program or non-read-only postings in the status table.
- **Level 3**: Enter level 3 password to collect data. Enter level 2 password to collect data, set public variable and set the clock. Enter level 1 password to open all datalogger functions to unrestricted use.

In addition to passwords, recording and monitoring program signatures are important components of a security scheme. Read more about use of program signatures in *SECTION. System Signatures* (p. 173).

3.1.9 Maintenance

Read More! See *SECTION. Care and Maintenance* (p. 409).

With reasonable care, the CR1000 should give many years of reliable service.

3.1.9.1 Protection from Water

The CR1000 and most of its peripherals must be protected from moisture. Moisture in the electronics will seriously damage, and probably render un-repairable, the CR1000. Water can come from flooding or sprinkler irrigation, but most often comes as condensation. In most cases, protecting from water is as easy as placing the CR1000 in a weather tight enclosure with desiccant and elevating the enclosure above the ground. The CR1000 is shipped with desiccant to reduce humidity. Desiccant should be changed periodically. Do not completely seal the enclosure if lead acid batteries are present; hydrogen gas generated by the batteries may build up to an explosive concentration. Refer to *APPENDIX. Enclosures* (p. 497) for information on available weather tight enclosures.

3.1.9.2 Protection from Voltage Transients

Read More! See *SECTION. Grounding* (p. 105).

The CR1000 must be grounded to minimize the risk of damage by voltage transients associated with power surges and lightning induced transients. Earth grounding is required to form a complete circuit for voltage clamping devices internal to the CR1000. Refer to *APPENDIX. Voltage Transient Suppressors* (p. 503) for information on available surge protection devices.

3.1.9.3 Calibration

Read More! See *SECTION. Self-Calibration* (p. 60).

The CR1000 uses an internal voltage reference to routinely calibrate itself. To maintain electrical specifications, Campbell Scientific recommends factory recalibration every two years. For calibration services, contact Campbell Scientific to obtain a Return Materials Authorization (RMA) prior to shipping.

3.1.9.4 Internal Battery

Caution -- Misuse of the lithium battery or installing it improperly can cause severe injury. Fire, explosion, and severe burn hazard! Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, nor expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not externally powered. In a CR1000 stored at room temperature, the lithium battery should last approximately 3 years (less at temperature extremes). In installations where the CR1000 is powered most of the time, the lithium cell should last much longer. Lithium battery voltage can be monitored from the CR1000 Status Table. Operating range of the battery is 2.7 to 3.6 Vdc. Replace the battery as directed in *SECTION. Replacing the Internal Battery* (p. 411) when the voltage is below 2.7 Vdc.

3.2 PC Support Software

Read More! See *SECTION. Support Software* (p. 395).

Several datalogger support software products for Windows are available. Software for datalogger setup and simple applications, PC200W and Short Cut, are available at no cost at *www.campbellsci.com*. For more complex programming, telecommunications, networking, and reporting features, full-featured products are available from Campbell Scientific.

- PC200W Starter Software is available at no charge at *www.campbellsci.com*. It supports a transparent RS-232 connection between PC and CR1000, and includes Short Cut for creating CR1000 programs. Tools for setting the datalogger clock, sending programs, monitoring sensors, and on-site viewing and collection of data are also included.

- PC400 supports a variety of telecommunication options, manual data collection, and data monitoring displays. Short Cut, CRBASIC Editor, and Transformer Utility are included for creating CR1000 programs. PC400 does not support complex communication options, such as phone-to-RF, PakBus® routing, or scheduled data collection.

- LoggerNet supports combined telecommunication options, customized data monitoring displays, and scheduled data collection. It includes Short Cut, CRBASIC Editor, and Transformer Utility programs for creating CR1000 programs. It also includes tools for configuring, trouble-shooting, and managing datalogger networks. LoggerNet Admin and LoggerNet Remote are also available for more demanding applications.

3.3 CR1000 Specifications

SPECIFICATIONS valid from -25° to +50°C, non-condensing environment, unless otherwise specified. Recalibration recommended every two years. Critical specifications and system configuration should be confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE
(10) ms to 1 day @ 10 ms increments

ANALOG INPUTS (SE 1-16 or DIFF 1-8)
(8) differential (DF) or 16 single-ended (SE) individually configured input channels. Channel expansion provided by optional analog multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. Resolution of DF measurements with input reversal is half the Basic Res.

Range (mV)[1]	DF Res (µV)[2]	Basic Res (µV)
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ≈9% on all ranges guarantees full-scale voltage will not cause over-range.
[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset),-55° to 85°C(-XT only)

[3]Accuracy does not include sensor and measurement noise. Offsets are defined as:

Offset for DF w/input reversal = 1.5 x Basic Res+1.0 µV
Offset for DF w/o input reversal = 3 x Basic Res+2.0 µV
Offset for SE = 3 x Basic Res + 3.0 µV

ANALOG MEASUREMENT SPEED:

Integration Type Code	Integration Time	Settling Time	----Total Time[5]---- SE w/ No Rev	DF w/ Input Rev
250	250µs	450µs	≈1ms	≈12ms
60Hz[4]	16.67ms	3ms	≈20ms	≈40ms
50Hz[4]	20.00ms	3ms	≈25ms	≈50ms

[4]AC line noise filter
[5]Includes 250 µs for conversion to engineering units

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range (digital resolution dominates for higher ranges).

250 µs Integration: 0.34 µV RMS
50/60 Hz Integration: 0.19 µV RMS

INPUT LIMITS: ±5 Vdc

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

PERIOD AVERAGE: Any of the 16 SE analog inputs can be used for period averaging. Accuracy is ±(0.01% of reading + resolution), where resolution is 136 ns divided by the specified number of cycles to be measured.

Input amplitude and frequency:

Voltage Gain	± Input Range mV	Signal Peak-Peak[6] Min mV	Max V	Min Pulse Width µs	Max[7] Freq kHz
1	250	500	10	2.5	200
10	25	10	2	10	50
33	7.5	5	2	62	8
100	2.5	2	2	100	5

[6]With signal centered at CR1000 ground.
[7]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

ANALOG OUTPUTS (Vx 1-3)
(3) switched voltage outputs sequentially active only during measurement.

RANGES / RESOLUTION:

Chan	Range	Res-olution	Current Source / Sink
V_x	±2.5V	0.67mV	±25 mA

spacer
spacer

V_x ACCURACY
±(0.06% of setting + 0.8 mV, 0° to 40°C
±(0.12% of setting + 0.8 mV, -25° to 50°C
±(0.18% of setting + 0.8 mV,-55° to 85°C(-XT only)

V_x FREQUENCY SWEEP FUNCTION: Switched outputs provide a programmable swept frequency, 0 to 2500 mV square waves for exciting vibrating wire transducers.

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS
MEASUREMENT TYPES: Ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation for voltage excitation eliminates DC errors. Offset values are reduced by a factor of 2 when excitation reversal is used.

VOLTAGE RATIO ACCURACY[8]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error:

±(0.04% of reading + offset)/V_x

[8]Accuracy does not include sensor and measurement noise. Offsets are defined as:

Offset for DF w/input reversal = 1.5 x Basic Res + 1.0 µV
Offset for DF w/o input reversal = 3 x Basic Res + 2.0 µV
Offset for SE = 3 x Basic Res + 3.0 µV

PULSE COUNTERS (P 1-2)
(2) inputs individually selectable for switch closure, high frequency pulse, or low-level ac. Independent 24-bit counters for each input.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 µs time constant.

LOW LEVEL AC MODE: Internal ac coupling removes dc offsets up to ±0.5 Vdc.

Input Hysteresis: 12 mV RMS @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	Range (Hz)
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS (C 1-8)
(8) ports software selectable as binary inputs or control outputs. Provide edge timing, subroutine interrupts / wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UARTs), SDI-12 communications, and SDM communications

HIGH FREQUENCY MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

EDGE TIMING RESOLUTION: 540 ns

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 16 V; low -8.0 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE:
100 kohms with inputs <6.2 Vdc
220 ohm with inputs ≥ 6.2 Vdc

SERIAL DEVICE/RS-232 SUPPORT: 0 to 5 Vdc UART

SWITCHED 12 Vdc (SW-12)
(1) independent 12 Vdc unregulated source is switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

CE COMPLIANCE
STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

COMMUNICATION
RS-232 PORTS:
9-pin: DCE (not electrically isolated) for computer or non-CSI modem connection.
COM1 to COM4: Four independent Tx/Rx pairs on control ports (non-isolated); 0 to 5 Vdc UART
Baud Rate: Selectable from 300 to 115.2 kbps.
Default Format: 8 data bits; 1 stop bits; no parity.
Optional Formats: 7 data bits; 2 stop bits; odd, even parity.

CS I/O PORT: Interface with CSI telecommunications peripherals.

SDI-12: Digital control ports 1, 3, 5 or 7 are individually configurable and meet SDI-12 Standard version 1.3 for datalogger mode. Up to ten SDI-12 sensors are supported per port.

PERIPHERAL PORT: 40-pin interface for attaching CompactFlash or Ethernet peripherals.

PROTOCOLS SUPPORTED: PakBus, Modbus, DNP3, FTP, HTTP, XML, POP3, SMTP, Telnet, NTCIP, NTP, SDI-12, and SDM.

SYSTEM
PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core, running at 7.3 MHz)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and final data storage.

RTC CLOCK ACCURACY: ±3 min. per year. Correction via GPS optional.

RTC CLOCK RESOLUTION: 10 ms

SYSTEM POWER REQUIREMENTS
VOLTAGE: 9.6 to 16 Vdc

EXTERNAL BATTERIES: 12 Vdc nominal (power connection is reverse polarity protected)

INTERNAL BATTERIES: 1200 mAhr lithium battery for clock and SRAM backup typically provides 3 years of back-up.

TYPICAL CURRENT DRAIN: Sleep Mode: ≈0.6 mA
1 Hz Sample Rate (one fast SE meas.): 1 mA
100 Hz Sample Rate (one fast SE meas.): 16.2 mA
100 Hz Sample Rate (one fast SE meas. w/ RS-232 communications): 27.6 mA
optional keyboard display on: add 7 mA to current drain
Backlight on: add 100 mA to current drain

PHYSICAL
DIMENSIONS: 239 x 102 x 61 mm (9.4 x 4.0 x 2.4 in); additional clearance required for cables and leads.

MASS/WEIGHT (datalogger + base):

MASS: 1.0 kg
WEIGHT: 2.1 lbs

WARRANTY
(3) years against defects in materials and workmanship.

Section 4. Measurements

Several features give the CR1000 the flexibility to measure many sensor types. Contact a Campbell Scientific applications engineer if assistance is required in assessing CR1000 compatibility to a specific application or sensor type. Some sensors require precision excitation or a source of power. See *SECTION. Powering Sensors and Devices* (p. 100).

4.1 Time

Measurement of time is an essential function of the CR1000. Time measurement with the on-board clock enables the CR1000 to attach time stamps to data, measure the interval between events, and time the initiation of control functions.

4.1.1 Time Stamps

A measurement without an accurate time reference has little meaning. Data on the CR1000 are stored with time stamps. How closely a time stamp corresponds to the actual time a measurement is taken depends on several factors.

The time stamp in common CRBASIC programs matches the time at the beginning of the current scan as measured by the real time clock in the CR1000. If a scan starts at 15:00:00, data output during that scan will have a time stamp of 15:00:00 regardless of the length of the scan or when in the scan a measurement is made. The possibility exists that a scan will run for some time before a measurement is made. For instance, a scan may start at 15:00:00, execute time consuming code, then make a measurement at 15:00:00.51. The time stamp attached to the measurement, if the CallTable () instruction is called from within the Scan ... NextScan construct, will be 15:00:00, resulting in a time stamp skew of 510 ms.

Time stamp skew is not a problem with most applications because,

- program execution times are usually short, so time stamp skew is only a few milliseconds. Most measurement requirements allow for a few milliseconds of skew.
- data processed into averages, maxima, minima, etc are composites of several measurements. Associated time stamps only reflect the time the last measurement was made and processing calculations were completed, so the significance of the exact time a specific sample was measured diminishes.

Applications measuring and storing sample data wherein exact time stamps are required can be adversely affected by time stamp skew. Skew can be avoided by

- Making measurements early in a scan interval, before time consuming code.

- Programming the CR1000 such that the time stamp reflects the system time rather than the scan time. When CallTable () is executed from within the Scan ... NextScan construct, as is normally done, the time stamp reflects scan time. By executing the CallTable () instruction outside the Scan ... NextScan construct, the time stamp will reflect system time instead of scan time. *CRBASIC EXAMPLE. Time Stamping with System Time* (p. 44) shows the basic code requirements.

CRBASIC EXAMPLE 1. Time Stamping with System Time

```
'Declare Variables
Public value

'Declare Data Table
DataTable(Test,True,1000)
    Sample(1,Value,FP2)
EndTable

SequentialMode

BeginProg

    Scan(1,Sec,10,0)

        'Delay -- in an operational program, delay may be caused by other code
        Delay(1,500,mSec)

        'Measure Value -- can be any analog measurement
        PanelTemp(Value,0)

        'Immediately call SlowSequence to execute CallTable()
        TriggerSequence(1,0)

    NextScan

    'Allow data to be stored 510 ms into the Scan with a s.51 timestamp
    SlowSequence
        Do: WaitTriggerSequence: CallTable(Test): Loop

EndProg
```

Other time processing CRBASIC instructions are governed by these same rules. Consult CRBASIC Editor Help for more information on specific instructions.

4.2 Voltage

The CR1000 incorporates a programmable gain input instrumentation amplifier (PGIA), as illustrated in *FIGURE. PGI Amplifier* (p. 45). The voltage gain of the instrumentation amplifier is determined by the user selected range code associated with voltage measurement instructions. The PGIA can be configured to measure either single-ended (SE) or differential (DIFF) voltages. For SE measurements, the voltage to be measured is connected to the H input while the L input is internally connected to signal ground (⏚). CRBASIC instructions BrHalf (), BrHalf3W (), TCSE (), Therm107 (), Therm108 (), Therm109 (), and VoltSE () perform SE voltage measurements. For DIFF measurements, the

voltage to be measured is connected between the H and L inputs on the PGIA. CRBASIC instructions BrFull (), BrFull6W (), BrHalf4W (), TCDiff (), and VoltDiff () instructions perform DIFF voltage measurements.

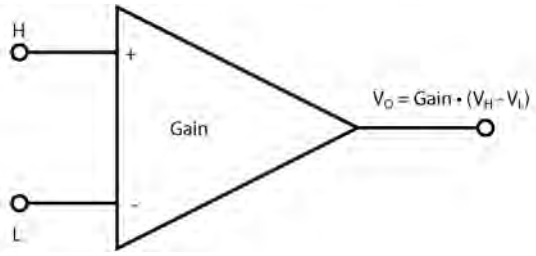


FIGURE 28. PGI Amplifier

A PGIA processes the difference between the H and L inputs, while rejecting voltages that are common to both inputs. *FIGURE. PGIA with Input Signal Decomposition* (p. 45), illustrates the PGIA with the input signal decomposed into a common-mode voltage (V_{cm}) and a DIFF mode voltage (V_{dm}). The common-mode voltage is the average of the voltages on the V_H and V_L inputs, i.e., $V_{cm} = (V_H + V_L)/2$, which can be viewed as the voltage remaining on the H and L inputs with the DIFF voltage (V_{dm}) equal to 0. The total voltage on the H and L inputs is given as $V_H = V_{cm} + V_{dm}/2$, and $V_L = V_{cm} - V_{dm}/2$, respectively.

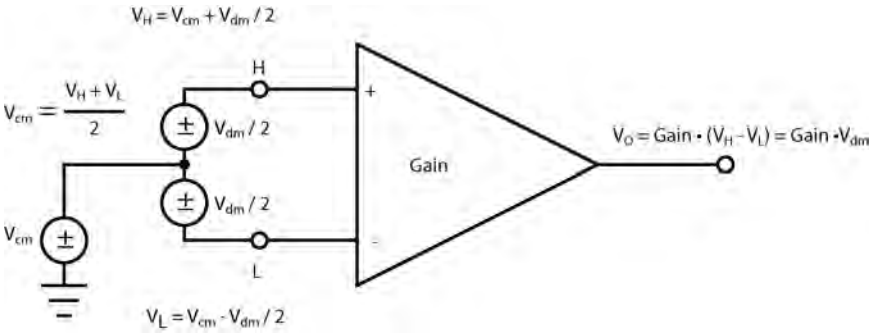


FIGURE 29. PGIA with Input Signal Decomposition

4.2.1 Input Limits

The Input Limits specifies the voltage range, relative to CR1000 ground, which both H and L input voltages must be within to be processed correctly by the PGIA. Input Limits for the CR1000 are ±5 Vdc. Input voltages in which V_H or V_L are beyond the ±5 Vdc Input Limits may suffer from undetected measurement errors. The term "Common-mode Range", which defines the valid range of common-mode voltages, is often used instead of "Input Limits." For DIFF voltages that are small compared to the Input Limits, Common-mode Range is essentially equivalent to Input Limits. Yet from *FIGURE. PGIA with Input Signal Decomposition* (p. 45),

Common-mode Range = ± | Input Limits – $V_{dm}/2$ |,

indicating a reduction in Common-mode Range for increasing DIFF signal amplitudes. For example, with a 5000 mV DIFF signal, the Common-mode Range is reduced to ±2.5 Vdc, whereas Input Limits are always ±5 Vdc. Hence for non-negligible DIFF signals, "Input Limits" is more descriptive than "Common-mode Range."

Note Two sets of numbers are assigned to analog channels. For differential measurements, analog channels are numbered 1 - 8. Each differential channel as two inputs: high (H) and low (L). For single-ended measurement, analog channels are numbered 1-16.

Note Sustained voltages in excess of ±16 V input to the analog channels will damage CR1000 circuitry.

4.2.2 Reducing Error

Read More! Consult the following White Papers at *www.campbellsci.com* for in-depth treatment of the advantages of differential and single-ended measurements: "Preventing and Attacking Measurement Noise Problems", "Benefits of Input Reversal and Excitation Reversal for Voltage Measurements", and "Voltage Measurement Accuracy, Self-Calibration, and Ratiometric Measurements.

Deciding whether a differential or single-ended measurement is appropriate for a particular sensor requires sorting through trade-offs of accuracy and precision, available measurement hardware, and fiscal constraints.

In broad terms, analog voltage is best measured differentially because these measurements include noise reduction features, listed below, not included in single-ended measurements.

- Passive Noise Rejection
    - No voltage reference offset
    - Common-mode noise rejection
        - Rejects capacitively coupled noise
- Active Noise Rejection
    - Input reversal
        - Review *SECTION. Input and Excitation Reversal* (p. 53) for details
        - Doubles input reversal signal integration time

Reasons for using single-ended measurements, however, include:

- Sensor is not designed for differential measurement.
- Sensor number exceeds available differential channels.

Sensors with a high signal-to-noise ratio, such as a relative humidity sensor with a full scale output of 0 to 1000 mV, can normally be measured single-ended without a significant reduction in accuracy or precision.

Sensors with low signal-to-noise ratio, such as thermocouples, should normally be measured differentially. However, if the measurement to be made does not require high accuracy or precision, such as thermocouples measuring brush fire temperatures, a single-ended measurement may be appropriate. If sensors require differential measurement, but adequate input channels are not available, an analog multiplexer should be acquired to expand differential input capacity. Refer to *APPENDIX. Analog Multiplexers* (p. 497) for information concerning available multiplexers.

Because a single-ended measurement is referenced to CR1000 ground, any difference in ground potential between the sensor and the CR1000 will result in an error in the measurement. For example, if the measuring junction of a copper-constantan thermocouple being used to measure soil temperature is not insulated, and the potential of earth ground is 1 mV greater at the sensor than at the point where the CR1000 is grounded, the measured voltage will be 1 mV greater than the thermocouple output, or approximately 25°C high. A common problem with ground potential difference occurs in applications wherein external signal conditioning circuitry is powered by the same source as the CR1000, such as an ac mains power receptacle. Despite being tied to the same ground, differences in current drain and lead resistance may result in a different ground potential between the two instruments. Hence, a differential measurement should be made on the analog output from an external signal conditioner. Differential measurements MUST be used when the low input is known to be different from ground.

4.2.3 Measurement Sequence

The CR1000 measures analog voltage by integrating the input signal for a fixed duration, then holding the integrated value during the successive approximation analog-to-digital (A/D) conversion. The CR1000 can make and store measurements from up to 8 differential or 16 single-ended channels at the minimum scan rate of 10 ms (100 Hz) using the burst mode voltage measurement (*SECTION. Burst* (p. 310)). The maximum conversion rate is 2000 per second for measurements made on a single channel.

The timing of CR1000 measurements is precisely controlled. The measurement schedule is determined at compile time and loaded into memory. This schedule sets interrupts that drive the measurement task.

Using two different voltage measurement instructions with the same voltage range takes the same measurement time as using one instruction with two repetitions.

Note This is not the case with legacy CR10(X), 21X, CR23X, and CR7(X) dataloggers. Using multiple measurement "reps" in these dataloggers reduced overall measurement time.

Several parameters in CRBASIC voltage measurement instructions VoltDiff () and VoltSE () vary the sequence and timing of measurements. *TABLE.*

CRBASIC Parameters Varying Measurement Sequence and Timing (p. 48) lists these parameters.

TABLE 4. CRBASIC Parameters Varying Measurement Sequence and T

CRBASIC Parameter	*Description*
MeasOfs	Correct ground offset on single-ended measurements.
RevDiff	Reverse high and low differential inputs.
SettlingTime	Sensor input settling time.
Integ	Duration of input signal integration.
RevEx	Reverse polarity of excitation voltage.

4.2.4 Measurement Accuracy

CR1000 analog measurement error is calculated as

Error = Gain Error (%) + Offset Error

Gain error is expressed as ±% and is a function of input voltage and CR1000 temperature. It is minimized by factory calibration and increases with component temperature and aging. Between 0°C and 40°C, gain error is ±0.06% of input voltage.

Offset error is expressed as

Offset Error = Resolution + 1 µV

where

Resolution = published resolution of the programmed input voltage range (see *SECTION. Specifications* (p. 42)).

FIGURE. Voltage Measurement Accuracy (0° to 40°C) (p. 49) illustrates that as magnitude of input voltage decreases, measurement error decreases.

Note The accuracy specification includes only the CR1000's contribution to measurement error. It does not include the error of sensors.

For example, assume the following (see *SECTION. Specifications* (p. 42)):

- Input Voltage: +2500 mV
- Programmed Input Voltage Range: ±2500 mV
- Programmed Measurement Instruction: VoltDiff()
- Input Measurement Reversal = True
- CR1000 Temperature: Between 0°C and 40°C

Accuracy of the measurement is calculated as follows:

Error = Gain Error + Offset Error,

where

Gain Error = ± (2500 * 0.0006)

= ±1.5 mV

and

Offset Error = Differential (DF) Resolution + 1 µV

= 333 µV + 1 µV

= 334 µV

Therefore,

Error = Gain Error + Offset Error

= ±1.5 mV + 334 µV.

= ±1.834 mV

In contrast, the error for a 500 mV input under the same constraints is ± 0.634 mV.

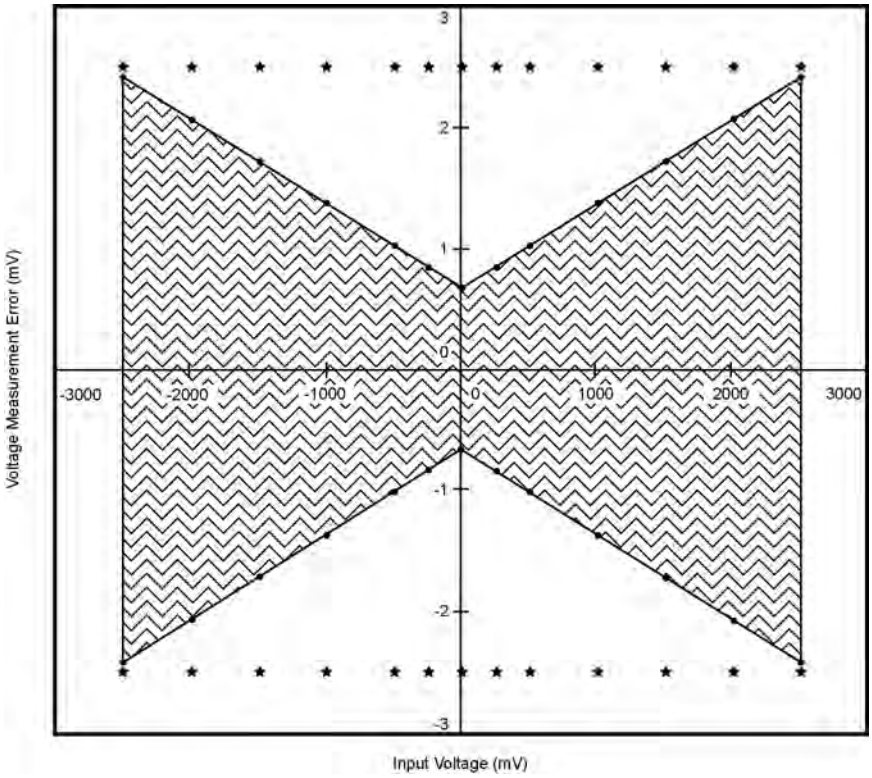


FIGURE 30. Voltage Measurement Accuracy (0° to 40° C)

4.2.5 Voltage Range

In general, a voltage measurement should use the smallest fixed input range that will accommodate the full scale output of the sensor being measured. This results in the best measurement accuracy and resolution. The CR1000 has fixed input ranges for voltage measurements and an auto range to automatically determine the appropriate input voltage range for a given measurement. *TABLE. Analog Voltage Input Ranges with CMN / OID* (p. 50) lists input voltage ranges and range codes.

4.2.5.1 AutoRange

For signals that do not fluctuate too rapidly, AutoRange allows the CR1000 to automatically choose the voltage range to use. AutoRange makes two measurements. The first measurement determines the range to use, and is made with the 250 µs integration on the ±5000 mV range. The second measurement is made using the appropriate range with the integration specified in the instruction. Both measurements use the settling time programmed in the instruction. AutoRange optimizes resolution but takes longer than a measurement on a fixed range, because of the two measurements required.

An AutoRange measurement will return NAN (Not-A-Number) if the voltage exceeds the range picked by the first measurement. To avoid problems with a signal on the edge of a range, AutoRange selects the next larger range when the signal exceeds 90% of a range.

AutoRange is recommended for a signal that occasionally exceeds a particular range, for example, a Type J thermocouple measuring a temperature usually less than 476°C (±25 mV range) but occasionally as high as 500°C (±250 mV range). AutoRange should not be used for rapidly fluctuating signals, particularly signals traversing several voltage ranges rapidly. The possibility exists that the signal can change ranges between the range check and the actual measurement.

TABLE 5. Analog Voltage Input Ranges with Options for Common Mod Input Detect (OID)

Range Code	*Description*
mV5000	measures voltages between ±5000 mV
mV2500[1]	measures voltages between ±2500 mV
mV250[2]	measures voltages between ±250 mV
mV25[2]	measures voltages between ±25 mV
mV7_5[2]	measures voltages between ±7.5 mV
mV2_5[2]	measures voltages between ±2.5 mV
AutoRange[3]	datalogger determines the most suitable range

[1] Append with "C" to enable CMN/OID and set excitation to full-scale DAC (~2700 mV)

[2] Append with "C" to enable CMN/OID

[3] Append with "C" to enable CMN/OID on ranges ≤ ±250 mV, CMN on ranges > ±250 mV

4.2.5.2 Fixed Voltage Ranges

An approximate 9% range overhead exists on fixed input voltage ranges. For example, over-range on the ±2500 mV input range occurs at approximately +2725 mV and -2725 mV. The CR1000 indicates a measurement over-range by returning a NAN (Not-A-Number) for the measurement.

4.2.5.3 Common Mode Null / Open Input Detect

For floating differential sensors such as thermocouples, nulling of any residual common-mode voltage prior to measurement pulls the H and L input amplifier (IA) inputs within the ±5 V Input Limits. Appending a "C" to the range code (i.e. "mV2_5C") enables the nulling of the common-mode voltage prior to a differential measurement on the ±2.5 mV, ±7.5 mV, ±25 mV, and ±250 mV input ranges. Another useful feature for both SE and DIFF measurements is the detection of open inputs due to a broken or disconnected sensor wire, to prevent otherwise undetectable measurement errors. Range codes ending with "C" also enable open detect for all input ranges, except the ±5000 mV input range (See *TABLE. Analog Voltage Input Ranges with CMN / OID* (p. 50)).

On the ±2.5 mV, ±7.5 mV, ±25 mV, and ±250 mV input ranges, the "C" range code option results in a brief 50 microseconds internal connection of the H and L inputs of the IA to 300 mV and ground, respectively, while also connected to the sensor to be measured. The resulting internal common-mode voltage is ±150 mV, which is well within the ±5 V Input Limits. Upon disconnecting the internal 300 mV and ground connections, the associated input is allowed to settle to the desired sensor voltage and the voltage measurement made. If the associated input is open (floating) the input voltages will remain near the 300 mV and ground, resulting in an over range (NAN) on the ±2.5 mV, ±7.5 mV, ±25 mV, and the ±250 mV input range. If the associated sensor is connected and functioning properly, a valid measured voltage will result after the input settling associated with open input detect.

On the ±2500 mV input range the "C" option (i.e. mV2500C) can be used for open input detect with some limitations, as an internal voltage large enough to cause measurement over range is not available. The "C" option for a voltage measurement on the ±2500 mV input range (i.e. mV2500C), results in the H input being briefly connected to a voltage greater than 2500 mV, while the L input is connected to ground. The resulting common-mode voltage is > 1.25 V which is not very helpful in nulling residual common-mode voltage. However, open input detect is still possible by including an If…Then…Else statement in the CRBASIC program to test the measured results. For example, the result of a voltage measurement on the ±2500 mV input range with the "C" option could be tested for > 2500 mV to indicate an open input. For bridge measurements, the returned value X being > 1 would indicate an open input. For example, the BrHalf() instruction returns the value X defined as V1/Vx, where V1 is the measured single-ended voltage and Vx is the user defined excitation voltage having a 2500 mV maximum value. For a BrHalf() measurement utilizing the "C" option on the ±2500 mV input range (i.e. mV2500C), a result of X > 1 indicates an open input for the V1 measurement. The "C" option is not available on the ±5000 mV input range.

Open Input Detect Cautionary Notes

- if the input is not a truly open circuit, such as might occur on a wet cut cable end, the open circuit may not be detected because the input capacitor discharges through external leakage to ground to a normal voltage within the settling time of the measurement. This problem is worse when a long settling time is selected, as more time is given for the input capacitors to discharge to a "normal" level.
- if the open circuit is at the end of a very long cable, the test pulse (300 mV) may not charge the cable (with its high capacitance) up to a voltage that generates NaN or a distinct error voltage. The cable may even act as an aerial and inject noise which also might not read as an error voltage.
- the sensor may "object" to the test pulse being connected to its output, even for 100 microseconds. There is little or no risk of damage, but the sensor output may be kicked into temporary oscillation. Programming a longer settling time in the CRBASIC measurement instruction to allow oscillations to decay before the A/D conversion may mitigate the problem.

4.2.6 Offset Voltage Compensation

Analog measurement circuitry in the CR1000 may introduce a small offset voltage to a measurement. Depending on the magnitude of the signal, this offset voltage may introduce significant error. For example, an offset of 3 µV on a 2500 mV signal introduces an error of only 0.00012%; however, the same offset on a 0.25 mV signal introduces an error of 1.2%.

The primary source of offset voltage is the Seebeck effect, which arises at the junctions of differing metals in electronic circuits. A secondary source of offset voltage are return currents incident to powering external devices through the CR1000. Return currents create voltage drop at the ground terminals that may be used as signal references.

CR1000 measurement instructions incorporate techniques to cancel these unwanted offsets. *TABLE. Analog Measurement Instructions and Offset Voltage Compensation Options* (p. 52) lists available options.

TABLE 6. Analog Measurements and Offset Voltage Compensation				
CRBASIC Voltage Measurement Instruction	***Input Reversal (RevDiff = True)***	***Excitation Reversal (RevEx = True)***	***Measure Ground Reference Offset (MeasOff = True)***	***Background Calibration (RevDiff = False) (RevEx = False) (MeasOff = False)***
VoltDiff()	*			*
VoltSe()			*	*
TCDiff()	*			*
TCSe()			*	*
BrHalf()		*		*
BrHalf3W()		*		*
Therm107()		*		*
Therm108()		*		*
Therm109()		*		*
BrHalf4W()	*	*		*
BrFull()	*	*		*
BrFull6W()	*	*		*
AM25T()	*	*		*

4.2.6.1 Input and Excitation Reversal

Reversing inputs (differential measurements) or reversing polarity of excitation voltage (bridge measurements) cancels stray voltage offsets. For example, if there is a +3 μVolt offset in the measurement circuitry, a 5 mV signal is measured as 5.003 mV. When the input or excitation is reversed, the measurement is -4.997 mV. Subtracting the second measurement from the first and dividing by 2 cancels the offset:

5.003 mV - (-4.997 mV) = 10.000 mV

10.000 mV / 2 = 5.000 mV.

When the CR1000 reverses differential inputs or excitation polarity, it delays the same settling time after the reversal as it does before the first measurement. Thus there are two delays per channel when either RevDiff or RevEx is used. If both RevDiff and RevEx are True, four measurements are performed; positive and negative excitations with the inputs one way and positive and negative excitations with the inputs reversed. To illustrate,

- the CR1000 switches to the channel
- sets the excitation, settles, **measures**,
- reverses the excitation, settles, **measures**,
- reverses the excitation, reverses the inputs, settles, **measures**,
- reverses the excitation, settles, **measures.**

There are four delays per channel measured. The CR1000 processes the four sub-measurements into a single reported value. In cases of excitation reversal, excitation "on time" for each polarity is exactly the same to ensure that ionic sensors do not polarize with repetitive measurements.

Read More! A white paper entitled "The Benefits of Input Reversal and Excitation Reversal for Voltage Measurements" is available at *www.campbellsci.com*.

4.2.6.2 Ground Reference Offset Voltage

When MeasOff is enabled (= True), the CR1000 measures the offset voltage of the ground reference prior to each VoltSe () or TCSe () measurement. This offset voltage is subtracted from the subsequent measurement.

4.2.6.3 Background Calibration (RevDiff, RevEx, MeasOff = False)

If RevDiff, RevEx, or MeasOff is disabled (= False) in a measurement instruction, offset voltage compensation is still performed, albeit less effectively, by using measurements from automatic background calibration. Disabling RevDiff, RevEx, or MeasOff speeds up measurement time; however, the increase in speed comes at the cost of accuracy 1) because RevDiff, RevEx, and MeasOff are more effective techniques, and 2) because background calibrations are performed only periodically, so more time skew occurs between the background calibration offsets and the measurements to which they are applied.

Note Disable RevDiff, RevEx and MeasOff when CR1000 module temperature and return currents are slow to change or when measurement duration must be minimal to maximize measurement frequency.

4.2.7 Integration

Read More! See White Paper "Preventing and Attacking Measurement Noise Problems" at *www.campbellsci.com*.

The CR1000 incorporates circuitry to perform an analog integration on voltages to be measured prior to the A/D conversion. The magnitude of the frequency response of an analog integrator is a SIN(x) / x shape, which has notches (transmission zeros) occurring at 1 / (integer multiples) of the integration duration. Consequently, noise at 1 / (integer multiples) of the integration duration is effectively rejected by an analog integrator. *TABLE. Measurement Integration Times and Codes* (p. 55) lists three integration durations available in the CR1000 and associated CRBASIC codes. If reversing the differential inputs or reversing the excitation is specified, there are two separate integrations per measurement; if both reversals are specified, there are four separate integrations.

TABLE 7. CRBASIC Measurement Integration Times and Codes		
Integration Time (ms)	*CRBASIC Code*	*Comments*
250 µs	250	Fast integration
16.667 ms	_60Hz	filters 60 Hz noise
20 ms	_50Hz	filters 50 Hz noise

4.2.7.1 ac Power Line Noise Rejection

Grid or mains power (50 or 60 Hz, 230 or 120 Vac) can induce electrical noise at integer multiples of 50 or 60 Hz. Small analog voltage signals, such as thermocouples and pyranometers, are particularly susceptible. CR1000 voltage measurements can be programmed to reject (filter) 50 or 60 Hz related noise.

4.2.7.1.1 ac Noise Rejection on Small Signals

The CR1000 rejects ac power line noise on all voltage ranges except mV5000 and mV2500 by integrating the measurement over exactly one ac cycle before A/D conversion as illustrated in *TABLE. ac Noise Rejection on Small Signals* (p. 55) and the full cycle technique of *FIGURE. ac Power Line Noise Rejection* (p. 55).

TABLE 8. ac Noise Rejection on Small Signals		
Applies to all analog input voltage ranges except mV2500 and mV5000.		
ac Power Line Frequency	*Measurement Integration Duration*	*CRBASIC Integration Code*
60 Hz	16.667 ms	_60Hz
50 Hz	20 ms	_50Hz

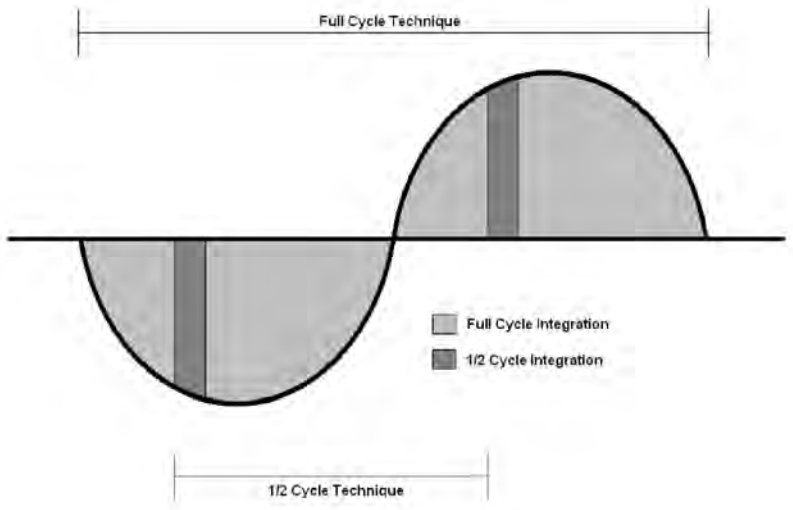


FIGURE 31. ac Power Line Noise Rejection Techniques

4.2.7.1.2 ac Noise Rejection on Large Signals

When rejecting ac noise on the 2500 mV and 5000 mV ranges, the CR1000 makes two fast measurements separated in time by ½ line cycle, as illustrated in *FIGURE. ac Power Line Noise Rejection Techniques* (p. 55). For 60 Hz rejection, ½ line cycle = 8333 µs, meaning that the 2nd measurement must start 8333 µs after the integration for the first measurement was started. The A/D conversion time is approximately 170 µs, leaving a maximum input settling time of approximately 8333 µs - 170 µs = 8160 µs before the 2nd measurement is delayed too long to result in a rejection notch at 60 Hz. For 50 Hz rejection on the mV5000 and mV2500 input ranges, the maximum input settling time of approximately 10,000 - 170 µs = 9830 µs before the 2nd measurement is delayed too long to result in a rejection notch at 50 Hz. The CR1000 does not prevent or warn against setting the settling time beyond the ½ cycle limit. *TABLE. ac Noise Rejection on Large Signals* (p. 56) lists details of the ½ line cycle ac power line noise rejection technique.

TABLE 9. ac Noise Rejection on Large Signals

Applies to analog input voltage ranges mV2500 and mV5000.

ac Power Line Frequency	*Measurement Integration Time*	*CRBASIC Integration Code*	*Default Settling Time*	*Maximum Recommended Settling Time**
60 Hz	250 µs x 2	_60Hz	3000 µs	8330 µs
50 Hz	250 µs x 2	_50Hz	3000 µs	10000 µs

*Excitation time equals settling time in measurements requiring excitation. The CR1000 cannot excite VX/EX excitation channels during A/D conversion. The ½ cycle technique with excitation limits the length of recommended excitation / settling time for the first measurement to ½ cycle. The CR1000 does not prevent or warn against setting a settling time beyond the ½ cycle limit. For example, a settling time of up to 50000 microseconds can be programmed, but the CR1000 will execute the measurement as follows:

1. CR1000 turns excitation on, waits 50000 microseconds, then makes the first measurement.
2. During A/D, CR1000 turns off excitation for ≈ 170 microseconds.
3. Excitation is switched on again for ½ cycle, then the second measurement is made.

Restated, when using the ½ cycle 50 Hz or 60 Hz rejection method, a sensor does not see a continuous excitation of the length entered as the settling time before the second measurement if the settling time entered is greater than ½ cycle. Depending on the sensor used, a truncated second excitation may cause measurement errors.

4.2.8 Signal Settling Time

When the CR1000 switches to an analog input channel or activates excitation for a bridge measurement, a settling time is required for the measured voltage to settle to its true value before being measured. The rate at which the signal settles is determined by the input settling time constant which is a function of both the source resistance and input capacitance.

Rise and decay waveforms are exponential. *FIGURE. Input Voltage Rise and Transient Decay* (p. 57) shows rising and decaying waveforms settling to the true signal level, V_{so}.

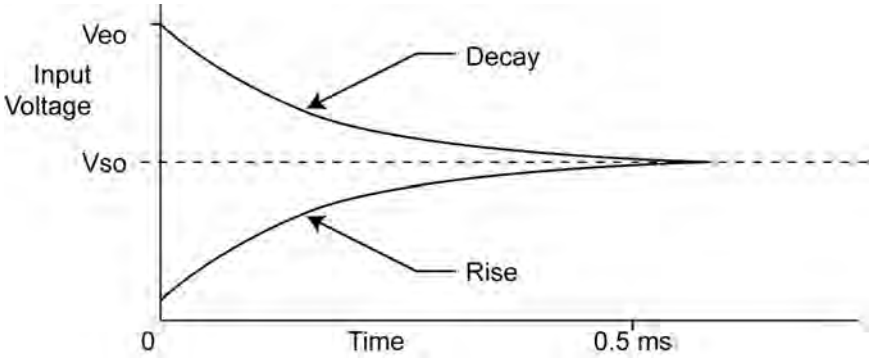


FIGURE 32. Input Voltage Rise and Transient Decay

The CR1000 delays after switching to a channel to allow the input to settle before initiating the measurement. The SettlingTime parameter of the associated measurement instruction is provided to allow the user to tailor measurement instructions settling times with 100 µs resolution up to the maximum settling time of 50000 µs. Default settling times are listed in *TABLE. CRBASIC Measurement Settling Times* (p. 57), and are meant to provide sufficient signal settling in most cases. Additional settling time may be required when measuring high resistance (impedance) sensors and / or sensors connected to the datalogger by long leads. Measurement time of a given instruction increases with increasing settling time. For example, a 1 ms increase in settling time for a bridge instruction with input reversal and excitation reversal results in a 4 ms increase in time for the CR1000 to perform the instruction.

TABLE 10. CRBASIC Measurement Settling Times

Settling Time Entry	*Input Voltage Range*	*Integration Code*	*Settling Time**
0	All	250 µs	450 µs (default)
0	All	_50Hz	3 ms (default)
0	All	_60Hz	3 ms (default)
>100	All	All	µs entered

*Minimum settling time required to allow the input to settle to CR1000 resolution specifications.

A settling time is required for voltage measurements to minimize the effects of the following sources of error:

- A small switching transient occurs when the CR1000 switches to the single-ended or differential channel to be measured.
- A relatively large transient may be induced on the signal conductor via capacitive coupling during a bridge measurement from an adjacent excitation conductor.

- 50 or 60 Hz integrations require a relatively long reset time of the internal integration capacitor before the next measurement due to dielectric absorption.

4.2.8.1 Minimizing Settling Errors

When long lead lengths are required the following general practices can be used to minimize or measure settling errors:

1. DO NOT USE WIRE WITH PVC INSULATED CONDUCTORS. PVC has a high dielectric which extends input settling time.

2. Where possible, run excitation leads and signal leads in separate shields to minimize transients.

3. When measurement speed is not a prime consideration, additional time can be used to ensure ample settling time. The settling time required can be measured with the CR1000.

4.2.8.2 Measuring the Necessary Settling Time

Settling time for a particular sensor and cable can be measured with the CR1000. Programming a series of measurements with increasing settling times will yield data that indicates at what settling time a further increase results in negligible change in the measured voltage. The programmed settling time at this point indicates the true settling time for the sensor and cable combination.

CRBASIC EXAMPLE. Measuring Settling Time (p. 59) presents CRBASIC code to help determine settling time for a pressure transducer utilizing a high capacitance semi-conductor. The code consists of a series of full-bridge measurements (BrFull ()) with increasing settling times. The pressure transducer is placed in steady-state conditions so changes in measured voltage are attributable to settling time rather than changes in the measured pressure. Reviewing *SECTION. Programming* (p. 129) may help in understanding the CRBASIC code in the example.

The first six measurements are shown in *TABLE. First Six Values of Settling Time Data* (p. 60). Each trace in *FIGURE. Settling Time for Pressure Transducer* (p. 59) contains all 20 PT() values for a given record number, along with an average value showing the measurements as percent of final reading. The reading has settled to 99.5% of the final value by the fourteenth measurement, PT(14). This is a suitable accuracy for the application, so a settling time of 1400 µs is determined to be adequate.

CRBASIC EXAMPLE 2. Measuring Settling Time

```
'Program to measure the settling time of a sensor measured with a differential
'voltage measurement

Public PT(20)                                   'Variable to hold the measurements

DataTable(Settle,True,100)
    Sample(20,PT(),IEEE4)
EndTable

BeginProg
    Scan(1,Sec,3,0)

        BrFull(PT(1),1,mV7.5,1,Vx1,1,2500,True,True,100,250,1.0,0)
        BrFull(PT(2),1,mV7.5,1,Vx1,1,2500,True,True,200,250,1.0,0)
        BrFull(PT(3),1,mV7.5,1,Vx1,1,2500,True,True,300,250,1.0,0)
        BrFull(PT(4),1,mV7.5,1,Vx1,1,2500,True,True,400,250,1.0,0)
        BrFull(PT(5),1,mV7.5,1,Vx1,1,2500,True,True,500,250,1.0,0)
        BrFull(PT(6),1,mV7.5,1,Vx1,1,2500,True,True,600,250,1.0,0)
        BrFull(PT(7),1,mV7.5,1,Vx1,1,2500,True,True,700,250,1.0,0)
        BrFull(PT(8),1,mV7.5,1,Vx1,1,2500,True,True,800,250,1.0,0)
        BrFull(PT(9),1,mV7.5,1,Vx1,1,2500,True,True,900,250,1.0,0)
        BrFull(PT(10),1,mV7.5,1,Vx1,1,2500,True,True,1000,250,1.0,0)
        BrFull(PT(11),1,mV7.5,1,Vx1,1,2500,True,True,1100,250,1.0,0)
        BrFull(PT(12),1,mV7.5,1,Vx1,1,2500,True,True,1200,250,1.0,0)
        BrFull(PT(13),1,mV7.5,1,Vx1,1,2500,True,True,1300,250,1.0,0)
        BrFull(PT(14),1,mV7.5,1,Vx1,1,2500,True,True,1400,250,1.0,0)
        BrFull(PT(15),1,mV7.5,1,Vx1,1,2500,True,True,1500,250,1.0,0)
        BrFull(PT(16),1,mV7.5,1,Vx1,1,2500,True,True,1600,250,1.0,0)
        BrFull(PT(17),1,mV7.5,1,Vx1,1,2500,True,True,1700,250,1.0,0)
        BrFull(PT(18),1,mV7.5,1,Vx1,1,2500,True,True,1800,250,1.0,0)
        BrFull(PT(19),1,mV7.5,1,Vx1,1,2500,True,True,1900,250,1.0,0)
        BrFull(PT(20),1,mV7.5,1,Vx1,1,2500,True,True,2000,250,1.0,0)

        CallTable Settle

    NextScan
EndProg
```

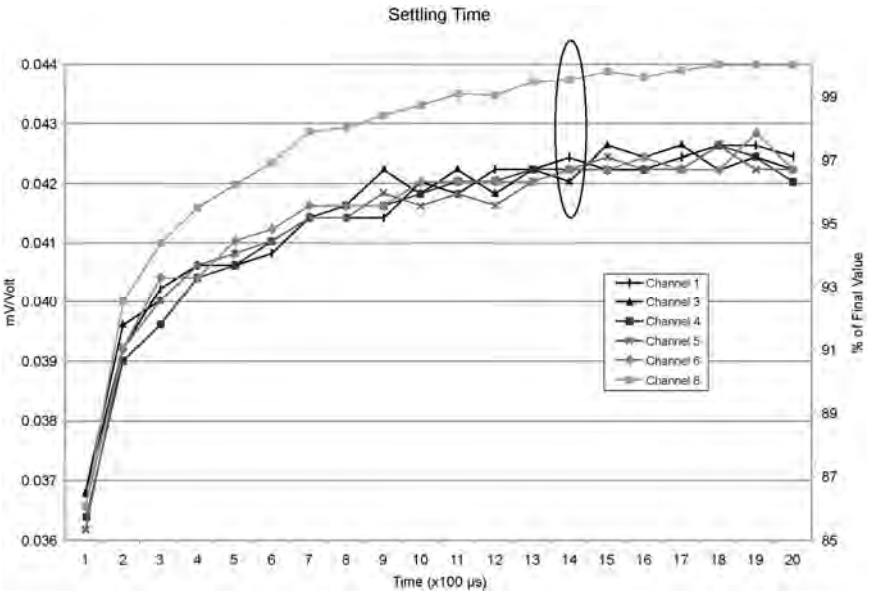


FIGURE 33. Settling Time for Pressure Transducer

TABLE 11. First Six Values of Settling Time Data

TIMESTAMP	*REC*	*PT(1)*	*PT(2)*	*PT(3)*	*PT(4)*	*PT(5)*	*PT(6)*
		Smp	*Smp*	*Smp*	*Smp*	*Smp*	*Smp*
1/3/2000 23:34	0	0.03638599	0.03901386	0.04022673	0.04042887	0.04103531	0.04123745
1/3/2000 23:34	1	0.03658813	0.03921601	0.04002459	0.04042887	0.04103531	0.0414396
1/3/2000 23:34	2	0.03638599	0.03941815	0.04002459	0.04063102	0.04042887	0.04123745
1/3/2000 23:34	3	0.03658813	0.03941815	0.03982244	0.04042887	0.04103531	0.04103531
1/3/2000 23:34	4	0.03679027	0.03921601	0.04022673	0.04063102	0.04063102	0.04083316

4.2.9 Self-Calibration

Read More! Related topics can be found in *SECTION. Offset Voltage Compensation* (p. 52)

The CR1000 self-calibrates to compensate for changes induced by fluctuating operating temperatures and aging. Without self-calibration, measurement accuracy over the operational temperature range is worse by about a factor of 10. That is, over the extended temperature range of -40°C to 85°C, the accuracy specification of ±0.12% of reading can degrade to ±1% of reading with self-calibration disabled. If the temperature of the CR1000 remains the same, there is little calibration drift with self-calibration disabled.

Note -- Self-calibration requires the CR1000 to have an internal voltage standard. The internal voltage standard should periodically be calibrated by Campbell Scientific. When high accuracy voltage measurements are required, a two year calibration cycle is recommended.

Unless a Calibrate() instruction is present in the running CRBASIC program, the CR1000 automatically performs self-calibration during spare time in the background as an automatic *slow sequence* (p. 160), with a segment of the calibration occurring every 4 seconds. If there is insufficient time to do the background calibration because of a scan consuming user program, the CR1000 will display the following warning at compile time: "Warning when Fast Scan x is running background calibration is disabled".

The composite transfer function of the instrumentation amplifier, integrator, and analog-to-digital converter of the CR1000 is described by the following equation:

```
COUNTS = G * Vin + B
```

where COUNTS is the result from an analog-to-digital conversion, G is the voltage gain for a given input range, and B is the internally measured offset voltage.

Automatic self-calibration only calibrates the G and B values necessary to run a given CRBASIC program, resulting in a program dependent number of self-calibration segments ranging from at least 6 to a maximum of 91. A typical number of segments required in self-calibration is 20 for analog ranges and 1 segment for the panel temperature measurement, totaling 21 segments. So, (21 segments) * (4 s / segment) = 84 s per complete self-calibration. The worst-case is (91 segments) * (4 s / segment) = 364 s per complete self-calibration.

During instrument power-up, the CR1000 computes calibration coefficients by averaging 10 complete sets of self-calibration measurements. After power up, newly determined G and B values are low-pass filtered as followed: **Next_Value** = (1/5) * **New** + (4/5) * **Old**. For a step change of the **New** value, the low-pass filter **Next_Value** = (1/5) * **New** + (4/5) * **Old** results in 20% settling for 1 **New** value, 49% settling for 3 **New** values, 67% settling for 5 **New** values, 89% settling for 10 **New** values, and 96% settling for 14 **New** values. If this rate of update for measurement channels is too slow, a user can utilize the Calibrate() instruction. The Calibrate() instruction computes the necessary G and B values every scan without any low-pass filtering.

For a VoltSe() instruction, B is determined as part of self-calibration only if the parameter **MeasOff** = 0. An exception is B for VoltSe () on the ±2500 mV input range with 250 µs integration, which is always determined in self-calibration for use internally. For a VoltDiff () instruction, B is determined as part of self-calibration only if the parameter **RevDiff** = 0.

VoltSe() and VoltDiff() instructions on a given input range with the same integration durations, utilize the same G, but different B values. The 6 input voltage ranges (±5000 mV, ±2500 mV, ±250 mV, ±25 mV, ±7.5 mV, ±2.5 mV) along with the 3 different integration durations (250 µs, _50Hz, and _60Hz) result in a maximum of 18 different gains (G), and 18 offsets for VoltSe() measurements (B), and 18 offsets for VoltDiff() measurements (B) to be determined during CR1000 self-calibration (maximum of 54 values). These values can be viewed in the Status Table, with entries identified as listed in *TABLE. Status Table Calibration Entries* (p. 62).

Automatic self-calibration can be overridden with the Calibrate() instruction, which forces a calibration for each execution, and does not employ any low-pass filtering on the newly determined G and B values. There are two parameters

associated with the Calibrate instruction; Dest and CalRange. The CalRange parameter determines whether to calibrate only the necessary input ranges for a given CRBASIC program (Value = 0) or to calibrate all input ranges (Value ≠ 0). The Dest parameter should be of sufficient dimension for all the returned G and B values, which is 2 minimum for the automatic self-calibration of VoltSE () including B (offset) for the ±2500 mV input range with first 250 µs integration, and 54 maximum for all possible integration durations and input voltage ranges chosen.

An example use of the Calibrate() instruction to calibrate all input ranges is given as

```
Calibrate(cal(1),true)
```

where Dest is an array of 54 variables, and Range ≠ 0 to calibrate all input ranges. Results of this command are listed in *TABLE. Calibrate () Instruction Results* (p. 63).

TABLE 12. Status Table Calibration Entries

Status Table Element	*Descriptions of Status Table Elements*			
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*
CalGain(1)		Gain	5000	250 ms
CalGain(2)		Gain	2500	250 ms
CalGain(3)		Gain	250	250 ms
CalGain(4)		Gain	25	250 ms
CalGain(5)		Gain	7.5	250 ms
CalGain(6)		Gain	2.5	250 ms
CalGain(7)		Gain	5000	60 Hz Rejections
CalGain(8)		Gain	2500	60 Hz Rejection
CalGain(9)		Gain	250	60 Hz Rejection
CalGain(10)		Gain	25	60 Hz Rejection
CalGain(11)		Gain	7.5	60 Hz Rejection
CalGain(12)		Gain	2.5	60 Hz Rejection
CalGain(13)		Gain	5000	50 Hz Rejection
CalGain(14)		Gain	2500	50 Hz Rejection
CalGain(15)		Gain	250	50 Hz Rejection
CalGain(16)		Gain	25	50 Hz Rejection
CalGain(17)		Gain	7.5	50 Hz Rejection
CalGain(18)		Gain	2.5	50 Hz Rejection
CalSeOffset(1)	SE	Offset	5000	250 ms
CalSeOffset(2)	SE	Offset	2500	250 ms
CalSeOffset(3)	SE	Offset	250	250 ms
CalSeOffset(4)	SE	Offset	25	250 ms
CalSeOffset(5)	SE	Offset	7.5	250 ms

TABLE 12. Status Table Calibration Entries

Status Table Element	*Descriptions of Status Table Elements*			
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*
CalSeOffset(6)	SE	Offset	2.5	250 ms
CalSeOffset(7)	SE	Offset	5000	60 Hz Rejection
CalSeOffset(8)	SE	Offset	2500	60 Hz Rejection
CalSeOffset(9)	SE	Offset	250	60 Hz Rejection
CalSeOffset(10)	SE	Offset	25	60 Hz Rejection
CalSeOffset(11)	SE	Offset	7.5	60 Hz Rejection
CalSeOffset(12)	SE	Offset	2.5	60 Hz Rejection
CalSeOffset(13)	SE	Offset	5000	50 Hz Rejection
CalSeOffset(14)	SE	Offset	2500	50 Hz Rejection
CalSeOffset(15)	SE	Offset	250	50 Hz Rejection
CalSeOffset(16)	SE	Offset	25	50 Hz Rejection
CalSeOffset(17)	SE	Offset	7.5	50 Hz Rejection
CalSeOffset(18)	SE	Offset	2.5	50 Hz Rejection
CalDiffOffset(1)	Diff	Offset	5000	250 ms
CalDiffOffset(2)	Diff	Offset	2500	250 ms
CalDiffOffset(3)	Diff	Offset	250	250 ms
CalDiffOffset(4)	Diff	Offset	25	250 ms
CalDiffOffset(5)	Diff	Offset	7.5	250 ms
CalDiffOffset(6)	Diff	Offset	2.5	250 ms
CalDiffOffset(7)	Diff	Offset	5000	60 Hz Rejection
CalDiffOffset(8)	Diff	Offset	2500	60 Hz Rejection
CalDiffOffset(9)	Diff	Offset	250	60 Hz Rejection
CalDiffOffset(10)	Diff	Offset	25	60 Hz Rejection
CalDiffOffset(11)	Diff	Offset	7.5	60 Hz Rejection
CalDiffOffset(12)	Diff	Offset	2.5	60 Hz Rejection
CalDiffOffset(13)	Diff	Offset	5000	50 Hz Rejection
CalDiffOffset(14)	Diff	Offset	2500	50 Hz Rejection
CalDiffOffset(15)	Diff	Offset	250	50 Hz Rejection
CalDiffOffset(16)	Diff	Offset	25	50 Hz Rejection
CalDiffOffset(17)	Diff	Offset	7.5	50 Hz Rejection
CalDiffOffset(18)	Diff	Offset	2.5	50 Hz Rejection

TABLE 13. Calibrate() Instruction Results

Array Cal() Element	*Descriptions of Array Elements*				*Typical Value*
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*	
1	SE	Offset	5000	250 ms	±5 LSB
2	Diff	Offset	5000	250 ms	±5 LSB
3		Gain	5000	250 ms	-1.34 mV/LSB
4	SE	Offset	2500	250 ms	±5 LSB
5	Diff	Offset	2500	250 ms	±5 LSB
6		Gain	2500	250 ms	-0.67 mV/LSB
7	SE	Offset	250	250 ms	±5 LSB
8	Diff	Offset	250	250 ms	±5 LSB
9		Gain	250	250 ms	-0.067 mV/LSB
10	SE	Offset	25	250 ms	±5 LSB
11	Diff	Offset	25	250 ms	±5 LSB
12		Gain	25	250 ms	-0.0067 mV/LSB
13	SE	Offset	7.5	250 ms	±10 LSB
14	Diff	Offset	7.5	250 ms	±10 LSB
15		Gain	7.5	250 ms	-0.002 mV/LSB
16	SE	Offset	2.5	250 ms	±20 LSB
17	Diff	Offset	2.5	250 ms	±20 LSB
18		Gain	2.5	250 ms	-0.00067 mV/LSB
19	SE	Offset	5000	60 Hz Rejection	±5 LSB
20	Diff	Offset	5000	60 Hz Rejection	±5 LSB
21		Gain	5000	60 Hz Rejection	-0.67 mV/LSB
22	SE	Offset	2500	60 Hz Rejection	±5 LSB
23	Diff	Offset	2500	60 Hz Rejection	±5 LSB
24		Gain	2500	60 Hz Rejection	-0.34 mV/LSB
25	SE	Offset	250	60 Hz Rejection	±5 LSB
26	Diff	Offset	250	60 Hz Rejection	±5 LSB
27		Gain	250	60 Hz Rejection	-0.067 mV/LSB
28	SE	Offset	25	60 Hz Rejection	±5 LSB
29	Diff	Offset	25	60 Hz Rejection	±5 LSB
30		Gain	25	60 Hz Rejection	-0.0067 mV/LSB
31	SE	Offset	7.5	60 Hz Rejection	±10 LSB
32	Diff	Offset	7.5	60 Hz Rejection	±10 LSB
33		Gain	7.5	60 Hz Rejection	-0.002 mV/LSB
34	SE	Offset	2.5	60 Hz Rejection	±20 LSB
35	Diff	Offset	2.5	60 Hz Rejection	±20 LSB
36		Gain	2.5	60 Hz Rejection	-0.00067 mV/LSB

TABLE 13. Calibrate() Instruction Results

Array Cal() Element	*Descriptions of Array Elements*				*Typical Value*
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*	
37	SE	Offset	5000	50 Hz Rejection	±5 LSB
38	Diff	Offset	5000	50 Hz Rejection	±5 LSB
39		Gain	5000	50 Hz Rejection	-0.67 mV/LSB
40	SE	Offset	2500	50 Hz Rejection	±5 LSB
41	Diff	Offset	2500	50 Hz Rejection	±5 LSB
42		Gain	2500	50 Hz Rejection	-0.34 mV/LSB
43	SE	Offset	250	50 Hz Rejection	±5 LSB
44	Diff	Offset	250	50 Hz Rejection	±5 LSB
45		Gain	250	50 Hz Rejection	-0.067 mV/LSB
46	SE	Offset	25	50 Hz Rejection	±5 LSB
47	Diff	Offset	25	50 Hz Rejection	±5 LSB
48		Gain	25	50 Hz Rejection	-0.0067 mV/LSB
49	SE	Offset	7.5	50 Hz Rejection	±10 LSB
50	Diff	Offset	7.5	50 Hz Rejection	±10 LSB
51		Gain	7.5	50 Hz Rejection	-0.002 mV/LSB
52	SE	Offset	2.5	50 Hz Rejection	±20 LSB
53	Diff	Offset	2.5	50 Hz Rejection	±20 LSB
54		Gain	2.5	50 Hz Rejection	-0.00067 mV/LSB

4.2.10 Time Skew Between Measurements

Time skew between consecutive voltage measurements is a function of settling and integration times, A/D conversion, and the number of reps entered into the VoltDiff() or VoltSE() instruction. The relationship is:

Time Skew = Settling Time + Integration Time + A-D Conversion + Reps/NoReps*

*Reps/No Reps -- If Reps > 1(i.e., multiple measurements by a single instruction), no additional time is required. If Reps = 1 in consecutive voltage instructions, add 15uSec per instruction.

4.3 Bridge Resistance

Many sensors detect phenomena by way of change in a resistive circuit. Thermistors, strain gages, and position potentiometers are examples. Resistance measurements are special case voltage measurements. By supplying a precise, known voltage to a resistive circuit, then measuring the returning voltage, resistance can be calculated.

Read More! Available resistive bridge completion modules are listed in *APPENDIX. Signal Conditioners* (p. 500).

Five bridge measurement instructions are features of the CR1000. *TABLE. Resistive Bridge Circuits -- Voltage Excitation* (p. 66) show circuits that are typically measured with these instructions. In the diagrams, resistors labeled R_s are normally the sensors and those labeled R_f are normally precision fixed (static) resistors. Circuits other than those diagrammed can be measured, provided the excitation and type of measurements are appropriate. Program Code *CRBASIC EXAMPLE. 4 Wire Full Bridge Measurement* (p. 68) shows CR1000 code for measuring and processing four wire full bridge circuits.

All bridge measurements have the option (**RevEx**) to make one set of measurements with the excitation as programmed and another set of measurements with the excitation polarity reversed. The offset error in the two measurements due to thermal EMFs can then be accounted for in the processing of the measurement instruction. The excitation channel maintains the excitation voltage or current until the hold for the analog to digital conversion is completed. When more than one measurement per sensor is necessary (four wire half bridge, three wire half bridge, six wire full bridge), excitation is applied separately for each measurement. For example, in the four-wire half-bridge, when the excitation is reversed, the differential measurement of the voltage drop across the sensor is made with the excitation at both polarities and then excitation is again applied and reversed for the measurement of the voltage drop across the fixed resistor.

Calculating the resistance of a sensor that is one of the legs of a resistive bridge requires additional processing following the bridge measurement instruction. *TABLE. Resistive Bridge Circuits -- Voltage Excitation* (p. 66) lists the schematics of bridge configurations and related resistance equations.

TABLE 14. Resistive Bridge Circuits -- Voltage Excitation

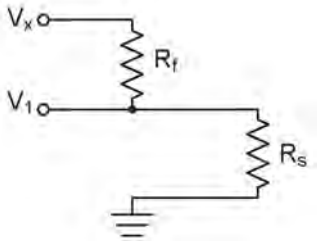
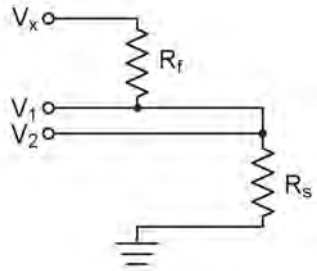
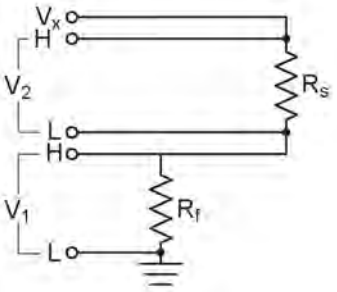
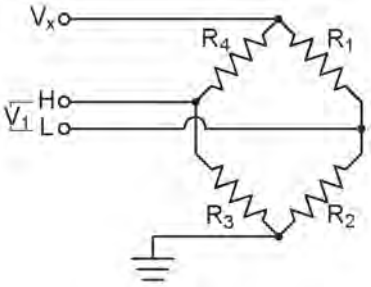
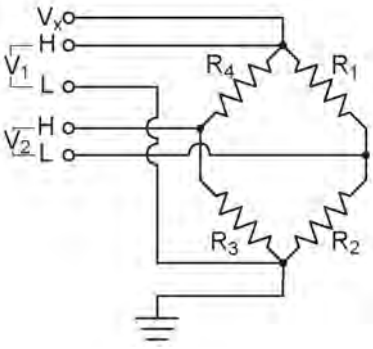
Resistive Bridge Type and Circuit Diagram	*CRBASIC Instruction and Fundamental Relationship*	*Relationships*
Half Bridge[1] 	CRBASIC Instruction: **BrHalf()** Fundamental Relationship[2]: $X = \frac{V1}{V_x} = \frac{R_S}{R_s + R_f}$	$R_s = R_f \frac{X}{1-X}$ $R_f = \frac{R_s(1-X)}{X}$
3 Wire Half Bridge[1,3]	CRBASIC Instruction: **BrHalf3W()** Fundamental Relationship[2]: $X = \frac{2V_2 - V_1}{V_x - V_1} = \frac{R_s}{R_f}$	$R_f = R_s / X$ $R_s = R_f X$

TABLE 14. Resistive Bridge Circuits -- Voltage Excitation

Resistive Bridge Type and Circuit Diagram	*CRBASIC Instruction and Fundamental Relationship*	*Relationships*
		
4 Wire Half Bridge[1,3] 	CRBASIC Instruction: **BrHalf4W()** Fundamental Relationship[2]: $X = \frac{V_2}{V_1} = \frac{R_s}{R_f}$	$R_s = R_f X$ $R_f = R_s / X$
Full Bridge[1,3] 	CRBASIC Instruction: **BrFull()** Fundamental Relationship[2]: $X = 1000\frac{V_1}{V_x}$ $= 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	These relationships apply to BrFull() and BrFull6W(). $X_1 = \frac{-X}{1000} + \frac{R_3}{R_3+R_4}$ $R_1 = \frac{R_2(1-X_1)}{X_1}$ $R_2 = \frac{R_1 X_1}{1-X_1}$
6 Wire Full Bridge[1] 	CRBASIC Instruction: **BrFull6W()** Fundamental Relationship[2]: $X = 1000\frac{V_2}{V_1}$ $= 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	$X_2 = \frac{X}{1000} + \frac{R_2}{R_1+R_2}$ $R_3 = \frac{R_4 X_2}{1-X_2}$ $R_4 = \frac{R_3(1-X_2)}{X_2}$

[1]Key: V_x = excitation voltage; V_1, V_2 = sensor return voltages; R_f = "fixed", "bridge" or "completion" resistor; R_s = "variable" or "sensing" resistor.
[2]Where X = result of the CRBASIC bridge measurement instruction with a multiplier of 1 and an offset of 0.
[3]See *APPENDIX. Resistive Bridge Modules* (p. 500) for a list of available terminal input modules to facilitate this measurement.

CRBASIC EXAMPLE 3. 4 Wire Full Bridge Measurement and Processing

```
'Declare Variables
Public X
Public X1
Public R1
Public R2
Public R3
Public R4

Main Program
BeginProg
    R2 = 1000                                   'Resistance of R2
    R3 = 1000                                   'Resistance of R3
    R4 = 1000                                   'Resistance of R4

    Scan(500,mSec,1,0)

        'Full Bridge Measurement:
        BrFull(X,1,mV2500,1,1,1,2500,True,True,0,_60Hz,1.0,0.0)
        X1 = ((-1 * X) / 1000) + (R3 / (R3 + R4))
        R1 = (R2 * (1 - X1)) / X1

    NextScan
EndProg
```

4.3.1 Measurements Requiring ac Excitation

Some resistive sensors require ac excitation. These include electrolytic tilt sensors, soil moisture blocks, water conductivity sensors and wetness sensing grids. The use of dc excitation with these sensors can result in polarization, which will cause erroneous measurement, shift calibration, or lead to rapid sensor decay.

Other sensors, e.g., LVDTs (Linear Variable Differential Transformers), require an ac excitation because they rely on inductive coupling to provide a signal. dc excitation will provide no output.

CR1000 bridge measurements can reverse excitation polarity to provide ac excitation and avoid ion polarization.

Note Sensors requiring ac excitation require techniques to minimize or eliminate ground loops. See *SECTION. Ground Looping in Ionic Measurements* (p. 109).

4.3.2 Strain Calculations

Read More! FieldCalStrain in *SECTION. FieldCa () Demonstration Programs* (p. 230).

A principal use of the four wire full bridge is the measurement of strain gages in structural stress analysis. StrainCalc () calculates microstrain, με, from an appropriate formula for the particular strain bridge configuration used. All strain gages supported by StrainCalc () use the full bridge electronic configuration. In strain gage parlance, "quarter bridge", "half bridge" and "full bridge" refer to the

number of active elements in the full bridge, i.e., 1, 2, or 4 active elements respectively.

StrainCalc() requires a bridge configuration code. *TABLE. StrainCalc() Instruction Equations* (p. 69) shows the equation used by each configuration code. Each code can be preceded by a negative sign (-). Use a positive code when the bridge is configured so the output decreases with increasing strain. Use a negative code when the bridge is configured so the output increases with increasing strain. In the equations in *TABLE. StrainCalc() Instruction Equations* (p. 69), a negative code sets the polarity of V_r to negative (-).

TABLE 15. StrainCalc() Instruction Equations

StrainCalc() BrConfig *Code*	*Configuration*
1	Quarter bridge strain gage: $\mu\varepsilon = \frac{-4*10^6 V_r}{GF(1+2V_r)}$
2	Half bridge strain gage. One gage parallel to strain, the other at 90° to strain. $\mu\varepsilon = \frac{-4*10^6 V_r}{GF[(1+\nu) - 2V_r(\nu-1)]}$
3	Half bridge strain gage. One gage parallel to $+\varepsilon$, the other parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-2*10^6 V_r}{GF}$
4	Full bridge strain gage. Two gages parallel to $+\varepsilon$, the other two parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-10^6 V_r}{GF}$
5	Full bridge strain gage. Half the bridge has to gages parallel to $+\varepsilon$ and $-\varepsilon$, and the other half to $+\nu\varepsilon$ and $-\nu\varepsilon$: $\mu\varepsilon = \frac{-2*10^6 V_r}{GF(\nu+1)}$
6	Full bridge strain gage. Half the bridge has two gages parallel to $+\varepsilon$ and $-\nu\varepsilon$, and the other half to $-\nu\varepsilon$ and $+\varepsilon$: $\mu\varepsilon = \frac{-2*10^6 V_r}{GF[(\nu+1) - V_r(\nu-1)]}$

where:

- ν: Poisson Ratio (0 if not applicable)
- **GF**: Gage Factor
- $\mathbf{V_r}$: 0.001 (Source-Zero) if BRConfig code is positive (+)
- $\mathbf{V_r}$: -0.001 (Source-Zero) if BRConfig code is negative (-)

where:

- "source": the result of the full Wheatstone bridge measurement ($X = 1000 * V_1 / V_x$) when multiplier = 1 and offset = 0.
- "zero": gage offset to establish an arbitrary zero (see FieldCalStrain in *FieldCal () Demonstration Programs* (p. 230)).

StrainCalc Example: See *SECTION. FieldCalStrain() Demonstration Program* (p. 237)

4.4 Thermocouple

Note Thermocouples are easy to use with the CR1000. They are also inexpensive. However, they pose several challenges to the acquisition of accurate temperature data, particularly when using external reference junctions. Campbell Scientific **strongly encourages** any user of thermocouples to carefully evaluate *SECTION. Error Analysis* (p. 71). An introduction to thermocouple measurements is located in *SECTION. Hands-on Exercise - Measuring a Thermocouple* (p. 13).

The micro-volt resolution and low-noise voltage measurement capability of the CR1000 is well suited for measuring thermocouples. A thermocouple consists of two wires, each of a different metal or alloy, joined at one end to form the measurement junction. At the opposite end, each lead connects to terminals of a voltage measurement device, such as the CR1000. These connections form the reference junction. If the two junctions (measurement and reference) are at different temperatures, a voltage proportional to the difference is induced in the wires. This phenomenon is known as the Seebeck effect. Measurement of the voltage between the positive and negative terminals of the voltage measurement device provides a direct measure of the temperature difference between the measurement and reference junctions. A third metal (e.g., solder or CR1000 terminals) between the two dissimilar metal wires form parasitic thermocouple junctions, the effects of which cancel if the two wires are at the same temperature. Consequently, the two wires at the reference junction are placed in close proximity so they remain at the same temperature. Knowledge of the reference junction temperature provides the determination of a reference junction compensation voltage, corresponding to the temperature difference between the reference junction and 0°C. This compensation voltage, combined with the measured thermocouple voltage, can be used to compute the absolute temperature of the thermocouple junction. To facilitate thermocouple measurements, a thermistor is integrated into the CR1000 wiring panel for measurement of the reference junction temperature by means of the PanelTemp() instruction.

TCDiff() and TCSe() thermocouple instructions determine thermocouple temperatures using the following sequence. First, the temperature (°C) of the reference junction is determined. A reference junction compensation voltage is next computed based on the temperature difference between the reference junction and 0 °C. If the reference junction is the CR1000 analog input terminals, the temperature is conveniently measured with the PanelTemp() instruction. The actual thermocouple voltage is measured and combined with the reference junction compensation voltage. It is then used to determine the

thermocouple junction temperature based on a polynomial approximation of NIST thermocouple calibrations.

4.4.1 Error Analysis

The error in the measurement of a thermocouple temperature is the sum of the errors in the reference junction temperature measurement plus the temperature-to-voltage polynomial fit error, the non-ideality of the thermocouple (deviation from standards published in NIST Monograph 175), the thermocouple voltage measurement accuracy, and the voltage-to-temperature polynomial fit error (difference between NIST standard and CR1000 polynomial approximations). The discussion of errors that follows is limited to these errors in calibration and measurement and does not include errors in installation or matching the sensor and thermocouple type to the environment being measured.

4.4.1.1 Panel Temperature Error

The panel temperature thermistor (Betatherm 10K3A1A) is just under the panel in the center of the two rows of analog input terminals. It has an interchangeability specification of 0.1°C for temperatures between 0 and 70°C. Below freezing and at higher temperatures, this specification is degraded. Combined with possible errors in the completion resistor measurement and the Steinhart and Hart equation used to calculate the temperature from resistance, the accuracy of panel temperature is estimated in *FIGURE. Panel Temperature Error Summary* (p. 72). In summary, error is estimated at ± 0.1°C over -0 to 40°C, ± 0.3°C from -25 to 50°C, and ± 0.8°C from -55 to 85°C.

The error in the reference temperature measurement is a combination of the error in the thermistor temperature and the difference in temperature between the panel thermistor and the terminals the thermocouple is connected to. The terminal strip cover should always be used when making thermocouple measurements. It insulates the terminals from drafts and rapid fluctuations in temperature as well as conducting heat to reduce temperature gradients. In a typical installation where the CR1000 is in a weather tight enclosure not subject to violent swings in temperature or uneven solar radiation loading, the temperature difference between the terminals and the thermistor is likely to be less than 0.2°C.

With an external driving gradient, the temperature gradients on the input panel can be much worse. For example, the CR1000 was placed in a controlled temperature chamber. Thermocouples in channels at the ends and middle of each analog terminal strip measured the temperature of an insulated aluminum bar outside the chamber. The temperature of this bar was also measured by another datalogger. Differences between the temperature measured by one of the thermocouples and the actual temperature of the bar are due to the temperature difference between the terminals the thermocouple is connected to and the thermistor reference (the figures have been corrected for thermistor errors). *FIGURE. Panel Temperature Gradients (Low Temperature to High)* (p. 72) shows the errors when the chamber was changed from low temperature to high in approximately 15 minutes. *FIGURE. Panel Temperature Gradients (High Temperature to Low)* (p. 72) shows the results when going from high temperature to low. During rapid temperature changes, the panel thermistor will

tend to lag behind terminal temperature because it is mounted deeper in the CR1000.

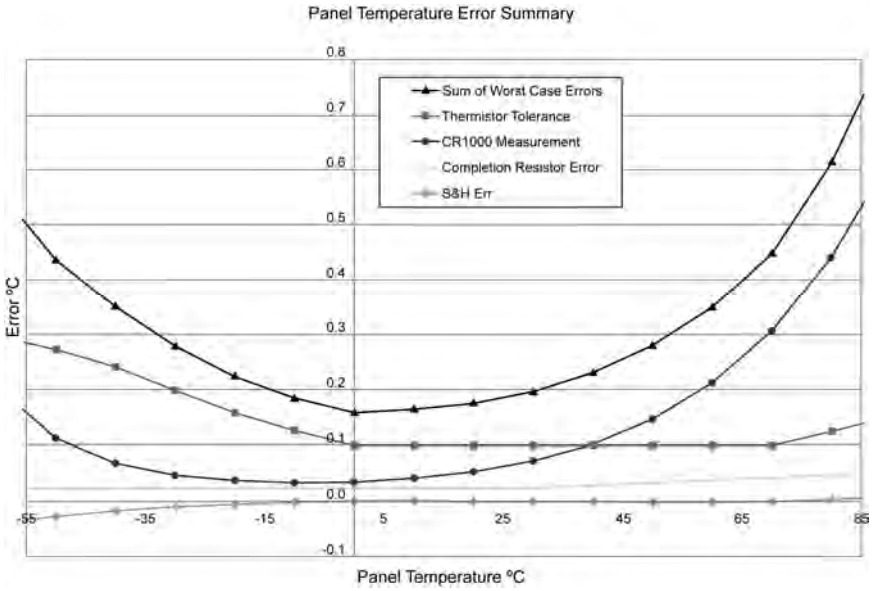


FIGURE 34. Panel Temperature Error Summary

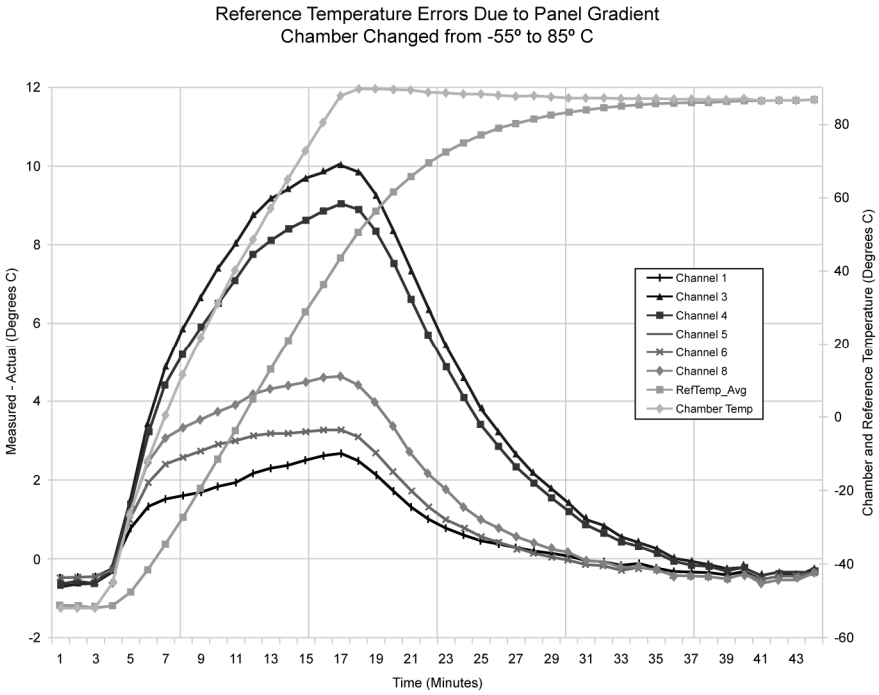


FIGURE 35. Panel Temperature Gradients (Low Temperature to High)

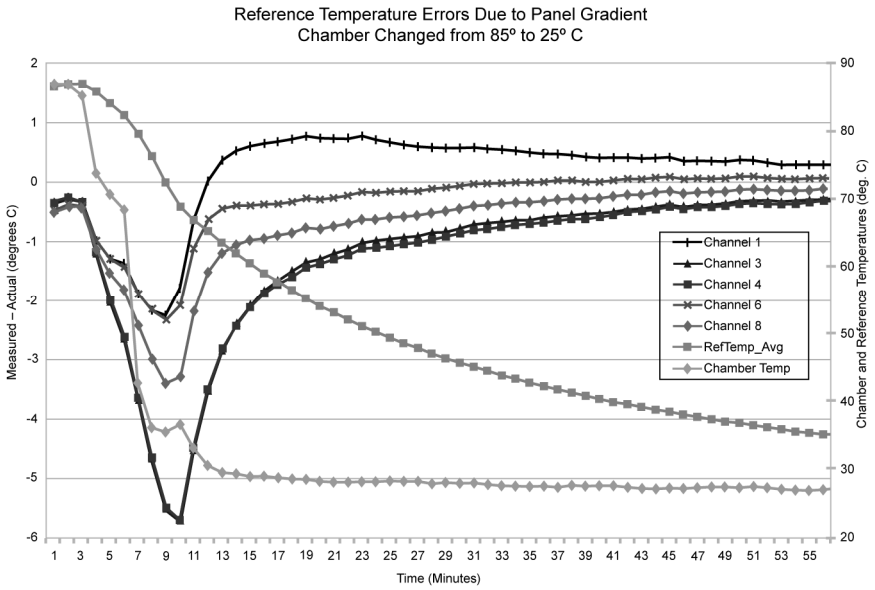


FIGURE 36. Panel Temperature Gradients (High Temperature to Low)

4.4.1.2 Thermocouple Limits of Error

The standard reference that lists thermocouple output voltage as a function of temperature (reference junction at 0°C) is the NIST (National Institute of Standards and Technology) Monograph 175 (1993). ANSI (American National Standards Institute) has established limits of error on thermocouple wire which is accepted as an industry standard (ANSI MC 96.1, 1975). *TABLE. Limits of Error for Thermocouple Wire* (p. 74) gives the ANSI limits of error for standard and special grade thermocouple wire of the types accommodated by the CR1000.

When both junctions of a thermocouple are at the same temperature there is no voltage produced (law of intermediate metals). A consequence of this is that a thermocouple cannot have an offset error; any deviation from a standard (assuming the wires are each homogeneous and no secondary junctions exist) is due to a deviation in slope. In light of this, the fixed temperature limits of error (e.g., ±1.0°C for type T as opposed to the slope error of 0.75% of the temperature) in the table above are probably greater than one would experience when considering temperatures in the environmental range (i.e., the reference junction, at 0°C, is relatively close to the temperature being measured, so the absolute error - the product of the temperature difference and the slope error - should be closer to the percentage error than the fixed error). Likewise, because thermocouple calibration error is a slope error, accuracy can be increased when the reference junction temperature is close to the measurement temperature. For the same reason differential temperature measurements, over a small temperature gradient, can be extremely accurate.

To quantitatively evaluate thermocouple error when the reference junction is not fixed at 0°C limits of error for the Seebeck coefficient (slope of thermocouple voltage vs. temperature curve) are needed for the various thermocouples. Lacking this information, a reasonable approach is to apply the percentage

errors, with perhaps 0.25% added on, to the difference in temperature being measured by the thermocouple.

TABLE 16. Limits of Error for Thermocouple Wire (Reference Junction a

Thermocouple	*Temperature*	*Limits of Error (Whichever is greater)*	
Type	*Range°C*	*Standard*	*Special*
T	-200 to 0	± 1.0°C or 1.5%	
	0 to 350	± 1.0°C or 0.75%	± 0.5°C or 0.4%
J	0 to 750	± 2.2°C or 0.75%	± 1.1°C or 0.4%
E	-200 to 0	± 1.7°C or 1.0%	
	0 to 900	± 1.7°C or 0.5%	± 1.0°C or 0.4%
K	-200 to 0	± 2.2°C or 2.0%	
	0 to 1250	± 2.2°C or 0.75%	± 1.1°C or 0.4%
R or S	0 to 1450	± 1.5°C or 0.25%	± 0.6°C or 0.1%
B	800 to 1700	± 0.5%	Not Established.

4.4.1.3 Thermocouple Voltage Measurement Error

Thermocouple outputs are extremely small -- 10 to 70 µV per °C. Unless high resolution input ranges are used when programming the CR1000, accuracy and sensitivity are compromised. *TABLE. Voltage Range for Maximum Thermocouple Resolution* (p. 74) lists high resolution ranges available for various thermocouple types and temperature ranges. The following four example calculations of thermocouple input error demonstrate how the selected input voltage range impacts the accuracy of measurements. *FIGURE. Input Error Calculation* (p. 75) shows from where various values are drawn to complete the calculations. See *SECTION. Measurement Accuracy* (p. 48) for more information on measurement accuracy and accuracy calculations.

When the thermocouple measurement junction is in electrical contact with the object being measured (or has the possibility of making contact) a differential measurement should be made to avoid ground looping.

TABLE 17. Voltage Range for Maximum Thermocouple Resolution (with refe 20°C)				
TC Type and Temperature Range (°C)	***Tem-perature Range (°C) for ±2.5 mV Input Range***	***Tem-perature Range (°C) for ±7.5 mV Input Range***	***Tem-perature Range (°C) for ±25 mV Input Range***	***Tem-perature Range (°C) for ±250 mV Input Range***
T: -270 to 400	-45 to 75	-270 to 180	-270 to 400	not used
E: -270 to 1000	-20 to 60	-120 to 130	-270 to 365	>365
K: -270 to 1372	-40 to 80	-270 to 200	-270 to 620	>620
J: -210 to 1200	-25 to 65	-145 to 155	-210 to 475	>475
B: -0 to 1820	0 to 710	0 to 1265	0 to 1820	not used
R: -50 to 1768	-50 to 320	-50 to 770	-50 to 1768	not used
S: -50 to 1768	-50 to 330	-50 to 820	-50 to 1768	not used
N: -270 to 1300	-80 to 105	-270 to 260	-270 to 725	>725

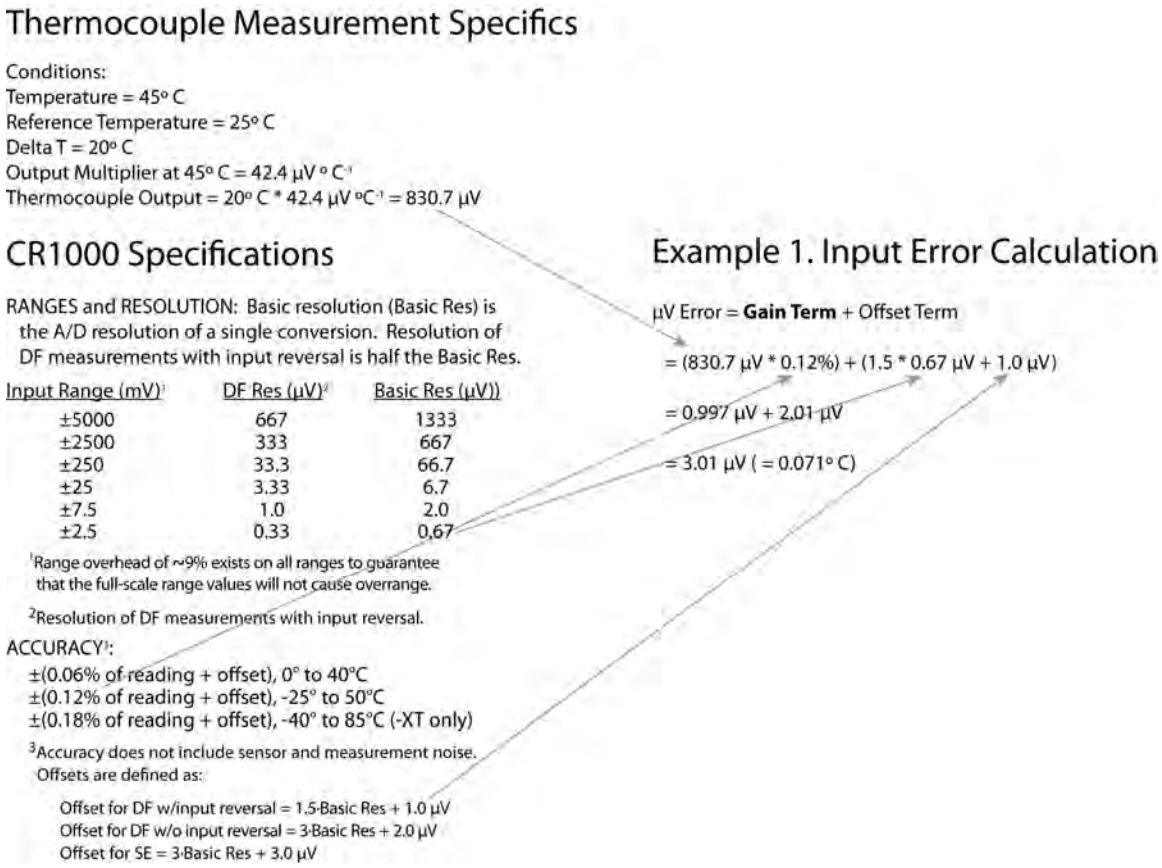


FIGURE 37. Input Error Calculation

4.4.1.3.1 Input Error Examples: Type T Thermocouple @ 45°C

These examples demonstrate that in the environmental temperature range, input offset error is much greater than input gain error because a small input range is used.

Conditions:

CR1000 module temperature between -25 to 50°C

Temperature = 45°C

Reference Temperature = 25°C

Delta T = 20°C

Thermocouple Output Multiplier at 45°C = 42.4 μV $°C^{-1}$

Thermocouple Output = 20°C * 42.4 μV $°C^{-1}$ = 830.7 μV

Input Range = ±2.5 mV

Error Calculations with Input Reversal = True

μV Error = Gain Term + Offset Term

= (830.7 μV * 0.12%) + (1.5 * 0.67 μV + 1.0 μV)

= 0.997 μV + 2.01 μV

= 3.01 μV (= 0.071 °C)

Error Calculations with Input Reversal = False

μV Error = Gain Term + Offset Term

= (830.7 μV * 0.12%) + (3 * 0.67 μV + 2.0 μV)

= 0.997 μV + 4.01 μV

= 5.01 μV (= 0.12 °C)

4.4.1.3.2 Input Error Examples: Type K Thermocouple @ 1300°C

Error in the temperature due to inaccuracy in the measurement of the thermocouple voltage increases at temperature extremes, particularly when the temperature and thermocouple type require using the ±200|250 mV range. For example, assume type K (chromel-alumel) thermocouples are used to measure temperatures around 1300°C.

These examples demonstrate that at temperature extremes, input offset error is much less than input gain error because the use of a larger input range is required.

Conditions

CR1000 module temperature between -25 to 50°C

Temperature = 1300°C

Reference Temperature = 25°C

Delta T = 1275°C

Thermocouple Output Multiplier at 1300°C = 34.9 μV $°C^{-1}$

Thermocouple Output = 1275°C * 34.9 μV $°C^{-1}$ = 44500 μV

Input Range = ±250 mV

Error Calculations with Input Reversal = True

μV Error = Gain Term + Offset Term

= (44500 μV * 0.12%) + (1.5 * 66.7 μV + 1.0 μV)

= 53.4 μV + 101.0 μV

= 154 μV (= 4.41 °C)

Error Calculations with Input Reversal = False

μV Error = Gain Term + Offset Term

= (44500 μV * 0.12%) + (3 * 66.7 μV + 2.0 μV)

= 53.4 μV + 200 μV

= 7.25 μV (= 7.25 °C)

4.4.1.4 Ground Looping Error

When the thermocouple measurement junction is in electrical contact with the object being measured (or has the possibility of making contact) a differential measurement should be made to avoid ground looping.

4.4.1.5 Noise Error

The typical input noise on the ±2.5 mV range for a differential measurement with 16.67 ms integration and input reversal is 0.19 μV RMS. On a type T thermocouple (approximately 40 μV/°C), this is 0.005°C. Note that this is an RMS value; some individual readings will vary by greater than this.

4.4.1.6 Thermocouple Polynomial Error

NIST Monograph 175 gives high order polynomials for computing the output voltage of a given thermocouple type over a broad range of temperatures. To speed processing and accommodate the CR1000's math and storage capabilities, four separate 6th order polynomials are used to convert from volts to temperature over the range covered by each thermocouple type. *TABLE. Limits of Error on CR1000 Thermocouple Polynomials* (p. 78) gives error limits for the thermocouple polynomials.

TABLE 18. Limits of Error on CR1000 Thermocouple Polynomials

TC Type	*Range °C*			*Limits of Error °C Relative to NIST Standards*
T	**-270**	**to**	**400**	
	-270	to	-200	+18 @ -270
	-200	to	-100	±0.08
	-100	to	100	±0.001
	100	to	400	±0.015
J	**-150**	**to**	**760**	±0.008
	-100	to	300	±0.002
E	**-240**	**to**	**1000**	
	-240	to	-130	±0.4
	-130	to	200	±0.005
	200	to	1000	±0.02
K	**-50**	**to**	**1372**	
	-50	to	950	±0.01
	950	to	1372	±0.04

4.4.1.7 Reference Junction Error

Thermocouple instructions TCDiff () and TCSe () include the parameter TRef to incorporate the reference junction temperature into the measurement. A reference junction compensation voltage is computed from TRef as part of the thermocouple instruction, based on the temperature difference between the reference junction and 0°C. The polynomials used to determine the reference junction compensation voltage do not cover the entire thermocouple range, as illustrated in *TABLE. Limits of Error on CR1000 Thermocouple Polynomials* (p. 78) and *TABLE. Reference Temperature Compensation Range and Polynomial Error* (p. 79). Substantial errors in the reference junction compensation voltage will result if the reference junction temperature is outside of the polynomial fit ranges given.

The reference junction temperature measurement can come from a PanelTemp () instruction, or from any other temperature measurement of the reference junction. The standard and extended (-XT) operating ranges for the CR1000 are

-25 to +50 °C and -55 to 85 °C, respectively. These ranges also apply to the reference junction temperature measurement using PanelTemp ().

Two sources of error arise when the reference temperature is out of the polynomial fit range. The most significant error is in the calculated compensation voltage; however a small error is also created by non-linearities in the Seebeck coefficient.

TABLE 19. Reference Temperature Compensation Range and Polynomia Standards

TC Type	*Range °C*	*Limits of Error °C*
T	-100 to 100	± 0.001
J	-150 to 296	± 0.005
E	-150 to 206	± 0.005
K	-50 to 100	± 0.01

4.4.1.8 Thermocouple Error Summary

The magnitude of the errors described in *SECTION. Error Analysis* (p. 71) illustrate that the greatest sources of error in a thermocouple temperature measurement are likely due to the limits of error on the thermocouple wire and in the reference temperature. Errors in the thermocouple and reference temperature linearizations are extremely small, and error in the voltage measurement is negligible.

TABLE. Example of Errors in Thermocouple Temperature (p. 79) illustrates the relative magnitude of these errors in the environmental range. It shows a worst case situation where all errors are maximum and additive. A temperature of 45°C is measured with a type T (copper-constantan) thermocouple, using the ±2.5 mV range. The reference thermistor measures 25.1 °C, The terminal the thermocouple is connected to is 0.05°C cooler than the reference thermistor (0.15°C error).

TABLE 20. Example of Errors in Thermocouple Temperature

Source	Error: °C : % of Total Error			
	Single Differential 250 µs Integration		Reversing Differential 50/60 Hz Rejection Integration	
	ANSI TC Error (1°C)	TC Error 1% Slope	ANSI TC Error (1°C)	TC Error 1% Slope
Reference Temp.	0.15°:11.5%	0.15°:29.9%	0.15°:12.2%	0.15°:34.7%
TC Output	1.0°:76.8%	0.2°:39.8%	1.0°:81.1%	0.2°:46.3%
Voltage Measurement	0.12°:9.2%	0.12°:23.9%	0.07°:5.7%	0.07°:16.2%
Noise	0.03°:2.3%	0.03°:6.2%	0.01°:0.8%	0.01°:2.3%
Reference Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Output Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Total Error	1.302°:100%	0.502°:100%	1.232°:100%	0.432°:100%

4.4.2 Use of External Reference Junction

An external junction in an insulated box is often used to facilitate thermocouple connections. It can reduce the expense of thermocouple wire when measurements are made long distances from the CR1000. Making the external junction the reference junction, which is preferable in most applications, is accomplished by running copper wire from the junction to the CR1000. Alternatively, the junction box can be used to couple extension grade thermocouple wire to the thermocouples, with the PanelTemp () instruction used to determine the reference junction temperature.

Extension grade thermocouple wire has a smaller temperature range than standard thermocouple wire, but meets the same limits of error within that range. One situation in which thermocouple extension wire is advantageous is when the junction box temperature is outside the range of reference junction compensation provided by the CR1000. This is only a factor when using type K thermocouples, since the upper limit of the reference compensation polynomial fit range is 100°C and the upper limit of the extension grade wire is 200°C. With the other types of thermocouples the reference compensation polynomial fit range equals or is greater than the extension wire range. In any case, errors can arise if temperature gradients exist within the junction box.

FIGURE. Diagram of Junction Box (p. 81) illustrates a typical junction box wherein the reference junction is the CR1000. Terminal strips are a different metal than the thermocouple wire. Thus, if a temperature gradient exists between A and A' or B and B', the junction box will act as another thermocouple in series, creating an error in the voltage measured by the CR1000. This thermoelectric offset voltage is also a factor when the junction box is used as the reference junction. This offset can be minimized by making the thermal conduction between the two points large and the distance small. The best solution in the case where extension grade wire is being connected to

thermocouple wire is to use connectors which clamp the two wires in contact with each other.

When an external junction box is also the reference junction, the points A, A', B, and B' need to be very close in temperature (isothermal) to measure a valid reference temperature, and to avoid thermoelectric offset voltages. The box should contain elements of high thermal conductivity, which will act to rapidly equilibrate any thermal gradients to which the box is subjected. It is not necessary to design a constant temperature box. It is desirable that the box respond slowly to external temperature fluctuations. Radiation shielding must be provided when a junction box is installed in the field. Care must also be taken that a thermal gradient is not induced by conduction through the incoming wires. The CR1000 can be used to measure the temperature gradients within the junction box.

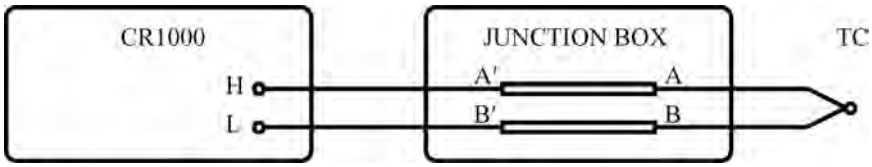


FIGURE 38. Diagram of a Thermocouple Junction Box

4.5 Pulse

FIGURE. Pulse Input Types (p. 9) illustrates pulse input types measured by the CR1000. *FIGURE. Switch Closure Pulse Sensor* (p. 82) is a generalized schematic showing connection of a pulse sensor to the CR1000. The CR1000 features two dedicated pulse input channels, P1 through P2, and eight digital I/O channels, C1 through C8, for measuring frequency or pulse output sensors.

As shown in *TABLE. Pulse Input Channels and Measurements* (p. 9), all CR1000 pulse input channels can be measured with CRBASIC instruction PulseCount (). PulseCount () has various parameters to customize it to specific applications. Digital I/O ports C1 through C8 can also be measured with the TimerIO () instruction. PulseCount () instruction functions include returning counts or frequency on frequency or switch closure signals. TimerIO () instruction has additional capabilities. Its primary function is to measure the time between state transitions.

Note Consult CRBASIC Editor Help for more information on PulseCount () and TimerIO () instructions.

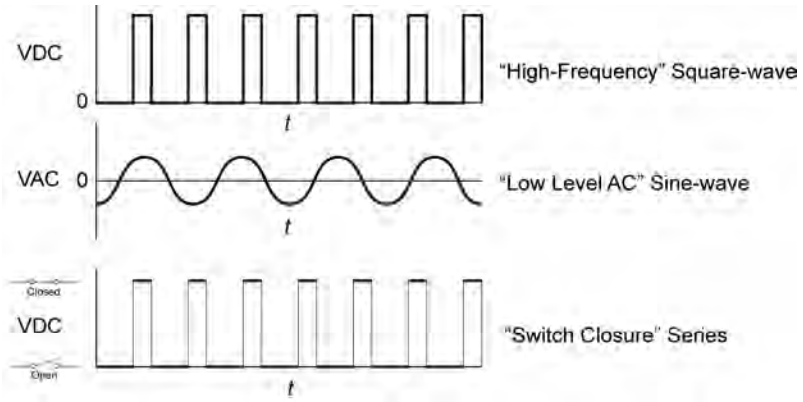


FIGURE 39. Pulse Sensor Output Signal Types

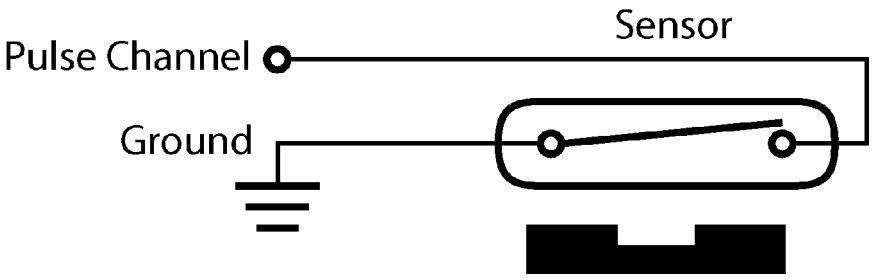


FIGURE 40. Switch Closure Pulse Sensor

TABLE 21. Pulse Input Channels and Measurements

Channels Available for Pulse Input	***Input Types***	***Data Option***	***CRBASIC Instruction***
P1, P2	High Frequency Low-Level ac Switch Closure	Counts Frequency Run Avg of Freq	PulseCount ()
C1, C2, C3, C4, C5, C6, C7, C8	High Frequency Switch Closure Low-Level ac (with LLAC4 Low-Level AC Conversion Module)	Counts Frequency Run Avg of Freq Interval Period State	PulseCount () TimerIO ()

4.5.1 Pulse Input Channels (P1 - P2)

Read More! Review pulse counter specifications at *SECTION. Specifications* (p. 42). Review pulse counter programming in CRBASIC Editor Help for the PulseCount () instruction.

Dedicated pulse input channels (P1 through P2), as shown in *FIGURE. Pulse Input Channels* (p. 83), can be configured to read high- frequency pulses, low-level ac signals, or switch closures.

Note Input channel expansion devices for all input types are available from Campbell Scientific. Refer to Sensors and Peripherals for more information.

Caution Maximum input voltage on pulse channels P1 through P2 is ±20 V. If pulse inputs of higher than ±20 V need to be measured, third party external signal conditioners should be employed. Contact a Campbell Scientific applications engineer if assistance is needed. Under no circumstances should voltages greater than ±50 V be measured.

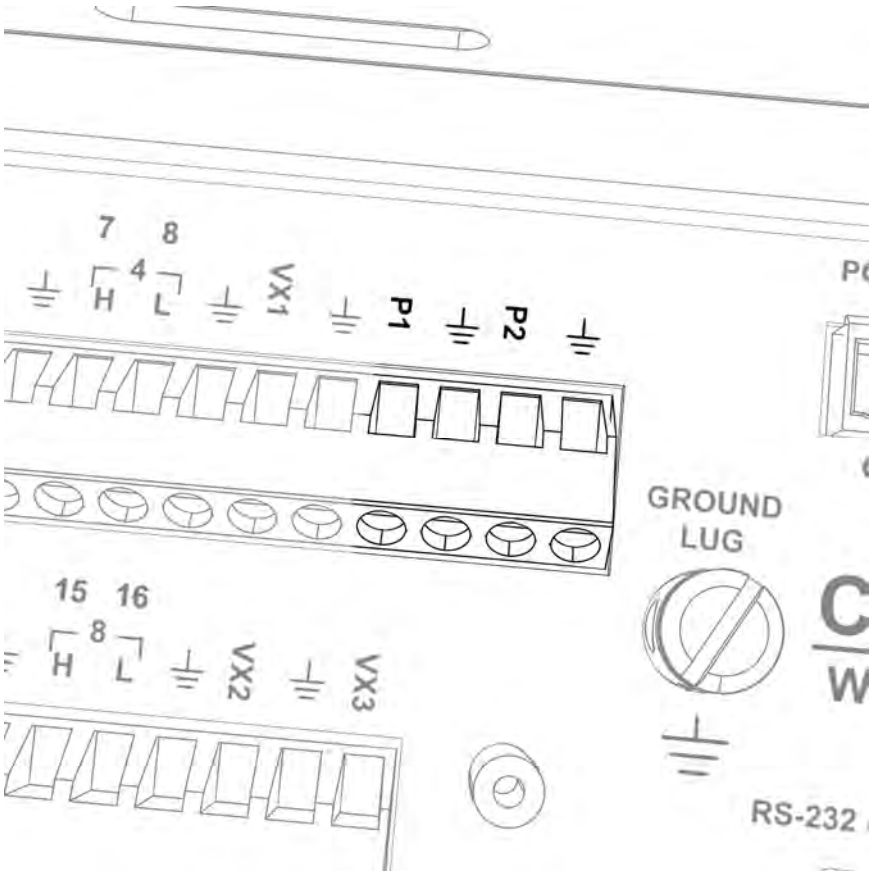


FIGURE 41. Pulse Input Channels

4.5.1.1 High-frequency Pulse (P1 - P2)

High-frequency pulse inputs are routed to an inverting CMOS input buffer with input hysteresis. The CMOS input buffer is an output 0 level with its input ≥ 2.2 V, and an output 1 with its input ≤ 0.9 V. When a pulse channel is configured for high-frequency pulse, an internal 100 kΩ pull-up resistor to 5 Vdc on the P1 or P2 input is automatically employed. This pull-up resistor accommodates open-collector (open-drain) output devices for high-frequency input.

4.5.1.2 Low-Level ac (P1 - P2)

Rotating magnetic pickup sensors commonly generate AC output voltages ranging from milliVolts at low rotational speeds to several volts at high rotational speeds. Pulse channels contain internal signal conditioning hardware for measuring low-level AC output sensors. When configured for low-level AC, P1 through P2 measure signals ranging from 20 mV RMS (±28 mV peak) to 14 V RMS (±20 V peak). Internal AC coupling is incorporated in the low-level AC hardware to eliminate dc offset voltages of up to ±0.5 Vdc.

4.5.1.3 Switch Closure (P1 - P2)

Switch-closure mode measures switch closure events, such as occur with a common tipping bucket rain gage. An internal 100 kΩ pull-up resistor pulls an input to 5 Vdc with the switch open, whereas a switch closure to ground pulls the input to 0 V. An internal 3.3 ms time constant RC debounce filter eliminates multiple counts from a single switch closure event.

4.5.2 Pulse Input on Digital I/O Channels C1 - C8

Read More! Review digital I/O channel specifications in *SECTION. Specifications* (p. 42). Review pulse counter programming with PulseCount () in CRBASIC Help.

Digital I/O channels C1 - C8 can be configured for edge timing or to measure high-frequency or switch closure signals. Input voltage must range between -8.0 and +16 Vdc.

Caution Contact Campbell Scientific for signal conditioning information if a pulse input < -8.0 or > +16 Vdc is to be measured. Under no circumstances should voltages greater than ±50 V be connected to channels C1 - C8.

Low-level ac signals cannot be measured directly by digital I/O channels C1 - C8. Refer to *APPENDIX. Pulse / Frequency Input Expansion Modules* (p. 498) for information on peripheral modules available to convert low-level ac signals to high-frequency square-wave.

4.5.2.1 High-frequency (C1 - C8)

Digital I/O channels C1 - C8 have a small 25 ns input RC filter time constant between the terminal block and the CMOS input buffer, which allows for higher frequency operation (400 kHz maximum) when compared with pulse input channels P1 through P2 (250 kHz maximum).

When configured for input, signals connected to C1 - C8 each go into a digital CMOS input buffer that recognizes inputs ≥ 3.8 V as high and inputs ≤ 1.2 V as low.

Open collector (bipolar transistors) or open drain (MOSFET) sensors are typically measured as high frequency sensors. Condition channels C1 - C8 for open collector or open drain with an external pull-up resistor as shown in *FIGURE. Connecting Switch Closures to Digital IO* (p. 86). The pull-up resistor counteracts an internal 100 kΩ pull-down resistor, allowing inputs to be pulled to > 3.8 V for reliable measurements.

4.5.2.2 Switch Closure (C1 - C8)

Two schemes are available for connecting switch closure sensors to the CR1000. If the switch closes to ground, an external pull-up resistor is used as shown in *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86). If the switch is to close directly to the control port, connect the sensor to the CR1000 as diagramed.

Mechanical switch closures have a tendency to bounce before solidly closing. Bouncing can cause multiple counts. The CR1000 incorporates software switch debounce in switch-closure mode for channels C1 - C8.

Note Maximum switch closure frequency measured is 150 kHz.

4.5.2.3 Edge Timing (C1 - C8)

Time between pulse edges can be measured. Results can be expressed in terms of microseconds or hertz. To read more concerning edge timing, refer to CRBASIC Help for the TimerIO() instruction. Edge timing resolution is 540 ns.

4.5.3 Pulse Measurement Tips

- Activated by the PulseCount() instruction, dedicated 24-bit counters on channels P1 through P2 and C1 through C8 accumulate all counts over the user specified scan interval. Counters are read at the beginning of each scan and cleared. Counters overflow, resulting in erroneous measurements, if accumulated counts exceed 16,777,216.
- Execution of PulseCount() within a scan involves determining the accumulated counts in each dedicated 24-bit counter since execution of the last PulseCount(). Counts are the preferred output option for measuring number of tips from a tipping bucket rain gage, or the number of times a door opens. Many pulse sensors, such as anemometers and flow meters, are

calibrated in terms of frequency (Hz or counts / second), and are usually measured with the frequency option.

- Accuracy of PulseCount() is limited by a small scan interval error of ±(3 ppm of scan interval + 10 µs) plus the measurement resolution error of ± 1 Hz. The sum is essentially ± 1 Hz.
- Use the LLAC4 module to convert non-TTL level signals, including low-level ac signals, to TTL levels for input into digital I/O channels C1 through C8.
- When digital I/O channels C1 through C8 measure switch closure inputs, pull-up resistors may be required. *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86) show how pull-up resistors can be incorporated into a wiring scheme.
- As shown *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86), digital I/O inputs, with regard to the 6.2 V Zener diode, have an input resistance of 100 kohms with input voltages < 6.2 Vdc. **For input voltages ≥ 6.2 Vdc, the inputs have an input resistance of only 220 ohms.**

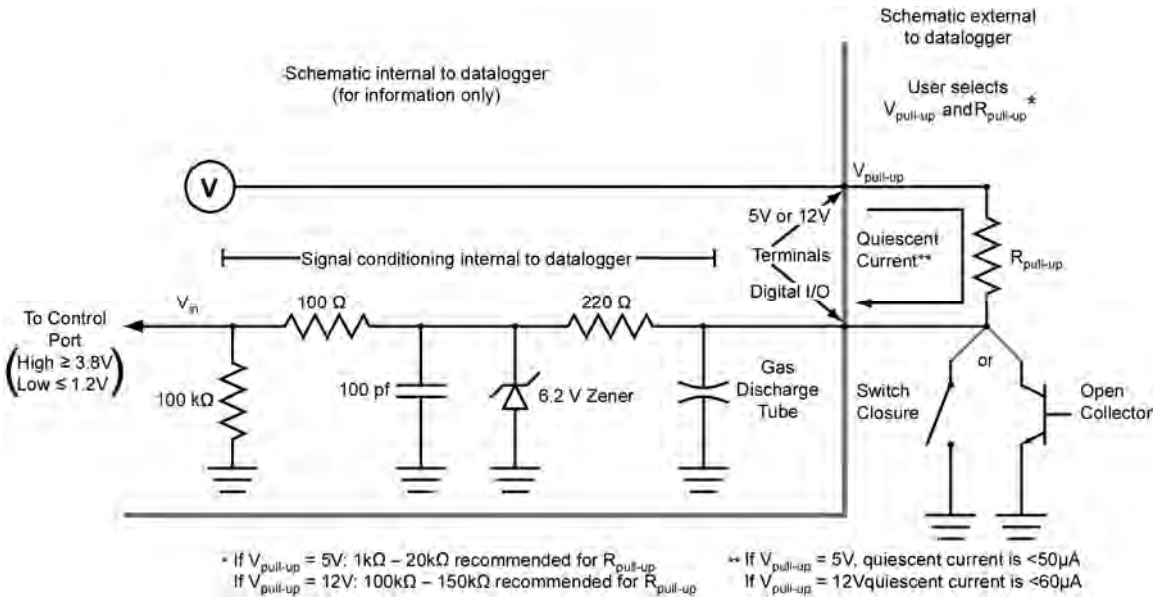


FIGURE 42. Connecting Switch Closures to Digital I/O

4.5.3.1 Frequency Resolution

Resolution of the 24-bit pulse counters is one count. Frequency resolution of a PulseCount () frequency measurement is

$$FR = \frac{1}{S}$$

where:

FR = Resolution of the frequency measurement (Hz)

S = Scan Interval of CRBASIC Program

Resolution of TimerIO () instruction is:

$$FR = \frac{R/E}{P * (P+(R/E))}$$

where:

FR = Frequency resolution of the measurement (Hz)

R = Timing resolution of the period measurement = 540 ns

P = Period of input signal (seconds) = 1 / 1000 Hz = 0.001 s

E = Rising edges per scan = 500 in 0.5 s scan, 5000 in 5.0 s scan)

TimerIO () instruction measures frequencies of ≤ 1 kHz with higher frequency resolution over short (sub-second) intervals. In contrast, sub-second frequency measurement with PulseCount () produce measurements of lower resolution. Consider a 1 kHz input. *TABLE. Frequency Resolution* (p. 87) lists frequency resolution to be expected for a 1 kHz signal measured by TimerIO () and PulseCount() at 0.5 s and 5.0 s scan intervals.

Increasing a 1 s measurement interval to 10 s, either by increasing the scan interval (when using PulseCount()) or by averaging (when using PulseCount() or TimerIO()), improves the resulting frequency resolution from 1 Hz to 0.1 Hz. Averaging can be accomplished by the Average(), AvgRun(), and AvgSpa() instructions. Also, PulseCount() has the option of entering a number greater than 1 in the POption parameter. Doing so enters an averaging interval in milliseconds for a direct running average computation. However, use caution when averaging, Averaging of any measurement reduces the certainty that the result truly represents a real aspect of the phenomenon being measured.

TABLE 22. Frequency Resolution Comparison

	0.5 s Scan	***5.0 s Scan***
PulseCount(), POption 1	FR= 2 Hz	FR = 0.2 Hz
TimerIO(), Function 2	FR = 0.0011 Hz	FR = 0.00011 Hz

4.5.4 Pulse Measurement Problems

4.5.4.1 Pay Attention to Specifications

TABLE. Example of Differing Specifications for Pulse Input Channels (p. 87) compares specifications for pulse input channels to emphasize the need for matching the proper device to application. Take time to understand signals to be measured and compatible channels.

TABLE 23. Example of Differing Specifications for Pulse Input Channels		
	Pulse Channels P1, P2	***Digital I/O Channels C1, C2, C3, C4, C5, C6, C7, C8***
High Frequency Max (kHz)	250	1
Max Input Voltage (Vdc)	20	16
State Transition Thresholds (Vdc)	Count upon transition from <0.9 to >2.2.	Count upon transition from <1.2 to >3.8.

4.5.4.2 Input Filters and Signal Attenuation

Pulse input channels are equipped with input filters to reduce spurious noise that can cause false counts. The higher the time constant (τ) of the filter, the tighter the filter. *TABLE. Time Constants* (p. 88) lists τ values for pulse input channels. So, while TimerIO () frequency measurement may be superior for clean signals, a pulse channel filter (much higher τ) may be required to get a measurement on a dirty signal.

Input filters, however, attenuate the amplitude (voltage) of the signal. The amount of attenuation is a function of the frequency passing through the filter. Higher frequency signals are attenuated more. If a signal is attenuated enough, it may not pass the state transition thresholds (thresholds are listed in *TABLE. Pulse Input Channels and Measurements* (p. 9)) required by the detection device. To avoid over attenuation, sensor output voltage must be increased at higher frequencies. As an example, *TABLE. Filter Attenuation of Frequency Signals* (p. 88) lists low-level ac frequencies and the voltages required to overcome filter attenuation.

For pulse input channels P1 - P2, an RC input filter with an approximate 1 μs time constant precedes the inverting CMOS input buffer. The resulting amplitude reduction is illustrated in *FIGURE. Amplitude Reduction of Pulse-Count Waveform.* (p. 89) For a 0 to 5 Vdc square wave applied to a pulse channel, the maximum frequency that can be counted in high-frequency mode is approximately 250 kHz.

TABLE 24. Time Constants (τ)	
Measurement	*τ*
Pulse Channel, High Frequency Mode	1.2
Pulse Channel, Switch Closure Mode	3300
Pulse Channel, Low-level AC Mode	See *TABLE. Filter Attenuation of Frequency Signals* (p. 88) footnote
Digital I/O, High Frequency Mode	0.025
Digital I/O, Switch Closure Mode	0.025

TABLE 25. Filter Attenuation of Frequency Signals.	
As shown for low-level ac inputs, increasing voltage is required at increasing frequencies to overcome filter attenuation on pulse input channels*.	
ac mV (RMS)	***Maximum Frequency***
20 200 2000 5000	20 200 10,000 20,000
*8.5 ms time constant filter (19 Hz 3 dB frequency) for low-amplitude signals. 1 ms time constant (159 Hz 3 dB frequency) for larger (> 0.7 V) amplitude signals.	

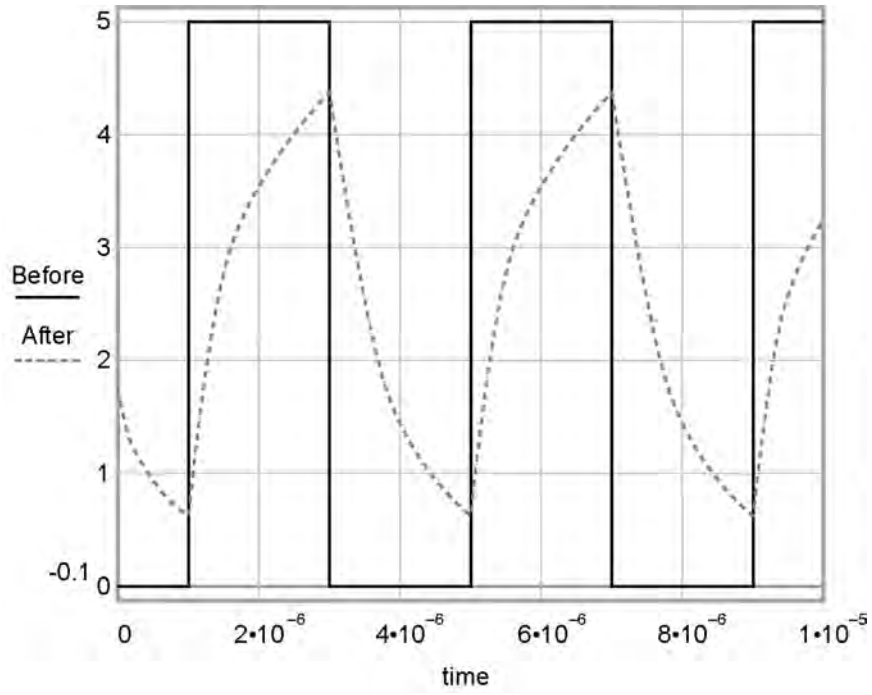


FIGURE 43. Amplitude Reduction of Pulse-Count Waveform (before and after 1 µs time constant filter)

4.6 Period Averaging

The CR1000 can measure the period of a signal on any single-ended analog input channel (SE 1 - 16). The specified number of cycles are timed with a resolution of 136 ns, making the resolution of the period measurement 136 ns divided by the number of cycles chosen.

Low-level signals are amplified prior to a voltage comparator. The internal voltage comparator is referenced to the user-entered threshold. The threshold parameter allows a user to reference the internal voltage comparator to voltages other than 0 V. For example, a threshold of 2500 mV allows a 0 to 5 Vdc digital signal to be sensed by the internal comparator without the need of any additional input conditioning circuitry. The threshold allows direct connection of standard digital signals, but is not recommended for small amplitude sensor signals. For

sensor amplitudes less than 20 mV peak-to-peak, a dc blocking capacitor is recommended to center the signal at CR1000 ground (threshold = 0) because of offset voltage drift along with limited accuracy (± 10 mV) and resolution (1.2 mV) of a threshold other than 0. *FIGURE. Input Conditioning Circuit for Period Averaging* (p. 90) shows an example circuit.

The minimum pulse width requirements increase (maximum frequency decreases) with increasing gain. Signals larger than the specified maximum for a range will saturate the gain stages and prevent operation up to the maximum specified frequency. As shown back-to-back diodes are recommended to limit large amplitude signals to within the input signal ranges.

Caution Noisy signals with slow transitions through the voltage threshold have the potential for extra counts around the comparator switch point. A voltage comparator with 20 mV of hysteresis follows the voltage gain stages. The effective input referred hysteresis equals 20 mV divided by the selected voltage gain. The effective input referred hysteresis on the ± 25 mV range is 2 mV; consequently, 2 mV of noise on the input signal could cause extraneous counts. For best results, select the largest input range (smallest gain) that meets the minimum input signal requirements.

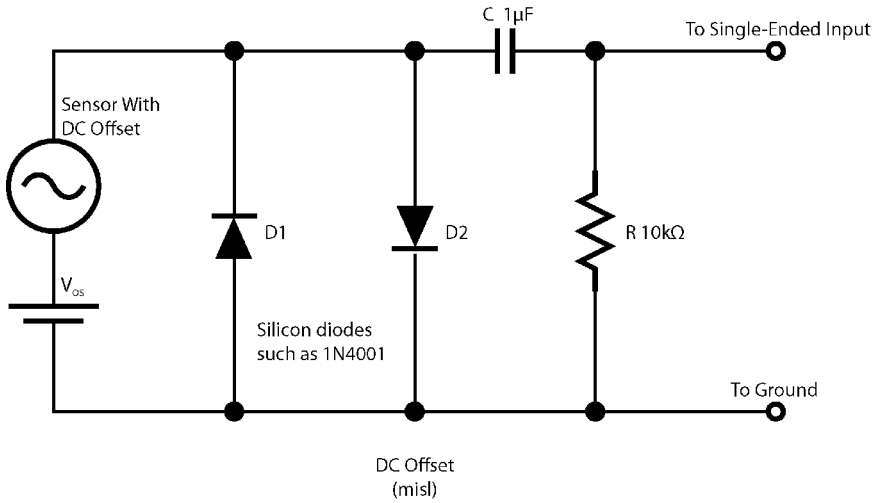


FIGURE 44. Input Conditioning Circuit for Period Averaging

4.7 SDI-12 Recording

Read More! *SECTION. SDI-12 Sensor Support* (p. 249) and *SECTION. Serial Input / Output* (p. 209).

SDI-12 is a communications protocol developed to transmit digital data from smart sensors to data acquisition units. It is a simple protocol, requiring only a single communication wire. Typically, the data acquisition unit also supplies power (12 Vdc and ground) to the SDI-12 sensor. The CR1000 is equipped with 4 SDI-12 channels (C1, C3, C5, C7) and an SDI12Recorder () CRBASIC instruction.

4.8 RS-232 and TTL Recording

Read More! *SECTION. Serial Input / Output* (p. 209) and *SECTION. Serial I/O* (p. 279).

The CR1000 can usually receive and record RS-232 and 0-5V logic data from sensors designed to transmit via these protocols. Data are received through the CS I/O port with the proper interface (*APPENDIX. CS I/O Serial Interfaces* (p. 499)), the RS-232 port, or the digital I/O communication ports (C1 & C2, C3 & C4, C5 & C6, C7 & C8). If additional serial inputs are required, serial input expansion modules (*APPENDIX. Serial Input Expansion Modules* (p. 499)) can be connected to increase the number of serial ports. Serial data are usually captured as strings, which are then parsed (split up) as defined in the user entered program.

Note Digital I/O communication ports (control ports) only transmit 0-5V logic. However, they read most true RS-232 input signals. When connecting serial sensors to an RX control port, the sensor power consumption may increase by a few milliamps due to voltage clamps. An external resistor may need to be added in series to the RX line to limit the current drain, although this is not advisable at very high baud rates. *FIGURE. Circuit to Limit Control Port Input to 5 Volts* (p. 91) shows a circuit that limits voltage input on a control port to 5 Vdc.

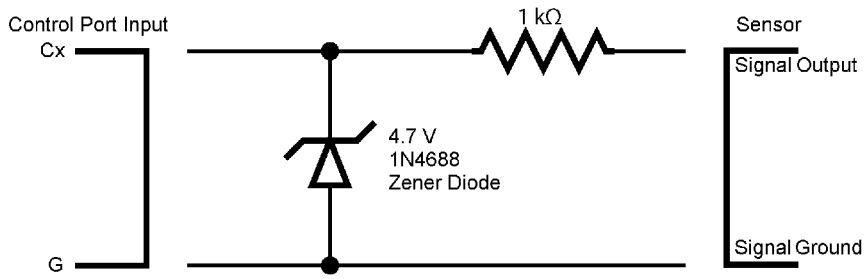


FIGURE 45. Circuit to Limit Control Port Input to 5 Volts

4.9 Field Calibration of Linear Sensor

Read More! *SECTION. Field Calibration of Linear Sensors (FieldCal)* (p. 227) has complete FieldCal information.

Calibration increases accuracy of a measurement device by adjusting its output, or the measurement of its output, to match independently verified quantities. Adjusting a sensor output directly is preferred, but not always possible or practical. By adding FieldCal() or FieldCalStrain() instructions to the CR1000 program, a user can easily adjust the measured output of a linear sensors by modifying multipliers and offsets.

4.10 Cabling Effects

Sensor cabling can have significant effects on sensor response and accuracy. This is usually only a concern with sensors acquired from manufacturers other than Campbell Scientific. Campbell Scientific sensors are engineered for optimal performance with factory installed cables.

4.10.1 Analog Sensor Cables

Cable length in analog sensors is most likely to affect the signal settling time. For more information, see *SECTION. Signal Settling Time* (p. 56).

4.10.2 Pulse Sensors

Because of the long interval between switch closures in tipping bucket rain gages, appreciable capacitance can build up between wires in long cables. A built up charge can cause arcing when the switch closes, shortening switch life. As shown in *FIGURE. Current Limiting Resistor in a Rain Gage Circuit* (p. 92), a 100 ohm resistor is connected in series at the switch to prevents arcing. This resistor is installed on all rain gages currently sold by Campbell Scientific.

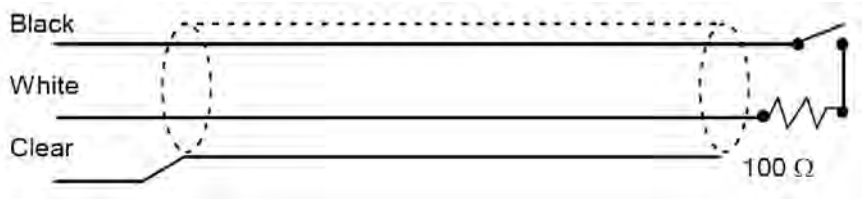


FIGURE 46. Current Limiting Resistor in a Rain Gage Circuit

4.10.3 RS-232 Sensors

RS-232 sensors cable lengths should be limited to 50 feet.

4.10.4 SDI-12 Sensors

The SDI-12 standard allows cable lengths of up to 200 feet. Campbell Scientific does not recommend SDI-12 sensor lead lengths greater than 200 feet; however, longer lead lengths can sometimes be accommodated by increasing the wire gage and/or powering the sensor with a second 12 Vdc power supply placed near the sensor.

4.11 Synchronizing Sensor Measurements

Timing of a measurement is usually controlled relative to the CR1000 clock. When sensors in a sensor network are measured by a single CR1000, measurement times are synchronized, often within a few milliseconds, depending on sensor number and measurement type. Large numbers of sensors, cable length restrictions, or long distances between measurement sites may require use of multiple CR1000s. Techniques outlined below enable network administrators to synchronize CR1000 clocks and measurements in a CR1000 network.

Care should be taken when a clock change operation is planned. Any time the CR1000 clock is changed, the deviation of the new time from the old time may be sufficient to cause a skipped record in data tables. Any command used to synchronize clocks should be executed after any CallTable() instructions and timed so as to execute well clear of data output intervals.

Time Synchronization Techniques:

1. LoggerNet Utility – When reliable telecommunications are common to all CR1000s in a network, LoggerNet's Automated Clock Check provides a simple time synchronization function. Accuracy is limited by the system clock on the PC running the LoggerNet server. Precision is limited by network transmission latencies. LoggerNet compensates for latencies in many telecommunications systems and can achieve synchronies within <100 ms deviation. Errors of 2 – 3 second may be seen on very busy RF connections or long distance internet connections.

Note Common PC clocks are notoriously inaccurate. An easy way to keep a PC clock accurate is to utilize public domain software available at http://tf.nist.gov/service/its.htm.

2. Digital Trigger – A digital trigger, rather than a clock, can provide the synchronization signal. When cabling can be run from CR1000 to CR1000, each CR1000 can catch the rising edge of a digital pulse from the Master CR1000 and synchronize measurements or other functions, using the WaitDigTrig() instructions, independent of CR1000 clocks or data time stamps. When programs are running in pipeline mode, measurements can be synchronized with a few microseconds.

3. PakBus Commands – The CR1000 is a PakBus device, so it is capable of being a node in a PakBus network.. Node clocks in a PakBus network are synchronized using the SendGetVariable(), ClockReport(), or PakBusClock() commands. The CR1000 clock has a resolution of 10 ms, which is the resolution used by PakBus clock sync functions. In networks without routers, repeaters, or retries, the communication time will cause an additional error (typically a few 10s of milliseconds). PakBus clock commands set the time at the end of a scan to minimize the chance of skipping a record to a data table.

An RF401 radio network has an advantage over Ethernet in that ClockReport() can be broadcast to all dataloggers within reach and set their clocks with a single PakBus broadcast from the master. Each datalogger in the network must be programmed with a PakBusClock() instruction.

Note Use of PakBus clock functions re-synchronizes the Scan() instruction. Use should not exceed once per minute. CR1000 clocks drift at a slow enough rate that a ClockReport() once per minute should be sufficient to keep clocks within 30 ms of each other.

4. GPS – Clocks in CR1000s can be synchronized to within about 10 ms of each other using the GPS () instruction. CR1000s built since October of 2008 (serial numbers >= 20409) can be synchronized within a few microseconds of each other and within ≈ 200 µs of UTC. While a GPS signal is available, the CR1000 essentially uses the GPS as its continuous clock source, so the chance of jumps in system time and skipped records is minimized.

5. Ethernet – Any CR1000 with a network connection (internet, GPRS, private network) can synchronize its clock relative to Coordinated Universal Time (UTC) using the NetworkTimeProtocol () instruction. Precisions are usually maintained to within 10 ms.

Section 6. Power Sources

Reliable power is the foundation of a reliable data acquisition system. When designing a power supply, consideration should be made regarding worst-case power requirements and environmental extremes.

Excessive switching noise or AC ripple present on a DC power supply can increase measurement noise. Noise sources include power transformers, regulators, and grid or mains power inclusively. Using high quality power regulators reduces noise due to power regulation. Utilizing 50 Hz or 60 Hz integration times for voltage measurements (see *SECTION. Sensor Support* (p. 43)) improves rejection of power supply induced noise. The CRBASIC standard deviation instruction, SDEV() can be used to evaluate measurement noise.

Contact Campbell Scientific if assistance in selecting a power supply is needed, particularly with applications in extreme environments.

6.1 Power Requirement

The CR1000 operates on dc voltage ranging from 9.6 to 16 V. It is internally protected against accidental polarity reversal. A transient voltage suppressor (TVS) diode on the 12 Vdc power input terminal provides transient protection by clamping voltages in the range of 19 to 21 V. Sustained input voltages in excess of 19 V can damage the TVS diode.

Caution The 12V and SW-12 terminals on the wiring panel are not regulated by the CR1000; they obtain the same power as that provided by the CR1000 primary power supply. When using the CR1000 wiring panel to source power to other 12 Vdc devices, be sure the power supply regulates the voltage within a the range specified by the manufacturer of the connected device.

6.2 Calculating Power Consumption

Read More! *SECTION. Power Requirements* (p. 32).

System operating time for batteries can be determined by dividing the battery capacity (ampere-hours) by the average system current drain (amperes). The CR1000 typically has a quiescent current draw of 0.5 mA (with display off), 0.6 mA with a 1 Hz sample rate, and >10 mA with a 100 Hz sample rate. With the optional keyboard display on, an additional 7 mA is added to the current drain while enabling the back light for the display adds 100 mA to the current drain.

6.3 Power Supplies

APPENDIX. Power Supplies (p. 495) lists external power supplies available from Campbell Scientific, including alkaline and solar options. Complete power supply information is available in manual or brochure form at *www.campbellsci.com*.

6.3.1 External Batteries

When connecting external power to the CR1000, remove the green POWER IN connector from the CR1000 front panel. Insert the positive 12 Vdc lead into the terminal marked "12V". Insert the ground lead in the terminal marked "G" (ground). The CR1000 is internally protected against, but will not function with, reversed external power polarity.

6.4 Vehicle Power Connections

If a CR1000 is powered by a motor vehicle supply, a second supply may be needed. When starting the motor of the vehicle, the battery voltage may drop below 9.6 V. This causes the CR1000 to stop measurements until the voltage again equals or exceeds 9.6 V. A second supply can be provided to prevent measurement lapses during vehicle starting. *FIGURE. Connecting CR1000 to Vehicle Power Supply* (p. 100) illustrate how a second power supply should be connected to the CR1000. The diode OR connection causes the supply with the largest voltage to power the CR1000 and prevents the second backup supply from attempting to power the vehicle.

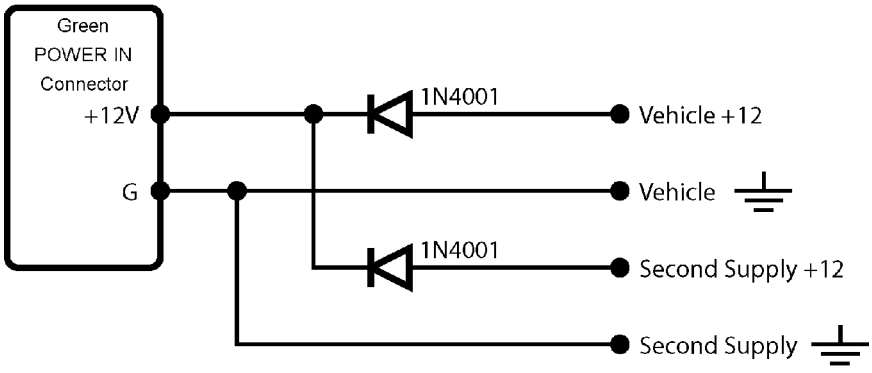


FIGURE 50. Connecting to Vehicle Power Supply

6.5 Powering Sensors and Devices

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

The CR1000 is a convenient distributor of power for sensors and peripherals requiring a 5 or 12 Vdc source. It has 2 continuous 12 Vdc terminals (12V), one program-controlled switched 12 Vdc terminal (SW-12), and one continuous 5 Vdc terminal (5V). SW-12, 12V, and 5V terminals limit current internally for protection against accidental short circuits. Voltage on the 12V and SW-12 terminals will change with the dc supply used to power the CR1000. The 5V terminal is internally regulated to within ±4%, which is typically not adequate accuracy for bridge sensor excitation. *TABLE. Current Sourcing Limits* (p. 102) lists the current limits of 12V and 5V. Greatly reduced output voltages associated with 12V, SW-12, and 5V due to current limiting may occur if the current limits given in the table are exceeded. Information concerning digital I/O control ports is available in *SECTION. Digital I/O Ports* (p. 96).

6.5.1 Switched Excitation

Switched Voltage Excitation

Three switched analog output (excitation) terminals (VX1 - VX3) operate under program control to provide -2500 mV to +2500 mV excitation. Check the accuracy specification of these channels in *SECTION. Specifications* (p. 42) to understand their limitations. Specifications are only applicable for loads not exceeding ±25 mA. CRBASIC instructions that control excitation channels include:

- BrFull ()
- BrFull6W ()
- BrHalf ()
- BrHalf3W ()
- BrHalf4W ()
- ExciteV ()

Note Excitation channels can be configured through the RevEx parameter of bridge instructions to provide a square wave ac excitation for use with polarizing bridge sensors.

6.5.2 Continuous Regulated (5 Volt)

The 5V terminal is regulated and remains near 5 Vdc (±4%) so long as the CR1000 supply voltage remains above 9.6 Vdc. Measurement of the output from 5V (by means of jumpering to an analog input on the same CR1000) enables an accurate bridge measurement if the 5V terminal must be used for excitation.

6.5.3 Continuous Unregulated (Nominal 12 Volt)

Voltage on the 12V terminals will change with CR1000 supply voltage.

6.5.4 Switched Unregulated (Nominal 12 Volt)

SW-12 is often used to control low power devices such as sensors that require 12 Vdc during measurement. Current sourcing must be limited to 900 mA or less at 20°C. See *TABLE. Current Sourcing Limits* (p. 102). Voltage on a SW-12 terminal will change with CR1000 supply voltage. Two CRBASIC instructions, SW12 () and PortSet (), control a SW-12 terminal. Each is handled differently by the CR1000. SW12 () is a processing task instruction. Use it when controlling power to SDI-12 and serial sensors, which use SDI12Recorder () or SerialIn () instructions respectively. CRBASIC programming using IF THEN constructs to control SW-12, such as when used for cell phone control, should also use the SW12 () instruction. PortSet () is a measurement task instruction. Use it when powering analog input sensors that need to be powered just prior to measurement.

A 12 Vdc switching circuit, driven by a digital I/O port, is also available from Campbell Scientific.

Note The SW-12 supply is unregulated and can supply up to 900 mA at 20°C. See *TABLE. Current Sourcing Limits* (p. 102). A resettable polymeric fuse protects against over-current. Reset is accomplished by removing the load or turning off the SW-12 for several seconds.

TABLE 26. Current Source (+) & Sink (-) Limits	
Terminal	***Limit***
Voltage Excitation (VX, EX)[1]	±25 mA Maximum
SW-12[2]	< +900 mA @ 20°C < +630 mA @ 50°C < +450 mA @ 70°C
12V + SW-12 (Combined)[3]	< +3.00 A @ 20°C < +2.34 A @ 50°C < +1.80 A @ 70°C < +1.50 A @ 85°C
5V + CSI/O (Combined)[4]	< +200 mA

[1] Greater magnitude current than stated limits will cause voltage to become unstable. Voltage should stabilize once current is again established under maximum magnitude.

[2] Polyfuse is used to limit power. Result of overload is a voltage drop. To reset, disconnect and allow circuit to cool. Operating at the current limit is OK so long a a little fluctuation can be tolerated.

[3] Polyfuse protected. See 2.

[4] Maximum current is maintained by a current limiting circuit, which holds the current at the maximum by dropping the voltage when the load is too great.

Section 12. Memory and Final Data Storage

12.1 Storage Media

CR1000 memory consists of four non-volatile storage media:

- Internal battery backed SRAM
- Internal Flash
- Internal Serial Flash
- External Flash (optional CSI Flash drive)
- External CompactFlash® (*optional module* (p. 503))

TABLE. CR1000 Memory Allocation (p. 349) and *TABLE. CR1000 SRAM Memory* (p. 350) illustrate how CR1000 memory is structured around these media. The CR1000 utilizes and maintains most memory features automatically. However, users should periodically review areas of memory wherein data files, CRBASIC program files, and image files reside. Review and management of memory are accomplished with LoggerNet / PC400 / RTDAQ / PC200W File Control feature.

TABLE 72. CR1000 Memory Allocation

Memory Sector	Comments
Internal battery-backed SRAM[1] 4 Mbytes*	See *TABLE. CR1000 SRAM Memory* (p. 350) for detail.
Internal Flash[2] 2 Mbytes	Operating system
Internal Serial Flash[3]	Device Settings: A backup of settings such as PakBus Address, Station Name, Beacon Intervals, Neighbor lists, etc. Rebuilt when a setting changes.
12 kbytes: Device Settings	
500 kbytes: CPU: drive	CPU: Drive: Holds program files, field calibration files, and other files not over written frequently. Slower than SRAM. When a program is compiled and run, it is copied here automatically for loading on subsequent power-ups. Files accumulate until deleted with File Control or the FilesManage() instruction. Use USR: drive to store other file types. Available CPU: memory is reported in Status Table field "CPUDriveFree."

External Flash (Optional) 2 Gbytes: USB: drive	USB: drive: Holds program files. Holds a copy of final storage table data as files when TableFile() instruction is used. USB: data can be retrieved from the storage device with Windows Explorer. Can facilitate use of Powerup.ini.
External CompactFlash (Optional) <= 2 Gbytes: CRD: drive	CRD: drive: Holds program files. Holds a copy of final storage table data as files when CardOut() instruction is used. When data are requested by a PC, data first are provided from SRAM. If the requested records have been overwritten in SRAM, data are sent from CRD:. Alternatively, CRD: data can be retrieved in a binary format using File Control. Binary files are converted using CardConvert software. 10% or 80 kbytes of CF memory (whichever is smaller) is reserved for program storage. Can facilitate use of Powerup.ini.

[1]SRAM

·CR800 series changed from 2 to 4 Mbytes SRAM in Sept 2007. SNs >= 3605 are 4 Mbytes

·CR1000 changed from 2 to 4 Mbytes SRAM in Sept 2007. SNs >= 11832 are 4 Mbytes

·CR3000 has always shipped with a 4 Mbytes SRAM.

[2]Flash is rated for > 1 million overwrites.

[3]Serial Flash is rated for 100,000 overwrites (50,000 overwrites on 128 kbyte units). Care should be taken in programs that do overwrites to use the CRD: or USR: drives so as not to wear-out the CPU: drive.

·The CR800 series changed from 128 to 512 kbytes Serial Flash in May 2007. SNs >=2787 are 512 kbytes

·The CR1000 changed from 128 to 512 kbytes Serial Flash in May 2007. SNs >= 9452 are 512 kbytes

·The CR3000 changed from 128 512 kbytes Serial Flash in May 2007. SNs > 1948 are 512 kbytes

TABLE 73. CR1000 SRAM Memory

Use	*Comments*
Static Memory	Operational memory used by the operating system regardless of the user program. This sector is rebuilt at power-up, program re-compile, and watchdog events.
Operating Settings and Properties	"Keep" memory. Stores settings such as PakBus address, station name, beacon intervals, neighbor lists, etc. Also stores dynamic properties such as the routing table, communications timeouts, etc.
CRBASIC Program Operating Memory	Stores the currently compiled and running user program. This sector is rebuilt on power-up, recompile, and watchdog events.
Variables & Constants	Stores variables in the user program. These values may persist through power-up, recompile, and watchdog events if the PreserveVariables instruction is in the running program.
Final Storage Data Tables Final Storage is given lowest priority in SRAM memory allocation.	Stores data resulting from CR1000 measurements. This memory is termed "Final Storage." Fills memory remaining after all other demands are satisfied. Configurable as ring or fill and stop memory. Compile error occurs if insufficient memory is available for user allocated data tables.
Communications Memory 1	Construction and temporary storage of PakBus® packets.
Communications Memory 2	Constructed Routing Table: list of known nodes and routes to nodes. Routers use more space than leaf nodes because routes to neighbors must be remembered. Increasing the PakBusNodes field in the Status Table will increase this allocation.
USR: drive <= 3.6 Mbytes (4 Mbyte Mem) <= 1.5 Mbytes (2 Mbyte Mem) Less on older units with more limited memory.	Optionally allocated. Holds image files. Holds a copy of Final Storage when TableFile() instruction used. Provides memory for FileRead / FileWrite operations. Managed in File Control. Status reported in Status Table fields "USRDriveSize" and "USRDriveFree."

12.1.1 Data Storage

Data table SRAM and the CPU: drive are automatically partitioned for use in the CR1000. The USR: drive can be optionally partitioned at programmer discretion.

The USB: drive is automatically partitioned when a CS mass storage device is connected.

TABLE 74. Data Storage Drives

Drive	*Recommended File Types*
CPU:	CR1, .CAL
USR:	.DAT, .JPG
USB:	.DAT
CRD:	Principal use is to expand *Final Storage* (p. 442), but also used to store .JPG, CR1, and .DAT files.

The CRD: drive is automatically partitioned when a CF card is installed.

12.1.1.1 Data Table SRAM

Primary storage for measurement data are those areas in SRAM allocated to data tables as detailed in *FIGURE. CR1000 SRAM Memory* (p. 350). Measurement data can be also be stored as discrete files on USR:, or USB: by using TableFile() instruction.

The CR1000 can be programmed to store each measurement or, more commonly, to store processed values such as averages, maxima, minima, histograms, FFTs, etc. Data are stored periodically or conditionally in data tables in SRAM as directed by the CRBASIC program (see *SECTION. Structure* (p. 133)). The DataTable () instruction allows the user to set the size of a data table. Discrete data files are normally created only on a PC when data are retrieved using *datalogger support software* (p. 439, p. 490).

Data are usually erased from this area when a program is sent to the CR1000. However, options are available in *datalogger support software* (p. 439, p. 490) File Control and CRBASIC Editor to preserve data when downloading programs.

12.1.1.2 CPU: Drive

CPU: is the default drive to which programs and calibration files are stored. Do not store data on CPU: or premature failure of CPU: memory may result.

12.1.1.3 USR: Drive

SRAM can be partitioned to create a FAT32 USR: drive, analogous to partitioning a second drive on a PC hard disk. Certain types of files are stored to USR: to reserve limited CPU: memory for datalogger programs and calibration files. Partitioning also helps prevent interference from data table SRAM. USR: is configured using DevConfig settings or SetStatus() instruction in a CRBASIC program. Partition USR: drive to at least 11264 bytes in 512 byte increments. If the value entered is not a multiple of 512 bytes, the size is rounded up. Maximum size of USR: is the total RAM size less 400 Kbytes; i.e., for a CR1000 with 4 Megabyte memory, the maximum size of USR: is about 3.6 Megabytes.

USR: is not affected by program recompilation or formatting of other drives. It will only be reset if the USR: drive is formatted, a new operating system is loaded, or the size of USR: is changed. USR: size is changed manually using the optional keyboard display or by loading a program with a different USR: size entered in a SetStatus() instruction.

Measurement data can be stored on USR: as discrete files by using the TableFile() instruction. *TABLE. TableFile() Instruction Data File Formats* (p. 355) describes available data file formats.

Note Placing an optional USR: size setting in the user program over-rides manual changes to USR: size. When USR: size is changed manually, the user program restarts and the programmed size for USR: takes immediate effect.

The USR: drive holds any file type within the constraints of the size of the drive and the limitations on filenames. Files typically stored include image files from cameras (see *APPENDIX. Cameras* (p. 504)), certain configuration files, files written for ftp retrieval, html files for viewing via web access, and files created with the TableFile() instruction. Files can be collected by ftp using *datalogger support software* (p. 439, p. 490) File Control utility, or automatically using the LNCMD program supplied exclusively with top-level *datalogger support software* (p. 439, p. 490).

Monitor use of available USR: memory to ensure adequate space to store new files. FileManage() command is used within the CR1000 user program to remove files. Files also can be removed using *datalogger support software* (p. 439, p. 490) File Control utility.

Two status table registers monitor use and size of the USR: drive. Bytes remaining are indicated in register "USRDriveFree." Total size is indicated in register "USRDriveSize." Memory allocated to USR: drive, less overhead for directory use, is shown in *datalogger support software* (p. 439, p. 490) File Control.

12.1.1.4 USB: Drive

USB: drive uses Flash memory on a CS mass storage device (see *APPENDIX. Mass Storage Devices* (p. 504)). Its primary purpose is the storage of ASCII data files. Measurement data can be stored on USB: as discrete files by using the TableFile() instruction. *TABLE. TableFile() Instruction Data File Formats* (p. 355) describes available data file formats.

Caution When removing mass storage devices, do so when the LED is not flashing or lit.

Removing a mass storage device from the CR1000 while the storage device is active can cause data corruption.

CS mass storage devices connect to the CR1000 via the CS I/O port.

CS mass storage devices should be formatted as FAT32.

12.1.1.5 CRD: Drive

CRD: drive uses CompactFlash® memory exclusively. Its primary purpose is the storage of binary data files.

Caution When installing or removing card storage modules, first turn off CR1000 power.

Removing a card from the module while the CF card is active can cause data corruption and may damage the card. Always press the removal button to disable the card and wait for the green LED before removing the card or switching off power prior to removal of the card.

To prevent losing data, collect data from the CF card before sending a program to the datalogger. When a program is sent to the datalogger all data on the CF card may be erased.

CSI CF card modules connect to the CR1000 peripheral port. Each has a slot for Type I or Type II CF cards. A maximum of 30 data tables can be created on a CF card. Refer to *APPENDIX. Card Storage Modules* (p. 503) for information on available CF card modules.

Note CardConvert software, included with mid- and top-level *datalogger support software* (p. 439, p. 490), converts binary card data to the standard Campbell Scientific data format.

When a data table is sent to a CF card, a data table of the same name in SRAM is used as a buffer for transferring data to the card. When the card is present, the status table will show the size of the table on the card. If the card is removed, the size of the table in SRAM is shown.

When a new program is compiled that sends data to the CF card, the CR1000 checks if a card is present and if the card has adequate space for the data tables. If no card is present, or if space is inadequate, the CR1000 will warn that the card is not being used. However, the user program is run and data stored to SRAM. When a card is later inserted, accumulated data is copied to the card.

The CR1000 accepts cards formatted as FAT or FAT32; however, **FAT32 is recommended**. Otherwise, some functionality, such as the ability to manage large numbers of files (>254) is lost. Older CR1000 operating systems formatted cards as FAT or FAT32. Newer operating systems always format cards as FAT32.

See *SECTION. File System Errors* (p. 366) for explanation of error codes associated with CRD: use.

12.1.1.6 Data File Formats

TableFile() instruction data file formats contain time series data and may have an option to include header, timestamp and record number. *TABLE. TableFile() Instruction Data File Formats* (p. 355) lists available formats. For a format to be compatible with *datalogger support software* (p. 439, p. 490) graphing and reporting tools, header, timestamps, and record numbers are usually required. Fully compatible formats are indicated with an asterisk. A more detailed discussion of data file formats is available in the Campbell Scientific publication "LoggerNet Instruction Manual" available at www.campbellsci.com.

TABLE 75. TableFile() Instruction Data File Formats

TableFile() Format Option	*Base File Format*	*Elements Included*		
		Header Information	*Time Stamp*	*Record Number*
0*	TOB1	X	X	X
1	TOB1	X	X	
2	TOB1	X		X
3	TOB1	X		
4	TOB1		X	X
5	TOB1		X	
6	TOB1			X
7	TOB1			
8*	TOA5	X	X	X
9	TOA5	X	X	
10	TOA5	X		X
11	TOA5	X		
12	TOA5		X	X
13	TOA5		X	
14	TOA5			X
15	TOA5			
16*	CSIXML	X	X	X
17	CSIXML	X	X	
18	CSIXML	X		X
19	CSIXML	X		
32*	CSIJSON	X	X	X
33	CSIJSON	X	X	
34	CSIJSON	X		X
35	CSIJSON	X		

*Formats compatible with *datalogger support software* (p. 439, p. 490) data viewing and graphing utilities

12.1.1.6.1 Data File Format Examples

TOB1

TOB1 files may contain an ASCII header and binary data. The last line in the example contains cryptic text which represents binary data.

Example:

```
"TOB1","11467","CR1000","11467","CR1000.Std.20","CPU:file
    format.CR1","61449","Test"
"SECONDS","NANOSECONDS","RECORD","battfivoltfiMin","PTemp"
"SECONDS","NANOSECONDS","RN","",""
"","","","Min","Smp"
"ULONG","ULONG","ULONG","FP2","FP2"
}Ÿp'    E1HŒŸp'    E1H›Ÿp'    E1HªŸp'    E1H¹Ÿp'        E1H
```

TOA5

TOA5 files contain ASCII (American Standard Code for Information Interchange) header and comma separated data.

Example:

```
"TOA5","11467","CR1000","11467","CR1000.Std.20","CPU:file
    format.CR1","26243","Test"
"TIMESTAMP","RECORD","battfivoltfiMin","PTemp"
"TS","RN","",""
"","","Min","Smp"
"2010-12-20 11:31:30",7,13.29,20.77
"2010-12-20 11:31:45",8,13.26,20.77
"2010-12-20 11:32:00",9,13.29,20.8
```

CSIXML

CSIXML files contain header information and data in an XML (eXtensible Markup Language) format.

Example:

```
<?xml version="1.0" standalone="yes"?>
<csixml version="1.0">
<head>
    <environment>
        <station-name>11467</station-name>
        <table-name>Test</table-name>
        <model>CR1000</model>
        <serial-no>11467</serial-no>
        <os-version>CR1000.Std.20</os-version>
        <dld-name>CPU:file format.CR1</dld-name>
    </environment>
    <fields>
        <field name="battfivoltfiMin" type="xsd:float"
            process="Min"/>
        <field name="PTemp" type="xsd:float" process="Smp"/>
    </fields>
</head>
    <data>
        <r time="2010-12-20T11:37:45"
            no="10"><v1>13.29</v1><v2>21.04</v2></r>
        <r time="2010-12-20T11:38:00"
            no="11"><v1>13.29</v1><v2>21.04</v2></r>
```

```
        <r time="2010-12-20T11:38:15"
            no="12"><v1>13.29</v1><v2>21.04</v2></r>
    </data>
</csixml>
```

CSIJSON

CSIJSON files contain header information and data in a JSON (Java Script Object Notation) format.

Example:

```
"signature": 38611,"environment":  {"stationfiname":
    "11467","tablefiname":  "Test","model":
    "CR1000","serialfino":  "11467",
"osfiversion":  "CR1000.Std.21.03","progfiname":  "CPU:file
    format.CR1"},"fields":  [{"name":
    "battfivoltfiMin","type":  "xsd:float",
"process":  "Min"},{"name":  "PTemp","type":
    "xsd:float","process":  "Smp"}]},
"data": [{"time":  "2011-01-06T15:04:15","no":  0,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:04:30","no":  1,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:04:45","no":  2,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:05:00","no":  3,"vals":
    [13.28,21.29]}]}
```

12.1.1.6.2 Data File Format Elements

HEADER

File headers provide metadata that describe the data in the file. A TOA5 header contains the metadata described below. Other data formats contain similar information unless a non-header format option is selected in the TableFile() instruction in the CR1000 CRBASIC program.

Line 1 – Data Origins

Includes the following metadata series: file type, station name, CR1000 model name, CR1000 serial number, OS version, CRBASIC program name, program signature, data table name.

Line 2 – Data Field Names

Lists the name of individual data fields. If the field is an element of an array, the name will be followed by a comma separated list of subscripts within parentheses that identifies the array index. For example, a variable named “values” that is declared as a two by two array, i.e.,

```
Public Values(2,2)
```

will be represented by four field names: “values(1,1)”, “values(1,2)”, “values(2,1)”, and “values(2,2)”. Scalar (non-array) variables will not have subscripts.

Line 3 – Data Units

Includes the units associated with each field in the record. If no units are programmed in the CR1000 CRBASIC program, an empty string is entered for that field.

Line 4 – Data Processing Descriptors

Entries describe what type of processing was performed in the CR1000 to produce corresponding data, e.g., Smp indicates samples, Min indicates minima. If there is no recognized processing for a field, it is assigned an empty string. There will be one descriptor for each field name given on Header Line 2.

TIMESTAMP

Data without timestamps are usually meaningless. Nevertheless, the TableFile() instruction optionally includes timestamps in some formats.

RECORD NUMBER

Record numbers are optionally provided in some formats as a means to ensure data integrity and provide an upcount data field for graphing operations.

12.2 Memory Conservation

One or more of the following memory saving techniques can be used on the rare occasions when a program reaches memory limits:

- Declare variables as DIM instead of Public. DIM variables do not require buffer memory for data retrieval.
- Reduce arrays to the minimum size needed. Each variable, whether or not part of an array, requires about the same amount of memory. Approximately 192000 (4 kbyte memory) or 87000 (2 kbyte memory) variables will fill available memory.
- Use variable arrays with aliases instead of individual variables with unique names. Aliases consume less memory than unique variable names.
- Confine string concatenation to DIM variables.
- Dimension string variables only to the size required.

Read More! More information on string variable memory use and conservation is available in *SECTION. String Operations* (p. 317).

12.3 Memory Reset

Four features are available for complete or selective reset of CR1000 memory.

12.3.1 Full Memory Reset

Full memory reset occurs when an operating system is sent to the CR1000 using DevConfig or when entering "98765" in the status table field "FullMemReset." A full memory reset does the following:

- Clears and Formats CPU: drive (all program files erased)
- Clears SRAM data tables
- Clears Status Table Elements
- Restores settings to default
- Initializes system variables
- Clears communications memory

Full memory reset does not affect the CRD: drive directly. Subsequent user program uploads, however, can affect CRD:.

Operating systems can also be sent using the Program Send feature in *datalogger support software* (p. 439). Beginning with operating system version 16, settings and status are preserved when sending a subsequent OS by this method; data tables are erased. Rely on this feature with caution, however, when sending an OS to CR1000s in remote and difficult to access locations.

12.3.2 Program Send Reset

Final Storage (p. 442) data are erased when user programs are uploaded, unless preserve / erase data options are used. Preserve / erase data options are presented when sending programs from *datalogger support software* (p. 439, p. 490) File Control and CRBASIC Editor Compile | Save | Send. See *SECTION. Preserving Data at Program Send* (p. 131) for a more detailed discussion of preserve / erase data at program send.

12.3.3 Manual Data Table Reset

Data table memory is selectively reset from

- *datalogger support software* (p. 439) Station Status option
- optional keyboard display: Data | Reset Data Tables

12.3.4 Formatting Drives

CPU:, USR:, USB:, and CRD: drives can be formatted individually. Formatting a drive erases all files on that drive. If the currently running user program is found on the drive to be formatted, the program will cease running and any SRAM data associated with the program is erased. Drive formatting is performed through datalogger support software File Control.

12.4 File Management

Files in CR1000 memory (program, data, CAL, image) can be managed or controlled with Campbell Scientific support software as summarized in *TABLE. File Control Functions* (p. 360).

TABLE 76. File Control Functions

File Control Functions	*Accessed Through*
Sending programs to the CR1000.	**Send**[1], File Control[2], DevConfig[3], keyboard with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive)[4], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Setting file attributes. See *File Attributes* (p. 361).	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive)[5], FileManage() instruction[6].
Sending an OS to the CR1000. Reset settings.	DevConfig[3], automatic with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Sending an OS to the CR1000. Preserve settings.	**Send**[1], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) with default.CR1 file.[5]
Formatting CR1000 memory drives.	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Retrieving programs from the CR1000.	Connect[7], File Control[2], keyboard with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[4]
Setting disposition of old CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) files	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Deleting files from memory drives.	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Stopping program execution.	File Control[2].
Renaming a file.	FileRename()[6]
Time stamping a file.	FileTime()[6]
List files.	File Control[2], FileList()[6]

TABLE 76. File Control Functions	
File Control Functions	*Accessed Through*
Create a data file from a data table	TableFile()[6]
JPEG files manager	optional keyboard display , LoggerNet | PakBusGraph

[1] *Datalogger support software* (p. 439, p. 490) Program Send Button. See software Help.

[2] *Datalogger support software* (p. 439, p. 490) File Control. See software Help.

[3] Device Configuration Utility (DevConfig). See DevConfig Help.

[4] Manual with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive). See *Data Storage* (p. 352).

[5] Automatic with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) and Powerup.ini. See *Power-up* (p. 363).

[6] CRBASIC commands. See *Data Table Declarations* (p. 177) and *File Management* (p. 215) and CRBASIC Editor Help.

[7] *Datalogger support software* (p. 439, p. 490) Retrieve button. See software Help.

12.4.1 File Attributes

A feature of program files is the file attribute. *TABLE. CR1000 File Attributes* (p. 361) lists available file attributes, their functions, and when attributes are typically used. For example, a program file sent via the **Send** option in *datalogger support software* (p. 439), runs a) immediately ("Run Now") and b) when power is cycled on the CR1000 ("Run on Power-up). This functionality is invoked because **Send** sets two CR1000 file attributes on the program file, i.e., "Run Now" and "Run on Power-up." When together, "Run Now" and "Run on Power-up" are tagged as "Run Always."

Note Activation of the Run on Power-up file can be prevented by holding down the Del key on the optional keyboard display while the CR1000 is being powered up.

TABLE 77. CR1000 File Attributes		
Attribute	*Function*	*Attribute for Programs Sent to CR1000 with:*
Run Always (Run on Power-up + Run Now)	Runs now and on power-up	a) **Send**[1] b) File Control[2] with Run Now & Run on Power-up checked. c) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using commands 1 & 13 (see *TABLE. Powerup.ini Commands* (p. 364)).
Run on Power-up	Runs only on power-up	a) File Control[2] with Run on Power-up checked. b) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using command 2 (see *TABLE. Powerup.ini Commands* (p. 364)).

TABLE 77. CR1000 File Attributes

Attribute	*Function*	*Attribute for Programs Sent to CR1000 with:*
Run Now	Runs only when file sent to CR1000	a) File Control[2] with Run Now checked. b) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using commands 6 & 14 (see *TABLE. Powerup.ini Commands* (p. 364)). But, if CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) is left in, program loads again from CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).

[1] *Datalogger support software* (p. 439, p. 490) Program Send Button. See software Help.

[2] *Datalogger support software* (p. 439, p. 490) | File Control. See software Help & *Preserving Data at Program Send* (p. 131).

[3] Automatic on power-up of CR1000 with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) and Powerup.ini. See *Power-up* (p. 363).

12.4.2 Data Preservation

Associated with file attributes is the option to preserve data in CR1000 memory when a program is sent. This option applies to data table SRAM, CompactFlash(R), and datalogger support software cache data. Depending on the application, retention of data files when a program is downloaded may be desirable. When sending a program to the CR1000 with the datalogger support software Send, data are always deleted before the program runs. When the program is sent using datalogger support software File Control or CRBASIC Editor "Compile, Save, and Send," options to preserve (do not erase) or not preserve (erase) data are presented. The logic in *TABLE. Data Preserve Options* (p. 362) summarizes the disposition of CR1000 data depending on the data preservation option selected.

TABLE 78. Data Preserve Options

```
if "Preserve data if no table changed"
    keep CF data from overwritten program
    if current program = overwritten program
        keep CPU data
        keep cache data
    else
        erase CPU data
        erase cache data
    end if
end if

if "erase CF data"
    erase CF data from overwritten program
    erase CPU data
    erase cache data
end if
```

12.4.3 External Memory Power-up

Uploading a CR1000 operating system file or user program file in the field can be challenging, particularly during weather extremes. Heat, cold, snow, rain, altitude, blowing sand, and distance to hike influence how easily programming with a laptop or palm PC may be. An alternative is to carry the file to field on a light weight external memory device such as a *USB:* (p. 504) or *CRD:* (p. 503) drive. Including a powerup.ini file with the OS / program file on an external drive, connecting the external device to the CR1000, and then cycling power, will result in the file automatically uploading to the CR1000 and running. Powerup.ini options also allows final data storage management comparable to the *datalogger support software* (p. 489) File Control feature. CRD: drive has precedence over USB: drive.

Caution Test Power-up options in the lab before going to the field. Always carry a laptop or palm PC into difficult or expensive to access places.

Power-up functions include

1. Sending programs to the CR1000
2. Setting attributes of CR1000 program files
3. Setting disposition of old CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) files
4. Sending an OS to the CR1000
5. Formatting memory drives
6. Deleting data files

Note Back in the old days of volatile RAM, life was simple. Lost power meant lost programs, variables, and data. The advent of non-volatile memory has saved a lot of frustration in the field, but it requires thought in some applications. For instance, if the CR1000 loses power, do you want it to power back up with the same program, or another one? with variables intact or erased? with data intact or erased?

The powerup.ini file enables the power-up function. The powerup.ini file usually resides on an external drive. It contains a list of one or more command lines. At power-up, the CR1000 searches for a powerup.ini file on a drive and executes the command line(s) prior to compiling a program. Powerup.ini performs three operations:

1. Copies the specified program file to a specified memory drive.
2. Sets a file attribute on the program file.
3. Optionally deletes data left in memory from a just previous, and now overwritten, program.

A powerup.ini file takes precedence during power-up. Although it sets file attributes for the programs it uploads, its presence on a drive does not allow

those file attributes to control the power-up process. To avoid confusion, either remove the external drive on which the powerup.ini file resides or delete the file after the powerup.ini operation is complete.

12.4.3.1 Creating and Editing Powerup.ini

A powerup.ini file is created with a text editor on a PC, then saved as "powerup.ini" on a memory drive of the CR1000. The file is saved to the memory drive, along with the operating system or user program file, using the File Control | Send function in *datalogger support software* (p. 489).

Note Some text editors (such as MicroSoft® WordPad®) will attach header information to the powerup.ini file causing it to abort. Check the text of a powerup.ini file in the CR1000 with the optional keyboard display to see what the CR1000 actually sees.

Comments can be added to the file by preceding them with a single-quote character ('). All text after the comment mark on the same line is ignored.

12.4.3.1.1 Syntax

```
Command,File,Device
```

where

- Command = one of the numeric commands in *TABLE. Powerup.ini Commands* (p. 364).
- File = accompanying operating system or user program file. Name can be up to 22 characters.
- Device: the CR1000 memory drive to which the accompanying operating system or user program file is copied (usually CPU:). If left blank or with an invalid option, default device will be CPU:. Use the same drive designation as the transporting external device if the preference is to not copy the file.

TABLE 79. Powerup.ini Commands

Command	*Description*
1*	Run always, preserve data
2	Run on power-up
5	Format
6*	Run now, preserve data
9	Load OS (File = .obj)
13	Run always, erase data
14	Run now, erase files
*By using PreserveVariables() instruction in the CRBASIC program, with commands 1 & 6, data and variables can be preserved.	

12.4.3.1.2 Applications

- Commands 1, 2, 6, 13, and 14 (Run Now and / or Run On Power-up). File is copied to Device.
- Command 1, 2, 13 (Run On Power-up). If the copy (first application, above) succeeds, the new Run On Power-up program is accepted. If the copy fails, no change is made to the Run On Power-up program.
- Commands 1, 6, 13, and 14 (Run Now). The Run Now program is changed whether or not the copy (first application, above) occurs. If the copy does succeed, the Run Now program is opened from the device specified.
- Commands 13 and 14 (Delete Associated Data). Since powerup.ini is only processed at power-up, there is not a compiled program to delete associated data for. The information from the last running program is still available for the CR1000 to delete the files used by that program.

12.4.3.1.3 Program Execution

After File is processed, the following rules determine what CR1000 program to run:

- If the Run Now program is changed then it is the program that runs.
- If no change is made to Run Now program, but Run on Power-up program is changed, the new Run on Power-up program runs.
- If neither Run on Power-up nor Run Now programs are changed, the previous Run on Power-up program runs.

12.4.3.1.4 Example Power-up.ini Files

Powerup.ini Example

Code Form / Syntax

```
'Command = numeric power-up command
'File = file associated with the action
'Device = device to which File is copied. Defaults to CPU:

'Command,File,Device
13,Write2CRD 2.cr1,cpu:
```

Powerup.ini Example

Copy program file pwrup.cr1 from the external drive to CPU:. File will run only when CR1000 powered-up later

```
2,pwrup.cr1,cpu:
```

Powerup.ini Example

Format the USR: drive

```
5,,usr:
```

Powerup.ini Example.
Load an operating system (.obj) file into FLASH as the new OS
`9,CR1000.Std.04.obj`

Powerup.ini Example
A program file is carried on an external USB: drive. Do not copy program file from USB:. Run program always, erase data.
`13,toobigforcpu.cr1,usb:`

Powerup.ini Example
Run a program file always, erase data
`13,pwrup_1.cr1,cpu:`

Powerup.ini Example
Run a program file now, erase data now
`14,run.cr1,cpu:`

12.5 File Names

The maximum size of the file name that can be stored, run as a program, or FTP transferred in the CR1000 is 59 characters. If the name is longer than 59 characters an "Invalid Filename" error is displayed. If several files are stored, each with a long filename, memory allocated to the root directory can be exceeded before the actual memory of storing files is exceeded. When this occurs, an "insufficient resources or memory full" error is displayed.

12.6 File System Errors

TABLE. File System Error Codes (p. 366) lists error codes associated with the datalogger file system. Errors can occur when attempting to access files on any of the available drives. All occurrences are rare, but they are most likely to occur when using the CRD: drive.

TABLE 80. File System Error Codes

Error Code	*Description*
1	Invalid Format
2	Device capabilities error
3	Unable to allocate memory for file operation
4	Max number of available files exceeded
5	No file entry exists in directory
6	Disk change occurred

TABLE 80. File System Error Codes

Error Code	*Description*
7	Part of the path (subdirectory) was not found
8	File at EOF
9	Bad cluster encountered
10	No file buffer available
11	Filename too long or has bad chars
12	File in path is not a directory
13	Access permission, opening DIR or LABEL as file, or trying to open file as DIR or mkdir existing file
14	Opening read only file for write
15	Disk full (can't allocate new cluster)
16	Root directory is full
17	Bad file ptr (pointer) or device not initialized
18	Device does not support this operation
19	Bad function argument supplied
20	Seek out of file bounds
21	Trying to mkdir an existing dir
22	Bad partition sector signature
23	Unexpected system ID byte in partition entry
24	Path already open
25	Access to uninitialized ram drive
26	Attempted rename across devices
27	Subdirectory is not empty
31	Attempted write to Write Protected disk
32	No response from drive (Door possibly open)
33	Address mark or sector not found
34	Bad sector encountered
35	DMA memory boundary crossing error
36	Miscellaneous I/O error
37	Pipe size of 0 requested
38	Memory release error (relmem)
39	FAT sectors unreadable (all copies)
40	Bad BPB sector
41	Time-out waiting for filesystem available
42	Controller failure error
43	Pathname exceeds _MAX_PATHNAME

Section 18. Care and Maintenance

Temperature and humidity can affect the performance of the CR1000. The internal lithium battery must be replaced periodically.

18.1 Temperature Range

The CR1000 is designed to operate reliably from -25 to +50°C (-40°C to +85°C, optional) in non-condensing environments.

18.2 Moisture Protection

When humidity tolerances are exceeded and condensation occurs, damage to CR1000 electronics can result. Effective humidity control is the responsibility of the user.

Internal CR1000 module moisture is controlled at the factory by sealing the module with a packet of silica gel inside. The desiccant is replaced whenever the CR1000 is repaired at Campbell Scientific. The module should not be opened by the user except to replace the lithium coin cell providing back up power to the clock and SRAM. Repeated disassembly of the CR1000 will degrade the seal, leading to potential moisture problems.

Adequate desiccant should be placed in the instrumentation enclosure to prevent corrosion on the CR1000 wiring panel.

18.3 Enclosures

Illustrated in *FIGURE. Enclosure* (p. 410) is a typical use of an enclosure available from Campbell Scientific for housing a CR1000 and peripherals. This style of enclosures is classified as NEMA 4X (watertight, dust-tight, corrosion-resistant, indoor and outdoor use). Refer to *APPENDIX. Enclosures* (p. 497) for information concerning available enclosures.

FIGURE 127. Enclosure

18.4 Replacing the Internal Battery

Caution Fire, explosion, and severe burn hazard! Misuse or improper installation of the lithium battery can cause severe injury. Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not powered. The CR1000 does not draw power from the lithium battery while it is powered by a 12 Vdc supply. In a CR1000 stored at room temperature, the lithium battery should last approximately 3 years (less at temperature extremes). In installations where the CR1000 remains powered the lithium cell should last much longer.

While powered from an external source, the CR1000 measures the voltage of the lithium battery daily. This voltage is displayed in the status table (*APPENDIX. Status Table and Settings* (p. 457)). A new battery supplies approximately 3.6 volts. The CR1000 Status Table has a "Lithium Battery" field. This field shows lithium battery voltage. Replace the battery when voltage is approximately 2.7 V. If the lithium cell is removed or allowed to discharge below the safe level, the CR1000 will still operate correctly while powered. Without the lithium battery, the clock will reset and data are lost when power is removed.

- The CR1000 is partially disassembled to replace the lithium cell. See *FIGURE. Loosening Thumbscrews* (p. 411) through *FIGURE. Remove and Replace Battery* (p. 413). When the lithium battery is removed, the user program and most settings are maintained. Items not retained include
  - Run now and run on power-up settings.
  - Routing and communications logs (relearned without user intervention).
  - Time. Clock will need resetting when the battery is replaced.
  - Final storage data tables.

A replacement lithium battery (pn 13519) can be purchased from Campbell Scientific or another supplier. *TABLE. Internal Lithium Battery Specifications* (p. 411) lists battery specifications.

TABLE 88. Internal Lithium Battery Specifications

Manufacturer	*Tadiran*
Model	TL-5902S (3.6 V)
Capacity	1.2 Ah
Self-discharge rate	1%/year @ 20°C
Operating temperature range	-55°C to 85°C

When reassembling the module to the wiring panel, assure that the module is fully seated or connected to the wiring panel by firmly pressing them together by hand.

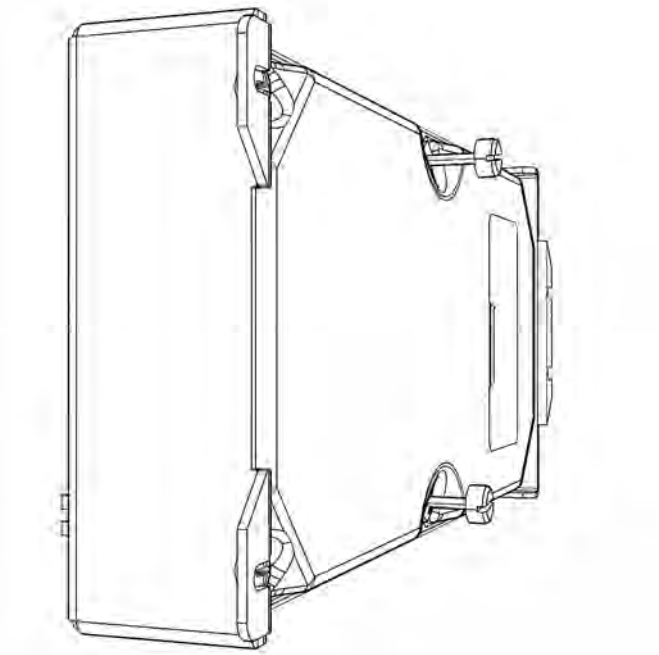


FIGURE 128. Loosening Thumbscrews

Fully loosen the two knurled thumbscrews. Only loosen the screws. They will remain attached to the module.

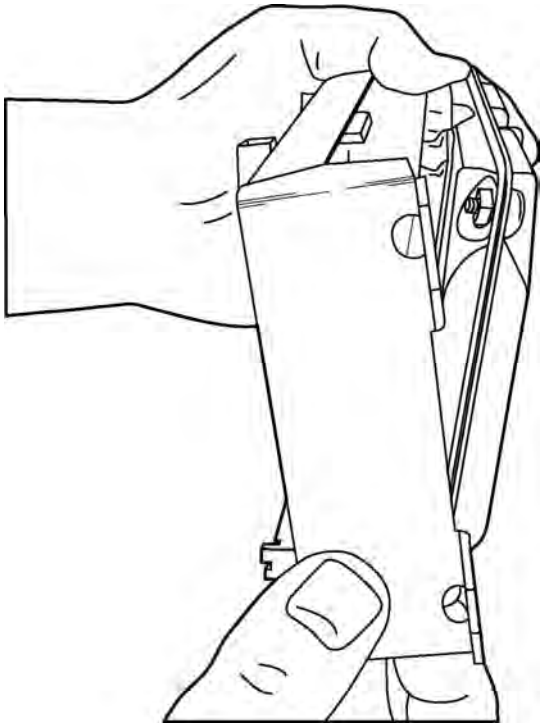


FIGURE 129. Pulling Edge Away from Panel

Pull one edge of the canister away from the wiring panel to loosen it from three connector seatings.

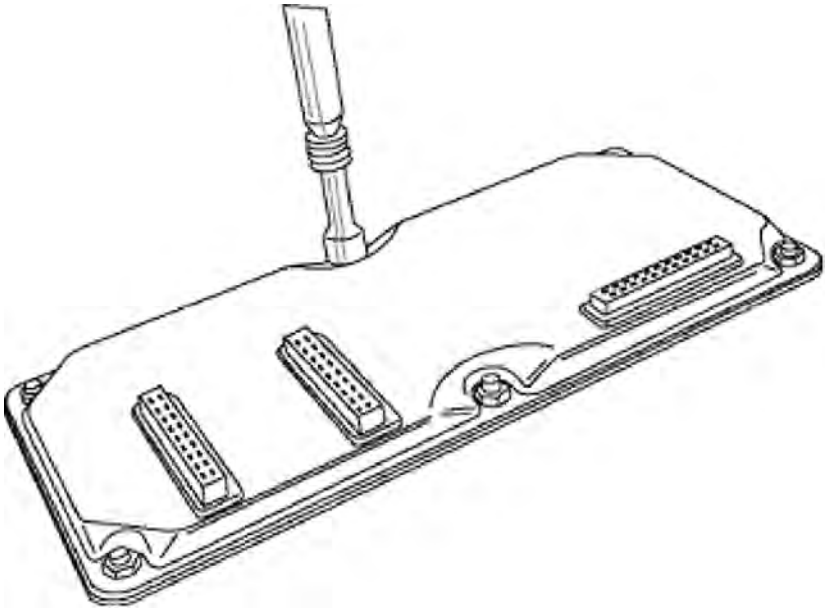


FIGURE 130. Removing Nuts to Disassemble Canister

Remove six nuts, then open the clam shell.

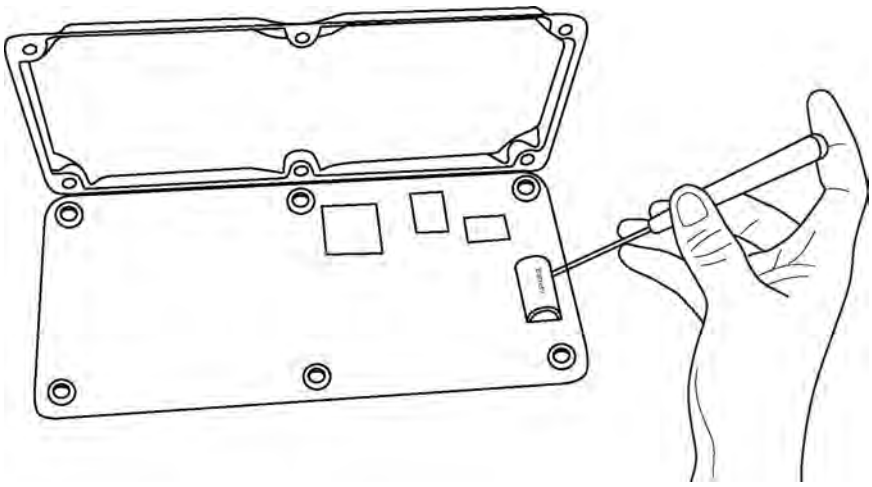


FIGURE 131. Remove and Replace Battery

Remove the lithium battery by gently prying it out with a small flat point screwdriver. Reverse the disassembly procedure to reassemble the CR1000. Take particular care to ensure the canister is reseated tightly into the three connectors.

18.5 Repair

Occasionally, a CR1000 requires repair. Consult with a Campbell Scientific applications engineer before sending any product for repair. Be prepared to perform some troubleshooting procedures while on the phone with the applications engineer. Many problems can be resolved with a telephone conversation. If a repair is warranted, the following procedures should be followed when sending the product.

Products may not be returned without prior authorization. The following contact information is for US and International customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit *www.campbellsci.com* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a "Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. The form is available from our web site at *www.campbellsci.com/repair*. A completed form must be either emailed to *repair@campbellsci.com* or faxed to 435-750-9579. Campbell Scientific will not process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Appendix A2 - CFM100 CompactFlash Module

INSTRUCTION MANUAL

CFM100 CompactFlash® Module

Revision: 6/12

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This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. (“CSC”) to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

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CFM100 CompactFlash® Module

1. Introduction

Campbell Scientific's CFM100 CompactFlash® Module stores the datalogger's data on a removable CompactFlash (CF) card. The CFM100 module connects to the datalogger via the 40-pin peripheral port. Currently, only our CR1000 and CR3000 dataloggers have the 40-pin peripheral port; the CFM100 is not compatible with the CR200-series, CR800, CR850, CR5000, and CR9000X dataloggers.

Before using the CFM100, please study:

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quickstart*

The Quickstart explains how to quickly begin using a CFM100 for straightforward data storage operations. The remainder of the manual is a technical reference which describes in detail such operations as: file formats, datalogger programming and data retrieval.

2. Cautionary Statements

- The CFM100 is rugged, but it should be handled as a precision scientific instrument. There are no user-serviceable parts inside the module.
- The 28033 surge suppressor and/or a shielded 10baseT Ethernet cable should be used for locations susceptible to power surges and for cable length longer than 9 ft.
- Always power down the datalogger before installing or removing the CFM100 to/from the datalogger.
- Removing a CompactFlash card while it is active can cause garbled data and can actually damage the card. **Always** press the control button and wait for a green light before removing card.
- LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

3. Initial Inspection

Upon receipt of the CFM100, inspect the packaging and contents for damage. File damage claims with the shipping company.

4 Quickstart

This section describes the basics of storing and retrieving datalogger data. These operations are discussed in detail in Section 7, *Operation* of this manual.

4.1 Preparation

CAUTION Always power down the datalogger before installing or removing the CFM100 to/from the datalogger.

After powering down the datalogger, plug the CFM100 into the datalogger peripheral port. Restore power to the datalogger. Insert formatted CF card. (For instructions on formatting a CF card, see Appendix A.)

4.2 Programming the Datalogger to Send Data to the CFM100

The **CardOut()** instruction is used in the datalogger program to send data to the CF card. The **CardOut()** instruction must be entered within each **DataTable()** declaration that is to store data to the CF card. The file is saved to the card with the name stationname.tablename and a .DAT extension.

The **CardOut()** instruction has the following parameters:

StopRing: A constant is entered for the *StopRing* parameter to specify whether the **DataTable()** created should be a Ring Mode table (0) or a Fill and Stop table (1).

Size: The *Size* parameter is the minimum number of records that will be included in the **DataTable()**. If –1000 is entered, the size of the file on the card will be the same as the size of the internal table on the datalogger. If any other negative number is entered, the memory that remains after creating any fixed-size tables on the card will be allocated to this table. If multiple DataTables are set to a negative number, the remaining memory will be divided among them. The datalogger attempts to size the tables so that all of them will be full at the same time

In the following example, the minimum batt_voltage and a sample of PTemp is written to the card each time the data table is called. The *StopRing* parameter is 0 for ring mode. This means that once the data table is full, new data will begin overwriting old data. The *size* parameter is –1, so all available space on the card will be allocated to the table.

DataTable(*Table1,1,-1***)**

CardOut(*0,-1***)**

Minimum(*1,batt_volt,FP2,0,False***)**

Sample(*1,PTemp,IEEE4***)**

EndTable

CAUTION To prevent losing data, collect data from the CF card before sending the datalogger a new or modified program. When a program is sent to the datalogger using the Send button in the Connect screen of LoggerNet or PC400, an attribute is sent along with the program that commands the datalogger to erase all data on the CF card from the currently running program.

4.3 Data Retrieval

Data stored on cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer with a CF adapter. With large files, transferring the CF card to a computer may be faster than collecting the data over a communication link. Data retrieval is discussed in detail in Section 7.3, *Data Retrieval*.

CAUTION Removing a card while it is active can cause garbled data and can actually damage the card. **Always** press the control button and wait for a green light before removing card.

CAUTION LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

5. Overview

The CFM100 connects to a datalogger's peripheral port and has a slot for a Type I or Type II CompactFlash (CF) card (3.3 V, 75 mA). The CFM100/CF card combination can be used to expand the datalogger's memory, transport data/programs from the field site(s) to the office, upload datalogger power up functions, and store JPEG images from the CC640 camera. Data stored on cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer. The computer can read the CF card either with the CF1 adapter or 17752 Reader/Writer. The CF1 adapter allows the PC's PCMCIA card slot to read the CF card; the 17752 Reader/Writer allows the PC's USB port to read the CF card. User-supplied CF adapters may also be used.

CAUTION LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

FIGURE 5-1. CompactFlash Module

5.1 LEDs/Buttons

There is one red-green-orange LED (light emitting diode) and two buttons: control and eject. The LED indicates the status of the module. The LED will flash red when the CF card is being accessed, solid green when it is OK to remove the card, solid orange to indicate an error, and flashing orange if the card has been removed and has been out long enough that CPU memory has wrapped and data is being overwritten without being stored to the card. The control button must be pressed before removing a card to allow the datalogger to store any buffered data to the card and then power it off.

NOTE The CFM100 will consume more current if a Status LED is continuously on. When a red or green LED is continuously on, add 1 mA to the power consumption. When an orange LED is continuously on, add 2 mA to the power consumption.

5.2 Power

5.2.1 Primary Power

The CompactFlash module is powered by 12 VDC received from the datalogger through the peripheral port.

5.2.2 Backup Power and Data Retention

The CompactFlash (CF) cards do not require power to retain data.

Typically, a CF card can be erased and rewritten a minimum of 100,000 times. Industrial CF cards, graded for 2,000,000 write cycles, are recommended for most applications.

6. Specifications

Storage Capacity:	Depends on card size (up to 2 GB supported)
Dimensions:	10.0 x 8.3 x 6.5 cm (4.0 in x 3.3 in x 2.6 in)
Weight:	132.5 g
Operating Temp. Range:	-35° to +65°C (-55° to +85°C optional)
Typical Access Speed:	200 to 400 kbits s^{-1}
Memory Configuration:	User selectable for either ring style (default) or fill and stop.

6.1 Power

The CFM100 receives 12 V power from the datalogger through the peripheral port. The following currents are for the CR1000 with the CFM100 attached and can vary with the card.

Writing to card with RS-232 port active:	30 mA (avg.)
Reading from card with RS-232 port active:	20 mA (avg.)
Writing to card with RS-232port not active:	20 mA (avg.)
Reading from card with RS-232 port not active:	15 mA (avg.)
Low Power Standby State:	700 to 800 μA
Red or green LED continuously on:	Add 1 mA to current drain
Orange LED continuously on:	Add 2 mA to current drain

7. Operation

7.1 File Formats

This section covers the different types of files stored on the CF card

7.1.1 Data Files

The datalogger stores data on the CF card in TOB3 Format. TOB3 is a binary format that incorporates features to improve reliability of the CF cards. TOB3 allows the accurate determination of each record's time without the space required for individual time stamps.

TOB3 format is different than the data file formats created when data are collected via a communications link. Data files read directly from the CF card generally need to be converted into another format to be used

When TOB3 files are converted to another format, the number of records may be slightly greater or less than the number requested in the data table declaration. There is always some additional memory allocated. When the file is converted this will result in additional records if no lapses occurred. If more lapses occur than were anticipated, there may be fewer records in the file than were allocated.

The CardConvert software included in LoggerNet, PC400, and PC200 will convert data files from one format to another.

7.1.2 Program Files

The CF card can be used to provide extra program storage space for the datalogger. Program files can be copied to the card while it is attached as a drive on the computer. They can also be sent to the card using LoggerNet's File Control. They may also be copied from CPU memory to the card (or from the card to CPU memory) using the keyboard display.

7.1.3 Power-up Files (powerup.ini)

Users can insert a properly-configured CF card into the CFM100, cycle through the datalogger power, and have power up functions automatically performed.

Power-up functions of CompactFlash® cards can include

a) Sending programs to the CR1000 or CR3000
b) Setting attributes of datalogger program files
c) Setting disposition of old CF files
d) Sending an OS to the CR1000 or CR3000
e) Formatting memory drives
f) Deleting data files

CAUTION Test the power-up functions in the office before going into the field to ensure the power-up file is configured correctly.

The key to the CF power-up function is the powerup.ini file, which contains a list of one or more command lines. At power-up, the powerup.ini command line is executed prior to compiling the program. Powerup.ini performs three operations:

1) Copies the specified program file to a specified memory drive.

2) Sets a file attribute on the program file

3) Optionally deletes CF data files from the overwritten (just previous) program.

Powerup.ini takes precedence during power-up. Though it sets file attributes for the programs it uploads, its presence on the CF does not allow those file attributes to control the power-up process. To avoid confusion, either remove the CF card or delete the powerup.ini file after the powerup.ini upload.

7.1.3.1 Creating and Editing Powerup.ini

Powerup.ini is created with a text editor, then saved as "powerup.ini".

NOTE Some text editors (such as WordPad) will attach header information to the powerup.ini file causing it to abort. Check the text of a powerup.ini file with the datalogger keyboard display to see what the datalogger actually sees.

Comments can be added to the file by preceding them with a single-quote character (‘). All text after the comment mark on the same line is ignored.

Syntax
Syntax allows functionality comparable to File Control in LoggerNet. Powerup.ini is a text file that contains a list of commands and parameters. The syntax for the file is:

Command,File,Device

where

Command = one of the numeric commands in Table 7.1-1.
File = file on CF associated with the action. Name can be up to 22 characters.
Device = the device to which the associated file will be copied to. Options are CPU:, USR:, and CRD:. If left blank or with invalid option, will default to CPU:.

TABLE 7.1-1. Powerup.ini Commands	
Command	**Description**
1	Run always, preserve CF data files
2	Run on power-up
5	Format
6	Run now, preserve CF data files
9	Load OS (File = .obj)
13	Run always, erase CF data files now
14	Run now, erase CF data files now

By using **PreserveVariables()** instruction in the datalogger CRBasic program, with options 1 and 6, data and variables can be preserved.

EXAMPLE 7.1-1. Powerup.ini code.

```
'Command = numeric power-up command
'File = file on CF associated with the action
'Device = the device to which File will be copied.  Defaults to CPU:

'Command,File,Device
13,Write2CRD_2.cr1,CPU:
```

7.1.3.2 Applications

- Commands 1, 2, 6, 13, and 14 (Run Now and / or Run On Power-up). If a device other than CRD: drive is specified, the file will be copied to that device.
- Command 1, 2, 13 (Run On Power-up). If the copy (first application, above) succeeds, the new Run On Power-up program is accepted. If the copy fails, no change will be made to the Run On Power-up program.
- Commands 1, 6, 13, and 14 (Run Now). The Run Now program is changed whether or not the copy (first application, above) occurs. If the copy does succeed, the Run Now program will be opened from the device specified.
- Commands 13 and 14 (Delete Associated Data). Since CRD:powerup.ini is only processed at power-up, there is not a compiled program to delete associated data for. The information from the last running program is still available for the datalogger to delete the files used by that program.

7.1.3.3 Program Execution

After File is processed, the following rules determine what datalogger program to run:

1) If the Run Now program is changed then it will be the program that runs.
2) If no change is made to Run Now program, but Run on Power-up program is changed, the new Run on Power-up program runs.
3) If neither Run on Power-up nor Run Now programs are changed, the previous Run on Power-up program runs.

7.1.3.4 Example Power-up.ini Files

Example 7.1-2 through Example 7.1-7 are example powerup.ini files.

EXAMPLE 7.1-2. Run Program on Power-up.

```
'Copy pwrup.cr1 to USR:, will run only when powered-up later
2,pwrup.cr1,usr:
```

EXAMPLE 7.1-3. Format the USR: drive.

```
'Format the USR: drive
5,,usr:
```

EXAMPLE 7.1-4. Send OS on Power-up.

```
'Load this file into FLASH as the new OS
9,CR1000.Std.04.obj
```

EXAMPLE 7.1-5. Run Program from CRD: drive.

```
'Leave program on CRD:, run always, erase CRD: data files
13,toobigforcpu.cr1,crd:
```

EXAMPLE 7.1-6. Run Program Always, Erase CF data.

```
'Run always, erase CRD: data files
13,pwrup_1.cr1,crd
```

EXAMPLE 7.1-7. Run Program Now, Erase CF data.

```
'Copy run.cr1 to CPU:, erase CF data, run CPU:run.cr1, but not if later powered-up
14,run.cr1,cpu:
```

7.1.4 Camera Files

JPEG images taken by a digital camera connected to the datalogger can be stored to the CF card rather than CPU memory. This is done by configuring the PakBus setting "Files Manager" for the datalogger. This can be done using the Device Configuration Utility or PakBus Graph.

7.2 Programming

7.2.1 The CardOut() Instruction

The **CardOut()** Instruction is used to send data to a CF card. The **CardOut()** Instruction must be entered within each **DataTable** declaration that is to store data to the CF card. Data is stored to the card when a call is made to the data table.

CardOut(*StopRing, Size***)**

Parameter *& Data Type*	**Enter**
StopRing *Constant*	A code to specify if the Data Table on the CF card is fill and stop or ring (newest data overwrites oldest). **Value** — **Result** 0 — Ring 1 — Fill and Stop
Size *Constant*	The size to make the data table. The number of data sets (records) for which to allocate memory in the CF card. Each time a variable or interval trigger occurs, a line (or row) of data is output with the number of values determined by the Output Instructions within the table. This data is called a record.
	Note Enter –1000 and the size of the table on the card will match the size of the internal table on the datalogger Enter any other negative number and all remaining memory (after creating any fixed size data tables) will be allocated to the table or partitioned among all tables with a negative value for size. The partitioning algorithm attempts to have the tables full at the same time.

7.2.2 Program Examples

7.2.2.1 Ring Mode

The following program outputs the maximum and minimum of the panel temperature to the card once a second. The first parameter of the **CardOut()** instruction is 0, which sets the table on the card to ring mode. The second parameter is negative, so all available memory on the card will be allocated to the data table. Once all available memory is used, new data will begin overwriting the oldest data.

PROGRAM

```
'CR1000

Public temp

DataTable (Table1,1,-1)
    CardOut (0, -1)
    Maximum (1,temp,FP2,False,False)
    Minimum (1,temp,FP2,False,False)
EndTable

BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        CallTable Table1
    NextScan
EndProg
```

7.2.2.2 Fill and Stop Mode

The following program outputs a sample of the panel temperature to the card once a second. The first parameter of the **CardOut()** instruction is 1, which sets the table on the card to fill and stop mode. The second parameter (1000) is the number of records which will be written before the table is full and data storage stops. Once 1000 records have been stored, data storage will stop.

PROGRAM

```
'CR1000

Public temp

DataTable (Table1,1,1000)
    CardOut (1,1000)
    Sample(1,temp,IEEE4)
EndTable

BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        CallTable Table1
    NextScan
EndProg
```

To reset a table after a fill and stop table has been filled and stopped, either use the reset button in LoggerNet (LN Connect | Datalogger | View Station Status | Table Fill Times, Reset Tables button) or use the CRBasic **ResetTable** instruction.

7.2.2.3 Mixed Modes

The following program stores four data tables to the card. The first two tables will output samples of the panel temperature and battery voltage to the card once a second. The first parameter of the **CardOut()** instructions is 1, which sets the tables on the card to fill and stop mode. The second parameter is 1000, so 1000 records will be written to each table before stopping.

Tables 3 and 4 will output the maximum and minimum of the panel temperature and battery voltage to the card once every five seconds. (The tables will be called once a second. The **DataInterval()** instruction causes data to only be stored every five seconds.) The first parameter of the **CardOut()** instructions is 0, which sets the tables on the card to ring mode. The second parameter is negative, so all available memory on the card will be allocated to these tables, once space for the fixed-size tables has been allocated. The datalogger will attempt to size the tables so that both of them will be full at the same time.

PROGRAM

```
'CR1000

Public temp
Public batt

DataTable (Table1,1,-1)
    CardOut (1,1000)
    Sample(1,temp,IEEE4)
EndTable

DataTable (Table2,1,-1)
    CardOut (1,1000)
    Sample(1,batt,IEEE4)
EndTable

DataTable (Table3,1,1000)
    DataInterval(0,5,sec,4)
    CardOut (0 ,-1)
    Maximum (1,temp,FP2,False,False)
    Minimum (1,temp,FP2,False,False)
EndTable

DataTable (Table4,1,1000)
    DataInterval(0,5,sec,4)
    CardOut (0 ,-1)
    Maximum (1batt,FP2,False,False)
    Minimum (1,batt,FP2,False,False)
EndTable
```

```
BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        Battery(Batt)
        CallTable Table1
        CallTable Table2
        CallTable Table3
        CallTable Table4
    NextScan
EndProg
```

7.2.3 Table Size and Mode

The size of each data table in CPU memory is set as part of the **DataTable()** instruction and the size of each data table on the CF card is set with the **CardOut()** instruction. Because they are set independently, they can be different. It is important to note that if the CPU memory is set to fill and stop mode, once a table is full, all data storage to the table will stop. No more records will be stored to the CPU memory or the card.

7.3 Data Retrieval

Data stored on CF cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer.

7.3.1 Via a Communication Link

Data can be transferred to a computer via a communications link using one of Campbell Scientific's datalogger support software packages (e.g., PC200, PC400, LoggerNet). There is no need to distinguish whether the data is to be collected from the CPU memory or a CF card. The software package will look for data in the CPU memory and then the CF card.

The datalogger manages data on a CF card as final storage table data, accessing the card as needed to fill data collection requests initiated with the Collect button in datalogger support software. If desired, binary data can be collected using the File Control utility in datalogger support software. Before collecting data this way, stop the datalogger program to ensure data are not written to the CF card while data are retrieved. Otherwise, data corruption and confusion will result.

7.3.2 Transporting CF Card to Computer

With large files, transferring the CF card to a computer may be faster than collecting the data over a link.

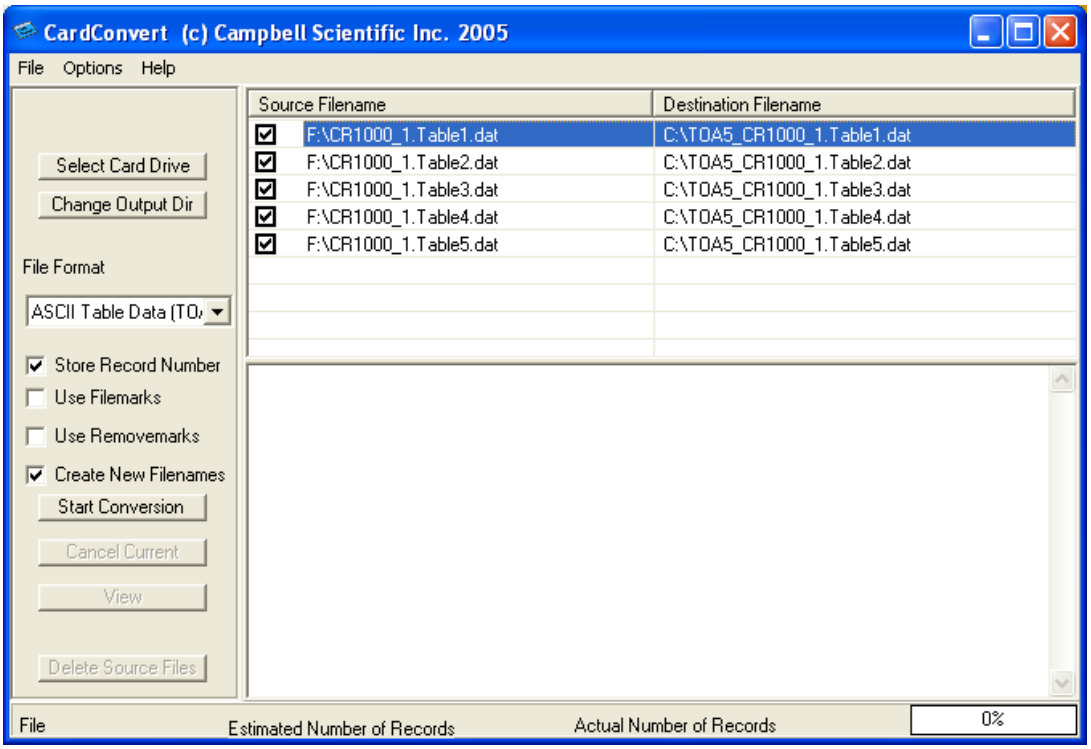
CAUTION Removing a card while it is active can cause garbled data and can actually damage the card. Do not switch off the CR1000 power if a card is present and active.

To remove a card, press the control button on the CFM100. The CR1000 or CR3000 will transfer any buffered data to the card and then power off. The Status LED will turn green when it is OK to remove the card. The card will be reactivated after 20 seconds if it is not removed.

When the CF card is inserted in a computer, the data files can be copied to another drive or used directly from the CF card just as one would from any other disk. In most cases, however, it will be necessary to convert the file format before using the data.

7.3.2.1 Converting File Formats

Files can be converted using LoggerNet's CardConvert. Begin by using "Select Output Drive" to indicate where the files to be converted are stored. Then use "Change Output Dir" to choose where you would like the converted files to be stored. Place check marks next to the files to be converted. A default destination filename is given. It can be changed by right-clicking with the filename highlighted. Use the drop-down to select what file format to convert to. Then press "Start Conversion" to begin converting files. Green checkmarks will appear next to each filename as conversion is complete.



7.3.2.2 Reinserting the Card

If the same card is inserted again into the CFM100, the datalogger will store all data to the card that has been generated since the card was removed that is still in the CPU memory. If the data tables have been left on the card, new data will be appended to the end of the old files. If the data tables have been deleted, new ones will be generated.

NOTE Check the status of the card before leaving the datalogger. If a CF card was not properly accepted, the CFM100 will flash orange. In that case, the user needs to reformat and erase all data contained on the CF card. Formatting or erasing a CF card might be done on a PC or datalogger. The procedure for formatting a CF card is explained in Section OV5 of the CR1000 and CR3000 manuals.

7.3.2.3 Card Swapping

When transporting a CF card to a computer to retrieve data, most users will want to use a second card to ensure that no data is lost. For this method of collection, use the following steps.

1. Insert formatted card ("CF-A") in CFM100 attached to datalogger.
2. Send program containing **CardOut()** instruction(s).
3. When ready to retrieve data, press CFM100 button to remove card. LED will show red while the most current data is stored to the card and then go green. Eject card, while LED is green.
4. Put in clean card ("CF-B").
5. Use CardConvert to copy data from CF-A to PC and convert. The default CardConvert filename will be TOA5_*stationname_tablename*.dat Once the data is copied, use Windows Explorer to delete all data files from the card. NOTE: Windows98 and WindowsME users need to shift-delete to completely delete files. Using standard delete may create an invisible recycle bin on the CF card.
6. At the next card swap, eject CF-B and insert the clean CF-A.
7. Running CardConvert on CF-B will result in separate data files containing records since CF-A was ejected. CardConvert can increment the filename to TOA5_*stationname_tablename*_0.dat.
8. The data files can be joined using a software utility such as WordPad or Excel.

CardConvert File	CF-A Record Numbers	CF-B Record Numbers
TOA5_*tablename*.dat	0-100	
TOA5_*tablename*.dat		101-1234
TOA5_*tablename*.dat	1235-….	

Appendix A. Formatting CF Card

The CF card can be formatted using 1) Windows Explorer, 2) the CR1000KD or 3) LoggerNet File Control.

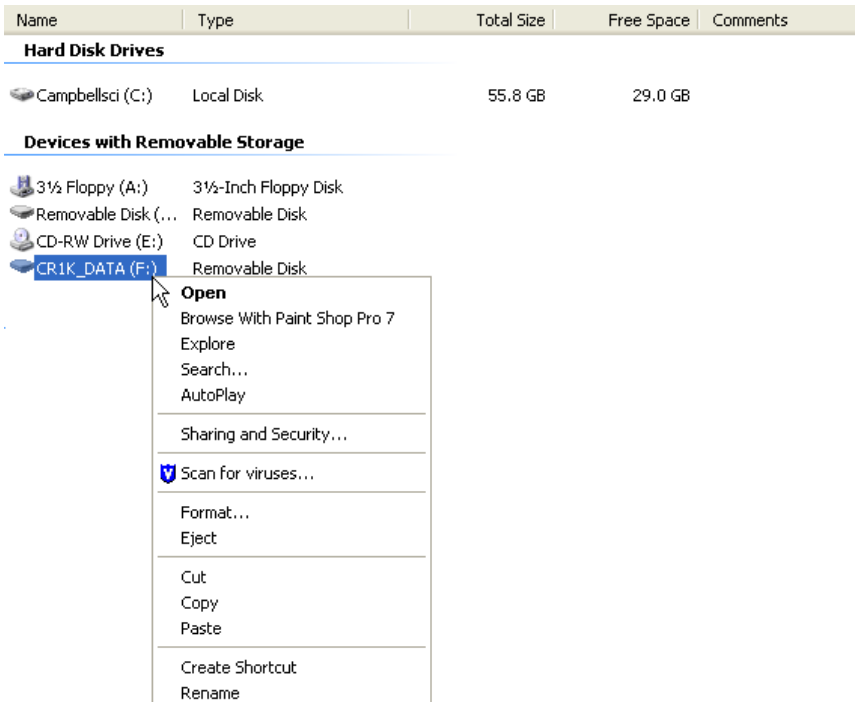
A.1 Windows Explorer

To format card using Windows Explorer:

1) Insert CF card into CF adapter or CF reader.

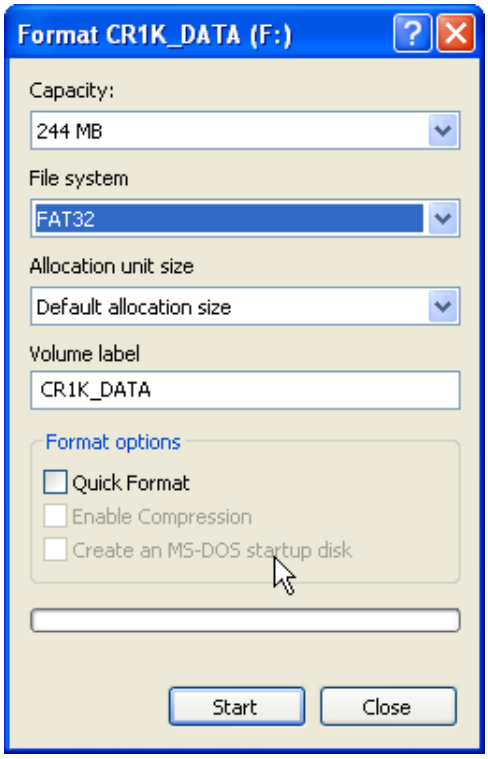
2) Windows Explorer should identify a drive as a removable disk (F:\).

3) Select that drive and right click.



4) Choose Format.

5) Choose FAT32 under file system, give the card a label, then Start. (The CR1000 will work with either FAT or FAT 32.)



A.2 CR1000KD

To format card using the CR1000KD:

1) Insert CF card into CFM100.

2) From Main Menu of CR1000KD, choose PCCard.

3) Choose Format Card..

4) Choose Yes to proceed.

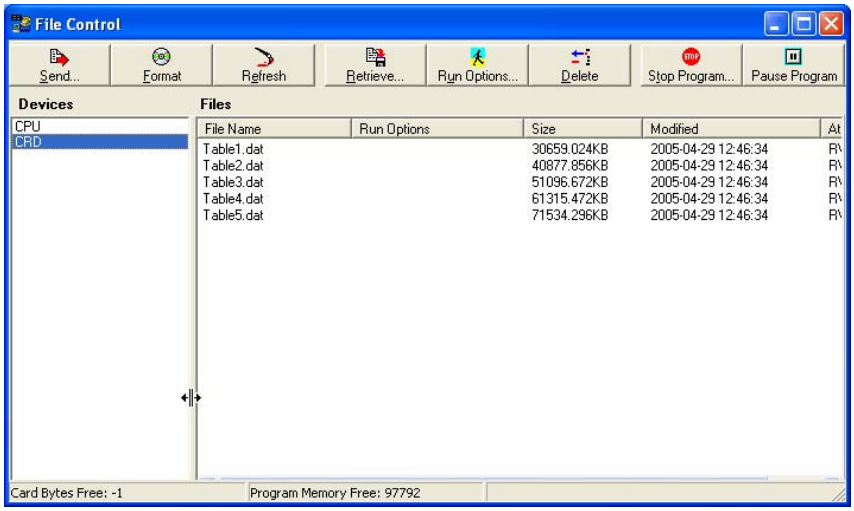
A.3 LoggerNet File Control

To format card using LoggerNet File Control:

1) Insert CF card into CFM100.

2) Use LoggerNet to connect to datalogger

3) Choose FileControl under the Tools menu of the Connect screen.



4) Highlight CRD.

5) Press Format.

6) Press Yes to confirm.

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Appendix A3 - Digital Inclinometer Probe

Digitilt Inclinometer Probe

Applications

Digitilt® inclinometers are used to monitor subsurface movements of earth in landslide areas and deep excavations. They are also used to monitor deformations in structures such as dams and embankments.

Operation

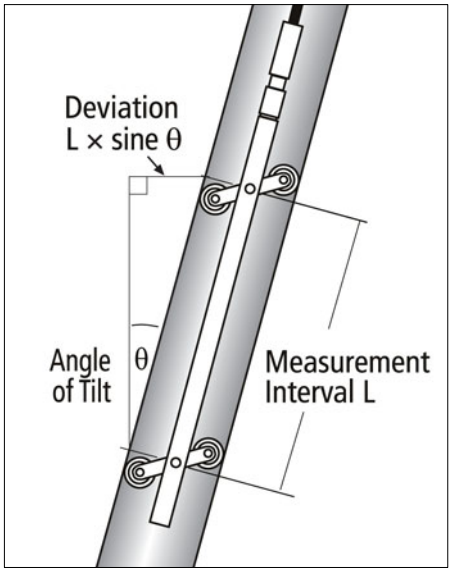
Inclinometer casing is typically installed in a vertical borehole that passes through suspected zones of movement into stable ground. The Digitilt inclinometer probe, control cable, pulley assembly, and readout are used to survey the casing. The first survey establishes the initial profile of the casing. Subsequent surveys reveal changes in the profile if ground movement occurs.

During a survey, the probe is drawn upwards from the bottom of the casing to the top, halted in its travel at 0.5 m or 2' intervals for tilt readings.

The inclination of the probe body is measured by two force-balanced, servo-accelerometers. One accelerometer measures tilt in the plane of the inclinometer wheels, which track the longitudinal grooves of the casing. The other accelerometer measures tilt in the plane perpendicular to the wheels.

Inclination measurements are converted to lateral deviations, as shown in the drawing below. Changes in deviation, determined by comparing current and initial surveys, indicate ground movement.

Plotting changes in deviation yields a high resolution displacement profile. Displacement profiles are useful for determining the magnitude, depth, direction, and rate of ground movement.



Advantages

Proven Performance: Digitilt inclinometer probes have earned a world-wide reputation for durability, high precision, and rapid response.

Repeatable Tracking: To ensure consistent tracking in all types of casing, the probe is equipped with robust wheel carriages, sealed wheel bearings, and specially designed wheels.

Extended Installation Life: The compact size of the Digitilt probe allows it to pass through small radius curves, extending the useful life of the installation beyond that provided by other inclinometer probes.

Computerized Testing: Each probe undergoes thorough testing on a computerized calibration table.

Reliable Control Cable: Digitilt control cable is durable and easy to handle, stays flexible in cold weather, resists chemicals and abrasion, and provides excellent dimensional stability. Flexible rubber depth marks are permanently vulcanized to the cable jacket. The marks cannot loosen and have no rigid edges that can damage the cable jacket and conductors.

Consistent Depth Control: The pulley assembly, a recommended accessory, helps the operator achieve uniform depth control. The one-way action of its cable clamp ensures consistent positioning of the probe.

Complete Solutions: Slope Indicator's inclinometer system includes high-quality casing, vertical and horizontal traversing probes, vertical and horizontal in-place sensors, recording readouts, graphing software, and specialized accessories.

DIGITILT INCLINOMETER PROBE

Metric-Unit Probe 50302510
English-Unit Probe 50302500

Digitilt inclinometer probe includes a carrying case and instruction manual. Control cable, pulley, and readout are not included.

METRIC PROBE SPECIFICATIONS

Wheel base: 500 mm.
Range: ±53° from vertical.
Resolution: 0.02 mm per 500 mm.
Repeatability: ±0.01% FS.
Calibration: 14 point calibration with NIST traceable calibration device.
Temperature Rating: -20 to +50 °C.
Dimensions: 25.4 x 653 mm. Control cable connector adds 92 mm to length of probe.
Weight: 1.8 kg.
Material: Stainless steel.

ENGLISH PROBE SPECIFICATIONS

Wheel base: 24".
Range: ±35° from vertical.
Resolution: 0.0012 inch per 24 inches.
Repeatability: ±0.01%FS.
Calibration: 14 point calibration with NIST traceable calibration device.
Temperature Rating: -4 to +122 °F.
Dimensions: 1 x 30". Control cable connector adds 3.75"to length of probe.
Weight: 4 lb.
Material: Stainless steel.

ACCURACY SPECIFICATIONS

Metric Systems: ±0.25 mm per reading and ±6 mm per 50 readings.

English Systems: ±0.01 inch per reading and ±0.3 inch per 50 readings.

These system accuracy specifications were derived empirically from the analysis of a large number of surveys and include both random and systematic errors introduced by casing, probe, cable, readout, and operator. Casing was installed within 3 degrees of vertical, and operators followed recommended reading practices.

When corrections for systematic error are made, the remaining error is random. It accumulates with the square root of the number of readings. Thus the best precision obtainable with a metric system is approximately ±1.4 mm per fifty readings, and the best precision of an English unit system is approximately ±0.05 inch per fifty readings.

CONTROL CABLE

30m Control Cable, Complete . . . 50601030
50m Control Cable, Complete . . . 50601050
100m Control Cable, Complete . . 50601100

100 ft Control Cable, Complete . . 50601002
150 ft Control Cable, Complete . . 50601003
300 ft Control Cable, Complete . . 50601004

Metric Cable, Custom Length. . . . 50601010
English Cable, Custom Length . . . 50601000
Connector for Readout 50301800
Connector for Probe. 50303100

Control cables listed as complete are standard lengths of cable and include connectors. If you order a custom length cable, you must also order connectors.

Control cable is supplied with no splices or surface defects and has a rated strength of 480 lb and a working strength of 120 lb.

Metric cable is graduated with yellow 0.5-meter marks and red 1-meter marks. English cable is graduated with yellow 2-foot marks and red 10-foot marks.

Cable has a steel core wire to control stretching, a dacron torsion braid to counter cable torque and eliminate slipping of cable jacket relative to the steel core, and depth marks that are molded onto the cable jacket. The Santoprene cable jacket resists chemicals and abrasions and stays flexible in cold temperatures.

PULLEY ASSEMBLY

Small Pulley 51104604
Large Pulley 51104606

Pulley assembly clamps onto top of casing to help operator control depth of probe. Cable clamp serves as reference for depth marks. Clamp is made of carbon-fiber and does not freeze in cold weather. Removable pulley wheel facilitates insertion of probe into casing.

Use small pulley with 48 or 70 mm (1.9 or 2.75") casing. Use large pulley with 70 or 85mm (2.75 or 3.34") casing.

READOUTS

Digitilt DataMate II. 50310900

The Digitilt DataMate II is a recording readout. The Digitilt 09 is a manual readout. See separate data sheets for details.

DUMMY PROBE

Metric Wheel Base 50304810
English Wheel Base. 50304800
Reel & Line for Dummy Probe. . . .50304900

Dummy probe is used to test for casing continuity, groove continuity, and obstructions or severe distortions of casing that could hinder retrieval of Digitilt probe and control cable. Dummy probe is stainless steel and has dimensions and wheels identical to those of Digitilt probe.

Reel with 60 m (200') of nylon line is used to lower and retrieve dummy probe.

SLIP-RING REEL

200 m (650') capacity 50503100
300 m (1150') capacity 50503300

Slip-ring cable reel allows the readout to remain connected while the reel is operated. Includes jumper cable to connect reel to readout.

STORAGE REEL

30m (100') capacity. 50502030
70 m (230') capacity 50502050
100 m (360') capacity 50502110

Sturdy storage reel with large diameter hub keeps cable neat when not in use.

Note: The use of reels is optional. Cable can also be stored in a figure-8 or using the over-under method of coiling cable, as presented in the manual. If you choose to use a reel, be sure that the hub of the reel has a diameter of eight inches or larger (as do the reels above). Power reels should be sixteen inches or larger.

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Digitilt Inclinometer Probe 50302599

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NOVA METRIX

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Introduction

Inclinometer System

An inclinometer system includes inclinometer casing, an inclinometer probe and control cable, and an inclinometer readout unit.

Inclinometer casing is typically installed in a near-vertical borehole that passes through a zone of suspected movement. The bottom of the casing is anchored in stable ground.

The inclinometer probe is used to survey the casing and establish its initial position. Ground movement causes the casing to move away from its initial position. The rate, depth, and magnitude of this movement is calculated by comparing data from the initial survey to data from subsequent surveys.

This Manual

This manual addresses the use and maintenance of the inclinometer probe and control cable. It also provides an overview of taking readings and reducing data.

Other manuals cover casing installation, inclinometer readouts, and software for reducing data.

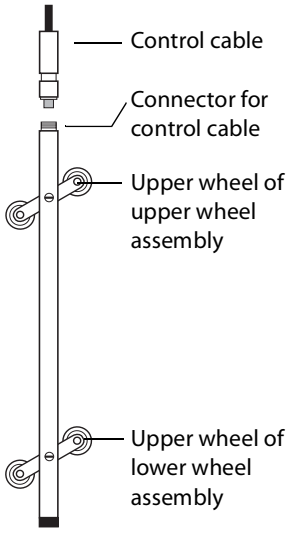
The Inclinometer Probe

Parts of the Probe

The inclinometer probe consists of a stainless steel body, a connector for control cable, and two pivoting wheel assemblies.

When properly connected to the control cable, the probe is waterproof and has been used deeper than 1000 feet.

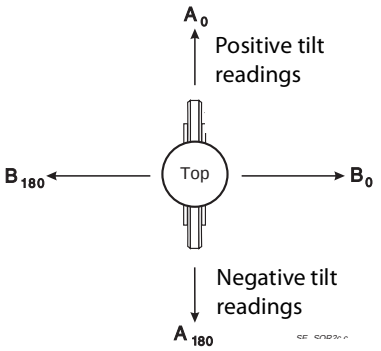
The wheel assemblies consists of a yoke and two wheels. One of the wheels in each assembly is higher than the other. This wheel is called the "upper wheel" and has special significance, as explained below.



Measurement Planes

The inclinometer probe employs two force-balanced servo-accelerometers to measure tilt. One accelerometer measures tilt in the plane of the inclinometer wheels. This is the "A"axis. The other accelerometer measures tilt in the plane that is perpendicular to the wheels. This is the "B" axis.

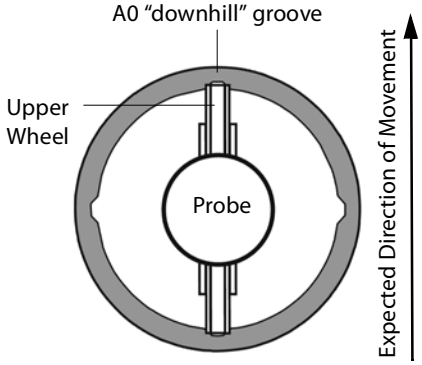
The drawing at right shows the probe from the top. When the probe is tilted toward the A0 or B0 direction, readings are positive. When the probe is tilted in the A180 or B180 directions, readings are negative.



Orientation of the Probe

Inclinometer casing is installed so that one set of grooves is aligned with the expected direction of movement. One groove, typically the "downhill" groove should be marked A0.

In a standard inclinometer survey, the probe is drawn from the bottom to the top of the casing two times. In the first pass, the upper wheels of the probe should be inserted into the A0 groove. This ensures that movements are positive values.



Always start surveys with upper wheel in A0 groove.

Handling the Probe

The inclinometer probe is a sensitive measuring instrument. Handle it with care.

- Transport the probe in its carrying case. If you drive to the site, carry the casing in the passenger compartment, preferrably on a passenger seat.
- When you connect control cable to the probe, avoid overtightening the nut, since this will flatten the O-ring and reduce its effectiveness.
- Before you lower the probe into the casing, turn the power on.
- When you insert the probe into the casing, cup the wheels with your hands to compress the springs and allow smooth insertion.
- When you lower the probe into the borehole, do not allow it to strike the bottom.
- When you withdraw the probe from the casing, again cup the wheels with your hands to prevent them from snapping out.
- When you rotate the probe, keep it upright and perform the rotation smoothly.
- The probe is rated for temperatures from -20 to 50 °C (-4 to 122 °F). Avoid using the probe in temperatures outside this range.

Caring for the Probe

This is an overview. See the last chapter, Inspection and Maintenance, for additional information.

Cleaning the Probe: When you finish a survey, wipe moisture off the probe and replace the protective cap. If necessary, rinse the probe in clean water or wash it with a laboratory grade detergent when you return to the office.

Cleaning the Connectors: Do not clean connectors with spray lubricants or electrical contact cleaners. Solvents in these products will attack the neoprene inside the connector. When it is necessary to clean the connectors, use a cotton swab slightly moistened with alcohol. Be careful to use only a small amount of alcohol.

Drying the Probe: When you return to the office, remove protective caps from the control cable, probe, and readout unit. Allow connectors to air-dry thoroughly for a number of hours. Afterwards, replace the caps.

Storing the Probe: The probe, control cable, and readout unit should be stored in a dry place. For extended storage, keep the probe in a vertical position.

Lubricating the Wheels: Lubricate the wheels regularly. Spray a small amount of lubricant or place a drop of oil on both sides of the wheel bearings. Check that the wheels turn smoothly.

O-Ring Care: Periodically clean and lubricate the O-ring on the connector end of the inclinometer probe. Use O-ring lubricant.

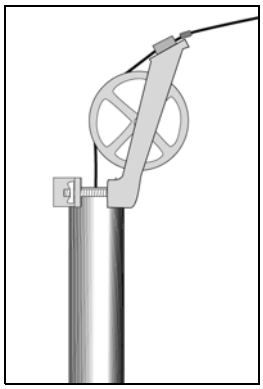
Control Cable

Introduction

Control cable is used to control the depth of the inclinometer probe. It also conducts power to the probe and returns signals to the readout.

- Metric control cables are graduated with yellow marks at 0.5 meter intervals and red marks at 1-meter intervals. There are numeric marks at 5-meter intervals.
- English control cables are graduated with yellow markers at 2-foot intervals and red marks at 5-foot intervals. There are numeric marks at 50-foot intervals. In addition, there are yellow bands of tape at 10 foot intervals. Each band represents 10 feet from the last numeric mark. For example, 4 bands represent 40 feet from the last numeric depth mark.

Depth Control



Accurate inclinometer measurements depend on consistent placement of the inclinometer probe. Always align the depth marks on the control cable with the same reference. Aim for placement repeatability of 6 mm (1/4 inch) or better.

We recommend using a pulley assembly to assist with depth control. The jam cleat on the pulley assembly holds the cable and the top edge of the chassis provides a convenient reference for cable depth marks.

The small pulley assembly is used with 48 mm and 70 mm casing (1.9 and 2.75 inch). The large pulley assembly is used with 70 mm and 85 mm casing (2.75 and 3.34 inch).

Using the Pulley Assembly

1. Remove the pulley from the chassis.
2. Clamp the chassis to the top of the casing.
3. Insert the inclinometer probe and control cable.
4. Replace the pulley.

Note: The distance between the top edge of the pulley chassis and the top of the casing is one foot. Your data reduction software can automatically adjust for this, so keep your survey procedure simple: use the marks on the cable and the top edge of the pulley chassis for reference. Let the software do any extra work required.

Check that operators consistently use the pulley assembly. If the pulley is used for one survey and not for the next, the resulting data sets will not be directly comparable. Sometimes a monument case or a protective pipe makes it impossible to attach the pulley assembly to the casing. In this case, you can make a removable adapter for the pulley assembly. If you use an adapter, be sure to use it consistently.

Cable Tips

Connecting Cable: When you connect control cable to the probe, avoid overtightening the nut, since this will flatten the O-ring and reduce its effectiveness.

Calibrate your Cable: If you have time, "calibrate" your cable, recording the exact position of cable marks. This can be important for long term monitoring projects.

Caring for Cable

Cleaning the cable: If necessary, rinse the cable in clean water or wash the cable in a laboratory-grade detergent, such as Liquinox.® Do not use solvents to clean the cable. Be sure the protective cap is in place before immersing the end of the cable in water. Do not immerse the Lemo connector.

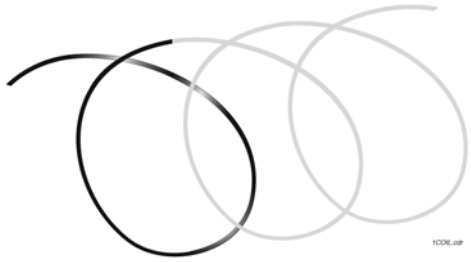
Cleaning Connectors: If it is necessary to clean the connector, use a cotton swab moistened with a small amount of alcohol. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.

Drying Connectors: When you return to the office, remove protective caps from the control cable, probe, and readout unit. Allow connectors to air-dry well for a number of hours.

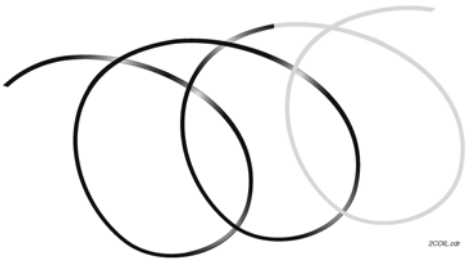
Storage: Store cable on a cable reel when possible. The reel should have a minimum hub diameter of 300 mm (12 inches). If a reel is not available, use the technique below to coil the cable.

Coiling Cable

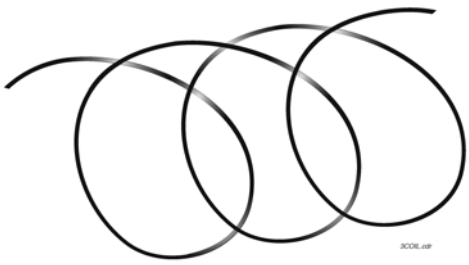
1. Loop cable forward as shown in drawing.



2. Twist cable backwards to make a second loop as shown in drawing.



3. Continue coiling cable, alternating loops as in steps 1 and 2.



Taking Readings

Good Practices

- Use the same probe and control cable for each survey, if possible.
- Use a pulley assembly, if possible. It protects the control cable and provides a good reference.
- Use a consistent top reference. The goal is placement repeatability within 5 mm or 1/4 inch. If one technician uses a pulley and another technician does not, probe positioning will be inconsistent, and data will have to be manipulated before it is useful.
- Always draw the probe upward to the reading depth. If you accidentally draw the probe above the intended depth, lower the probe down to the previous depth, then draw it back up to the intended depth. This technique ensures the probe will be positioned consistently.
- Wait 10 minutes for the probe to adjust to the temperature of the borehole.
- Wait for displayed readings to stabilize as much as possible. If the readings do not stabilize, try to record an average reading.

Setting Up

1. When you arrive at the site, lay out a plastic sheet or tarp to set the equipment on. You should have the inclinometer probe, the indicator, the control cable, and the pulley assembly. Some people find it is useful to bring a basket or box to hold the control cable and a rag to wipe off the probe and cable after readings have been taken.
2. Unlock and remove the protective cap from the casing. Attach the pulley assembly.
3. Remove protective caps from probe and control cable.
4. Align the connector key with the keyway in the probe. Then insert the connector and tighten the nut to secure the connection. Do not over-tighten the nut, since this will flatten the O-ring and reduce its effectiveness.

Position the Probe

1. Turn on the indicator. This energizes the accelerometers, making them less susceptible to shock.
2. Insert the probe into the casing with the upper wheels of both wheel assemblies in the A0 groove. (Cup the wheels with your hands to compress the springs for a smooth insertion). If you are using the pulley assembly, take out the pulley wheel, insert the probe, and then replace the wheel.
3. Lower the probe slowly to the bottom. Do not allow it to strike the bottom. Allow the probe to adjust to the temperature inside the casing. Five or ten minutes is usually sufficient.

Record Data

1. Raise the probe to the starting depth. Wait for the numbers on the readout to stabilize. If you are using the DataMate, press the button to record both the A and B axis readings. If you are using a manual indicator, write down the A-axis reading, then switch to the B-axis and record that reading.
2. Raise the probe to the next depth. Wait for a stable reading, and then record it. Repeat this process until the probe is at the top of the casing.
3. Remove the probe and rotate it 180 degrees, so that the lower wheels of both wheel assemblies are inserted into the A0 groove. When you remove the probe, cup the wheels with your hands to prevent them from snapping outwards. Also, hold the probe upright when rotating it.
4. Lower the probe to the bottom, raise it to the starting depth, and continue the survey. Take readings at each depth until you have reached the top. Remove the probe. At this point, you may want to validate the data set and make any corrections necessary.

Leaving the Site

Wipe off the probe and cable. Replace end-caps on cable and probe and return the probe to its protective case. Replace the indicator's protective plugs. Coil the cable. Remove the pulley assembly and replace and lock the protective cap.

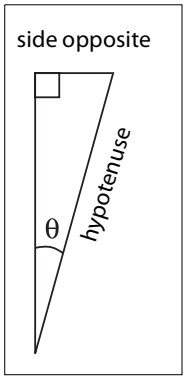
At the Office

Wipe off the indicator and recharge its batteries. Transfer the data set to a PC. Oil the probe wheels. If the storage place is dry, remove protective caps from probe, indicator, and control cable to allow all connectors to dry.

Data Reduction

Inclinometer Measurements

The inclinometer probe measures tilt, rather than lateral movement. How does tilt provide information about lateral movement? The basic principle involves the sine function, an angle, and the hypotenuse of a right triangle. We are interested in the length of the side opposite the angle θ.



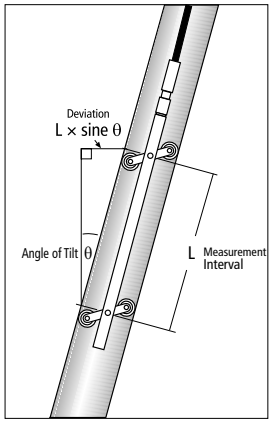
$$\sin\theta = \frac{\text{side opposite}}{\text{hypotenuse}}$$

$$\text{side opposite} = \text{hypotenuse} \times \sin\theta$$

Deviation

In the drawing at right, the hypotenuse of the right triangle is the measurement interval. The measurement interval is typically 0.5 m with metric-unit inclinometers or 2 feet with English-unit inclinometers.

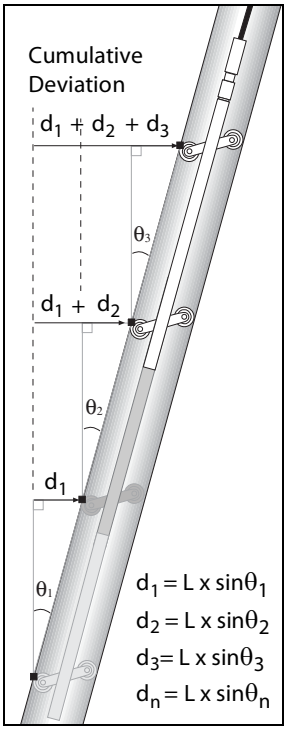
The side opposite the angle of tilt is deviation. It is calculated by multiplying the sine of the angle of tilt by the measurement interval. This calculation translates the angular measurement into a lateral distance and is the first step to calculating lateral movement.



Cumulative Deviation

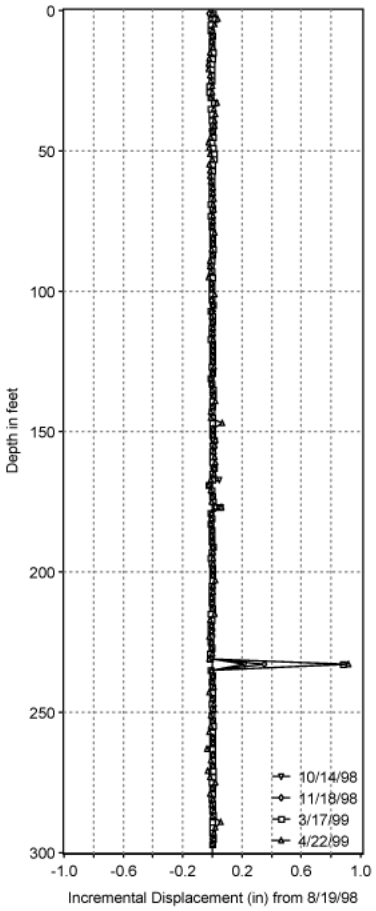
By summing and plotting the deviation values obtained at each measurement interval, we can see the profile of the casing.

The black squares at each measurement interval represent cumulative deviation values that would be plotted to show the profile of the casing.

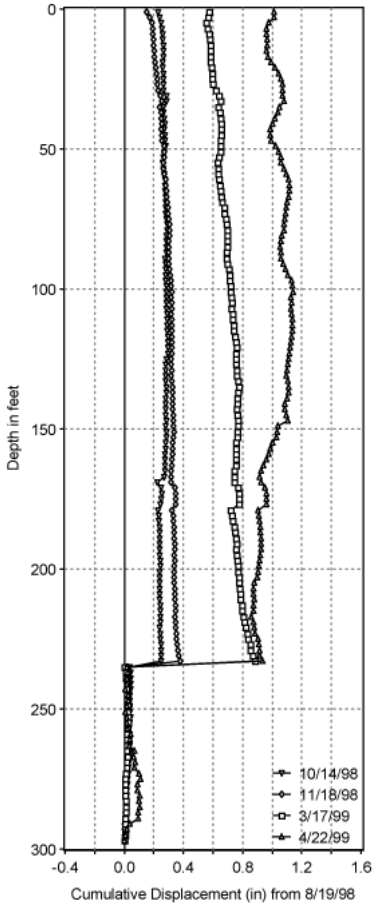


Displacements

Changes in deviation are called displacements, since the change indicates that the casing has moved away from its original position. When displacements are summed and plotted, the result is a high resolution representation of movement.



Incremental displacement plot shows movement at each measurement interval. The growing "spike indicates a shear movement.



Cumulative displacement plot shows a displacement profile. Displacements are summed from bottom to top.

Reducing Data Manually

Normally, computer software is used to reduce inclinometer data. Here, we show only a simple overview.

Displayed Readings

Slope Indicator's readouts display "reading units" rather than angles or deviation. Reading units are defined below:

$$\text{Displayed Reading} = \sin\theta \times \text{Instrument Constant}$$

$$\text{Reading}_{\text{English}} = \sin\theta \times 20{,}000$$

$$\text{Reading}_{\text{Metric}} = \sin\theta \times 25{,}000$$

Combining Readings

The standard two-pass survey provides two readings per axis for each interval. The probe is oriented in the "0" direction for the first reading and in the "180" direction for the second reading. During data reduction, we find the algebraic difference of the two readings, and then we divide by 2, since there were two readings. Use of the algebraic difference lets us preserve the direction of the tilt, as indicated with a positive or negative sign.

$$\text{A0 Reading} = 359 \qquad \text{A180 Reading} = -339$$

$$\frac{\text{Algebraic Difference}}{2} = \frac{359 - (-339)}{2} = 349$$

Calculating Deviation

To calculate lateral deviation, we find the algebraic difference of the two readings, divide by 2, divide by the instrument constant, and multiply by the measurement interval. In the example below, the English-unit measurement interval is 24 inches and the English-unit instrument constant is 20,000.

Lateral Deviation = Measurement Interval x $\sin\theta$

$$= 24 \text{ inches} \times \frac{359 - (-339)}{2 \times 20{,}000}$$

Find the algebraic difference of the A0 & 180 readings and divide by 2.

Divide reading unit by instrument constant to obtain sine of angle.

$$= 0.4188 \text{ inches}$$

Calculating Displacement

Displacement, the change in lateral deviation, indicates movement of the casing. To calculate displacement, we need two surveys. We subtract the algebraic difference of the initial reading from the algebraic difference of the current reading, divide by 2 x the instrument constant, and multiply by the length of the measurement interval.

$$\text{Algebraic Difference}_{\text{current}} = 700 \qquad \text{Algebraic Difference}_{\text{initial}} = 698$$

$$\text{Displacement} = \text{Measurement Interval} \times \Delta\sin\theta$$

$$= 24 \text{ inches} \times \frac{700 - 698}{2 \times 20{,}000}$$

$$= 0.0012 \text{ inches}$$

Calculating Checksums

A checksum is the sum of a "0" reading and a "180" reading at the same depth.

A0 reading = 359 A180 reading = -339

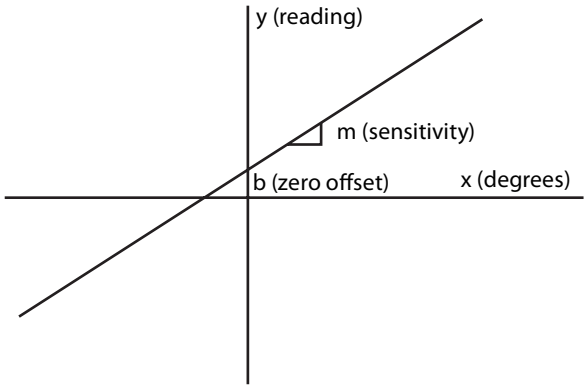
Checksum = 359 + (-339)

= 20

Bias (zero offset)

If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value for each axis. The non-zero value is the result of a slight bias in the output of the accelerometers. The bias (or zero offset) may be negative or positive and will change over the life of the probe. This is not normally a matter for concern, because the zero offset is effectively eliminated by the standard two-pass survey and the data reduction procedure.

Below, we show an readings that have a zero offset of 10. During the first pass the probe measures a tilt of 1 degree. During the second pass the probe measures a tilt of -1 degree, because it has been rotated 180 degrees. See how the offset increases the positive reading and decreases the negative reading, even though the measured angle has not changed. However, when the two readings are combined, as discussed in "Combining Readings" above, the offset is eliminated and the correct value emerges.



Tilt angle = 1 degree. Theoretical reading unit = 349 (20,000 x sin (1))

Offset = 10

Displayed A0 reading = 359 (349 + 10)

Displayed A180 reading = -339 (-349 + 10)

Algebraic Difference = 698 (359 - (-339))

$$\frac{\text{Algebraic Difference}}{2} = 349$$

Inspection & Maintenance

Probe Inspection

Part	What to check for	Remedy
Wheel yoke	Side to side movement	Check pivot pin, which looks like screw. If pivot pin has been turned too far, it may spread the wheel yoke. Turn the pivot pin counter-clockwise to see if movement disappears. If movement persists, replace the nylon spacers or the entire wheel assembly. The wheel assembly can be replaced by the user: kit number 50302555.
Wheel yoke	Yoke does not return to fully extended position.	If yoke is dirty, clean it. If problem persists, spring may be broken or weak. Replace spring and roll pins or replace wheel assembly using kit 50302555.
Wheel	Side to side movement	Bad bearing. Replace wheel assembly.
Wheel	Does not turn freely	Lubricate. If movement is still bad, replace wheel assembly.
Body screws	Loose screws, wobble in body, loose bumper	Tighten screws. (Do not tighten pivot pin).
Connector keyways	Wear, corrosion	Worn keyway may degrade O-ring seal. Learn how to connect cable without "hunting." Remove corrosion and change practice - allow connector to dry after use.
Connector O-ring	Flattened, split	Replace if flattened or split.
Connector pins	Bent pins	Bent pins are easily broken when straightened. Replacement of connector requires recuperation of probe (expensive). Change connection practice - no hunting.

Probe Maintenance

Moisture Management	Wipe off the control cable and probe when you finish the day's final survey, then wipe off the probe. Do not store wet cloth with the probe. Allow the connector to dry thoroughly: remove connector cap and allow connector to air-dry for a number of hours. Lubricate the wheels. This helps displace moisture.
Wheels	Lubricate the wheels by spraying a small amount of lubricant or placing drops of oil on both sides of the wheel bearings.
O-Ring	Lubricate regularly with O-ring lube or silicone based grease. Do *not* use WD-40 or any other lubricant spray that contains chlorinated solvents.
Connectors	Clean connectors as necessary. Use a slim cotton swab moistened with alcohol. Be careful not to bend pins. Do not use electrical contact cleaners, especially sprays. Solvents in these products will attack the neoprene inside the connectors. When attacked, the neoprene swells and reduces the effectiveness of the O-ring seal.
Storage	Store probe in dry place. Be sure that the box is dry, the wheels are oiled, the connector is dry. If probe is to be stored for an extended period, stand it vertically.

Control Cable Inspection

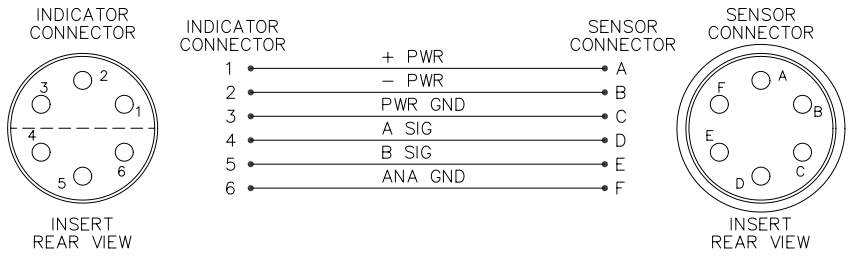
Part	What to check for	Remedy
Cable	Continuity	If you have intermittent failures, perform continuity tests. If a wire fails continuity test, you can check the Lemo connector or return cable for servicing or replacement.
Cable	Twists, worn markings, kinks, gouges	Twists indicate poor coiling technique. Change practice: use cable reel, figure-8 coils, or over-under coils. Worn markings: user is dragging cable over the edge of the casing. Change practice - but must keep consistent depths. Kinks: if kinks do not straighten, there is probably internal damage and likelihood of intermittent reading failures. If any deep gouges, water can enter cable. In both cases, bad section of cable must be removed, either by shortening the cable or replacing the cable.
Connector key	Wear, corrosion	Change connection practice - no hunting. Remove corrosion and change practice - allow connector to dry after use.
Connector rubber insert	Swelling, poor seal	Rubber swells when attacked by WD-40 or contact cleaners. Swelling may prevent good seal and allow water to enter connector. Return for service if sealing is compromised.
Connector for Indicator (Lemo)	Corrosion, bad connection.	Perform continuity check first. Then check this connector to eliminate as possible source of intermittent failures. Unscrew bottom nut, being careful not to twist cable. Slide shell off the end of the cable. Slide strain relief collet out of the way and inspect connections. Twist and pull wires gently. Good connections will not break. Repair as necessary.
Connector for Probe	Check O-ring	Do *not* disassemble this connector. Requires about two hours and a pressure test to reassemble.

Control Cable Maintenance

Moisture Management	Wipe off the control cable as you draw the probe up on the last run of the day. When you return to the office, remove connector caps and allow connectors to air-dry for a number of hours.
Cable	When necessary, rinse cable (but not connectors) in clean water or wash the cable in a laboratory-grade detergent, such as Liquinox. Do not use solvents to clean the cable.
Connectors	If it is necessary to clean the connector, use a cotton swab moistened with alcohol. Sockets can be cleaned with a brush. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.
Storing Control Cable	Improper coiling of any electrical cable twists conductors and can cause reliability problems. There are several ways to control twisting: • Use cable reel with hub diameter of at least 200mm or 8". • Coil cable in a figure-8. • Coil cable using over-under loops (2-foot diameter loops).

Control Cable Connectors

Below is the wiring diagram for the connectors on the control cable.



Testing

Connectors are made to mate with each other but not with any other objects. Never insert the probe of your multimeter into a socket. In making the measurements below, simply touch the probe to the top of the socket.

Continuity Test: Pin 1 to Pin A, Pin 2 to Pin B, etc, should measure a little less than 1 ohm per 30 m (100 feet).

Isolation Test: Pin to pin should measure infinity. Also any pin to the body of the connector should measure infinity.

Servicing

Use caution when attempting to service either connector.

The Lemo connector on the indicator end of the cable is easier to service. When you disassemble the connector, be sure that you do not twist the cables.

The heavy connector on the sensor (probe) end of the cable is more difficult to service. We recommend that you send it to the factory unless you are experienced and are willing to spend some time working with it.

Appendix A4 - Digitilt DataMate II

Digitilt DataMate II

Simple to operate, the compact Digitilt DataMate runs 16 hours on one charge, stores up to 320 surveys, and transfers data to a PC for processing.

The Digitilt DataMate II

The DataMate records data from inclinometer probes, tiltmeters, and spiral sensors. It stores up to 320 complete inclinometer surveys and can power a Digitilt inclinometer probe for 16 hours.

The DataMate II is compatible with the original DataMate but features updated electronics for faster operation, increased memory capacity, and a USB port for data transfers

The DataMate is designed for hard use in difficult environments. It has a bright, backlit display that is visible under all lighting conditions. The box is splashproof and sealed against humidity. In addition, all connectors are located on the top of the box, away from contact with mud, water, or snow.

Recording Surveys

The Digitilt DataMate stores a list of inclinometer installations in memory, so to begin a survey, the operator selects an installation from the list.

The DataMate then displays the starting depth for that installation, and the operator positions the probe at that depth.

The display shows the depth, the A-axis reading, and the B-axis reading. When both readings are stable, the DataMate displays a “ready” signal. The operator then records the reading, using the hand switch or the keypad. The DataMate beeps confirmation and then displays the next depth. The operator raises the probe to this depth, waits for the ready signal, and then records the readings, repeating these steps until the probe reaches the top of the casing. The DataMate then prompts the operator to rotate the probe 180 degrees and begin the second pass through the casing.

The operator can correct a mistake at any time by simply scrolling through the data to any depth, repositioning the probe, and continuing the survey from that point.

Validating Surveys

The DataMate provides checksum statistics to help the operator validate the survey. By comparing the mean and standard deviation of checksums for the current survey with those of previous surveys, the operator can be confident that the data are good.

The DataMate provides routines to help the operator identify questionable readings, which can then be corrected by repositioning the probe. The DataMate displays “live” and recorded readings side by side for comparison, and the operator can overwrite the recorded reading with the live reading, if appropriate.

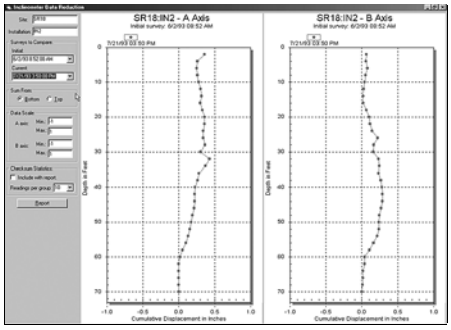
Convenient hand switch reduces fatigue and lets you keep the DataMate clear of the work area.

Retrieving Surveys

Returning to the office, the operator connects the DataMate to a PC, and then runs the DataMate Manager program. The manager program retrieves the recorded surveys and stores them in a database for easy access.

Processing Surveys

Slope Indicator inclinometer software eliminates repetitive work, ensures that calculations are performed accurately, and dramatically reduces the time required to process data.



DMM for Windows software lets you retrieve surveys and produce reports containing readings and graphics.

The DataMate Manager program is included with the DataMate. It can can print reports containing inclinometer readings, checksum statistics, and simple graphs. It also provides routines for settlement correction, spiral data set expansion, and bias shift analysis.

DigiPro for Windows is an optional graphing program that provides additional types of graphs, including some diagnostic plots, and a number of sophisticated correction routines. A trial version is available for download from the Slope Indicator web site.

DIGITILT DATAMATE II READOUT

Digitilt DataMate II 50310900

The Digitilt DataMate is a portable readout for Digitilt sensors. It provides depth prompts and stores readings in memory for transfer to a PC. Includes hand switch, battery charger, USB interface cable for PC, and CD with DMM for Windows and manual. Specify type of plug required for the charger. DigiPro software is not included.

Sensor Compatibility: English and metric versions of vertical and horizontal Digitilt inclinometer probes, tiltmeters, and spiral sensors.

Displayed Units: Metric indicator displays readings as 25000 x the sine of the angle of tilt. English indicator displays readings as 20000 x the sine of the angle of tilt.

Survey Types: 2-pass survey for inclinometer probes; 4-pass survey for spiral sensors.

Memory Capacity: Stores 160 installations and nominally 320 surveys of 100 depths each (a total of 32000 depths allocated to any number of surveys up to a maximum of 320).

Maximum Survey Depth: 500m or 2000 feet.

Reading Intervals: Fixed intervals. Minimum interval is 0.5 m with metric probe or 1 foot with English-unit probes.

Menu-Selected Functions

Record: Prompts operator with starting depth. Displays A and B axis readings. Displays ready signal when readings are stable. Displays next depth after readings are recorded.

Manual Read: Allows use of DataMate when memory is full or depth display is not required.

Validate: Calculates checksum statistics.

Correct: Allows user to correct mistakes.

Compare: Calculates a single value for cumulative deviation or cumulative displacement.

Comm: For communication with PC.

Print: Outputs ASCII data to a terminal program running on a non-DOS/Windows computer.

Operating Time: 16 hours @ 20°C (68°F) of continuous power to probe. Backup battery preserves data for six months.

Temperature Rating: -20 to 50°C (-4 to 122°F).

Display: 20 x 2 backlit LCD rated for extended temperatures.

Battery: 6 volt, 6 Ah, gelled electrolyte, lead-acid battery. Recharges to 80% capacity in 16 hours using the included charger.

Case: Splashproof, non-submersible, aluminum case with plastic shell. Connectors are waterproof when capped or in use.

Dimensions: 127 x 178 x 178 mm (5 x 7 x 7").

Weight: 3 kg (6.5 lb).

DMM FOR WINDOWS

DMM for Windows 50310970

The DataMate Manager program (DMM) transfers readings from Digitilt DataMate to a PC. DMM offers routines for checking surveys and maintaining the inclinometer database. DMM is supplied on a Resource CD with the purchase of the Digitilt DataMate. It can also also be downloaded free from www.slopeindicator.com. Note that DMM is not intended to replace DigiPro software. DigiPro software, available separately, is used to create presentation graphics and offers diagnostic and correction tools.

System Requirements: Windows computer with USB port.

Data Retrieval: DMM communicates with DataMate through a USB connection.

Data Storage: Surveys retrieved from DataMate are stored in an MDB database. DMM supports drag-and-drop operations between databases and provides easy functions for editing, renaming, moving, and archiving installations and surveys. Surveys retrieved from the DataMate can also be saved as ASCII files.

Data Manipulation: DMM provides a settlement correction routine and a spiral set expansion routine. Both routines generate new surveys.

Import Capabilities: DMM imports legacy data from Slope Indicator's previous formats and from GTILT®. The program also allows manual entry of data.

Report Capabilities: DMM prints inclinometer readings with checksums, compares two surveys (typically current vs initial) to generate A and B-axis graphs of cumulative displacement. The program generates graphs of cumulative deviation. Graphs are displayed on screen and can be printed in a report. Reports can also include checksum statistics, bias-shift analysis tables, and tabular data in digi units (differences and changes).

DIGIPRO SOFTWARE

DigiPro Trial . . . . . Free Download
DigiPro, 1-User License 50310001
DigiPro, 3-User License 50310000
DigiPro, 12-User License 50310002

DigiPro software processes and plots inclinometer data recorded by the Digitilt DataMate readout. It creates high-resolution graphs and supports advanced routines for identifying and correcting systematic error. DigiPro is not included with the Digitilt DataMate. See separate datasheet for details.

DIGITILT 09 INDICATOR

Digitilt 09, Metric 50300910
Digitilt 09, English 50300900

The Digitilt 09 Indicator is a portable readout for Digitilt sensors. It displays readings, but does not record them. The user must keep track of depths and readings on a field data sheet. A battery charge is included. Please specify 100, 115, 220, or 240 volt and 50 or 60Hz.

Compatibility: Digitilt inclinometer probes, Digitilt tiltmeters, and spiral sensors.

Displayed Units: Metric indicator displays readings as 2.5 x the sine of the angle of tilt. English indicator displays readings as 2 x the sine of the angle of tilt.

Readings can be entered into the DMM for Windows database and graphed with DigiPro for Windows. If you chose to do this, write down readings without the displayed decimal point and enter the readings as integers.

Resolution: Metric indicator provides resolution of 1 in 25,000. English indicator provides resolution of 1 in 20,000.

Display: Large, backlit 4.5 digit LCD with heater for cold weather operation.

Battery: Rechargeable 6 volt, 6 Ah gelled electrolyte, lead-acid battery. Battery life is 12 hours with fully changed battery. LCD heater reduces operating time up to 50% when temperature is below 5° C (40° F).

Temperature Rating: -20 to 50°C (-4 to 122°F).

Dimensions: 127 x 178 x 178 mm (5 x 7 x 7").

Weight: 3.4 kg (7.5 lb).

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DGSI
DURHAM GEO SLOPE INDICATOR

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Digitilt
DataMate II

50310999

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Digitilt DataMate II

What is the DataMate II?

The Digitilt DataMate II is a recording readout used with the Digitilt inclinometer probes, the portable Digitilt tiltmeter, and the spiral sensor. It works with both metric and English-unit versions of these sensors.

The Digitilt DataMate records readings from inclinometer surveys. DMM software is used to transfer the recorded readings to a PC. The use of DMM software is covered by a separate manual: DMM for Windows.

DataMate Controls

Power Switch

The power switch locks into position. To switch on, pull the lever up, then move it to the On position. To switch off, pull the lever up, and then move it to the off position. The DataMate displays a copyright notice for ten seconds when you switch it on. The copyright date serves as the version number for the DataMate.

Connector Sockets

Probe: Socket for inclinometer control cable.

Charger: Socket for battery charger or external power.

USB: Socket for computer interface cable and remote hand switch.

Sockets are waterproof only when connectors are plugged in or when protective caps are in place.

KeyPad

Up: Moves cursor up. Also scrolls forward through the alphabet (a...z).

Down: Moves cursor down. Also scrolls backwards through the alphabet (z...a).

Left: Moves cursor to the left.

Right: Moves cursor to the right.

Esc: Cancels current process and returns to menu.

Enter: Chooses menu items. In record mode, records readings.

DataMate Menus

1. Use the arrow keys to select a menu item with the cursor.
2. Press Enter to choose the item or Esc to exit the item.

Main Menu

The Main menu appears when you turn on the DataMate. The Main menu shows the main functions of the DataMate.

Read	Surveys
Comm	Utilities

Read Menu

The Read menu lets you record inclinometer readings, edit inclinometer installation parameters, review and correct readings, and operate the readout in manual mode, which displays readings but does not record them.

Record	Installation
Correct	Manual Read

Surveys Menu

The Surveys menu lets you list the surveys that are stored in memory, validate a survey, check available memory, delete a survey, compare one survey to another, and print a survey to a terminal program.

Dir	Validate	Memory
Del	Compare	Print

Comm Menu

Comm puts the DataMate into communications mode for transferring data to and from a computer. Communications requires that the DataMate II is connected to the computer's USB port via the interface cable that is supplied with the DataMate.

Waiting for PC . . .

Utilities Menu

The Utilities menu lets you set defaults, and check battery voltage and memory.

Batt	Beep	Light
Temp	Date	Contrast

Setting Defaults

Go to the Utilities menu to set the defaults below:

Date and Time: Choose Date. The DataMate displays the current date and time. Press Enter to edit the date. Press Up or Down to change the year, then press Right to move the cursor to month, etc. Press Enter when done.

Beeper: Choose Beep. Press Enter to toggle the beeper on or off. The beeper produces a noise when you record a reading.

Backlight: Choose Light to toggle the backlight on and off. Backlight increases battery drain by about 12 percent.

LCD Contrast: Choose Contrast. Press Up or Down to adjust contrast for easy viewing. Press Esc when done.

Checking the Battery

Go to the Utilities menu. Choose Batt. A new, fully charged battery shows approximately 6.6 volts with a full charge. Recharge if below 6 volts.

Recharging the Battery

Recharge the battery after every use of the DataMate. It is best to charge overnight.

Plug the charger into an AC mains socket. Plug the Lemo connector into the DataMate's Charger socket. You can verify that charging is taking place by going to the Utilities menu and choosing Batt. You should see increasing voltage value.

Checking Memory

Go to the Surveys menu. Choose Memory. The DataMate displays how many depths and surveys are free (available to store data). The maximum numbers are 32000 depths and 320 surveys.

Moisture Management

When you return to the office, remove caps from the DataMate's connectors and allow connectors to air-dry for a number of hours.

Use desiccant to keep the inside dry. This is particularly important in hot humid weather. Warm moist air trapped in the readout can condense when the readout is brought into a cool air-conditioned office.

To check the moisture level in the DataMate, go to the Utilities menu and choose Temp. The DataMate displays humidity and temperature. Humidity levels from 20% to 60% are normal. If humidity exceeds 75%, replace the desiccant. See instructions in the chapter on inspection and maintenance.

Set Up

Overview

Setting up the DataMate involves entering a list of inclinometer installations into the DataMate's memory. You can do this with DMM software or with the DataMate's keypad.

Setting Up with DMM Software

This method is convenient when you are in the office:

1. Use DMM to create a setup database on your PC.
2. Connect the DataMate to your PC.
3. Use DMM to transfer the setup to the DataMate.

Setting Up with DataMate Keypad

This method is convenient when you are in the field.

1. Choose Read.
2. Choose Installation.
3. Press Down key to scroll past any previously entered installations. The cursor stops on the word, "Create." Press Enter.
4. Enter the required information into each field. The fields are explained on the next page. To make an entry:

   Press the Right key to enter edit mode.

   Press the Up or Down key to change the character under the cursor.

   Press the Right key to move to the next column.

   Press Enter when you are done. The DataMate exits edit mode and moves the cursor to the next line.
5. To correct a mistake, press the Up or Down key to display the line that you want to correct. Then press the Right key to enter edit mode.

Installation Fields

Site & Installation: Every installation has a two-part identifier consisting of a "site" and an "installation." Enter a 6 character identifier for each.

A0 dir: (Optional) Enter up to 3 characters to identify the compass heading of the A grooves. Not used for any calculation.

Operator: Optional) Enter up to 3 characters to identify the operator. Optional.

Sensor#: Enter the serial number of the probe. Optional, but recommended.

Sens Type: Choose Digitilt for inclinometer probes or Spiral for spiral sensors.

Units: Choose Metric or English. If you don't know, check the distance between the upper and lower wheels of the probe: 0.5 m for metric systems; 2 feet for English-unit systems.

Ins Constant: Use 25000 for metric-unit systems or 20000 for English-unit systems.

Start: Enter the starting depth for the survey. Surveys typically start at the bottom of the casing. With English-systems, it is best to use an even number so that 2-foot intervals coincide with cable markings.

End: Enter the ending depth for the survey, typically 0.5 for metric-unit systems or 2 for English-unit systems.

Interval: Interval is typically 0.5 for metric-unit systems and 2 for English unit systems. For a Spiral Sensor, set the interval to 1.5 meters or 5 feet.

Check the Installations

Verify that the DataMate now holds your installation list:

1. Choose Read from the main menu.
2. Choose Installation.
3. Scroll through the list of installations.

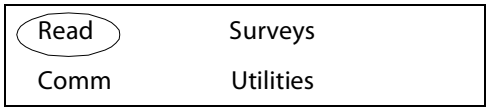
Recording Surveys

Good Practices

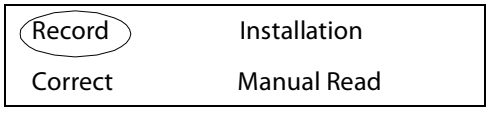
1. Use the same probe and control cable for each survey, if possible.
2. Use a pulley assembly, if possible. It prevents damage to the control cable.
3. Use a consistent top reference. The goal is repeatable placement of the probe within 5 mm or 1/4 inch. If one technician uses a pulley and another technician does not, probe positioning will be inconsistent, and data will be unusable.
4. Connect the probe to the DataMate and switch the power on before you insert the probe into the casing. Powered-up sensors resist shock better than unpowered sensors.
5. Wait 10 minutes for the probe to adjust to the temperature of the borehole. This helps prevent bias-shift (offset) errors.
6. Always pull the probe upward to the reading depth. If you accidentally pull the probe past the intended depth, lower it to the previous depth, then pull it back up to the intended depth. This ensures consistent placement.
7. Wait for displayed readings to stabilize. The DataMate displays 3 diamonds when readings have stabilized within two units. If the reading does not stabilize, watch the display and try to record an average reading.
8. When you remove the probe from the casing, use your hand to compress the wheels so that they don't spring free or force the body of the probe to strike the side of the casing. This helps prevent bias-shift errors.
9. Check your readings using the DataMate's Validate command. If necessary, reposition the probe at the required depth and use the Correct command to obtain a new reading for that depth. The Correct command is explained later.
10. If you accidently turn off the DataMate during a survey, turn it back on, and then use the Correct command resume the survey. There is no need to start a new survey.

Recording a Survey

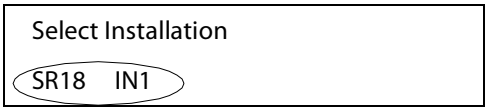
1. Connect the control cable to the probe. Do not over-tighten. Plug the other end of the control cable into the Probe socket on the DataMate. Plug the handswitch into the USB socket.
2. Insert the probe into the casing with upper wheels in the A0 direction. Lower the probe to slightly below the start depth.
3. Switch on the DataMate and wait for the main menu. Choose Read.



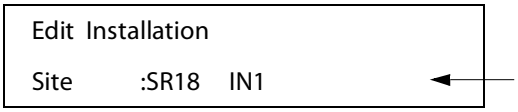
4. Choose Record.



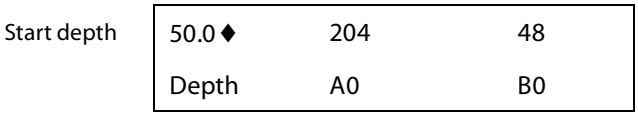
5. Choose an installation from the list.



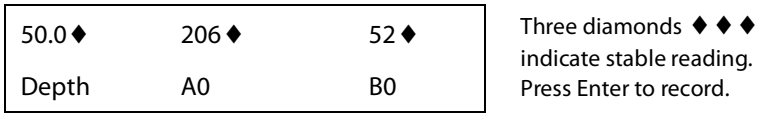
6. Press Enter to step past the installation parameters without making changes. Normally, no editing is required.



7. Finally, the DataMate displays the Start depth (bottom depth).



8. Wait ten minutes for the probe to adjust to the temperature at the bottom. This step is important for consistent readings.
9. Begin the survey. Raise the probe to the start depth, then watch for a stable reading. You will see three diamonds, as shown below. Press Enter to record the reading.



10. The DataMate beeps and scrolls to the next depth. The reading just recorded is now on the bottom line. Raise the probe to the next depth (shown in the top line of the display) and wait for the numbers to stabilize. Press Enter to record the reading.

After you record the reading, pull the probe up to the next depth.

48.0♦	210	55
50.0*	206*	52*

Recorded readings are marked with a *

11. Repeat this process until you have recorded the reading for the top depth. The DataMate displays a menu. Choose Continue.

Continue	0
Done	Del

12. The DataMate now displays the starting depth for the second pass. Remove the probe from the casing and rotate it 180 degrees so that the upper wheels point to the A180 direction. Insert the probe and lower to the bottom of the casing, or slightly below the start depth.

50.0♦	-210	-60
Depth	A180	B180

13. Pull the probe up to the start depth. Wait for the numbers to stabilize. Press Enter to record.

48.0♦	-215	-75
50.0π	-210π	-60π

Recorded readings for the second pass are marked with the Pi symbol.

14. Repeat these steps until you have recorded the reading for the top depth. A menu appears. This time, choose Done. Then remove the probe from the casing.

Continue	0
Done	Del

15. You may want to validate the survey using the DataMate's validate command. See Appendix 1 for instructions.

Making Corrections

If you make a mistake during the survey, you can easily correct it.

1. Use the Down key to return to the depth where the mistake was made. Stop scrolling when the depth appears in the top line of the display.
2. Now position the probe to that depth: lower it below the depth and then pull it upwards to the exact depth.
3. Press Enter to activate the top line of the display. A diamond appears next to the depth.
4. Wait for the readings to stabilize, then press Enter to record.
5. Continue recording just as you would in a normal survey. Or if you are finished, scroll to the top depth and complete the survey as you normally would.

Cancelling a Survey

1. Press Esc. If you press Esc by mistake, press Continue.
2. Choose Del to delete the survey that you cancelled. Cancelled surveys remain in memory until deleted.
3. The DataMate prompts for confirmation. Press Up to confirm.

Deleting a Survey

If you want to record a survey, but the DataMate prompts "no room in memory" or "too many surveys," you must free some memory by deleting a survey.

1. Choose Surveys from the main menu.
2. Choose Del.
3. Select a survey to delete and press Enter. (Surveys marked with the ^ symbol have been retrieved by a PC, so it might be safe to delete one of them.)
4. Press Up to confirm the deletion or Esc to cancel. The DataMate deletes the survey. To avoid possible loss of data, do not switch the DataMate off during this process.

Deleting an Installation

The DataMate itself provides no way to delete installations. DMM is required for deleting installations.

Retrieving Surveys

Overview

To retrieve surveys, connect your DataMate to your PC and run the DMM program. This is the normal and most efficient way to retrieve data.

Using DMM

Detailed instructions are provided in the DMM manual. The basic steps are:

1. Connect the DataMate to your PC. Choose Comm on the DataMate.
2. Start DMM, go to Datamate in the menu, and choose either Retrieve New or Retrieve all.
3. Drag and drop the retrieved surveys into your project database (or export surveys to a text file).

Using a Terminal Program

You can "print" surveys, one by one, to a PC that is running a terminal program on your PC to receive it. This is mainly for troubleshooting. The DMM program can import print files.

1. Connect the DataMate to the PC.
2. Start your terminal program. Set it for 8-bit, no parity at 9600 bps.
3. Set the terminal program to "capture" or "log" the data sent from the DataMate. Specify a file name for the captured data.
4. Choose Print from the DataMate survey menu. Set the baud rate for 9600 and press Enter. Then select the survey and press Enter to "print" it.
5. Your terminal program will usually display the readings as they are sent from the DataMate.
6. Close the file with your terminal program.

Validating Surveys

About Checksums

A checksum is the sum of 0 and 180 degree readings at the same depth. Ideally, the sum should be zero since the readings have opposite signs. In practice, checksums are rarely zero.

In general, you should look for consistency in checksums. A checksum that is significantly different from checksums above and below it may indicate that the probe wasn't positioned correctly or the reading was not stable when recorded. A large checksum may also be caused by debris in the groove, an out-of-round casing section, a separated casing section, or a wheel falling in the joint of a telescoping casing section.

A graph of checksums shows very clearly whether checksums are consistent or not. Alternatively, scanning through a column of checksums gives you an idea of consistency. Unfortunately, the DataMate provides neither graphs nor columns of checksums. However, the DataMate does provide the standard deviation of checksums, which can be used as a measure of reading quality, as explained below.

Standard Deviation of Checksums

The standard deviation of checksums can be used as a way to confirm that the current survey is comparable to other surveys for the same borehole.

You must first establish a "typical SD" for each axis. This is obtained from your initial survey. (It is good practice to take several surveys initially, then compare them and select one to be the "official" initial.) Since the initial survey represents good set of readings, the standard deviation of checksums for that survey can be used as a "typical SD" for that installation. Note that the "typical" is likely to be different for every installation.

When you obtain a new survey, run the DataMate's validation routine. Compare its SD to those of the initial survey. If the typical standard deviation of the A-axis is 3 to 5 units, the data is probably good. For example, if the typical standard deviation is 4, then acceptable standard deviations for subsequent surveys could range as high as 7 or 9 (typical for B-axis).

Narrower limits may be appropriate for deeper installations and critical measurements. Wider limits may be appropriate for shallower installations or for poorly-installed casing.

Validating a survey

Here is a typical validation procedure:

1. Check the standard deviation of checksums. Is it typical for this casing? If so, the survey is probably good and needs no further validation. You can quit the validation routine.
2. If the standard deviation is not typical, check the standard deviation for the different zones. If any group shows an obvious problem, examine the individual checksums in that group. Also look for drifting mean checksums. A drifting mean may indicate a problem with the electronics inside the probe.
3. If you find a checksum that is too large, examine the readings at that depth to determine whether the bad reading was recorded in the 0 or the 180 orientation. Afterwards, you can correct the data by taking another reading for that depth.
4. The steps below explain this in detail.

Check the Standard Deviation

1. Choose Validate from the Surveys menu.
2. Choose a survey to validate.
3. After a short delay, you will see a display that shows both the mean (MN) checksum and the standard deviation (SD) of checksums:

```
MN  A=51.337      B=45.674
SD  A=4.1781      B=5.7170
```

4. Compare the standard deviation with the "typical" SD that you have established for the installation. If the standard deviation is acceptable, press Esc to quit. Otherwise, look at the SD for each zone.

Check Zone Statistics

1. Press Enter to view the zone with the largest SD. You will see a display that looks something like this:

```
 25.  -  20.      S.D.
A=3.2264         B=10.3388
```

Zone statistics include 10 readings. In this case, there are 10 half-meter readings in the zone from 25m to 20m.

2. To view the mean checksum for this zone, press the Left arrow. Press Right to redisplay the SD.
3. Press Up or Down to display other zones. Again, the Left and Right keys toggle between mean and standard deviation.
4. If you decide the survey is acceptable, press Esc to quit. Otherwise, note the zones (depths) that you want to inspect and continue.

View Individual Checksums

Follow the steps below to find depths with large checksums:

1. After viewing the checksum statistics, press Enter to view checksums. The DataMate first displays the largest checksum in the survey. In this case, the 89 in the B axis is largest.

Depths	A	B
25.	20	89
25.5	25	34

2. Use the Up and Down keys to view checksums at other depths. When you are finished viewing checksums, press Esc.

Isolating the Bad Reading

A large checksum may indicate a bad reading, but does not indicate which reading was bad (Was it the 0 or the 180 reading?). To isolate the bad reading, you must view readings above and below the suspect reading.

1. Choose Read from the main menu.
2. Choose Correct, then choose a survey (If necessary, press Right to see dates).
3. Press the Enter key to skip through parameters.
4. Choose 0 (orientation). Scroll through readings to the suspect depth. Check readings above and below the depth. A bad reading does not fit with the readings above and below it.
5. To view 180 readings at the same depth, press the Right arrow. Press again to display the 0 readings.
6. Note the depth and orientation of the bad reading. Then press Esc.

Correcting a Reading

1. Choose Correct from the Read menu.
2. Choose 0 or 180, and scroll the DataMate to the required depth. The depth should be displayed on the top line.
3. Lower the probe to the required depth. Wait for the probe to adjust to the temperature in the borehole (5 to 10 minutes if the probe has been in open air)
4. Press Enter to activate the reading. Press Enter again to record the reading.

Comparing Surveys

Overview

The DataMate can calculate a single value for cumulative deviation or for cumulative displacement.

Cumulative Deviation

1. At the Main Menu, select "Surveys." Then select "Compare."
2. The DataMate prompts for the current survey. Press Enter to select the suggested survey or scroll to find a different survey.
3. The DataMate prompts for a "previous" survey. Press Esc since you do not want to calculate displacement.
4. The DataMate asks you to confirm a conversion value of 1. Press Enter. This will display metric data in meters and English data in feet.
5. The DataMate then calculates the cumulative deviation for the survey and displays it.
6. Press Esc to return to the Surveys menu.

Note The DataMate calculates cumulative deviation by summing incremental deviations from the bottom of the casing to the top.

If you are interested in borehole drift, you probably want the top of the borehole to be used as reference. The DataMate does not offer this as a choice, but when summing from the top, the deviation at the bottom of the borehole will be the same value except in the opposite direction.

Cumulative Displacement

To calculate displacement, the DataMate must contain two surveys for the same installation.

1. Choose Surveys from the main menu, then choose Compare.
2. The DataMate prompts for the current survey. Press Enter to select the suggested survey or scroll to find a different survey. Then the DataMate prompts for a "previous" survey. Scroll to find the initial set, then press Enter.
3. The DataMate prompts for a conversion value. Enter 1000 for a displacement in millimeters (with metric data). Enter 12 for a displacement in inches (with English unit data).
4. The DataMate then calculates the cumulative displacement for the survey and displays it. Press Esc when done.

Inspection and Maintenance

Inspection

Part	What to check for	Remedy
Desiccant	Check humidity under utilities menu.	If humidity exceeds 75%, replace or recharge desiccant.
Batteries	Check main battery and Memory keep alive power under utilities menu.	Main battery can be recharged. If battery does not hold charge, battery can be replaced. Lithium backup battery is good for 7 to 10 years if main battery keeps charge. Return for servicing if memory power is bad.
Connectors	Dirt, bent pins, o-ring	Clean with alcohol moistened swab. Note that connectors are "water proof" only when capped or when connector is plugged in.
Self Test	Error A input Error B input	Bad signal input. Return for servicing. A value is displayed, but is not useful.
	Error +12volt Error -12volt	±12V sensor power. Disconnect control cable and probe. Try again. If error goes away, problem could be in probe or cable. Connect cable only. If no error, then probe is the problem. This error could also be caused by discharged battery. Try recharging battery first. If error persists, some component must be returned for servicing.
	Error battery	Main battery is low. Try recharging. If error persists, replace battery.
	Error +3v pwr	Memory keep alive power is bad. Retrieve any data before switching off, then return for service.
	Error temp	Operating temperature range exceeded. Either below -20 or above 60C.
	Error humidity	Humidity above 80%. Replace desiccant.

Maintenance

Battery	Recharge battery after every use. Charge at least two hours for every hour of use. Charging overnight is common practice. Do not charge longer than 72 hours. Longer charge time may damage the battery. A new, recharged battery will show 6.6V or higher. The DataMate displays a low battery warning when voltage drops to 5.5 volts. Turn off the DataMate when the warning appears and then recharge as soon as possible. Deep discharge of the main battery can reduce its performance and shorten its life.
Desiccant	Check humidity under utilities menu. If humidity exceeds 75%, replace desiccant.
Connector sockets	If it is necessary to clean the connector, use a small brush or a slim cotton swab. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.

Replacing Desiccant

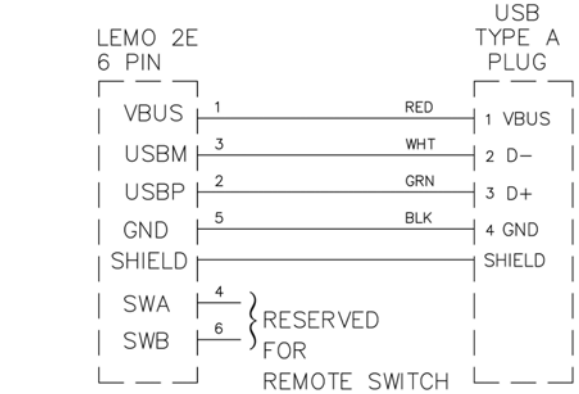
You must open the DataMate to change the desiccant. You should ground yourself to prevent a static discharge that could damage the DataMate's electronics.

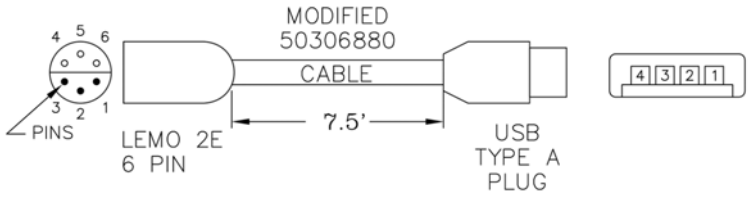
Remove the two screws from the bottom of the case. Hold the top panel and pull off the case. Look for the desiccant pack between the battery and the panel connectors. Replace the desiccant pack with a new one. You may be able to renew the desiccant in an oven at 250 °F (121 °C) for 16 hours. Do not use a microwave oven to renew the desiccant. You may damage your microwave oven.

Before you replace the case, apply a light coat of silicone grease to the gasket. Also lubricate the O-rings on the screws. Then slip the DataMate back into its case, checking that the gasket is seated properly. Replace the screws and tighten to draw the top panel squarely against the case. Do not over-tighten the screws

Wiring Diagram for USB Interface Cable

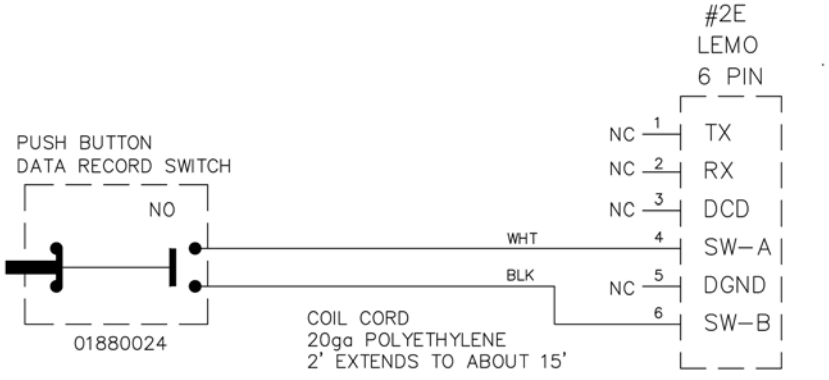
Below is the wiring diagram for the connectors on the USB interface.





Wiring Diagram for Hand Switch

Below is the wiring diagram for the hand switch.



Trouble-Shooting

Tech Notes on slopeIndicator.com

Many questions can be answered by a visit to the Tech Notes section of www.slopeindicator.com. Go to Support - TechNotes. Then scroll down the page to find the inclinometer tech notes. Take a look at the Digitilt DataMate Q & A page.

Readings Not Stable

The DataMate's ready signal is displayed when readings in both axes are stable within 2 digits. If this happens occasionally, but readings vary within 3 or 4 digits, you can record the readings with no significant loss of accuracy.

- If this problem always occurs at a single installation and at a just a few depths, it is possible that the backfill around the casing has washed away or was simply incomplete.
- In some situations, such as when there is no water in the inclinometer casing, control cable can go into a slow oscillation, shaking the probe, and preventing full stabilization of readings. The same may occur at sites where heavy construction machines are active. In this case, look for the average reading.
- Reading instability can also be caused by a low battery, so always check battery voltage before you leave the office.
- If readings always take a long time to stabilize, and this happens at all installations, contact Slope Indicator.

Strange Readings

A & B readings are midrange or higher (e.g. +6000 or -6000): Mid-range readings like this point to a cable problem. It is likely that one of the power wires is bad. The problem may be in a broken or corroded wire in the connector.

Readings are very high, for example 12,000: If your DataMate shows a full scale reading, such as 10,000 or 12,500, when the probe is near vertical, there is probably water in the connector or in the cable.

Reading of +1786 (English) or 3125 (Metric): This is the same number that the DataMate displays when the probe is not connected, so there is most likely a problem in the cable or a connector.

Reading of 60 or some other low number: If you see a low number that stays constant in one axis, the problem is mostly likely in the probe. The accelerometer for that axis is not working and the op amp is trying to compensate, resulting in a constant value.

Appendix A5 - DMM for Windows

DMM for Windows

50310970

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Introduction

Read This

- If you hate manuals, at least read the Quick-Tour pages.
- If you can't find a way to do something, read the "How To" pages.
- If you have the DataMate II, be sure to install the latest version of DMM.

What is DMM?

DMM (DataMate Manager) is software supplied for the Digitilt DataMate inclinometer readout. DMM is used to:

- Retrieve readings stored by the DataMate.
- Send setup data to the DataMate.
- Retrieve readings from the DataMate.
- Store readings on disk, either in a database or in an ASCII file.
- Edit and maintain the database.
- Print data, and statistics. DMM also has a simple graphing function to compare two surveys.

Installation

Obtaining DMM

We recommend that you download the DMM setup file from the the Slope Indicator web site: www.slopeindicator.com. The web site always offers the most recent version.

You can also install DMM from a Resource CD, but be sure to check the date on the Resource CD. If it is more than four months old, you may have better results by downloading DMM from the website.

Instructions for both methods follow.

Downloading DMM

1. Start your browser and navigate to www.slopeindicator.com.
2. Choose Downloads.
3. Choose Software.
4. Choose DMM for Windows.
5. Follow on screen instructions to download and install the software. You may want to print the instructions.

Installing DMM from a Resource CD

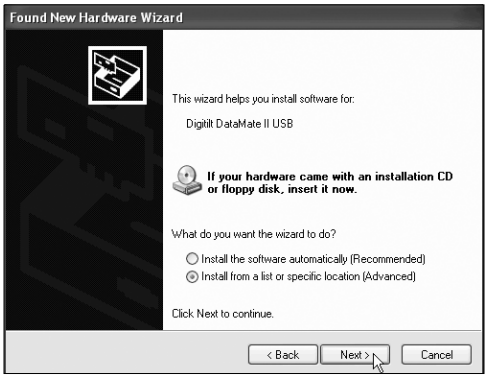
1. Insert the Resource CD in your CD-ROM drive.
2. Wait for your browser to start. If necessary, eject and reinsert the CD, or start your browser, navigate to the CD, and open the file called cdmenu.html.
3. Choose software from the menu.
4. Choose DMM for Windows.
5. Follow on screen instructions. It may be useful to print the instructions.

Installing USB Drivers (DataMate II Only)

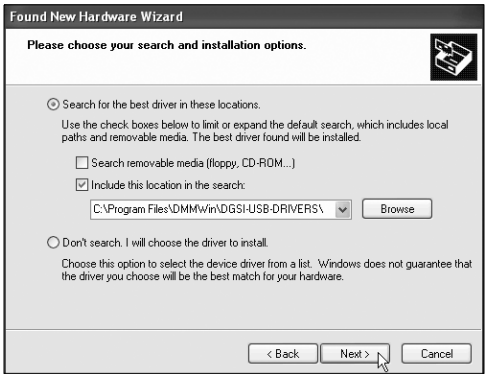
The DataMate II connects to the PC via a USB cable. Follow the steps below to install the USB software. There are two drivers, so you go through two installation procedures.

1. Start your PC.
2. Connect the DataMate to the PC.
3. Switch the DataMate on.
4. The hardware wizard appears and asks to search for software.
5. Choose “No, not this time.”
6. Click Next.

1. Windows wants to install software for the Digitilt DataMate II USB.
2. Choose “Install from a list or specific location.”
3. Click Next.



1. Windows asks for the location of the driver.
2. Click “Include this location in the search.”
3. Enter the following path. You can also browse to the path:



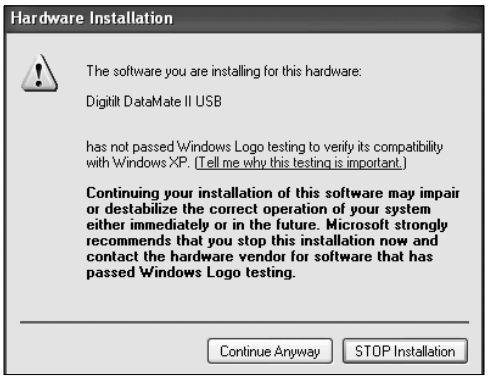
C: \program files\dmmwin\DGSI-USB-Drivers\Win2k-XP

This folder contains 32-bit drivers. In the future, there will also be a folder with 64-bit drivers, which you would choose if you have a 64 bit operating system.

4. Click Next.

Installing USB Drivers Continued

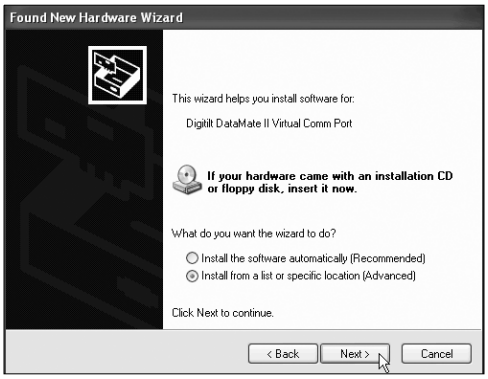
1. Windows starts the installation process.
2. If you see this warning message, choose "Continue Anyway."



1. Windows completes the installation and displays this screen.
2. Click Finish.

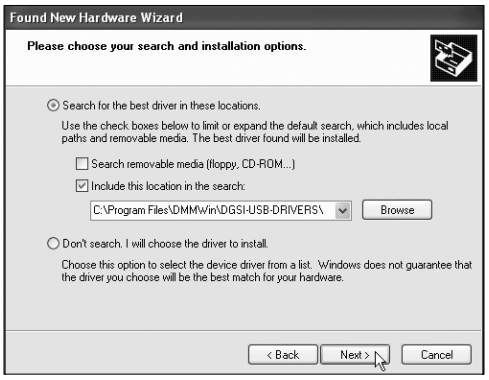
1. Windows immediately detects new hardware.
2. Another wizard appears and asks to search for software. Choose "No, not this time."
3. Click Next.

1. Windows wants to install software for the Digitilt DataMate II Virtual Comm Port.
2. Choose "Install from a list or specific location."
3. Click Next.



Installing USB Drivers Continued

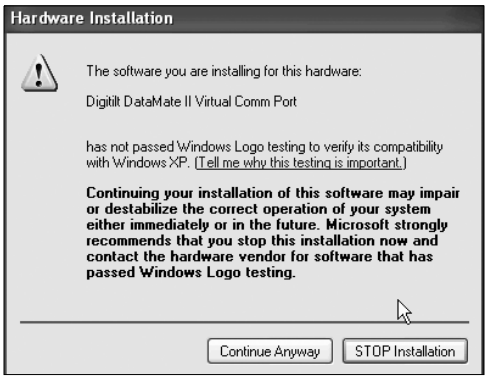
1. Windows asks for the location of the driver.
2. Click "Include this location in the search."
3. The path you recently entered should appear. If not, enter or browse to the following path:



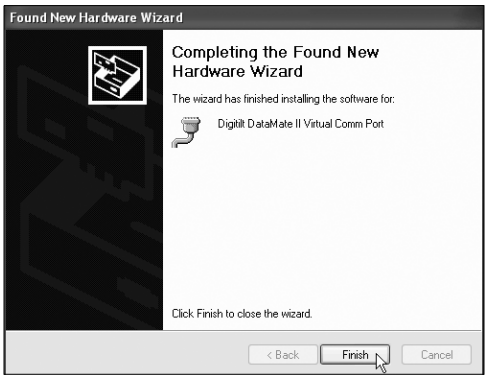
C: \program files\dmmwin\DGSI-USB-Drivers\Win2k-XP

(or the 64-bit folder name, if you have a 64-bit OS.)

1. Windows starts the installation process.
2. If you see this warning message, choose "Continue Anyway."



1. Windows completes the installation and displays this screen.
2. Click finish.



Note: You must tell DMM which com port to use for the USB device:

1. Start DMM.
2. Choose DataMate - Options. DMM displays the available com ports.

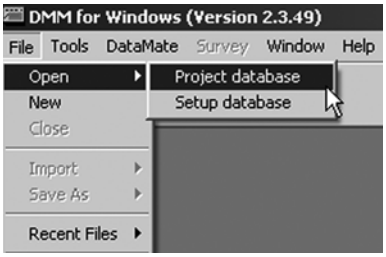
This USB device is likely to use the Com port with the highest number. For example, if DMM lists Com1, Com4, and Com7, try Com7 first.

Quick Tour of DMM

Start DMM

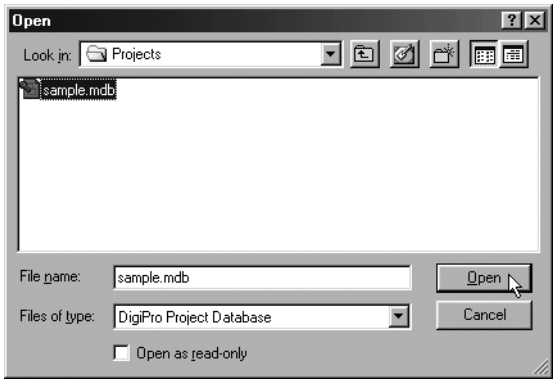
1. Click the Start button.
2. Choose Programs.
3. Choose DMM for Windows.
4. Click on DMMWin.exe from the slide-out menu.

Open the Sample Database



1. Choose File.
2. Choose Open - Project Database.
3. DMM displays a folder of project databases. The default folder is called Projects and is located in the DMM folder.

   You can use different folders for your projects. DMM remembers the last folder used. DMM keeps a recent file list, so you can also select your database from File-Recent Files.
4. For now, select “sample.mdb” and click the Open button.

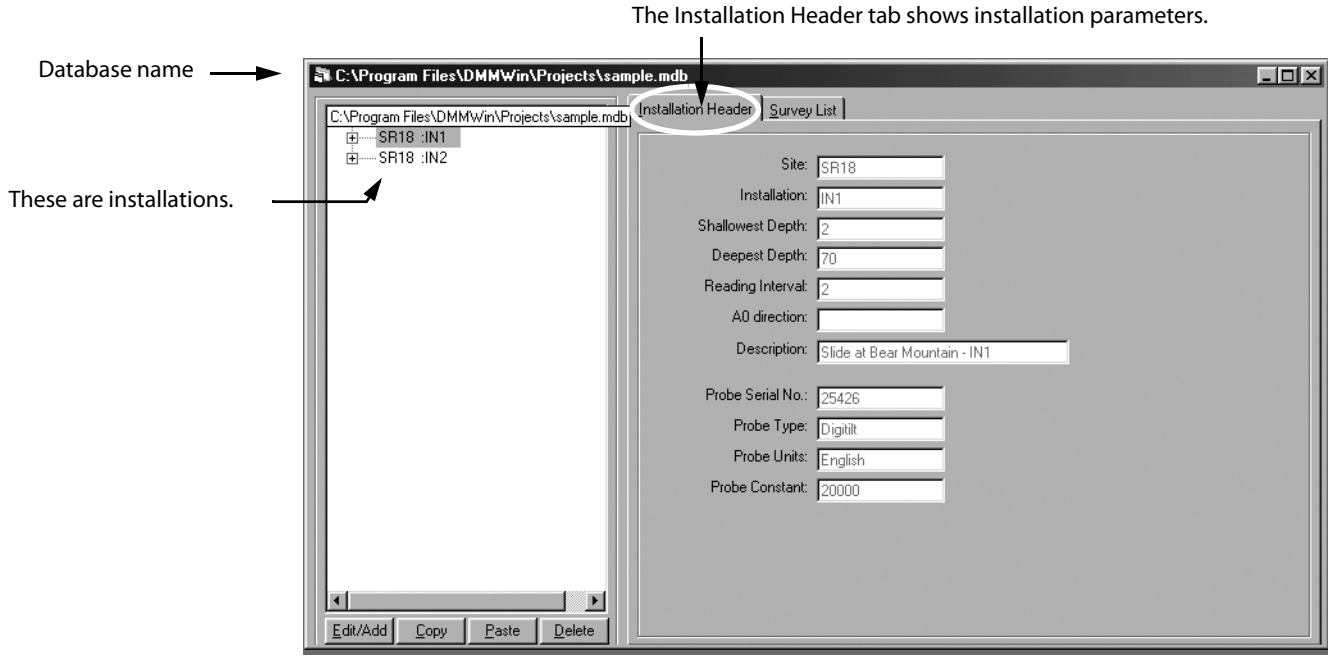


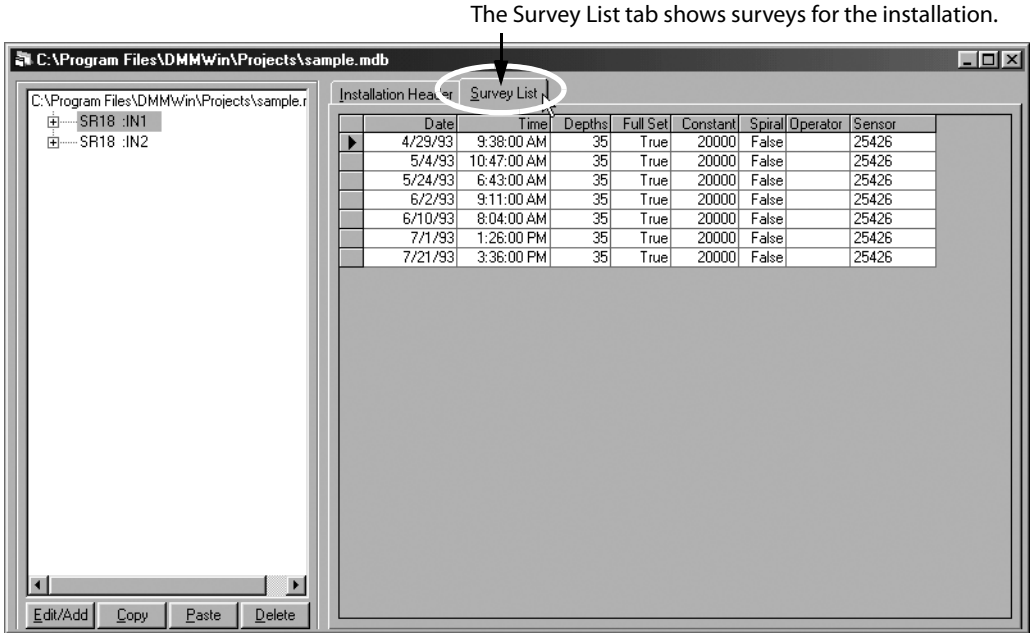
The Database Window

DMM opens a window to show the database. You can open other databases, too. Every database appears in its own window.

Viewing Installations

The first view of a database shows inclinometer installations. An installation, sometimes called a "borehole" or "hole" is the installed inclinometer casing.





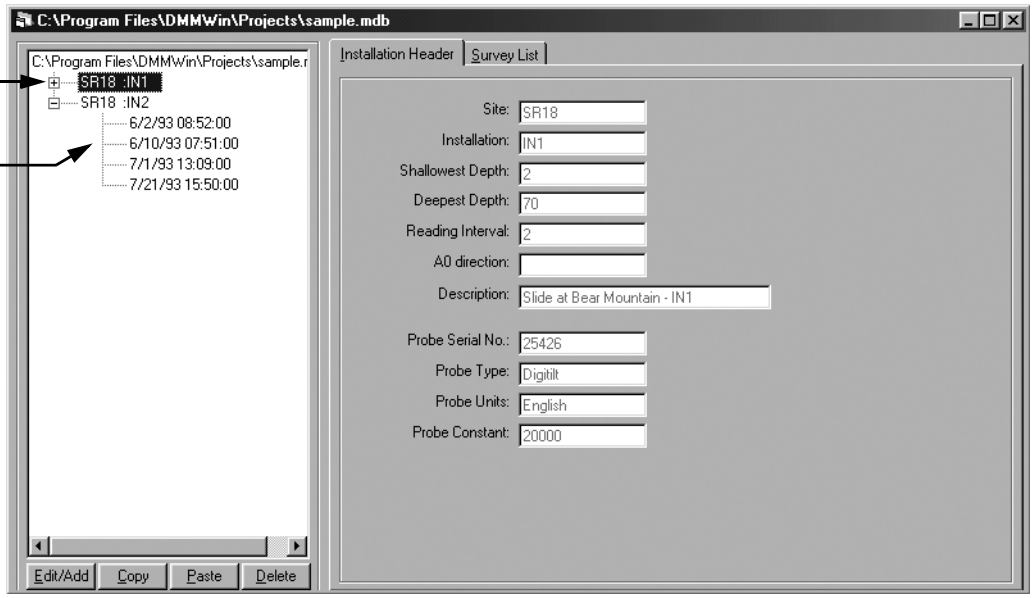
The fields in this view are mainly for trouble-shooting. It lets you check that the number of depths is the same for each survey, etc.

Viewing Surveys

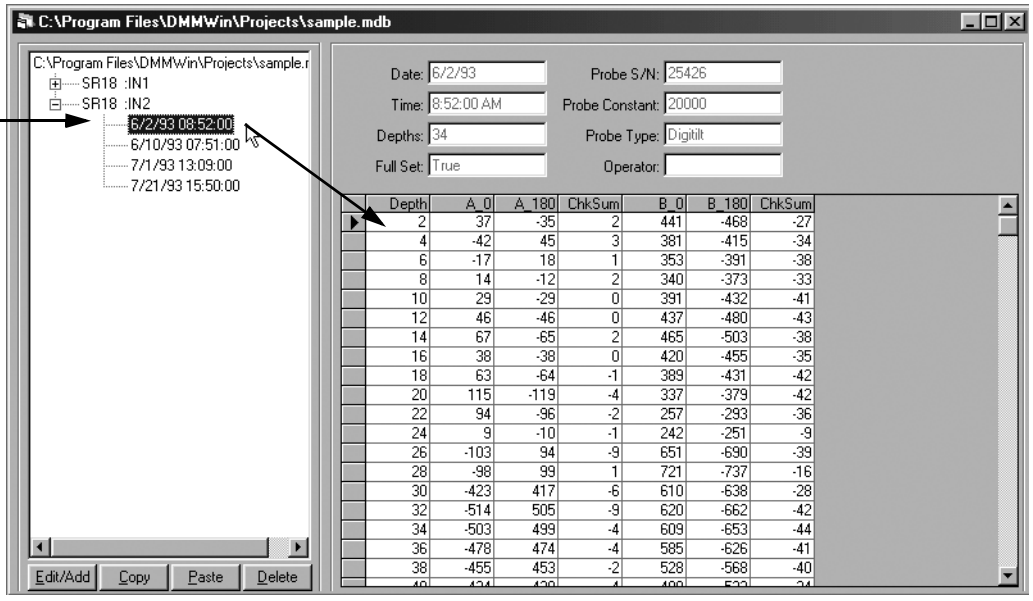
Click the + next to an installation to see surveys sorted by date. Surveys, sometimes called datasets, are the readings from the inclinometer probe.

Click + to see surveys.

Surveys are listed by date and time.

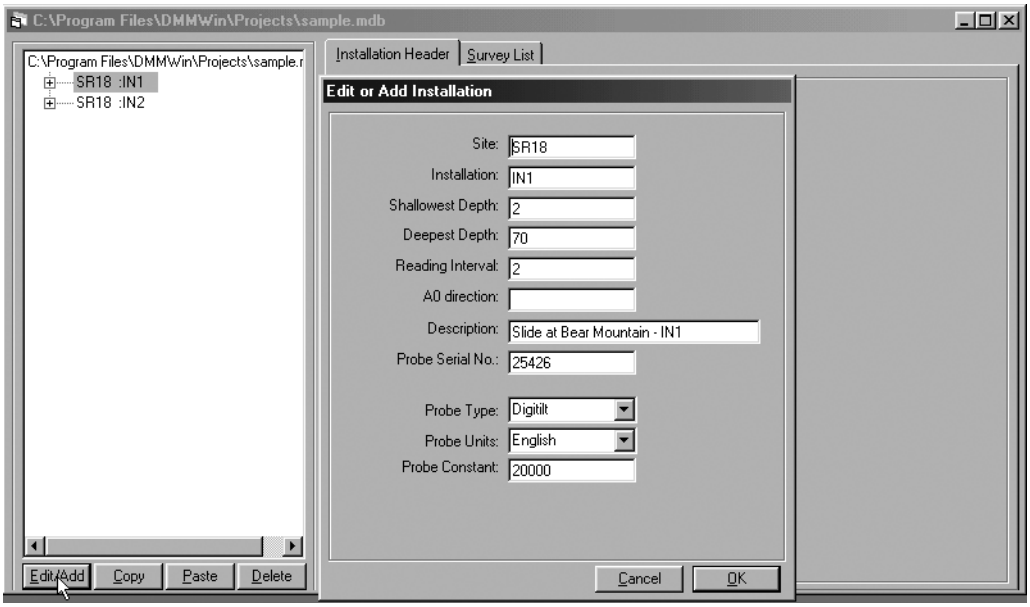


When you select a survey, readings appear at right



Editing Installations

Select an installation, then click the Edit/Add button.



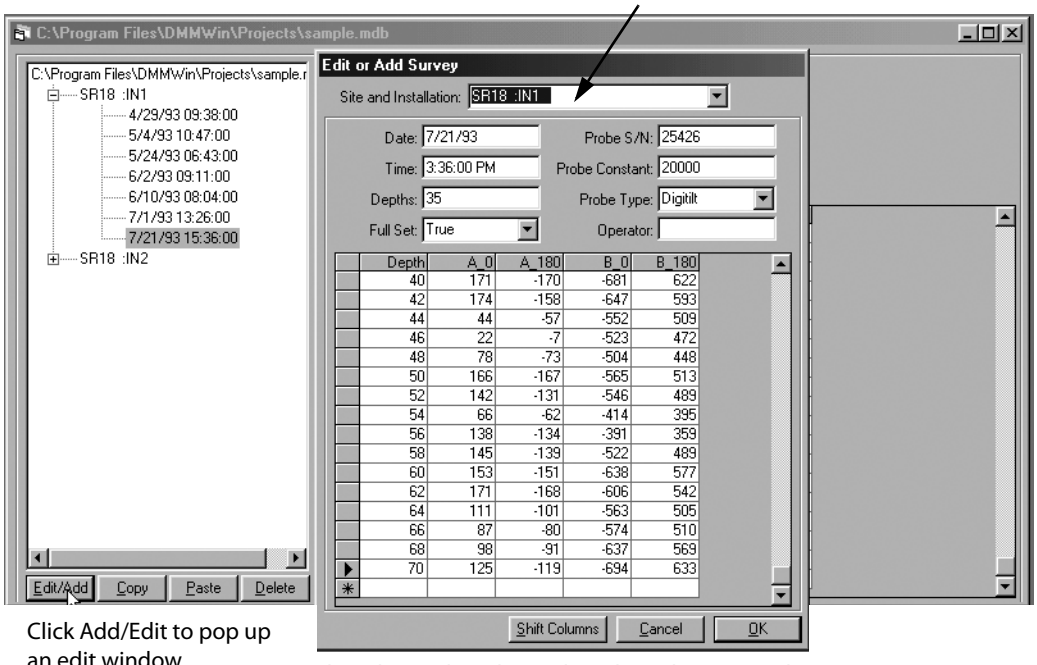
Click Add/Edit to pop up an edit window.

The edit window shows the selected installation and allows you to make changes.

Editing Surveys

Select a survey, then click the Edit/Add button.

Use this field to move a survey to a different installation.



Click Add/Edit to pop up an edit window

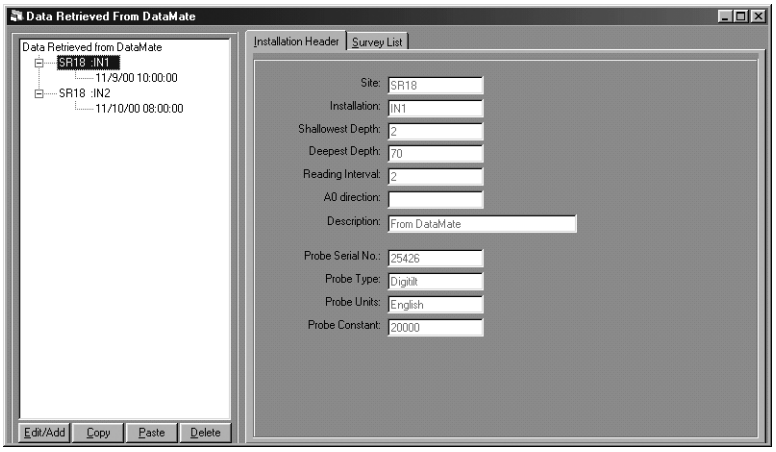
The edit window shows the selected survey and allows you to make changes.

Retrieving Data from the DataMate

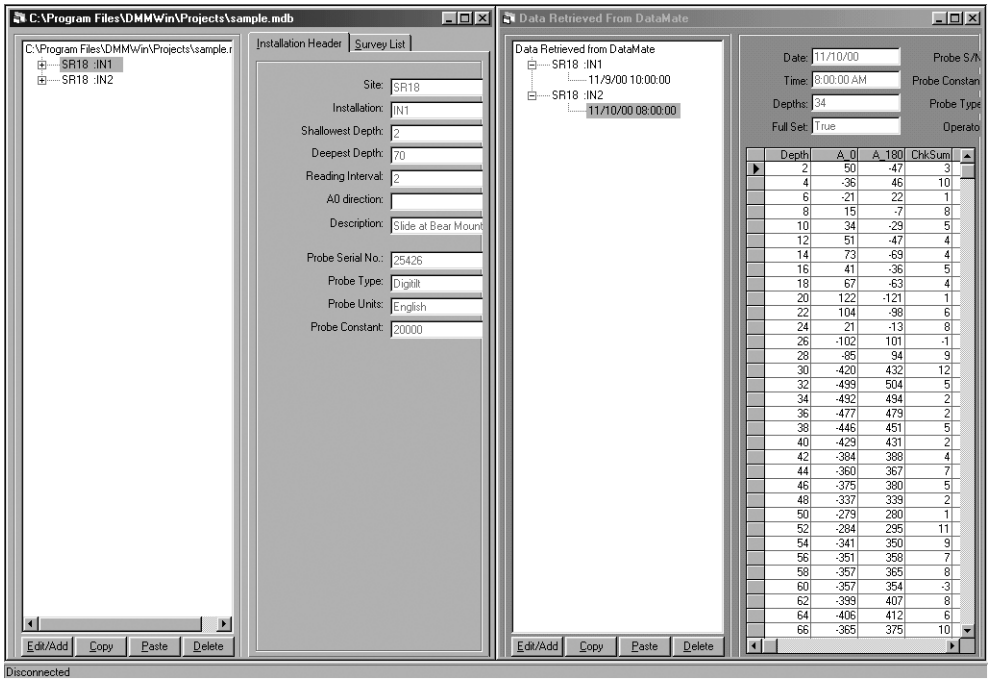
1. Connect the DataMate to your PC.
2. Run DMM and choose DataMate-Retrieve All or Retrieve New from the menu. DMM displays the retrieved data in a window.

This window is called: "Data retrieved from DataMate".

You will drag and drop surveys from this window into your project database.



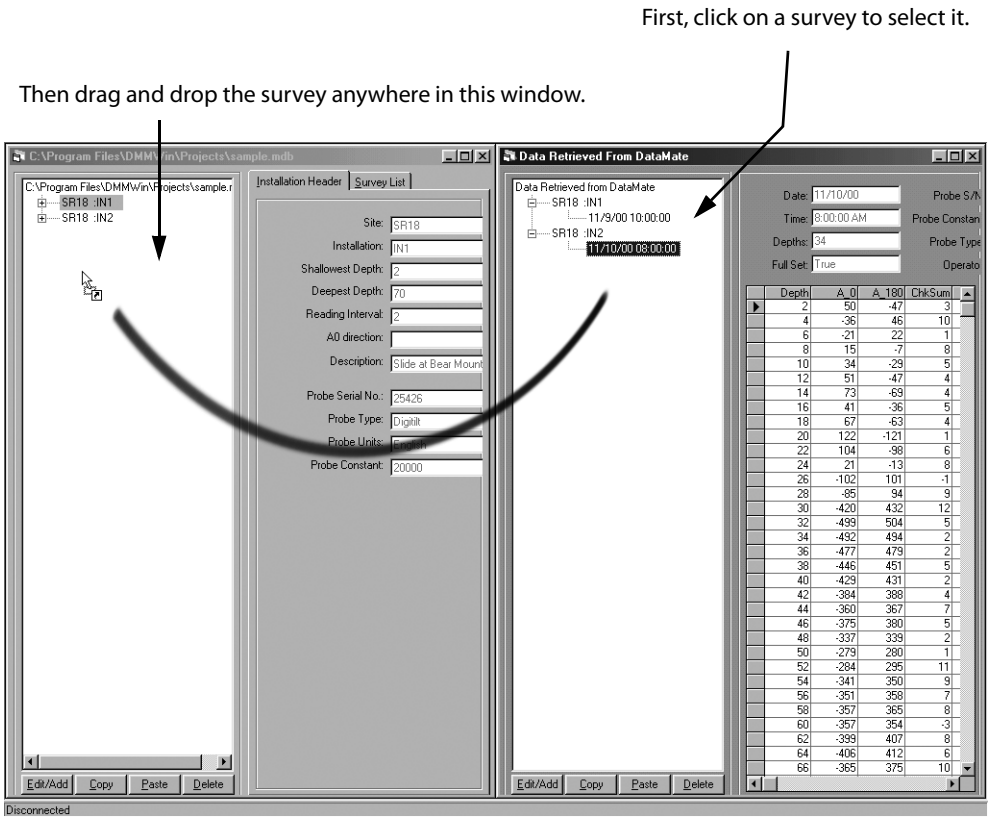
3. Open a project database to receive the data. Place the two windows side by side using the Windows-Tile command.



Project Database

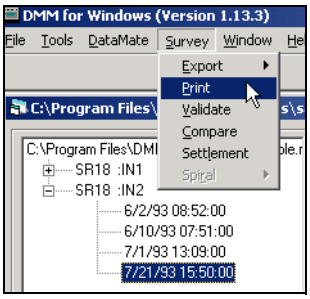
Data Retrieved from DataMate Window

4. Click, drag, and drop surveys one by one. Click on the survey to select it. Then drag and drop it into the project database. It is not necessary to drop the survey on the installation. You can also use the copy and paste buttons: copy from the temporary database, and paste into the project database.



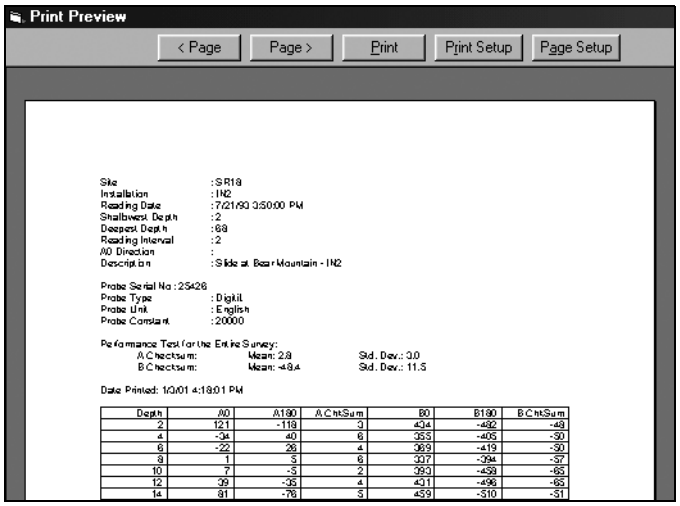
Printing a Survey

1. Choose Survey-Print from the menu bar.



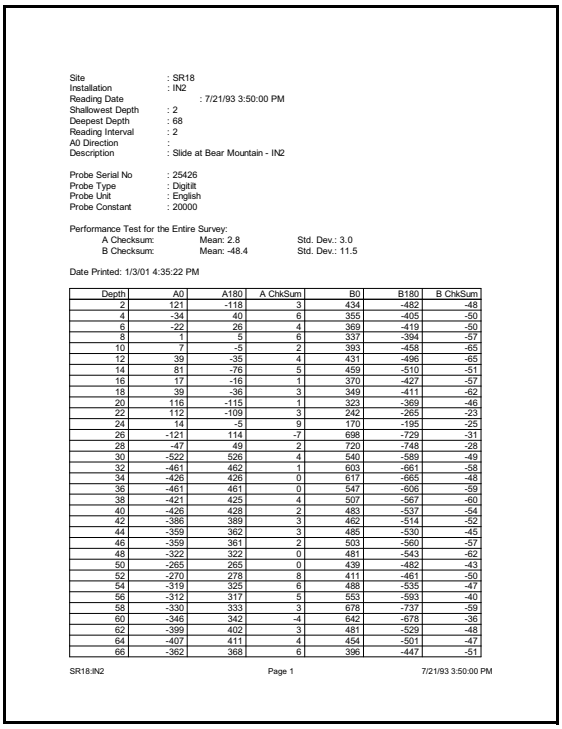
2. The print preview screen appears.

Zooming To zoom in, double-click the left mouse button. To zoom out, double-click the right mouse button.



Depth	A0	A180	A ChkSum	B0	B180	B ChkSum
2	121	-119	3	434	-482	-49
4	-34	40	6	355	-405	-50
6	-22	26	4	369	-419	-50
8	1	5	6	337	-394	-57
10	7	-5	2	393	-458	-65
12	39	-35	4	431	-496	-65
14	81	-76	5	459	-510	-51

3. The printed page looks like this:



Site : SR18
Installation : IN2
Reading Date : 7/21/93 3:50:00 PM
Shallowest Depth : 2
Deepest Depth : 68
Reading Interval : 2
A0 Direction :
Description : Slide at Bear Mountain - IN2

Probe Serial No : 25426
Probe Type : Digitilt
Probe Unit : English
Probe Constant : 20000

Performance Test for the Entire Survey:
A Checksum: Mean: 2.8 Std. Dev.: 3.0
B Checksum: Mean: -48.4 Std. Dev.: 11.5

Date Printed: 1/3/01 4:35:22 PM

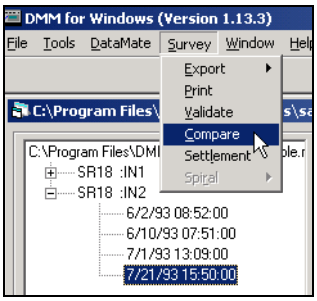
Depth	A0	A180	A ChkSum	B0	B180	B ChkSum
2	121	-118	3	434	-482	-48
4	-34	40	6	355	-405	-50
6	-22	26	4	369	-419	-50
8	1	5	6	337	-394	-57
10	7	-5	2	393	-458	-65
12	39	-35	4	431	-496	-65
14	81	-76	5	459	-510	-51
16	17	-16	1	370	-427	-57
18	39	-36	3	349	-411	-62
20	116	-115	1	323	-369	-46
22	112	-109	3	242	-265	-23
24	14	-5	9	170	-195	-25
26	-121	114	-7	698	-729	-31
28	-47	49	2	720	-748	-28
30	-522	526	4	540	-589	-49
32	-461	462	1	603	-661	-58
34	-426	426	0	617	-665	-48
36	-461	461	0	547	-606	-59
38	-421	425	4	507	-567	-60
40	-426	428	2	483	-537	-54
42	-386	389	3	462	-514	-52
44	-359	362	3	485	-530	-45
46	-359	361	2	503	-560	-57
48	-322	322	0	481	-543	-62
50	-265	265	0	439	-482	-43
52	-270	278	8	411	-461	-50
54	-319	325	6	488	-535	-47
56	-312	317	5	553	-593	-40
58	-330	333	3	678	-737	-59
60	-346	342	-4	642	-678	-36
62	-399	402	3	481	-529	-48
64	-407	411	4	454	-501	-47
66	-362	368	6	396	-447	-51

SR18:IN2 Page 1 7/21/93 3:50:00 PM

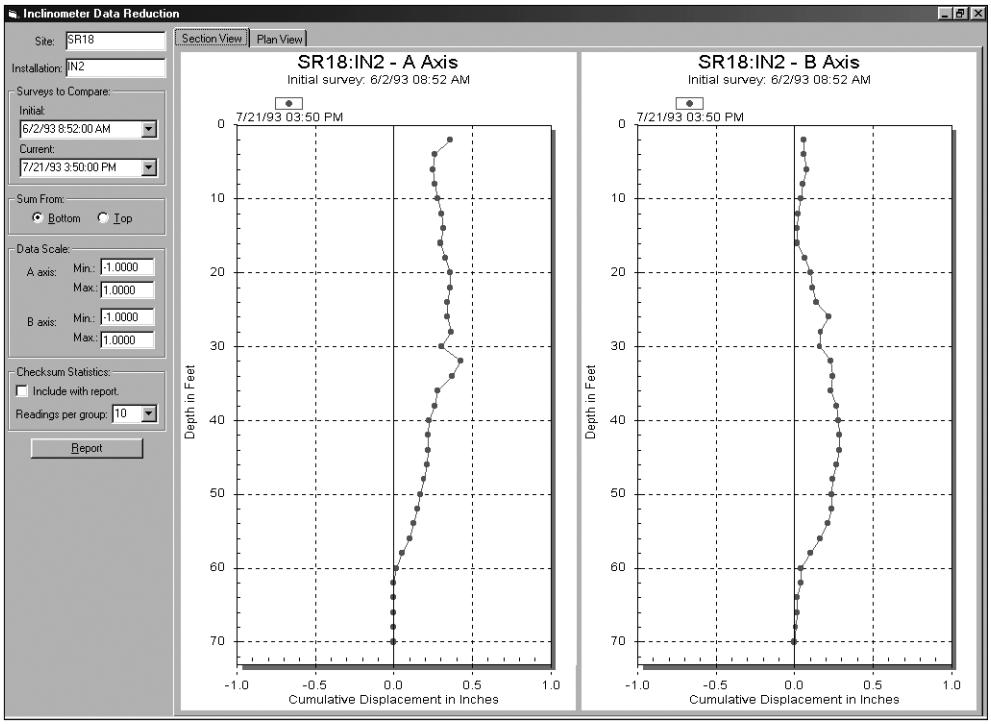
Plotting Survey Data

DMM has a convenient plotting routine that lets you compare two surveys.

1. Click on a survey, then choose Survey - Compare from the menu bar.



2. DMM displays a graph of cumulative displacement.



3. Now that you've seen DMM's main features, please take a look at the rest of the manual.

Menu Summary

File

Use this menu to create, save, open, and close databases.

Open: Offers a choice of project database or setup database. A project database contains your inclinometer surveys. A setup database contains a list of installations that you send to the DataMate.

New: Creates a new project database in its own window.

Close: Closes the database in the active window. All changes are saved. There is no explicit "Save" command.

Import: Imports surveys from RPP, PCSLIN, and GTILT. See Appendix 5, Importing Data.

Save As: Offers a choice of a project database or a setup database. Used to copy a database or create a setup database.

Recent Files: Shows the path and name of the most recently opened databases. Click on a database to open it.

Exit: Closes the DMM program.

Tools

Compact Database: Removes empty spaces left in the database after heavy editing.

Convert HDR to MDB: Starts the HDR2MDB utility to convert a DOS database to a Windows database. See Appendix 3.

DataMate

Use this menu to communicate with the DataMate.

Retrieve New: Retrieves only *new* surveys and displays them in a special window called "Data Retrieved from DataMate." In DataMate terms, "New" means a survey that is not stamped with a ^. The ^ stamp indicates that the survey has been retrieved at least once. If there are no new surveys, this command retrieves only a list of installations.

Retrieve All: Retrieves *all* surveys and displays data in a special window called "Data Retrieved from DataMate." This command always retrieve surveys, new and old, if there are any in the DataMate.

Send Setup: Used to transfer a setup database to the DataMate. Erases the DataMate's memory, then transfers the contents of the active database to the DataMate. This command is normally used to send a setup database to the DataMate, but it can be used to send a project database to the DataMate (within limits of memory).

DataMate Menu, Continued

Erase Memory: Erases installations and surveys from the DataMate and leaves the memory blank.

Options: Used to set the communications port. Also used to change the background color of the DataMate Window.

Survey

This menu becomes active when you have selected a survey. The same commands appear on a right-click menu, as well.

Export: Offers choice of exporting to RPP, Tab-Delimited ASCII, or PCSLIN. See Appendix 7.

Print: Prints the current survey along with checksum statistics.

Validate: Prints checksum statistics for the current survey.

Compare: Reduces data and displays a displacement graph of the A-axis and B-axis. Provides a "report" function that prints printing of the graphs along with data and statistics. See the chapter on data reduction and graphing for details.

Settlement: Generates a survey that is adjusted for settlement. See Appendix 10.

Spiral: Generates an interpolated spiral survey used for spiral corrections in DigiPro. This command becomes active only if there is a spiral survey found in the database. See Appendix 9.

Right-Click Survey Menu

The menu items above also appear on a right click menu. To display the menu, select a survey, then click the right button of your mouse.

Window

Use the Window menu to arrange windows on your screen. This is useful when you retrieve data from the DataMate.

Cascade: Stacks windows on top of each other, leaving only title bars visible, except for the window in front.

Tile Vertical: Arranges windows side by side. Useful for dragging surveys from the DataMate window to the project database window.

Tile Horizontal: Arranges windows side by side, using the full width of each window.

Help: Displays the version number of the program. The version number is also visible on the title bar.

Creating a Project Database

What's a Project Database?

The project database stores a list of inclinometer installations and the inclinometer surveys recorded for each installation.

Installation: This is a term used by Slope Indicator to refer to installed inclinometer casing. Other commonly used names are "inclinometer," "well," or "borehole." The project database holds the name of the installation, its depth, and measurement intervals.

Survey: This is a term used by Slope Indicator to refer to readings that are recorded for an installation. Other commonly used terms are "reading set" or "data set."

Creating a New Project Database

1. Start DMM.
2. Choose File-New.
3. Enter a name for the project, choose a folder, and click Save.
4. The new database is empty. The next steps explain how to add installations.

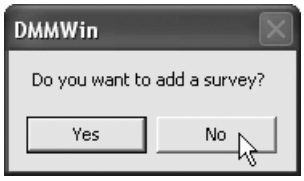
Overview of Adding Installations

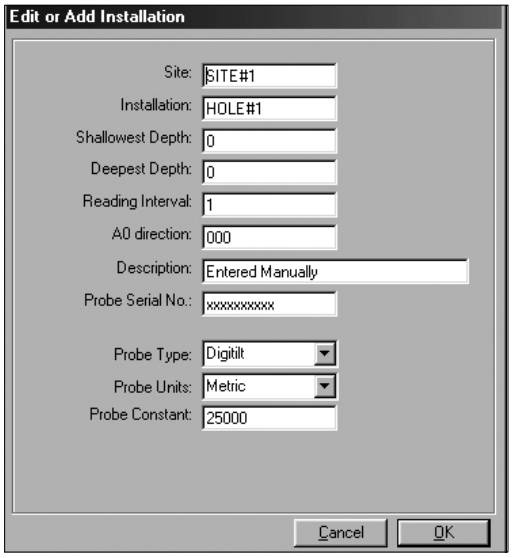
There are several ways to add installations to the new database.

- You can add installations manually, as discussed next.
- You can retrieve data from the DataMate. This adds both installations and surveys. See "Retrieving Surveys."
- You can drag and drop installations from other DMM databases into the new database. This brings surveys as well. See "How To - Make a Composite Database."
- You can import data from legacy formats. This brings in both installations and surveys. See Appendix 1.

Adding Installations Manually

1. Click Edit/Add.
2. Enter the required information. Each field is explained below.
3. Click OK.
4. Click No to the prompt asking if you want to add a survey.





Installation Fields

Site & Installation: Every installation has a two-part identifier: "site" and "installation." Enter up to 6 characters for each part.

Shallowest Depth: Typically, 0.5 for metric-unit systems or 2 for English-unit systems. Unit labels are not used.

Deepest Depth: Enter the appropriate value. With English-systems, it is best to use an even number so that 2-foot intervals coincide with cable markings. Unit labels are not used.

Reading Interval: Typically, 0.5 for metric-unit systems and 2 for English unit systems. Unit labels are not used.

A0 direction: Optional field of 3 characters for entering the compass heading of the A grooves. Not used for any calculation.

Description: Optional field up to 35 characters long.

Probe Serial No: Enter the serial number of the probe assigned to this installation.

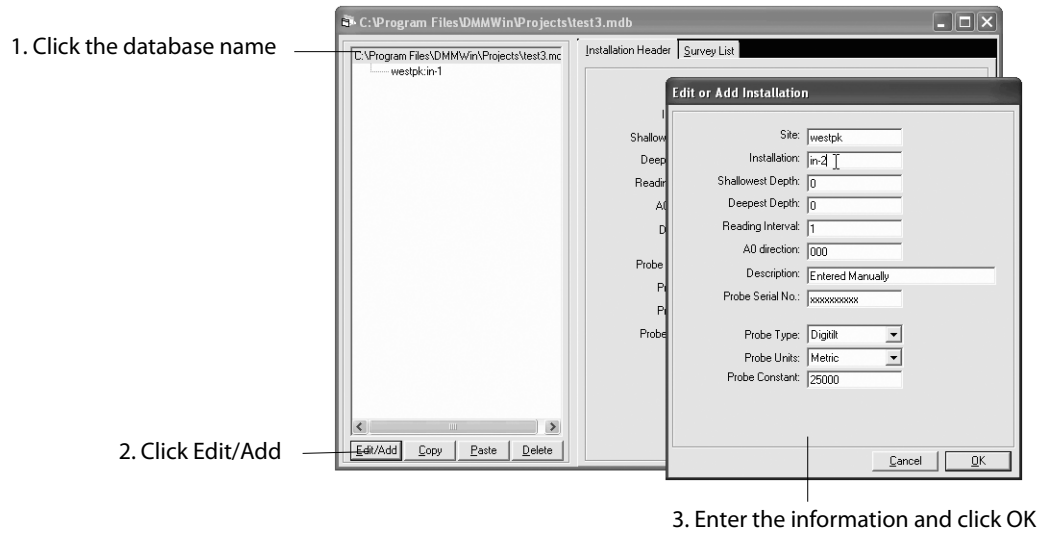
Probe Type: Choose Digitilt for inclinometers.

Probe Units: Choose Metric or English. If you don't know, check the distance between the upper and lower wheels of the probe: 0.5 m for metric systems; 2 feet for English-unit systems.

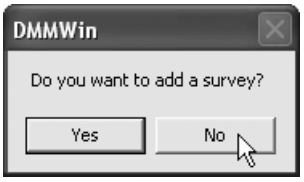
Probe Constant: Enter 25000 for metric-unit systems and 20000 for English-unit systems.

Add Another Installation

1. Click on the name of the database at the top of the column.
2. Click Edit/Add.
3. Enter the required information and click OK.



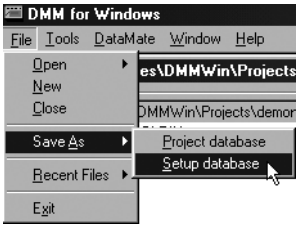
4. Answer No to the "Add Surveys" prompt.



Setting Up the DataMate

Create a Setup Database

1. Open your project database.
2. Choose File-Save As Setup Database.

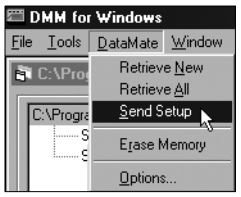


DMM copies installations from the project database into a setup database. No surveys are copied.

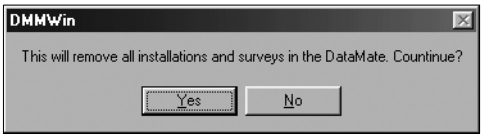
The default name for the setup database is "setup for [name of your project database]." The default folder is "Setups" and is located in the DMM folder. You can use a different name and folder for your setups.

Send the Setup to the DataMate

1. Connect the DataMate to your serial port. Switch on the DataMate and select Comm. The DataMate displays: Waiting for PC.
2. Choose File-Open-Setup Database, if necessary. The setup database must be displayed.
3. Choose DataMate-Send Setup.



4. Sending a new setup removes any data that is in the DataMate. This is normally what you want, so click Yes.



If you are not sure, click No. Then retrieve all surveys that are in the DataMate. You can store the retrieved surveys in a temporary project database, if necessary, and sort it out later.

5. DMM then sends the setup database to the DataMate. If you see an error message, try the troubleshooting steps listed on the next page.
6. When the database has been sent, check that the DataMate contains the required installations, then switch the DataMate off.

Note You can also send a project database to the DataMate, using the Send Setup command. Sending a project database sends the surveys as well, so check that you have not completely filled the memory.

Trouble-Shooting Communications

- If you see this error message, DMM may be using the wrong comm port. Choose DataMate-Options. DMM then scans for available comm ports and displays a list. Choose a different comm port and try again. Use this method even if you have a DataMate II, which uses USB communications.
- If DMM does not display a comm port that you think should be available, check if an "Active Sync" or "Hot Link" program is running and disable it. Such programs, supplied with Palm or Windows CE palmtop computers take control of the serial port and do not allow other devices to operate through it.
- All DataMates manufactured before the DataMate II use RS-232 serial communications. Most new notebook computers and many desktop computers no longer offer a serial port, so you can't connect the interface cable to the PC. (Note that serial port has 9 pins. Do not confuse it with a monitor port, which has 15 pins).

  You can solve this problem by purchasing a Serial to USB adaptor at your local computer store. One end connects to the USB port on your PC. The other end connects to the serial interface cable supplied with the DataMate. You must also install the USB drivers supplied with the adaptor. It is always a good idea to check the manufacturer's web site to download the most recent drivers.

More about Setup Databases

- The "File-Save As-Setup Database" command makes a copy of your project database, but removes survey data, so that only installation information remains.
- You can add installations from other project databases or other setup databases to your setup database. See the "How To" section for suggestions.
- When you send a setup database to the DataMate, it clears the entire data memory of the DataMate. If you share your DataMate, you may not want to erase installations and data that belong to someone else. In this case, add new installations using the DataMate's keypad.
- The original DataMate holds up to 40 installations. The DataMate II can hold 160. Your setup database must not have more installations than these maximums.
- The project database and the setup database are not linked. Thus, if you make changes to installation information in the project database, you should update your setup database or overwrite it with the Save-As Setup command.

Retrieving Surveys

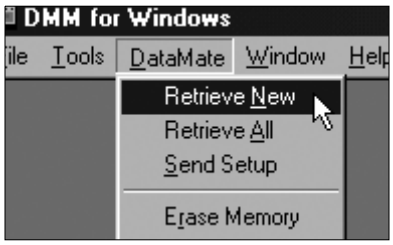
Overview

Retrieving surveys is a two step process.

1. Retrieve the surveys.
2. Copy the surveys into your project database.

Retrieve the Surveys

1. Connect the DataMate to your PC. Select Comm. The DataMate displays: Waiting for PC.
2. Run DMM. Choose DataMate - Retrieve All (or Retrieve New).



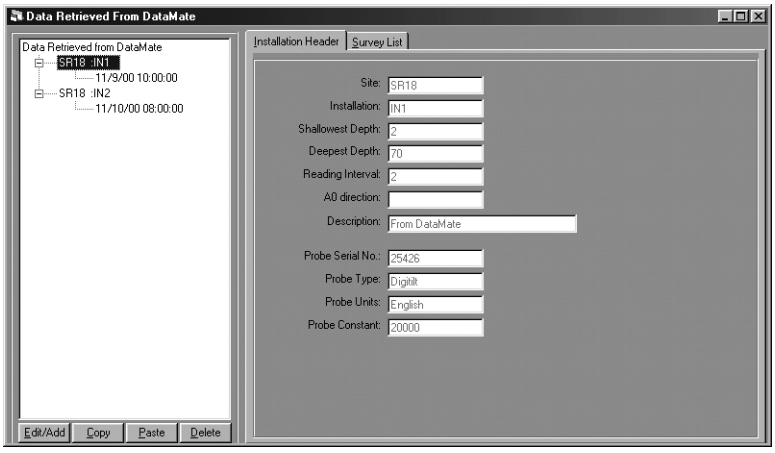
   If you choose Retrieve All, DMM displays all surveys. If you choose Retrieve New, DMM displays only new surveys (that have not been retrieved before).

   DMM retrieves the surveys from the DataMate. You can see its progress at the bottom left of the screen. If you have communications problems, see the troubleshooting steps in the previous chapter.

3. DMM displays the retrieved surveys in a temporary database window. This window is titled "Data Retrieved from DataMate" and is a slightly darker color. You can change the color of the window to make it easier to identify: Choose DataMate-Options. The color-change takes effect the next time that you retrieve surveys.

Data retrieved from DataMate is displayed in a temporary database.

You can change the color of this window to make it easy to identify.



Copy Surveys to your Project Database

1. Open a project database to receive the data. If your DataMate holds surveys from different projects, you can open other project databases at the same time.

The project database window opens in front of the DataMate window.

To transfer surveys, you must see both windows, as shown below.

2. To position the windows side by side for easy drag and drop, Choose Windows - Tile Vertical.

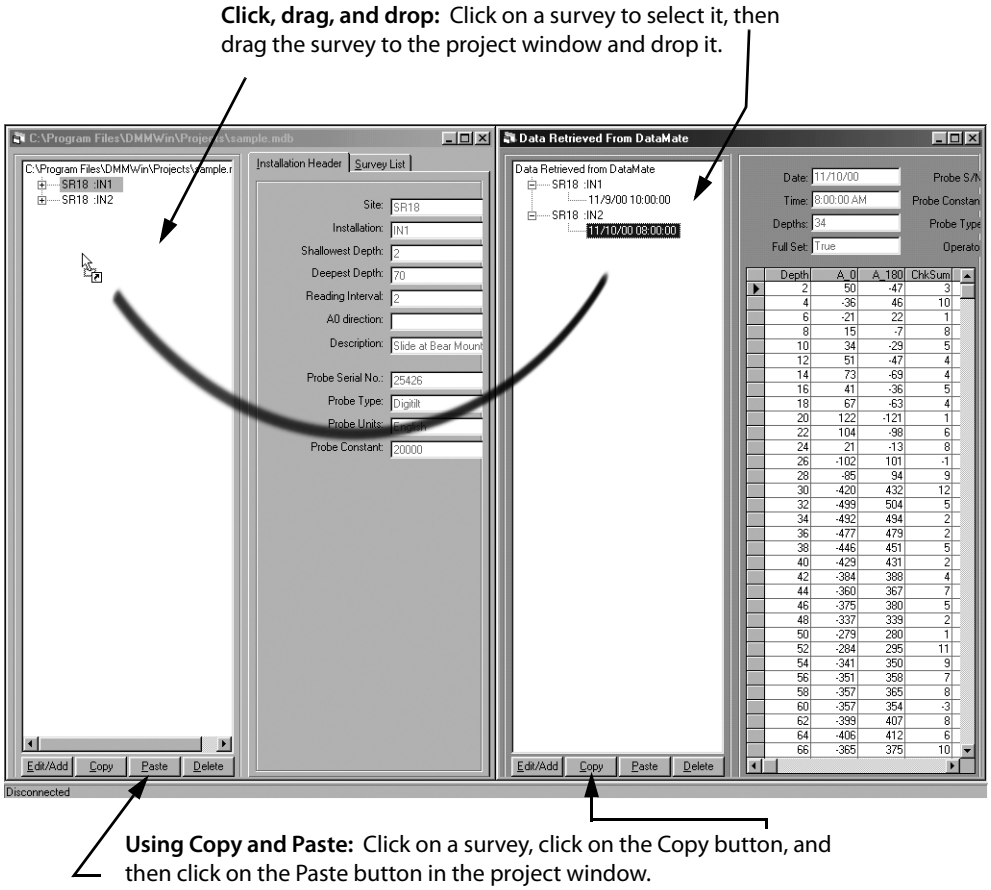
Use the Windows Tile command or press Ctrl-T to place the windows side by side.

Project Database Data Retrieved from DataMate

Retrieve Data continued

3. Click, drag, and drop surveys one by one from the DataMate window to the project window. It is not necessary to drop the survey on the installation. If you have difficulty copying surveys, you are probably trying to drag the survey before you select it. Instead of drag and drop, think: "Click, Drag, and Drop.

   You can also use the copy and paste buttons to copy from the temporary database and paste into the project database.



Data Reduction and Graphing

Introduction

Slope Indicator offers two programs for reducing inclinometer data: DMM for Windows and DigiPro for Windows.

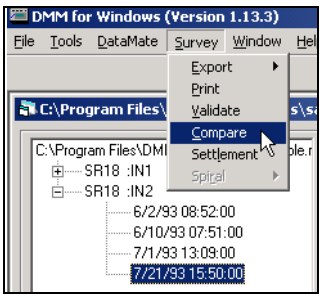
DMM for Windows can calculate checksum statistics, deviations, and displacements, and it can also create a graph of cumulative deviation or cumulative displacement (two surveys only).

DigiPro for Windows offers full graphing capabilities, more graph types, the ability to add titles, and a error correction routines. You can download a run-limited, full working version of DigiPro and the DigiPro manual from www.slopeindicator.com.

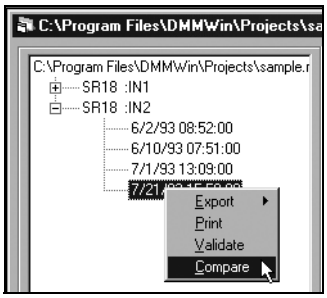
Data Reduction in DMM

DMM's data reduction functions are on the Survey menu or a right click menu. You must select a survey to activate the menus.

1. In the navigation window, click on the + next to an installation. Now you can see a list of surveys.
2. Select a survey.
3. Now click Surveys on the menu bar or click the right button on your mouse.



Select a survey, then click Survey on the menu bar.



The Right-Click Survey Menu

Print: DMM prints readings and checksums for the selected survey.

Validate: DMM displays the mean and standard deviation of checksums for the selected survey.

Compare: DMM compares the selected survey against an initial survey and displays graphs for the A and B axes. You can print a report that includes readings, graphs, and optionally, checksum statistics.

Printing Data

1. Select the survey that you want to print.
2. Click "Survey" on the menu bar.
3. Choose Print. DMM displays a print preview. It provides the following functions:

   Page: Page forward or backward through the preview.

   Print Setup: Choose a printer.

   Page Setup: Choose paper size and margins.

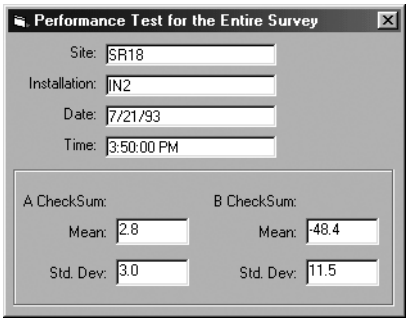
   Print: Print the data. You can print pages selectively.

   Left-Click: Double-click the left mouse button to zoom in. Drag the mouse to move the image.

   Right-click: Double-click the right mouse button to zoom out.

Validating Data

1. Select the survey that you want to validate.
2. Click "Survey" on the menu bar.
3. Choose Validate. DMM displays a table of checksum statistics. Click the X to close the table.



About Checksums

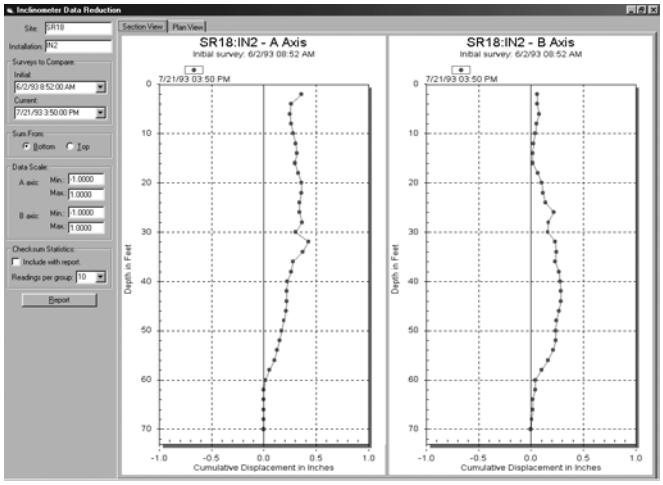
Checksums are one way to measure of the quality of your readings, but don't place too much importance on them. The consistency of checksums from survey to survey is more important than the actual value of the checksums. The standard deviation value is useful for comparing surveys.

Look at the checksums in DMM's display of survey data, especially if you have imported data or entered data manually. Very high checksums often reveal an omitted + or - sign.

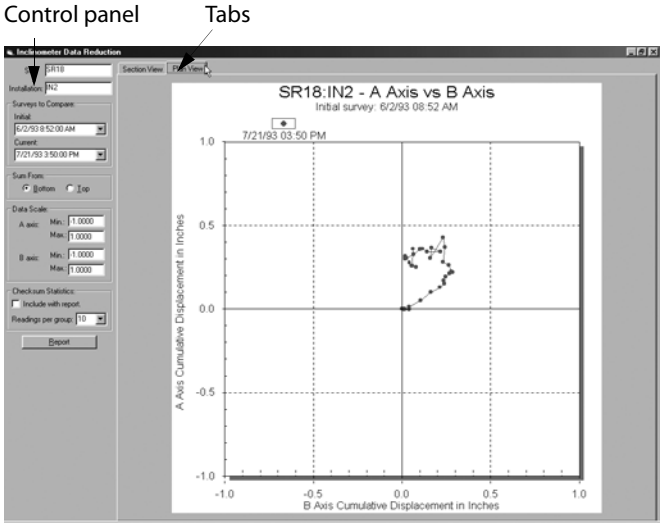
Look for a trend of checksums within a survey. A trend of decreasing checksums from bottom to top can be caused by omitting a warm up period for the probe. Trends of increasing or decreasing checksums within a survey may also indicate a problem with the probe.

Graphing

1. Select the survey that you want to compare.
2. Click "Survey" on the menu bar.
3. Choose Compare.
4. DMM displays a graph of cumulative displacement (movement). Note that DMM compares only two surveys.
5. Click on the tabs to show different views. Use the control panel to change options for the graphs and the printed report.

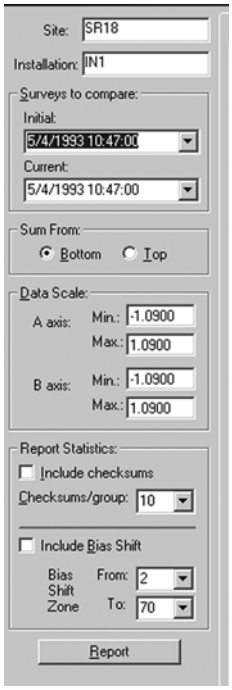


Section View: This view shows standard displacement graphs. A and B data are plotted against depth and shown in separate graphs.



Plan View: This view combines A and B-axis data by plotting the A value vs the B value at each depth.

Control Panel



Use the fields and buttons panel on the left side of the screen to control the graph.

Initial: Select a different initial survey. By default, DMM selects the earliest survey. You can also select "none" to force DMM to display a graph of cumulative deviation (the borehole profile).

Current: Select a different survey for comparison.

Sum From: Select top or bottom. Vertical inclinometers normally use sum from bottom since the bottom of casing is installed in stable ground.

Data Scale: We recommend that you use the scales set by DMM. You can enter other values, if necessary.

Printing a Report

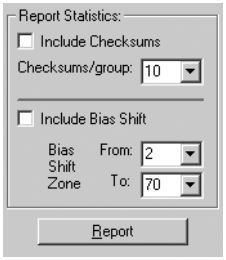
Report Button: When you click the Report button, DMM produces a report consisting of readings, graphs, and optional data. The report is displayed on screen as a print preview. You can page through the print preview and print all pages, the current page, or a range of pages. Some additional pages are added when you include checksum statistics and bias shift analysis.

Plain Report

With no checksum or bias shift information, the report contains:

- A-Axis readings, deviations & displacements in table form.
- B-Axis readings, deviations & displacements in table form.
- Graphs containing A-axis and B-axis displacement plots.
- Graphs of A-axis vs B-axis.

Include Checksums



To include checksum information with your report, click in the checkbox. (A check shows that checksum information will be included). Checksum statistics include a mean checksum and standard deviation of checksums for all readings in the survey. If the installation is deep, you may want to see statistics for smaller number of readings. To do this, enter a value from 1 to 10 in the groups field. Checksum information adds these pages to the report.

- A-axis readings, checksums, and change in checksums.
- A-axis checksum statistics.
- B-axis readings, checksums, and change in checksums.
- B-axis checksum statistics.
- A-axis readings, differences, and changes in digi units.
- B-axis readings, differences, and changes in digi units.

Include Bias Shift

The bias shift report, explained in Appendix 8, adds one page to the report:

- Differences and shifts for A and B axes.

How To . . .

Move a survey

This is useful if your survey is stored in the wrong place. For example, you chose the wrong installation when you started the survey and now you want to move the data to the correct installation.

1. Select the misplaced survey.
2. Click Edit Add to pop up the edit window.
3. Choose the correct installation from the drop down list at the top of the edit window, and click OK. This makes a copy of the survey and places it under the correct installation.
4. Finally, clean up the database. The original survey - the one you copied - is still there. Select it and click the delete button to remove it from the database.

Rename an Installation

1. Select the installation that you want to rename.
2. Click on Edit/Add to open the edit window.
3. Change the name of the installation and click OK. DMM adds a new installation to your database. There are no surveys under the installation.
4. Copy surveys one by one from the old installation to the new installation using the "misplaced survey" technique above.
5. After the surveys are copied, delete the old installation.

Enter Data Manually

Detailed instructions appear in Appendix 6, but here's an overview.

- Click on an installation, then click Edit/Add. If there are no surveys, DMM asks if you want to add a survey. Answer yes.
- If there are already surveys for that installation, you click on an existing survey and click Edit/Add to modify the existing survey. This saves you the time of entering header information and depths. Modify the survey as required, changing the date and time first, then entering the appropriate readings. When you click OK, the new survey is added.

Copy a Database

This is useful for making backup-copies of your database.

1. Open a project database.
2. Choose File - Save As.
3. Enter a name and location for the database, and click OK.

Split a Database

1. Open a project database.
2. Choose File - New to create a new project database.
3. Drag and drop installations from the original database to the new database. Surveys are dragged along with the installations.
4. Delete installations from the original database.

Send New Readings to the Head Office

Sometimes there are two project databases, one at the field office and one at the home office. The field office must maintain its own database and send new readings to the head office.

1. When you retrieve surveys from the DataMate, choose "DataMate - Retrieve New." DMM retrieves new readings and displays the temporary DataMate database.
2. Copy the new readings into your field database as usual.
3. Now, while the temporary DataMate database is still open,
4. Choose File - Save As. Enter a name and location for a database that will contain the new readings, and click OK. This saves the new readings in a database that you can send. Close the new database and update your local project database as usual.
5. Then, copy the new database onto disk or email it as an attachment. It will be fairly small because it contains only the new readings. You can use Winzip to make the file even smaller.
6. The DMM user at the head office then copies readings from the database that you sent to the permanent project database.

Delete a line of Data

1. Select the survey and click Edit/Add.
2. Click in the gray box to the left of the line of data. This selects the line.
3. Press the Delete key.

Make a Composite Setup Database

Suppose you have several projects and want the DataMate to hold inclinometers from each of those projects. You may also want the DataMate to hold a previous survey for each of those inclinometers.

To send installations and datasets (surveys) to the DataMate, you make a "setup" database. To make a setup database, simply save your project database as a setup database. DMM makes a copy of the database and then strips out any data, so all that remains is installation information.

To add a previous survey to the setup database, view your project database and setup database side by side (Use the Ctrl-T Tile command) and click-drag-and-drop the needed surveys from the project database to the setup database. Just drop the survey anywhere in the white window. It will find its own way home. Now you can close the project database, but keep your setup database open.

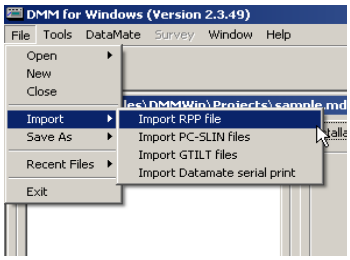
Now, open another project database and tile it side by side with your setup database. You'll be doing click-drag-and-drop operations again. Click-drag-and-drop surveys that you want in the DataMate. The surveys will bring installation information automatically. (Watch out: if you drag an installation, the installation will bring along all of its surveys. So drag a survey, not an installation).

Repeat this for any other installations that you need. Keep in mind that the DataMate has a 40 installation limit and the Datamate II has a 160 installation limit. If more than the maximum is installed, they will be arbitrarily truncated when sent to the DataMate. An alternative to this is to download the contents, save them, modify them (add new setups) and send them back to the DataMate

When the setup database holds the installations and surveys that you need, send the setup to the DataMate. This will cause the DataMate to delete everything that is in its memory and replace it with the contents of the setup database. So be sure that you have retrieved anything that you want from the DataMate before you send the setup.

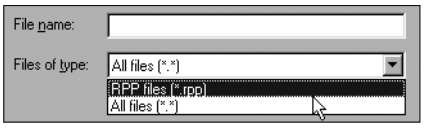
Appendix 1: Importing Data

Importing Data



1. Create a project database.
2. Choose File - Import.
3. Choose the type of import. These are explained below. To import data from a spreadsheet, see page 35.
4. Specify the file to import.
5. Click OK.

RPP Import Notes



- The import routine looks for an extension of RPP. If your RPP file has a different extension, click in the Files of Type field to show All Files.
- The first line of the RPP file must be a date. If DMM gives you an error message, open your RPP file with an ASCII editor such as notepad, and delete any lines above the date line
- If you have trouble importing, check that the date and time formats in the file match the date and time formats of your Windows computer.

The first line of the file must be time and date in this format.

Project and Hole # become Site and Installation. Check that these names are consistent in all surveys for this installation.

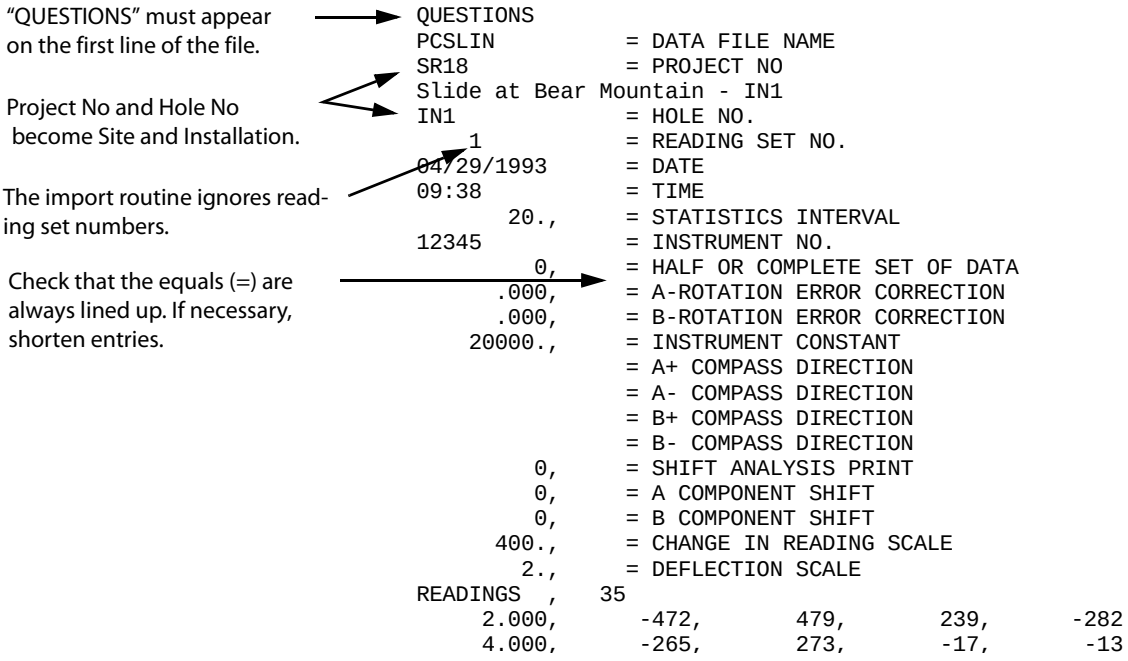
Check for missing equals (=).

```
TIME = 09:38:00   29 APR 1993
DIGITILT/SPIRAL = D
ENGLISH/METRIC = E
HOLE # = IN1
PROJECT = SR18
JOB DESC = Slide at Bear Mountain - IN1
DIR CODE =
PROBE SER # = 1
OPERATOR =
START DEPTH = +70.0
END DEPTH = +2.0
INCREMENT = 2.0
INSTR CONST = 20000
ROTATIONAL CORR A = 0.0000
ROTATIONAL CORR B = 0.0000
CALIBRATION CORR A = 0
CALIBRATION CORR B = 0


+2.00   A0   -472   B0    239
      A180    479 B180   -282
+4.00   A0   -265   B0    -17
      A180    273 B180    -13
```

PCSLIN Import Notes

- The import routine looks for an extension of PRN. If your PCSLIN file has a different extension, click in the Files of Type field to change to All Files.
- The first line of the file must start with the word "QUESTIONS." If there is an error, open the PCSLIN file with an ASCII editor such as Notepad and delete any lines before the word "QUESTIONS."



GTilt Import Notes

The Gtilt import routine looks for an extension of GTL. If your file has a different extension, click in the Files of Type field to change to All Files.

Metric files are assigned an instrument constant of 25000 and a reading interval of 0.5 m. English files are assigned an instrument constant of 20000 and a reading interval of 2 feet.

This is truncated to 6 characters and becomes Installation.

This is truncated to 6 characters and becomes Site.

```
SAMPLE1
NORTH PORTAL SLOPE
Urban Transit Authority
North Slope Investigation
E
4
2.25
37
M
637.0
45
10000
 5
*
07061998
1327
1400
Top of cable clamp
31.2
EDM
EDM
EDM
6.45
6.21
TAJ
TAJ


-150  131 -216  236
-54  36 -180  187
 69 -85 -204  218
```

DataMate Serial Print

This import function is included mostly for diagnostics. The DataMate can print a survey to a serial device. There are very few serial printers these days, so a terminal program, such as Hyperterm, is used to capture the output of the DataMate and save it as a text file. This import utility provides a way to import that text file.

```
Site     :SR18
Survey   :IN1
A0 dir   :
Operator :
Sensor # :25426
Axes     :DIGITILT
Units    :ENGLISH
Ins const:20000.0
Start    :70.0
End      :2.0
Interval :2.0
Time     :93/05/04

Depth     A0      A180    B0     B180
  2.0    -475     477     235    -286
  4.0    -270     274      -7     -14
  6.0     334    -329    -206     161
  8.0     393    -390    -129      78
 10.0     298    -293    -223     159
 12.0     246    -235    -258     210
 14.0     170    -167    -301     260
 16.0     123    -114    -363     321
 18.0      57     -56    -438     387
 20.0      -5      10    -421     374
 22.0      77     -72    -500     447
 24.0     174    -167    -418     376
 26.0     242    -238    -434     384
 28.0     173    -167    -406     352
 30.0      91     -88    -422     398
 32.0      85     -77    -615     586
 34.0     110    -103    -697     644
 36.0     193    -189    -669     615
 38.0     212    -208    -690     627
 40.0     172    -168    -683     622
 42.0     174    -155    -651     594
 44.0      47     -54    -559     510
 46.0      27     -11    -537     482
 48.0      86     -78    -511     462
 50.0     171    -167    -569     517
 52.0     152    -135    -566     511
 54.0      75     -72    -437     411
 56.0     146    -139    -389     369
 58.0     155    -147    -526     499
 60.0     155    -153    -645     590
 62.0     174    -167    -603     550
 64.0     115    -103    -557     510
 66.0      88     -81    -562     511
 68.0      99     -90    -629     569
```

Importing Data from a Spreadsheet

1. Export the data for a single survey to a text file (see sample below).
2. In DMM, select an installation then right-click and select "Add Survey".
3. Fill in the survey header information. Date, Time, Probe s/n, Probe Constant, Probe Type, Full Set, and Operator. Depths will be filled in during import.
4. Click "Import Data" at the bottom of the form.
5. Select the file to import.

Important:

- During the import, text lines will be ignored.
- Lines with at least 5 numeric values will be imported as data.
- When the import is complete, the data will be displayed and the number of depths will be set to the number of data lines read from the file.

Depth	A0	A180	B0	B180
2	289	-263	-194	208
4	60	-30	-23	40
6	-43	71	2	17
8	-67	98	38	-21
10	-57	87	3	19
12	-62	91	-17	43
14	-49	78	9	21
16	-4	34	-17	32
18	11	18	-62	82
20	29	-1	-88	107
22	63	-27	-104	127
24	66	-39	-96	127
26	29	2	-118	139
28	4	28	-111	131
30	2	28	-82	98
32	-12	48	-68	87
34	-63	89	-47	67
36	-104	133	-64	87
38	-103	133	-69	97
40	-124	153	-64	83
42	-110	143	-51	72
44	-140	169	-58	88
46	-167	196	-49	76
48	-126	157	-73	91
50	-74	101	-84	102
52	-30	60	-68	89

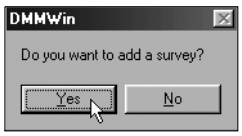
Appendix 2: Manual Entry of Data

Create a Database and Add Installations

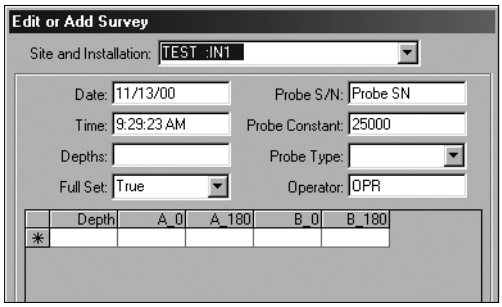
1. Create or open a project database.
2. Enter installation information. Both of these tasks are described in "Creating a Project Database."

Enter the First Survey

1. .Click on the installation, then click on the Edit/Add button. DMM asks if you want to enter survey data. Click Yes.



2. The edit window appears. Enter the survey header information as explained below.



Site and Installation: Verify that the site and installation are correct. If not, choose a different installation from the drop-down menu.

Date and Time: Enter the date and time of the survey. DMM displays the current date and time so that you can see the proper format. The actual format will change according to your Windows' short-date setting.

Depths: Skip this field. It will be entered automatically after you have entered readings.

Full Set: Enter True if you have readings for both the 0 and the 180 directions. Enter False if you have only the 0 readings. The Full-Set value is used in calculations later.

Probe S/N: Enter the serial number of the inclinometer probe.

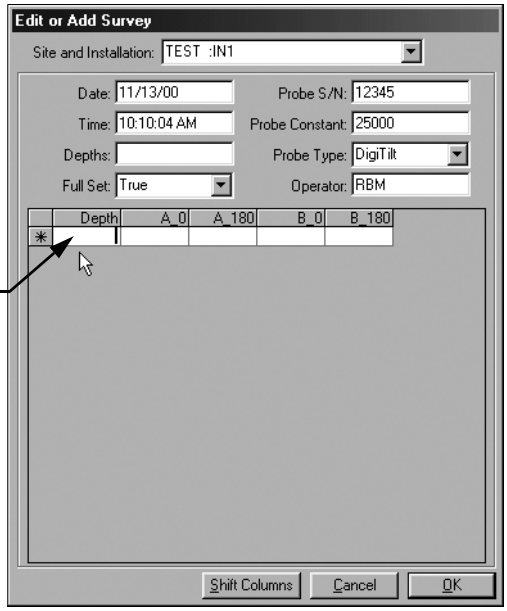
Probe Constant: Enter 25000 for metric-unit probes or 20000 for English-unit probes. This value is used in calculations

Probe Type: Enter Digitilt or Spiral. This value is used in calculations.

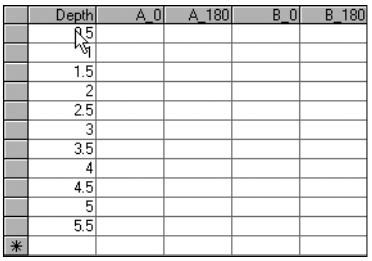
Operator: Enter initials of the operator (3 characters).

Enter the First Survey Continued

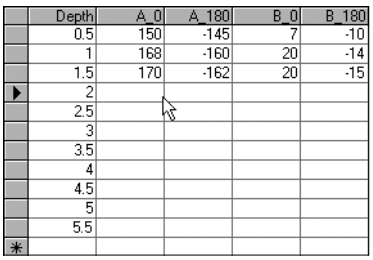
1. Enter depths, starting with the shallowest.
2. Enter the readings for each depth. When you are done, click OK.



Click here to enter a depth. Start with the shallowest depth.



Enter the depths first. Check that you have not missed any depths.



Enter readings for each depth. Press the arrow keys or tab to move from field to field.

Enter Subsequent Surveys

To enter other surveys for the same installation, you make a copy of the first survey (so that you do not have to enter depths again).

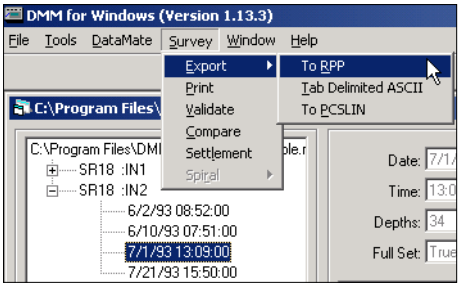
1. Select the first survey.
2. Click on Edit/Add. The edit window appears.
3. Correct the time and date for this survey.
4. Enter the readings and click OK.

Note: If there are many readings, you might want to save your work occasionally. To save your work simply click the OK button. To reopen the survey, select it (check the time and date), and click the Edit Add button.

Appendix 3: Exporting Data

Overview

1. Open a project database (or retrieve data from the DataMate).
2. Click on the + next to an installation. This makes surveys visible.
3. Select the survey that you want to export.
4. Click "Survey" on the menu bar and choose a format: RPP, Tab Delimited ASCII, or PCSLIN.
5. Specify a location and a name for the file and click OK.



RPP Format

This format includes header information, such as the installation ID and depth, the probe serial number, etc, followed by columns of data in fixed widths.

```
TIME = 10:00:00   09 Nov 2000
DIGITILT/SPIRAL = D
ENGLISH/METRIC = E
HOLE # = IN1
PROJECT = SR18
JOB DESC = From DataMate
DIR CODE =
PROBE SER # = 25426
OPERATOR =
START DEPTH = 70
END DEPTH = 2
INCREMENT = 2
INSTR CONST = 20000
ROTATIONAL CORR A = 0.0000
ROTATIONAL CORR B = 0.0000
SENSITIVITY FACTOR A = +0
SENSITIVITY FACTOR B = +0


+2.0    A0   -489   B0    209
      A180    494 B180   -293
+4.0    A0   -281   B0    -29
      A180    280 B180      9
+6.0    A0    337   B0   -220
      A180   -335 B180    185
+8.0    A0    411   B0   -139
      A180   -406 B180     90
+10.0   A0    323   B0   -207
      A180   -320 B180    169
+12.0   A0    267   B0   -263
      A180   -261 B180    219
+14.0   A0    192   B0   -305
      A180   -194 B180    264
+16.0   A0    142   B0   -373
```

Tab-delimited ASCII Format

This format includes column labels and tab-delimited values. It also includes checksums for both A and B readings.

Column labels can be excluded on import to the spreadsheet, as shown here.

2	-489	494	5	209	-293	-84
4	-281	280	-1	-29	9	-20
6	337	-335	2	-220	185	-35
8	411	-406	5	-139	90	-49
10	323	-320	3	-207	169	-38
12	267	-261	6	-263	219	-44
14	192	-194	-2	-305	264	-41
16	142	-139	3	-373	326	-47
18	81	-79	2	-451	393	-58
20	11	-9	2	-413	364	-49
22	91	-91	0	-493	445	-48
24	178	-171	7	-408	365	-43
26	245	-242	3	-431	377	-54
28	177	-170	7	-397	349	-48
30	93	-93	0	-414	393	-21
32	89	-85	4	-619	585	-34
34	112	-111	1	-700	646	-54
36	197	-193	4	-670	612	-58
38	213	-211	2	-691	631	-60
40	170	-168	2	-685	627	-58
42	164	-159	5	-650	599	-51
44	46	-55	-9	-557	515	-42
46	22	-8	14	-530	481	-49
48	80	-75	5	-505	455	-50
50	166	-166	0	-571	515	-56
52	145	-133	12	-554	507	-47
54	70	-66	4	-419	388	-31
56	138	-137	1	-397	365	-32
58	148	-143	5	-529	500	-29
60	152	-152	0	-641	593	-48
62	169	-169	0	-603	547	-56
64	110	-101	9	-558	511	-47
66	85	82	3	563	517	46

PCSLIN

This format includes a header followed by space delimited columns of data.

```
QUESTIONS
PCSLIN          = DATA FILE NAME
SR18            = PROJECT NO
Slide at Bear Mountain - IN1
IN1             = HOLE NO.
    1           = READING SET NO.
04/29/1993      = DATE
09:38           = TIME
      20.,      = STATISTICS INTERVAL
12345           = INSTRUMENT NO.
        0,      = HALF OR COMPLETE SET OF DATA
     .000,      = A-ROTATION ERROR CORRECTION
     .000,      = B-ROTATION ERROR CORRECTION
   20000.,      = INSTRUMENT CONSTANT
                = A+ COMPASS DIRECTION
                = A- COMPASS DIRECTION
                = B+ COMPASS DIRECTION
                = B- COMPASS DIRECTION
        0,      = SHIFT ANALYSIS PRINT
        0,      = A COMPONENT SHIFT
        0,      = B COMPONENT SHIFT
     400.,      = CHANGE IN READING SCALE
       2.,      = DEFLECTION SCALE
READINGS  ,   35
     2.000,      -472,       479,       239,      -282
     4.000,      -265,       273,       -17,       -13
```

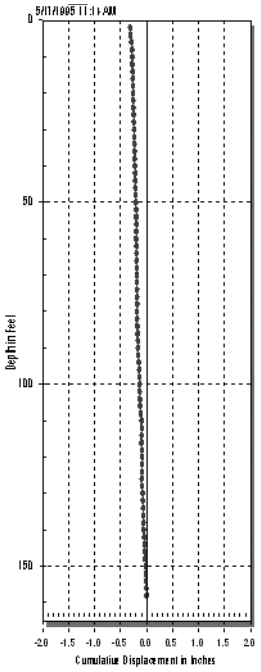
Appendix 4: Bias-Shift Analysis

What is Bias Shift

Bias: If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value. This is the probe's bias. The bias value is normally eliminated in the data reduction process when the 0 readings are combined with the 180 readings.

Bias-Shift Error: If the bias value changes during a survey, the data reduction process cannot eliminate all of the bias. The remaining value is error that is embedded in the reduced data.

The straight, but leaning plot at right is the result of bias-shift error.



Identifying Bias Shift

Appearance: A straightened, but leaning cumulative displacement plot is a signature of bias shift error. The embedded error grows larger at each interval, so the plot leans to the left or right.

Unlikely Behavior: The graph above shows rotation of the entire 150 foot span of soil or rock. This unlikely behavior suggests error in the data.

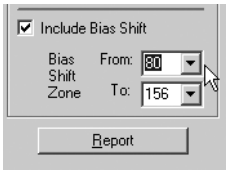
Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error. In our example, we know that the casing entered rock below 80 feet, and that no movement has occurred from 80 feet downwards. This again suggests error in the data.

More information on bias-shift can be found in the training section of Slope Indicator's website: www.slopeindicator.com. Click on the link for Sample Chapters. Then click on "Bias Shift Error."

Quantifying Bias Shift Error

DMM provides a routine for quantifying bias shift error. The routine provides an average bias shift value that can be used as a correction value in DigiPro (but not in DMM).

1. Right click on the survey. Choose Compare.
2. Click the checkbox to include a bias shift analysis. Use the From and To drop boxes to limit the analysis to depths that you know are stable. This is important so choose the depths carefully. In our example, the casing is stable below 80 feet, so we enter 80 to exclude readings above 80 feet.



3. Click the report button. Then page through the report to find the bias-shift page.
4. The analysis routine finds the difference between current and initial A0 readings and the difference between current and initial A180 readings. This is reported in the Diff column. Since movement affects the A0 and A180 passes in the same way, the values in the A0 column should match the values in the A180 column.

   The Shift column shows the difference between the A0 column and the A180 column. If you have limited the analysis to depths where no movement is likely to occur, the value in the Shift column represents bias shift error (plus some possible random error).
5. An average error appears at the bottom of the column. This is the correction value that you can enter into DigiPro.

Bias Shift for A and B Axes:

Depth (ft)	Diff. A0	Diff. A180	Shift A	Diff. B0	Diff. B180	Shift B
80	1.0	8.0	-7.0	27.0	-8.0	35.0
82	-1.0	6.0	-7.0	28.0	-19.0	47.0
84	-2.0	6.0	-8.0	25.0	-5.0	30.0
86	-1.0	7.0	-8.0	30.0	-14.0	44.0
88	4.0	8.0	-4.0	24.0	-13.0	37.0
90	-1.0	11.0	-12.0	28.0	-14.0	42.0
92	-6.0	11.0	-17.0	29.0	-21.0	50.0
94	-2.0	9.0	-11.0	25.0	-25.0	50.0
96	-3.0	6.0	-9.0	28.0	-12.0	40.0
98	-4.0	13.0	-17.0	14.0	17.0	-3.0
100	0.0	8.0	-8.0	24.0	-7.0	31.0
102	-1.0	11.0	-12.0	26.0	-5.0	31.0
104	-2.0	9.0	-11.0	20.0	-1.0	21.0
106	-6.0	11.0	-17.0	44.0	-10.0	54.0
108	-16.0	18.0	-34.0	20.0	4.0	16.0
110	4.0	9.0	-5.0	15.0	11.0	4.0
112	9.0	-1.0	10.0	32.0	5.0	27.0
114	7.0	0.0	7.0	20.0	-4.0	24.0
116	-8.0	13.0	-21.0	35.0	-15.0	50.0
118	1.0	2.0	-1.0	40.0	-35.0	75.0
120	5.0	5.0	0.0	23.0	-17.0	40.0
122	3.0	3.0	0.0	27.0	-20.0	47.0
124	0.0	4.0	-4.0	32.0	-21.0	53.0
126	-2.0	11.0	-13.0	28.0	-19.0	47.0
128	-5.0	11.0	-16.0	20.0	16.0	4.0
130	-2.0	11.0	-13.0	29.0	-13.0	42.0
132	0.0	8.0	-8.0	35.0	-1.0	36.0
134	-2.0	8.0	-10.0	30.0	-20.0	50.0
136	-3.0	9.0	-12.0	32.0	-29.0	61.0
138	-3.0	8.0	-11.0	32.0	-21.0	53.0
140	-4.0	5.0	-9.0	29.0	-6.0	35.0
142	-4.0	13.0	-17.0	21.0	14.0	7.0
144	-4.0	12.0	-16.0	31.0	-24.0	55.0
146	-6.0	12.0	-18.0	44.0	1.0	43.0
148	6.0	9.0	-3.0	20.0	-11.0	31.0
150	1.0	8.0	-7.0	26.0	-5.0	31.0
152	-2.0	10.0	-12.0	25.0	-5.0	30.0
154	-3.0	11.0	-14.0	13.0	2.0	11.0
156	-2.0	10.0	-12.0	-1.0	-1.0	0.0
Average			-9.9			35.4

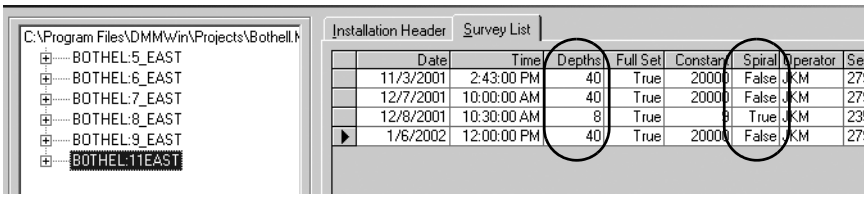
Averaged bias shift values

Appendix 5: Expanding Spiral Surveys

Spiral Surveys

Spiral surveys are obtained with a special-purpose spiral sensor. Please refer to the spiral sensor manual for instructions on conducting a spiral survey.

Spiral surveys are stored with inclinometer surveys in the project database. A typical spiral survey has depths and two or four columns of data, one column of data for each pass through the casing. The spiral survey can be identified as explained below:

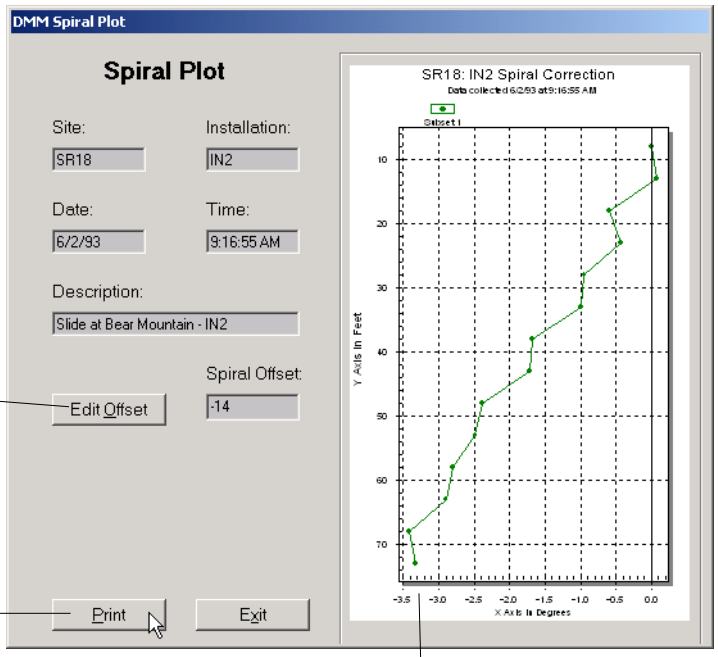


The spiral survey has fewer reading depths than an inclinometer survey. Also, it is marked True in the Spiral column.

Plotting Spiral Data

DMM can generate a plot from the spiral data. The spiral plot shows the magnitude of the spiral in the casing. If the accumulated spiral is small (<20 degrees), you may decide to ignore spiral.

1. Select the spiral survey.
2. Click Survey on the menu bar, then choose Spiral - Plot Spiral.



Click this button to enter an offset for the spiral sensor. See the spiral manual for detail.

You can print the spiral plot.

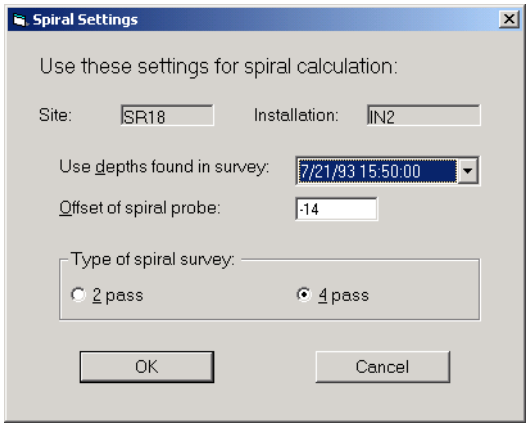
Spiral values are accumulated from top to bottom, so the maximum value appears at the bottom.

Expanding Spiral Data

To correct inclinometer surveys for Spiral, the DigiPro program requires a spiral value for each depth in the inclinometer survey.

DMM's spiral expansion routine reads the spiral survey and generates a new survey with values for each inclinometer depth. Later when you use DigiPro to graph inclinometer data, you simply switch on spiral correction and DigiPro automatically finds the expanded spiral survey and applies the data.

1. Select the unexpanded spiral set.
2. Click on Survey, and choose Spiral - Expand Spiral.
3. Specify which survey has the proper number of depths.
4. Enter the spiral sensor offset. (See the Spiral Manual).
5. Choose the number of data columns in the spiral survey (2 or 4).
6. Click OK. DMM then generates a new spiral survey. It has the same date as the original spiral survey, but the time is changed by one second. In addition, the operator field is marked EXP.

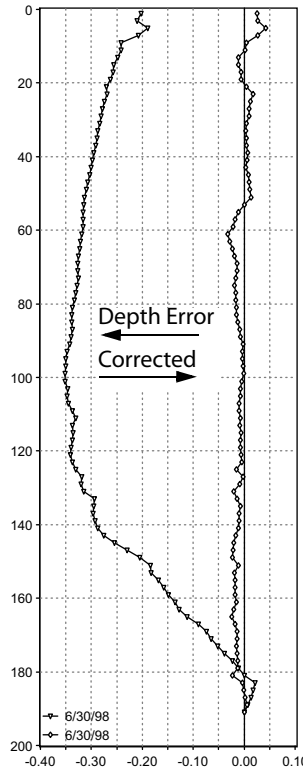


Appendix 6: Settlement Corrections

Depth Error

The accuracy of an inclinometer system depends on repeatable positioning of the inclinometer probe. When the probe is positioned consistently at each depth in the survey, readings can be compared reliably. If the reading changes, movement has occurred. If the reading stays the same, no movement has occurred.

However, if the probe is positioned above or below the proper depth, the reading will change, even if there is no movement. This changed reading is a depth error. In casing that is very straight, the change in reading is small, and can typically be ignored. But in casing that is "wavy," the change can result in obvious error, as shown in the DigiPro plot at right.



Sources of Depth Error

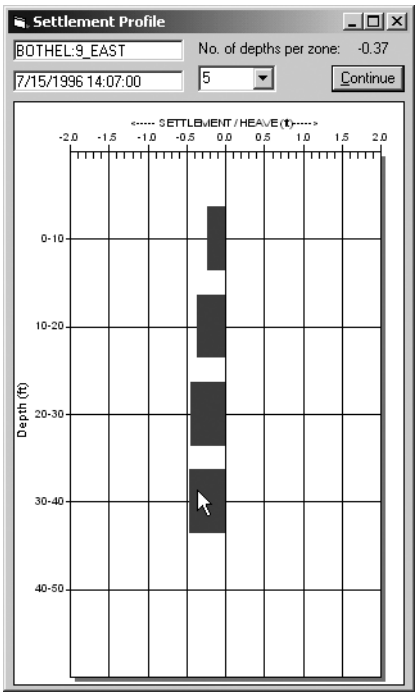
Changed reference: The operator positions the probe by aligning depth markers on the cable to a reference at the top of the casing. If the reference changes, every reading in the survey is affected. This can be corrected by DMM's settlement correction.

Change in casing length: If the casing is compressed by settlement, the probe will be positioned deeper in the casing. Readings are affected at and below the zone of settlement. This can be adjusted by DMM's settlement correction.

Change in cable length: Control cables may shrink or stretch over time. Cables may be interchanged with other cables that are not the same length. Repairs and splicing of cable may result in changed length. Readings are affected where differences in cable become active. This can be adjusted by DMM's settlement correction

Random positioning: A distracted operator accidently positions the probe at the wrong depth and take a reading. This cannot be adjusted by DMM's settlement correction. Edit the data instead.

Generating a Corrected Survey



1. Select the affected survey. Click on Survey. Choose Settlement.
2. Determine whether the depth error is settlement or heave (see explanation below).

Settlement	**Heave**
Reference is lower than before	Reference is higher than before
Casing is shorter than before	Casing is longer than before
Cable has stretched	Cable has shrunk

3. To enter a value, click on the zone line. A bar appears. You can see the numeric value of the bar in the upper right corner. Enter settlements on the left side and heave on the right side. Units are in feet or meters.

   If you reduce Sondex or Magnet extensometer readings as suggested in the manuals, your final calculations are changes for each ring or magnet. The values entered into DMM should be the complement of these changes (total settlement minus change).

   In the example below, the change for magnet 5 represents total settlement (the change in the distance between the datum magnet and the top magnet). You can see the required calculation. Although the values for DMM are positive, you should still enter them on the settlement side of the dialog.

Magnet	Change (feet)	Total Settlement - Change	Value for DMM
5	0.23	0.23 - 0.23	0
4	0.17	0.23- 0.17	.06
3	0.11	0.23 - 0.11	0.12
2	0.06	0.23 - 0.06	0.17
1	0.02	0.23 - 0.02	0.21

4. When you are done, click the Continue button. DMM generates a new survey, with the same date, but time changed to 23:59:59.

Appendix 7: Updating MDB Databases

Introduction

DigiPro for Windows version 1.26 and earlier had an automatic database conversion utility that copied data from a DOS "hdr" database into a Windows "mdb" database. The conversion was not perfect, so if you open these files with DMM for Windows, DMM will ask you to update the database.

To Update a MDB Database

1. Start DMM for Windows.
2. Navigate to your existing MDB database. They have the same name and are in the same location as your hdr databases, the ones created by the DOS version of DMM.
3. Open the mdb database.
4. Choose File-Save As and enter a new name for the database. After a short delay, DMM displays the new, updated database in its own window. From now on, you should use this new database. You may want to delete the old mdb database.

   Note: When you use the save-as command, DMM automatically assigns a file name using the words "copy of....." It also uses the default folder (Program Files\DMMWin\Project\). You will probably want to specify a different name. You may want to specify a different folder as well. If you save the program into the same folder, you must use a different name. DMM will not overwrite the existing database.
5. Check each installation record. If you use an English-unit system, check that you have English units and an instrument constant of 20,000 entered into the installation record.

   If you have metric-unit database, you must correct any decimal entry: shallowest depth, deepest depth, reading interval. You must also check that you have chosen metric units and have entered an instrument constant of 25,000.

   Note that these corrections affect only the installation information. Data is not affected and requires no corrections.

Appendix 8: Converting DOS DMM Databases

Introduction

- DMM for Windows uses an ".mdb" database. It replaces the old ".hdr" database used by the DOS version of DMM.
- If you use DigiPro for Windows, you already have an ".mdb" database, but you must update it with DMM. See the previous page.
- To convert "hdr" databases directly to mdb databases without going through DigiPro, use the utility program called HDR2MDB.EXE.

Using the Hdr2Mdb Utility

This program is installed in your DMM for Windows folder. It is used to convert DMM DOS databases to the DMM Windows format.

1. Start the Hdr2Mdb program.
2. Open an hdr database.
3. Specify a name and location for the mdb database, and click OK. After a short delay, the program announces a successful conversion.

   The program will prompt you if it cannot determine the serial number of your probe or whether it is a metric-unit or English-unit probe.

Work-Around for Double-Byte Windows

The Hdr2Mdb program does not work properly with double-byte Windows systems, such as Chinese, Japanese, and Korean Windows. We are sorry for this inconvenience. Here are two work-arounds:

- Install HDR2MDB on a computer that is running a US version of Windows. Do the conversion, then copy the new mdb database to your double-byte version of Windows.
- Use DMM DOS to export your surveys in RPP format, then import the surveys with DMM for Windows.

Appendix 9: Windows vs DOS DMM

Introduction

If you used the DOS version of DMM, you'll want to know what is different in the Windows version:

System Requirements

- DMM for Windows requires Windows 95/98/ME/NT4/2000.
- DMM for Windows does not run on DOS or Windows 3.1.

Project Database

- DMM for Windows uses an ".mdb" database. It replaces the old ".hdr" database used by the DOS version of DMM.
- You can convert your DOS hdr files to mdb files using DigiPro for Windows or the utility program called HDR2MDB.EXE.

DataMate Setup

- DMM for Windows creates a "setup database" to load installations (and surveys) into the DataMate. (There is no equivalent to the setup database in DMM for DOS.)
- The setup database lets you create an installation list from separate databases and is also used to manage the DataMate's memory.

Retrieving Data

- Datasets are called "surveys" in DMM for Windows.
- DMM lets you retrieve all surveys or new surveys. (In DMM DOS, you tagged each survey and then retrieved them).
- DMM holds retrieved surveys in a temporary database. You then drag and drop surveys into one or more project databases. (In DMM DOS, you retrieved surveys directly into the project database)

Managing DataMate Memory

- DMM provides two ways to clear the DataMate's memory. You can send a setup to the DataMate or you can use the erase memory command provided in DMM.
- To delete individual surveys, you must use the DataMate itself.

Managing the Database

- You can move misplaced datasets.
- You can shift columns of readings.
- You can easily copy installations and datasets between databases.
- You can easily create a database of new readings for emailing.

Appendix A6 - DigiPro for Windows

DigiPro
for Windows

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Introduction

Read This

- Even if you hate manuals, it is important that you read this introduction and the Quick Tour pages.
- If you have DigiPro version 1.26 or earlier on your computer, we suggest that you remove it before installing later versions. This will not affect your data files or your unlocking key.
- If you are working on an NTFS system (Windows NT 4, 2000, XP, or later), you may find that administrator rights are required to install DigiPro. See your IT person for help.

What is DigiPro?

DigiPro software is used to process and plot inclinometer data. It creates high-resolution graphs and provides advanced routines for identifying and correcting systematic errors.

DigiPro works with the project databases created by DMM for Windows. If your inclinometer readings are not in this format, see Appendix A.

DigiPro is not free software. It must be purchased. However, when you first install DigiPro, purchased or not, it will run 45 times, so you can get some work done without worrying about licensing. Read “About Unlocking Keys” on the next page.

Installing DigiPro from a Resource CD

1. Remove any earlier version of DigiPro first. Doing this will not affect your data or your unlocking key.
2. Insert the Resource CD in your CD-ROM drive. The CD will start automatically on some computers. On other computers, you have to open and close the CD-ROM drive a second time to make Autostart work.
3. The browser window appears: click on Software.
4. The software page appears: click on DigiPro for Windows.
5. The DigiPro page appears: click on “Download DigiPro.”
6. The File-Download dialog appears: choose "Run this program from its current location" and click OK. You may see an security warning. Click Yes to continue the install.
7. Follow on-screen instructions. You may be asked to restart your computer more than once.

Installing DigiPro from a Setup File.

If you downloaded DigiPro from www.slopeindicator.com, you have a setup file named "setupdpwin.exe" on your hard disk.

1. Remove any earlier version of DigiPro first. Doing this will not affect your data or your unlocking key.
2. Click the Start button and choose Run.
3. The Run dialog appears: click the Browse button to navigate to the setup file that you downloaded.
4. Select the setup file (setupdpwin.exe) and click Open.
5. Click OK when the Run dialog reappears.
6. Follow on-screen instructions. You may be asked to restart your computer more than once.

About Unlocking Keys

After DigiPro is installed, it will run 45 times. After that, it will stop running. To remove the run-limitation, you must purchase DigiPro and request an unlocking key (a coded number). If you have already purchased DigiPro, we have your company and city in our database, but you must contact us for the key. Follow the steps below:

To obtain a key

1. Find your DigiPro serial number. Start DigiPro. When the start screen appears, click on the "License" button. A dialog appears with the serial number.
2. Use one of the methods below to contact us. We need your serial number, name, company, and city.

- Visit www.slopeindicator.com. Click on "Support," then click on "Get a DigiPro Key" and fill out the form.
- Call Slope Indicator or your local distributor.
- Fax Slope Indicator or your local distributor.

3. We will generate a key to match your serial number and give it to you.

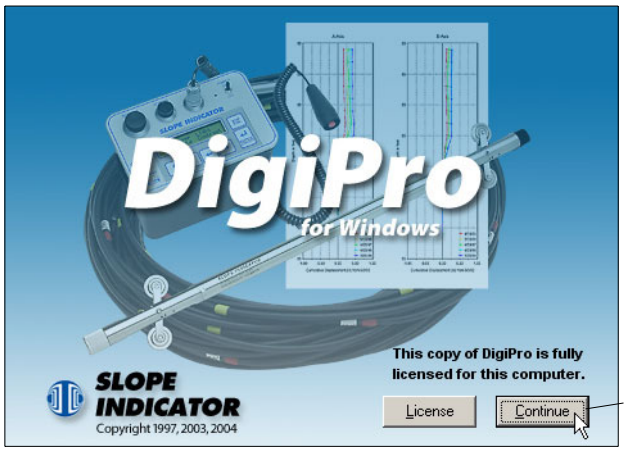
To enter the key

1. Start DigiPro. The start screen appears. Click on License.
2. Check that your serial number is the one that you sent us, then click on Modify.
3. Enter your the unlocking key, and click OK.
4. You should see the message: "This copy of DigiPro is fully licensed for this computer."

Quick Tour

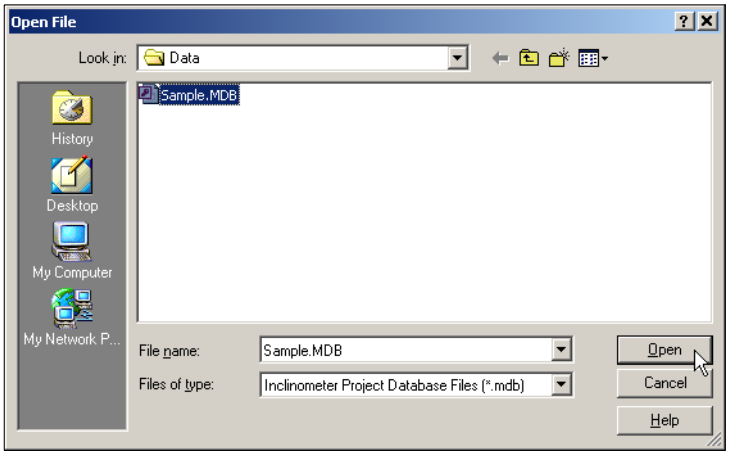
Start DigiPro

Click on the DigiPro shortcut, or go to:
Start > Programs > DigiPro > DigiPro.exe. Click Continue.



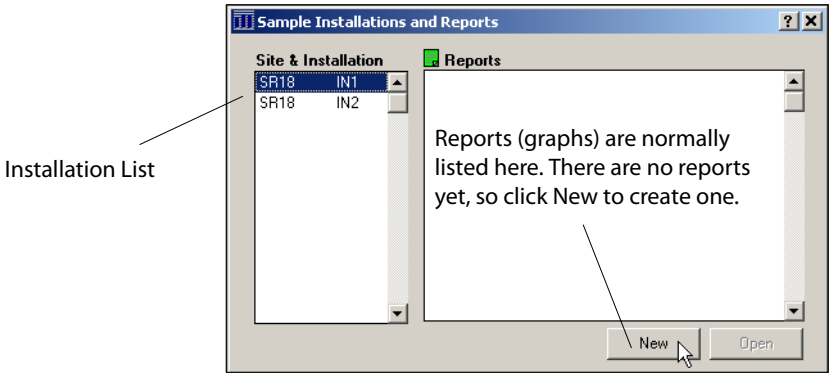
Open a Database

DigiPro displays the Open File dialog. Choose "Sample.MDB." If you don't see it, navigate to C:\Program Files\DigiPro\Data.



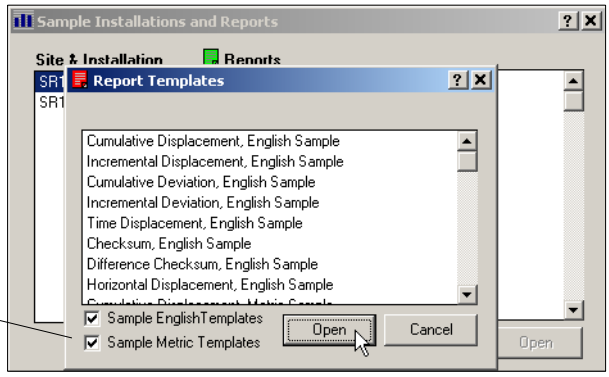
Choose an Installation and Create a Report

DigiPro displays a list of the installations in the database. Select the top one, SR18 IN1, and click New to create a report.



Choose a Report Template

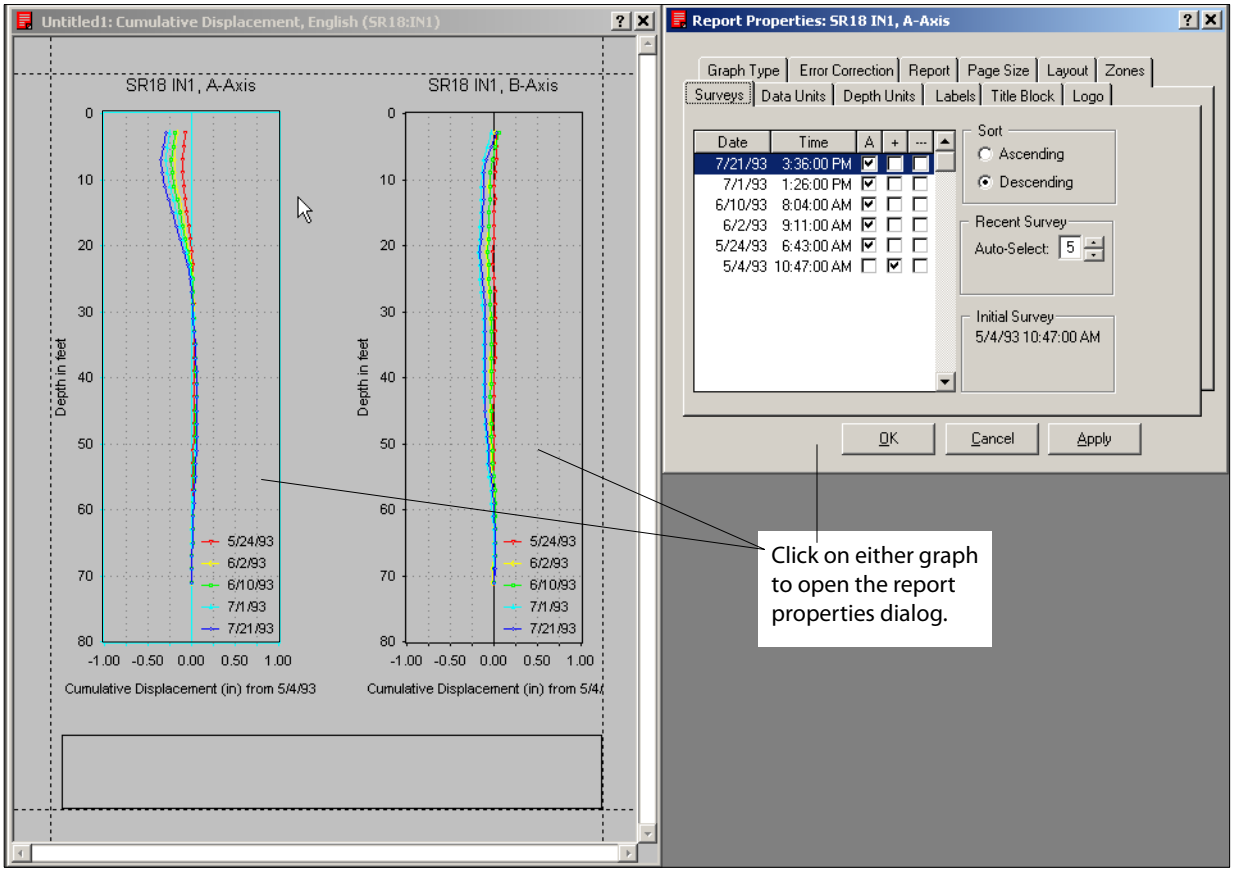
DigiPro displays a list of report templates. Each template offers a different type of graph. Choose “Cumulative Displacement, English Sample.” Click Open.



If you use metric data, you can hide the english-unit templates, and vice versa. You can also make your own templates.

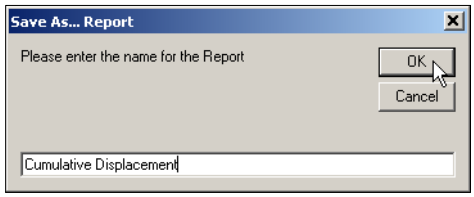
View and Modify the Report

The report appears with two graphs. Click on either graph to open the report properties dialog. Using the report properties dialog, you can select different surveys, modify scales and labels, add text to the title block, and make other changes.



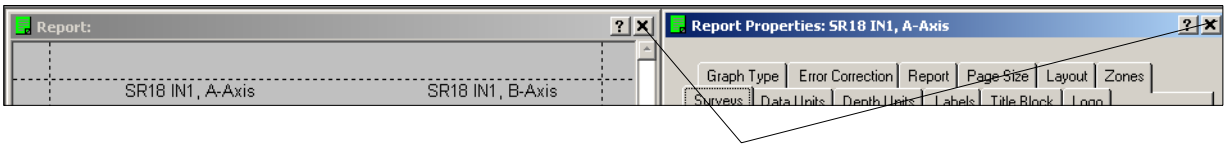
Save the Report

Click the disk icon or choose File > Save As >Report. Enter a name, and click OK. DigiPro stores the graph type and all the settings for the graphs.



Close the Report

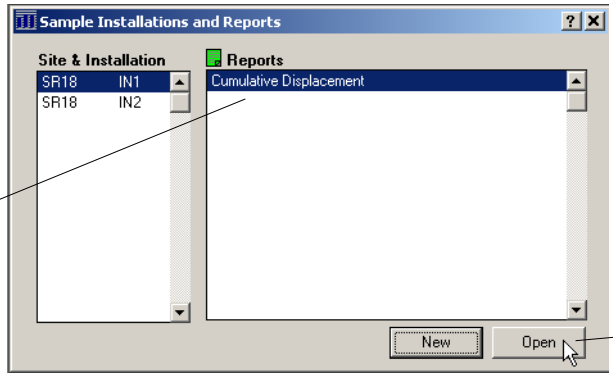
Click the X in the upper right corner of the graph. Close the report properties dialog too.



To close the dialog or graph, click the X box.

Open the Report to Recreate the Graphs

Select the report and click Open. DigiPro recreates your graphs. In addition, DigiPro automatically includes any new surveys that were added to the database, so the graphs are updated too.

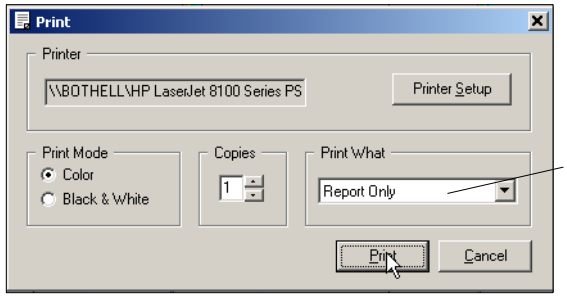


Reports are listed in the reports window. To recreate a graph, select a report and click Open.

Click Open to open a report.

Print the Report

When the graph appears on screen, click on the printer icon, or choose Print from the File menu.



This prints just the graph. You can also print a listing of the current survey.

Creating Reports

Overview of Reports

- It's easy to make reports: simply open a report template and save the resulting graph.
- Reports save time. You can reproduce or update a graph with just two mouse clicks.
- Reports can be customized. For example, you can specify two different types of graph for the report.
- You can create as many reports as you need.
- You can save the report as a template.

Creating a Report

These basic steps are explained in detail on the following pages.

1. Open a database.
2. Select an installation.
3. Choose a report template.
4. Save the report.

Open a Database

1. Start DigiPro, and click the Continue button.
2. The Open File dialog appears. DigiPro displays the most recently opened folder.
3. Select your database, and click Open.

How to find your database

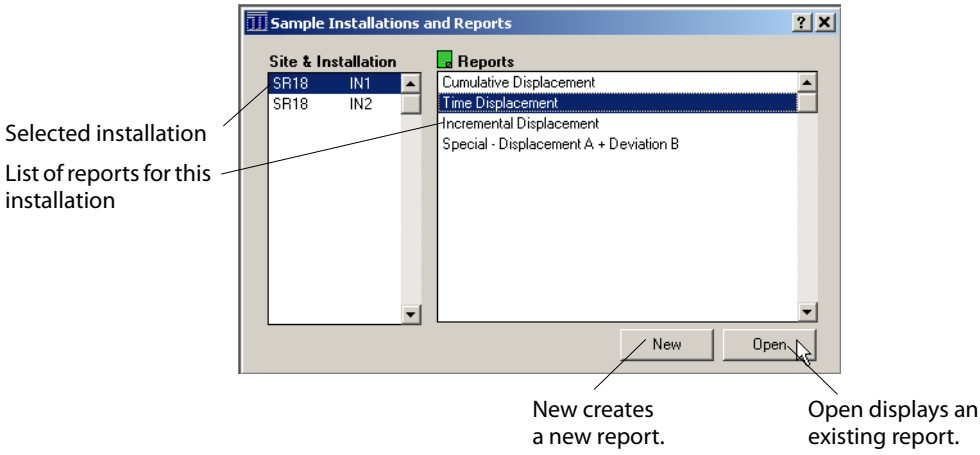
- If you can't see your database, click in the "Look-in" field to navigate to a different folder or drive.
- The default location used by DMM for Windows is: C:\Program Files\ DMMWin\Projects.
- DigiPro keeps a list of the last five databases that you opened. To see this list, click on the File menu (Close the Open File dialog first). The databases are listed at the bottom of the menu.

How to create a database

If you don't have a database, you must create one with DMM for Windows. DMM can also convert and import data. DMM is a free download from www.slopeindicator.com. See Appendix A for more information.

Select an Installation

After you open a project database, DigiPro displays the "Installations and Reports" dialog. The left side of this dialog shows a list of installations. Click on the installation of interest.



New vs Open

After you select an installation, you can choose to create a new report or open an existing report.

- To create a new report, click New.
- To open an existing report, select it and click Open.

Choose a Report Template

If you clicked New in the previous step, DigiPro displays a list of report templates. Each template offers a different type of graph. Graph types are explained on the following page.

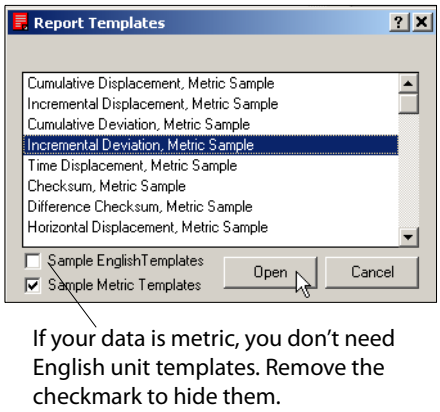
English-Units or Metric-Units?

1. Select a template. Note that there are English-unit templates and metric-unit templates.

   It is important to choose correctly because this controls how readings are processed.

   - Choose English if you use an English-unit probe.
   - Choose metric if you use a metric-unit probe.

2. Click Open.



If your data is metric, you don't need English unit templates. Remove the checkmark to hide them.

Note: DigiPro allows you to change the displayed units later, if necessary, but at this point, you must choose according to your probe units.

Creating Templates

You may find it convenient to make your own templates. For example, you may want templates that have:

- A title block with your company's name and logo.
- Standard depths.
- Different types of graph in the same report.

To Create a Custom Template

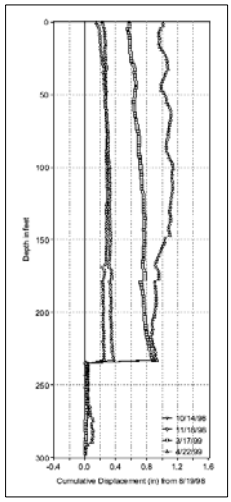
1. Open a report. Modify it as needed.
2. Choose File > Save As > Template.
3. The new template will appear in the Report Templates dialog.

Note: DigiPro's templates are stored in the "templates.mdb" file in the DigiPro\System folder. You can copy this file to other computers.

Graphs for Analyzing Movement

These graphs are the standard graphs used to analyze the behavior of the ground.

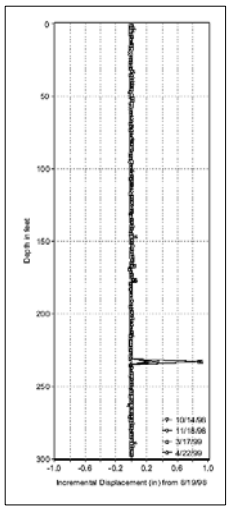
Cumulative Displacement



Displacements are changes in the position of the casing and are assumed to be equivalent to ground movement. A displacement graph requires at least two surveys: an initial survey and a current survey. The initial survey does not appear on the graph.

In a cumulative displacement graph, the plotted point at any depth is the sum of incremental displacements from the reference point (typically the bottom). The graph shows how subsurface movement relates to movement at the surface. Shear movements are easily seen.

Incremental Displacement

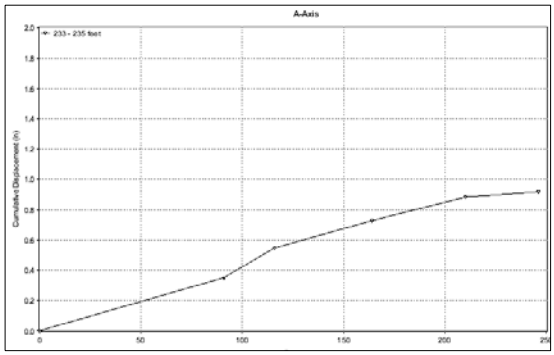


This graph shows displacements at discrete depths. A growing "spike" indicates movement. The graph at right uses the same data as the cumulative displacement plot above.

No summing is involved, so systematic error is minimized.

Time Displacement:

This graph shows the rate of movement at one or more zones. A steepening slope represents accelerating movements.



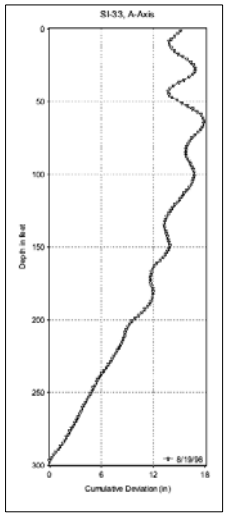
The plotted value for each zone is the difference between the displacement value at the top of the zone and the displacement value at the bottom of the zone. Zones are set in the "zone" tab of the report properties dialog.

Graphs for Diagnosing Systematic Error

These graphs are generally used for troubleshooting or verifying that graphs represent movements accurately.

Cumulative Deviation

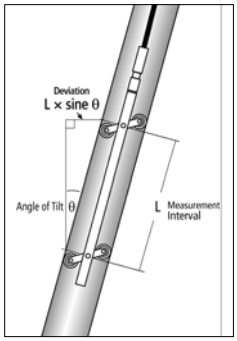
This graph shows the profile of the casing relative to vertical. Drillers can use this graph to see borehole drift.



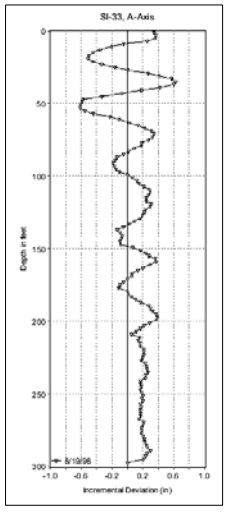
The plotted point at any depth is the sum of incremental deviations up to and including that depth. (Deviations are defined below).

In error analysis, this graph is used to show the potential for systematic error due to cross-axis tilt and a rotation of the sensitive axis of the inclinometer probe.

Incremental Deviation



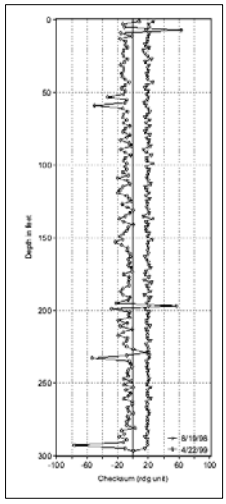
This graph shows the deviation at each depth. This represents the curvature of the casing. The drawing at left shows deviation. The angle of tilt is measured by the inclinometer, the hypotenuse is the measurement interval (typically the distance between the wheels) and the side opposite the angle is the deviation.



In error analysis, this graph is used to show the potential for systematic error due to casing curvature and settlements or inaccurate depth control.

Checksum and Difference Checksum

Checksums are the sum of the "0" and "180" readings at each depth.



In error analysis, this graph provides an indication of the potential for systematic error due to bias shift. A tilted plot may indicate problems with the electronics of the sensor.

The difference-checksum graph shows changes in checksum, and removes variations that are due solely to characteristics of the installed casing.

Save the Report

After you have selected a template and clicked Open, DigiPro displays the new report.

1. Choose File>Save from the menu or click the disk icon.
2. The Save As dialog appears. Enter a name for the report and click OK.

Naming a Report

- A simple name, such as “Cumulative Displacement” is sufficient, since it indicates the kind of graph that the report will produce.
- There is no need to make unique names for reports. Each installation has its own list of reports. For example, you can have a report named “cumulative displacement” for each of your installations. In fact, this is recommended.
- To rename a report, right-click on the report name and choose “Rename” from the pop-up menu.

Modifying Reports

Overview

The basic steps required to modify a report are:

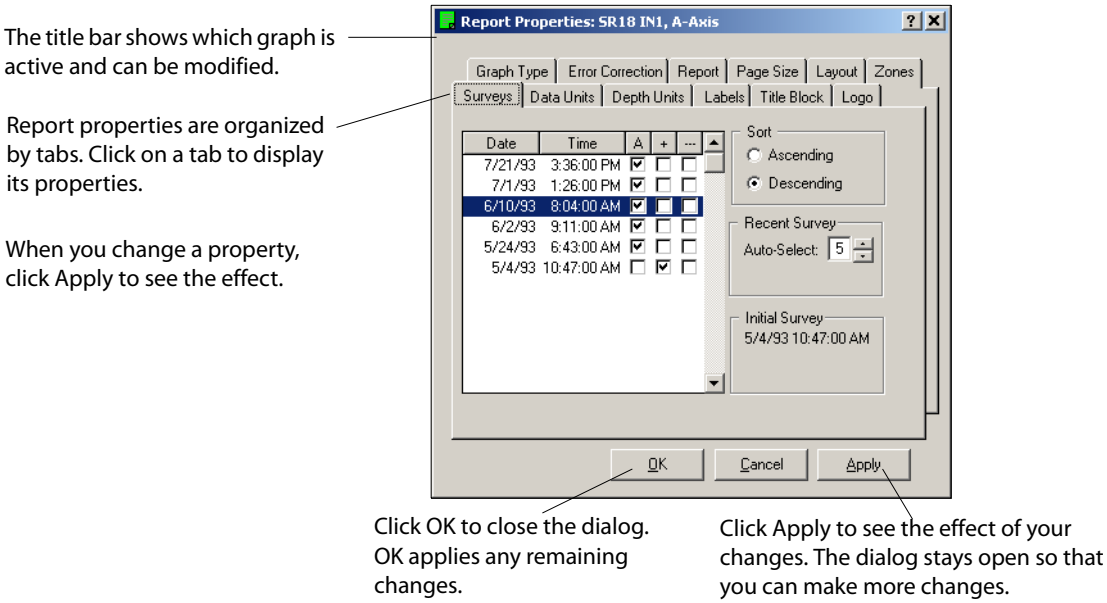
1. Open the report.
2. Open the Report Properties dialog.
3. Modify the properties for each graph.
4. The settings that you have changed are saved with the report and are automatically retrieved the next time you open the report.

Open a Report

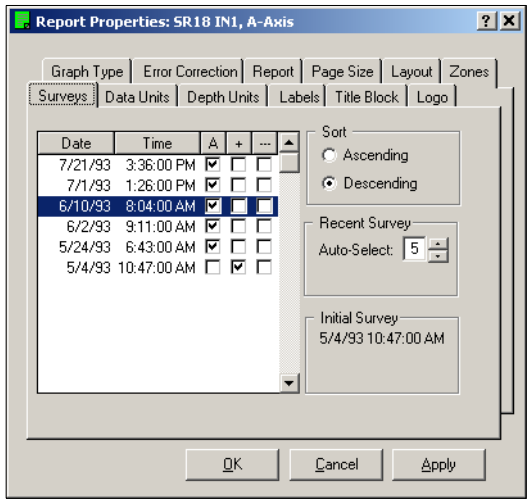
1. Start DigiPro.
2. Open a project database.
3. Choose an installation.
4. Click on the report that you want to modify.
5. Click on the Open button.

Open the Report Properties Dialog

1. Click on either graph. The report properties dialog appears.
2. The title bar shows which graph is active. To make the other graph active, just click on it.



Surveys



What is a Survey?

A survey is the data from one inclinometer survey. Each survey is identified by date and time.

Survey Selection

DigiPro graphs only surveys that have been selected. Check boxes for each survey indicate its selection status.

- A check mark in the A column indicates that the survey is auto-selected. New surveys are auto-selected so that DigiPro can update graphs automatically. The Recent Surveys field controls the number of auto-selected surveys.
- A check mark in the + column indicates that the survey is selected permanently. It will be used every time you run a report. Click the box to check or uncheck.
- A check mark in the – column indicates that the survey is excluded permanently. Click the box to check or uncheck.
- Surveys with no checkmark are not selected. When you have many surveys, most of them will have this status.

Sort

Sorts the order of the surveys in the Selection window.

- Ascending displays oldest survey first.
- Descending displays newest survey first.

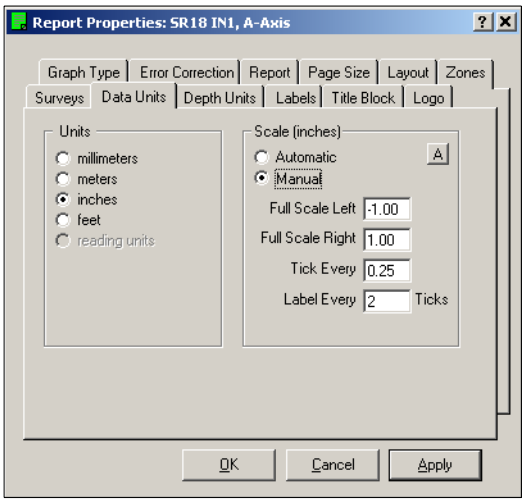
Recent Survey Auto-Select

Specifies the number of new surveys to be automatically selected for the report. To change the number, click the up and down arrows next to the number. Then click apply.

Initial Survey

Shows which survey is used as the initial. DigiPro automatically selects the oldest survey as the initial and puts a check mark in the + column. To choose a different initial survey, scroll the window until you can see it. Then right click on the + box and choose “Mark as Initial Survey” from the pop-up menu. Note that earlier surveys are ignored.

Data Units



Unit Conversion

The Unit conversion setting is provided for US users who need metric-unit reports from their English-unit inclinometer systems. These users should use the standard English-unit templates and make the conversion here by clicking the radio button for mm.

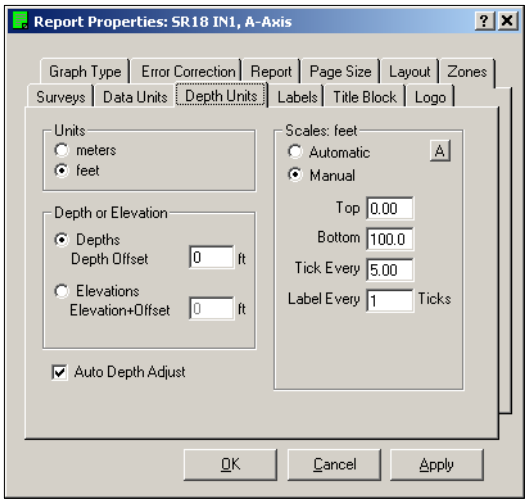
Other users will probably not need this setting because templates provide appropriate units automatically. Be sure to choose metric templates for metric inclinometer systems and English templates for English-unit inclinometer systems.

Troubleshooting Note: If you have used the correct templates but your units and values appear strange, don't try to correct the problem with the units conversion setting. Instead, go back to the Installation and Reports dialog, right-click on the installation, and choose "properties" from the pop up menu. Check that Units is properly set to English or Metric (the same units as your inclinometer system).

Scales

- Automatic: Sets full scale left and right to accommodate the maximum values found in the surveys.
- Manual: Allows manual control over the settings. Click on the Manual button to show the fields below:
- Full Scale Left: Enter a value to be used for full scale left.
- Full Scale Right: Enter the value to be used for full scale right.
- Tick every: Ticks are graduations on the data scale. For example, if you want a graduation every 10 mm, enter 10.
- Label every nth tick: DigiPro will label every nth tick. For example, enter a 2 to label every second tick. For example, if ticks are 10 mm apart, labels will appear every 20 mm.

Depth Units



Unit Conversion

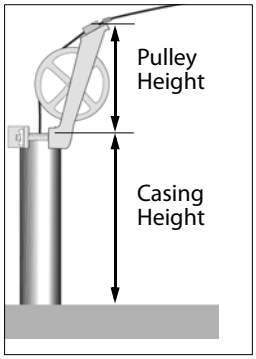
The Unit conversion setting is provided for US users who need metric-unit reports from their English-unit inclinometer systems. These users should use the standard English-unit templates and make the conversion here by clicking the radio button for m.

Other users will probably not need this setting because templates provide appropriate units automatically. Be sure to choose metric templates for metric inclinometer systems and English templates for English-unit inclinometer systems.

Depth or Elevation

You can show depth-axis labels as depths or elevations. Click the appropriate radio button. If you choose elevations, you must also enter the elevation at the top of the casing. See depth offset and elevation offset below.

Depth Offset



During a survey, depths are read from the control cable, which is referenced to the top of the casing or (preferably) to the top of the pulley assembly. If you want the depth-axis labels referenced to ground level, enter an offset:

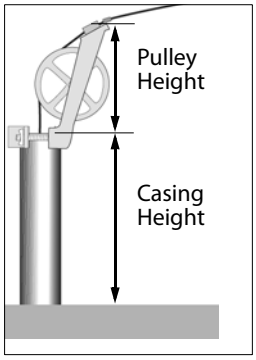
Depth Offset = casing height + pulley height

Casing height is the height of the casing above ground level. Pulley height is 1 foot or 0.3 meters.

Metric Example: The top of the casing is 0.5 meters above ground level. The pulley assembly adds 0.3 meters. Enter 0.8 meters for the depth offset. Now the depth-axis label scale will be referenced to ground level.

English Example: The top of the casing is 14 inches (1.17 ft.) above ground level. The pulley assembly adds 1 foot. Enter 2.17 feet for the depth offset.

Elevation + Offset



If you want the depth-axis label referenced to elevations, first click the radio button for elevations, then enter an offset:

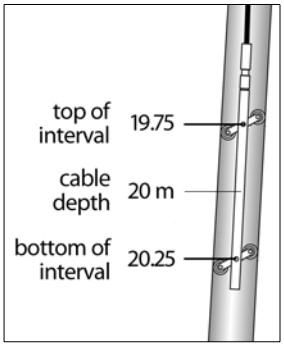
Elevation Offset = ground elevation + casing height + pulley height

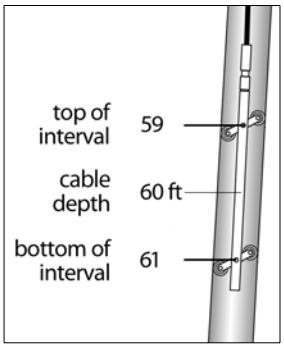
Casing height is the height of the casing above ground level. The pulley assembly adds 0.3 meters (1 foot).

Metric Example: Ground elevation is 200 meters above sea level. The top of the casing is 0.4 meters above ground level. The pulley assembly adds 0.3 meters. Enter 200.7 meters for the elevation offset. Labels will be referenced to ground elevation.

English Example: Ground elevation is 1200 feet above sea level. The top of the casing is 1.5 feet above ground level. The pulley assembly adds 1 foot. Enter 1202.5 feet for the elevation offset.

Auto Depth Adjustment





With auto-depth adjustment turned on, DigiPro correctly plot data points at the top (or bottom) of the measurement interval. Auto-depth is turned on by default.

Why is an adjustment provided? Depth marks on Digitilt control cable are measured from the middle of the inclinometer probe, but deviations and displacements are calculated for the top (or bottom) of an interval.

Metric example: The depth stored with the inclinometer reading is the cable depth of 20 meters, but the top of the interval is actually at 19.75 meters. With auto-depth adjust turned on, the plotted point will be placed correctly on the graph at 19.75 meters, not at the cable depth of 20 meters.

English example: The depth stored with the inclinometer reading is the cable depth of 60 feet, but the top of the interval is actually at 59 feet. With auto-depth adjust turned on, the plotted point will be placed on the graph at 59 feet, not at the cable depth of 60 feet.

On the graph, these adjustments are visually quite small, but if you print out the data, you will see the adjusted depths.

Scales

DigiPro sets the depth axis scales automatically, or lets you specify values for the top and bottom of the depth-axis scale.

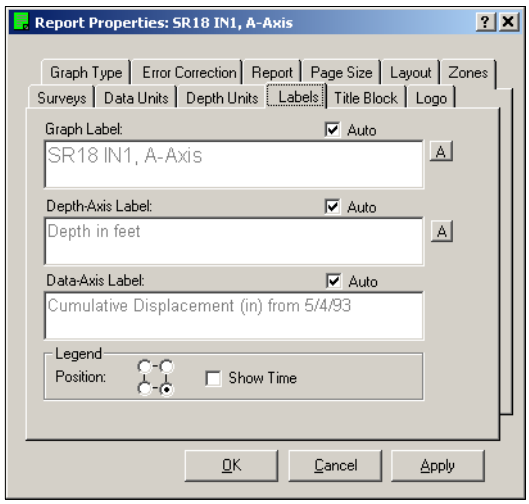
Automatic: Automatically displays the entire depth-axis and applies labels and ticks at multiples of 10.

Manual: Allows manual control of scales. Click on the Manual button and enter the desired values in each field. If your report shows elevations rather than depths, be sure to enter elevations for top and bottom. Click Apply when finished.

- Top: Enter a value for the top of the depth-axis scale.
- Bottom: Enter a value for the bottom of the depth-axis scale.
- Tick every: Ticks are graduations on the depth-axis scale. If you want a graduation every 5 meters, enter 5.
- Label every nth tick: DigiPro will label every nth tick. For example, enter 2 to label every second tick. For example, if ticks are 5 meters apart, labels will appear every 10 meters.

Tip: If you frequently zoom in to inspect a particular zone, you might find it useful to make a report that shows only that zone. Use manual scales to specify the top and bottom of the zone, then save the result as a new report.

Labels Tab



Editing a Label

DigiPro creates graph labels and legends automatically. This dialog lets you change the automatic labels. If you want these labels changed for all subsequent reports, save the report as a template (See page 8).

1. Click to remove the check mark from the Auto box above the Label field. When the check is removed, you can edit the text.
2. Enter text in the Label field. The Graph Label field accepts up two lines of text. The Depth-Axis and Data-Axis fields accept one line of text. The A button lets you choose a font.
3. Click Apply to see your changes.

Note: If your Windows display is set for Large Fonts, text appears larger on-screen than it prints on paper. Print the report to see the true effect, then modify as needed.

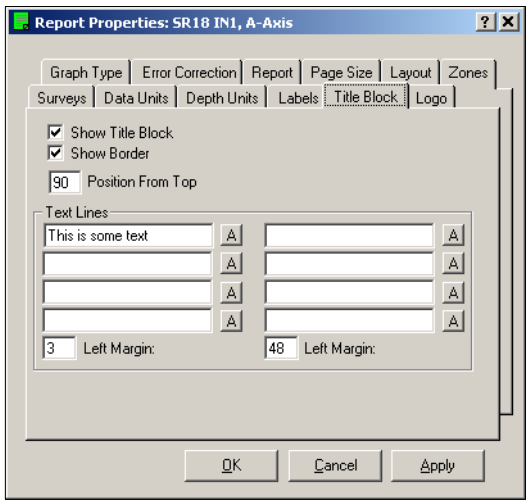
Legend Position

DigiPro can place the legend in one of the four corners of the graph. For example, if you click the upper right button in the square, the legend will appear in the upper right corner of the graph when you click Apply.

Show Time

DigiPro can append time to the date in the legend. Normally time is not required, but if you need it, click in the checkbox.

Title Block



Function

The title block provides a place to enter information about the graph. You can also include a company name, address, and company logo in the title block. If you want to add a logo to the title block, use the Logo tab before setting the title block text.

Text Lines

DigiPro provides eight cells for text arranged into two columns. Click in one of the eight fields to enter text. When finished, tab to the next field. Click Apply to see the result on screen.

Note: The screen display of text is not accurate, especially if your display is set for Large Fonts. Print the report to see the true appearance of the text.

Tip: Save the report as a template so you can base future reports on the same style with very little additional work. (See page 8).

Left Margin

There are two left margin fields, one for each column of text. Enter a percentage value, estimated from the left side of the page. Then click Apply.

Show Title Block

When the box is unchecked, DigiPro shows the title block. If you hide the title block, you can enlarge your graphs using the Layout tab.

Show Border

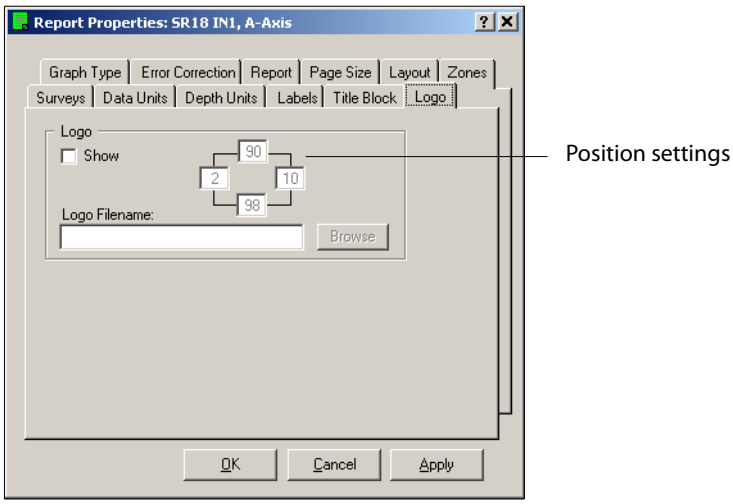
When the box is checked, DigiPro draws a line around the title block. You may find that hiding the rule provides a neater result.

Position from Top

Enter an estimated percentage value. By default, the title block appears at the bottom of the page. However, if you set the value to zero, it will print at the top of the page.

Note: If you change the position of the title block, you must move the graphs down using the Layout tab.

Logo



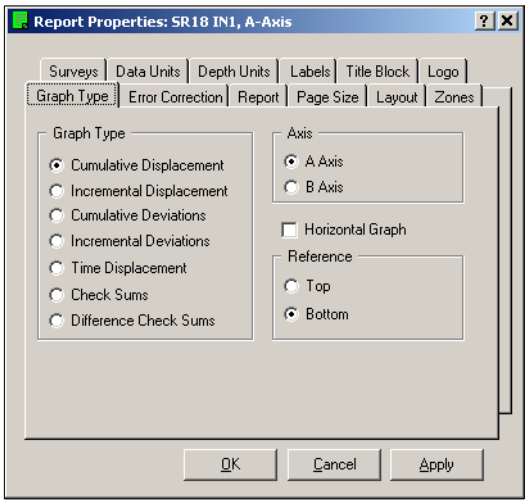
Displaying a Logo

DigiPro has a simple facility to print a bitmap (.bmp) image of your logo on the report.

1. Click (check) the Show check box.
2. Enter the path and file name of your logo. You can use the browse button to do this for you.
3. The position settings are percentages. They change the boundaries of the logo box and also the position of the logo box. You will probably need to make several adjustments to find the right setting.

Note: We recommend that you place the logo file in DigiPro's BMP folder so that it will not be accidentally lost during routine disk cleanups. The path will appear like this: C:\Program Files\DigiPro\BMP\myLogo.bmp.

Graph Type



Overview

This useful feature lets you change the type of graphs shown in the report. For example, you could place a graph of time displacement next to a graph of cumulative displacement. You could also show two versions of the same graph, one with error correction turned on and one with error correction turned off.

Graph Type

Graph types are explained in "Creating a Report." The radio button shows the type of graph currently displayed. To change, click a different radio button. When you click Apply, the graph is redrawn.

Axis

The sample templates use A-axis data for the left graph and B-axis data for the right graph, but you are not limited by this. You can show two A axis graphs or two B axis graphs, etc.

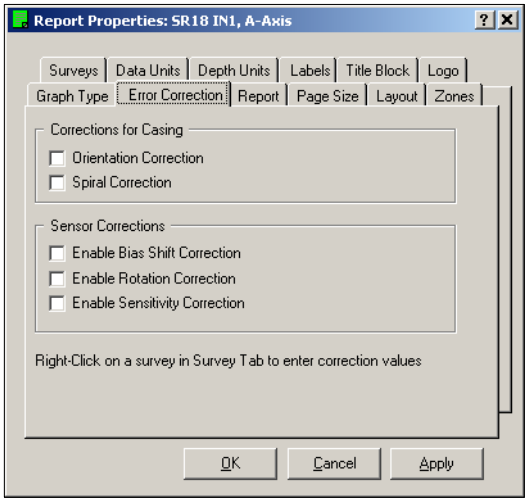
Horizontal

It is easier to use the Horizontal template to create a horizontal graph, but this checkbox is here for completeness.

Reference

Select top or bottom of the casing as the starting point for calculations of cumulative displacement and cumulative deviation. Bottom reference is the default.

Error Correction

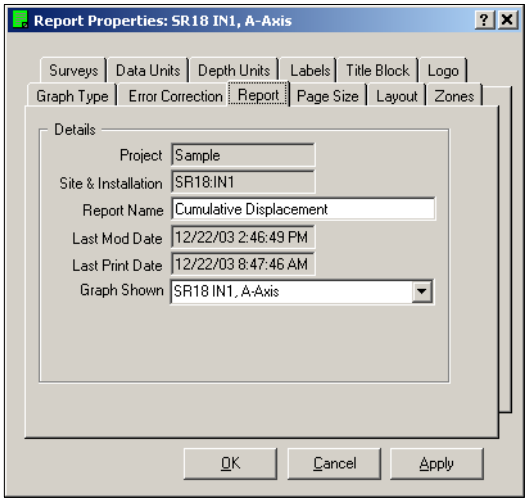


Overview

This dialog lets you enable and disable correction routines. Except for the orientation correction, values used by the routines are entered elsewhere. For information on corrections, see the chapter on error correction.

- To enable a correction routine, put a check in its checkbox.
- To disable a correction routine, remove the checkmark.

Report



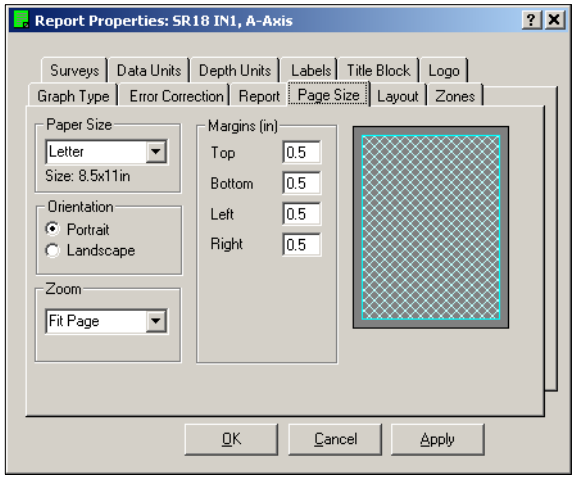
Overview

This dialog is generally not used. Only two fields can be manipulated: report name and graph shown.

Report Name: You can rename a report here. Note that you can also rename a report by right clicking on the report in the installations and reports dialog.

Graph Shown: This can be used to show a graph that was previously hidden.

Page Size



Overview

Page size and orientation are generally set by report templates. Global defaults are controlled by settings in the File > Options and Defaults dialog. The settings here affect only the current report.

Paper Size

Controls paper size.

Orientation

Controls the page orientation for the report. Choices are portrait (long side is vertical) or landscape (long side is horizontal).

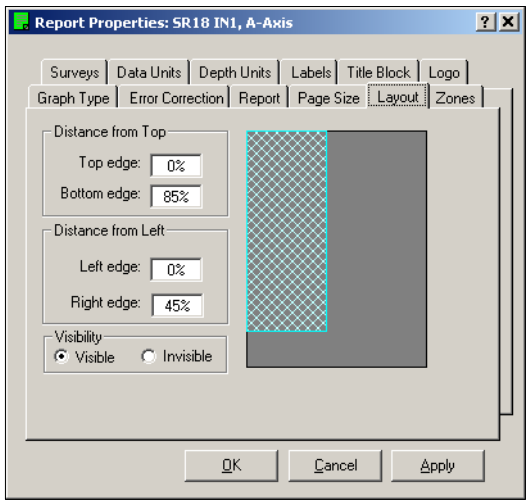
Margins

Controls the page margins for the report. The default margin values are in inches. If you select the A4 or B4 paper sizes, the margin values automatically convert to centimeters.

Zoom

Controls the screen size of the report. The default is “Fit Page,” which allows the report and report properties to be displayed on-screen simultaneously (with no overlap) on a monitor set to a resolution of 800x600 or better.

Layout



Overview

Layout settings determine the placement and size of each graph.

Distance from Top

This controls the vertical size and placement of a graph.

1. Click on a graph. An image of the graph appears in the dialog box.
2. Enter values for the top and bottom edges of the graph in percent from top of page.

Distance from Left

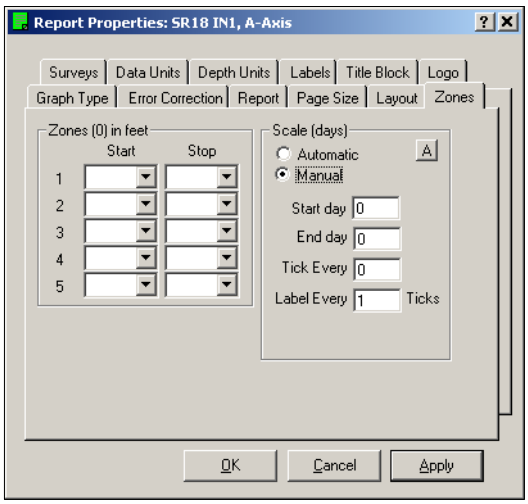
This controls the horizontal size and placement of the graph.

1. Click on a graph. An image of the graph appears in the dialog box.
2. Enter values for the left and right edges of the graph in percent from left side of page.

Visibility

This controls whether a graph is visible or not. For example, if you want only one graph on the page, you can hide the other graph and then adjust size and placement of the visible graph as needed.

Zones



Overview

The zone tab is used to select zones for time-displacement graphs.

Zones

You can graph up to five zones by specifying a start and stop depth for each zone. Click the drop list to choose a valid depth or elevation. The stop depth must be deeper than the start depth.

The value that DigiPro plots is the difference between cumulative displacement at the start depth and cumulative displacement value at the stop depth.

Scales

The automatic setting shows the number of days from the initial survey. The manual setting lets you choose a start and an end day to show only a portion of the available time span. You can also set the frequency of tick marks (in days) and labels (numbers). The current version of DigiPro does not allow display of dates.

Printing a Report

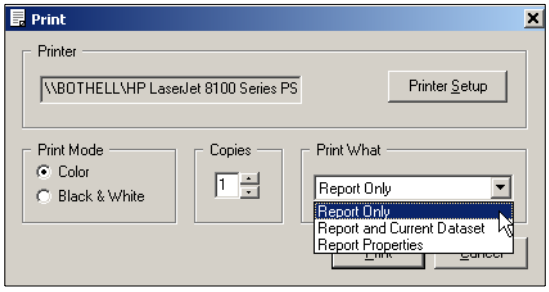
Overview

DigiPro offers the following options

- Print report only or report with current survey data.
- Print plotted data
- Write plotted data to a file

Printing a Report

1. Open a report.
2. Choose File>Print from the file menu, or click on the printer icon located on the tool bar. The Print dialog appears.



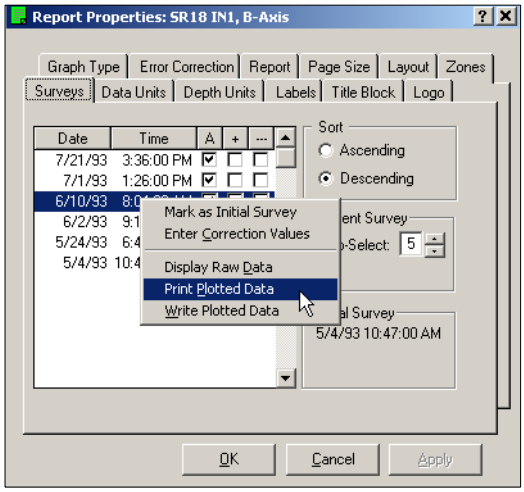
3. Click in the "Print What" field. Choose Report Only or Report with Current Survey.
4. Check the Printer window to be sure it displays the printer you want. To change printers or adjust the printer setup, click on the Printer Setup button.

   Note: If you change the printer in DigiPro's Print dialog, the new printer becomes the Windows default printer.
5. Click in the Copies field and enter the number of copies you want.
6. Select a print mode: color or black and white. (If you are using a black and white printer but choose the color print mode, the report will print in grayscale.)
7. Click Print to print the report.

Note: You can change the colors that DigiPro uses, if some plots are hard to see. Choose File>Options and Defaults>Preferences. You will see a band of eight colors. click on the color that you want to change and choose a different color from the pop up menu.

Printing Plotted Data

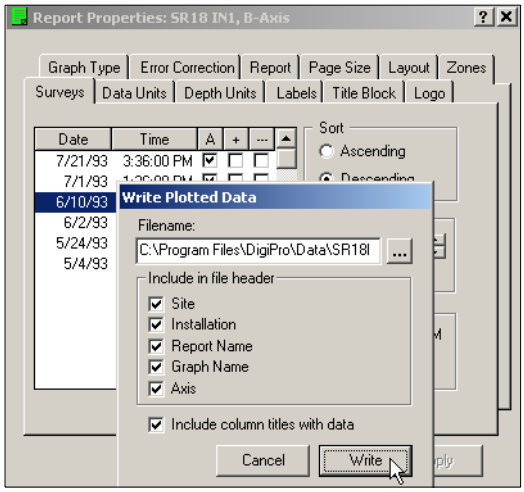
Plotted data are the data points plotted on the graph. DigiPro can print a maximum of 8 columns of data.



1. Open a report and click to open the report properties dialog.
2. Place the pointer in the Survey window and right click.
3. Choose Print Plotted Data from the pop-up menu.

Writing Plotted Data

You can write plotted data to a file for use in a spreadsheet. You can write a maximum of 8 columns of data



1. Open a report and click to open the report properties dialog
2. When the Report Properties dialog appears, click in the survey window.
3. A menu appears. Choose Write Plotted Data.
4. A submenu appears. Choose the items that you want to appear in the file header. You can also specify a filename and location if the default filename is not suitable.
5. Click Write to write the data to the file. The file is placed in the same folder as your project database. It has a .txt extension.

Error Correction

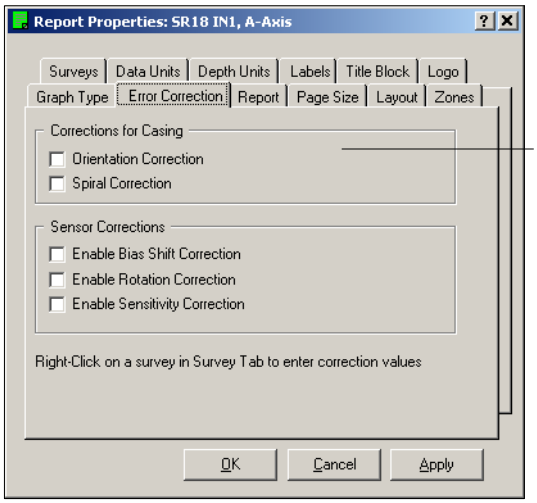
Introduction

The error correction routines that are built into DigiPro were requested by expert users. Error correction is not a simple subject, and applying corrections appropriately requires knowledge and experience.

In this chapter, we provide an brief introduction to some aspects of error correction. Those who need to know more should consider attending Slope Indicator's short course on Data Reduction and Error Correction. The course schedule is listed in the Training section at www.slopeindicator.com.

Enable or Disable Corrections

Correction values are stored separately from readings and are applied on-the-fly when the graphs are generated. Thus corrections can be enabled and disabled at any time



Use the report properties dialog to enable or disable corrections.

- Correction routines are disabled by default.
- If you want to use correction routines, use the report properties dialog to enable them.
- Correction routines apply at the graph level. Thus a report can show one graph with corrections turned on and another graph with corrections turned off.
- Corrections values for casing are entered once for each installation and are applied to any survey selected for the graph.
- Corrections values for sensors (inclinometer probes) are entered for each survey that requires them. A special dialog is used for this.

Corrections for Casing

Corrections for casing are accessed with the report properties dialog.

Orientation Correction

If casing grooves are not oriented to the direction of movement, you can use DigiPro to mathematically rotate the orientation of the measurement axes into the direction of interest.

1. Enable the Orientation Correction. An entry field appears.
2. Enter an orientation correction in degrees. For example, enter 10 to rotate the orientation 10 degrees clockwise.
   Enter -10 to rotate orientation 10 degrees counterclockwise.

Spiral Correction

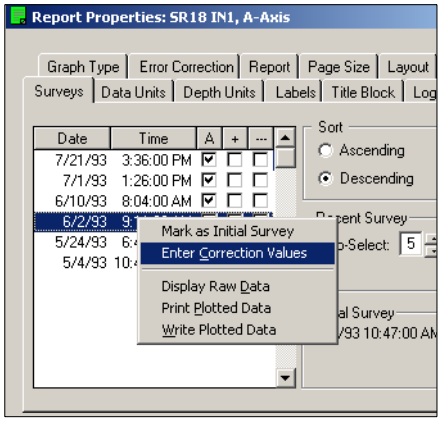
A spiral survey, obtained with a spiral sensor, provides measurements that can be used to correct for spiraled (twisted) casing. The spiral survey is processed and placed in the database by DMM for Windows. DigiPro has no entry fields for spiral data.

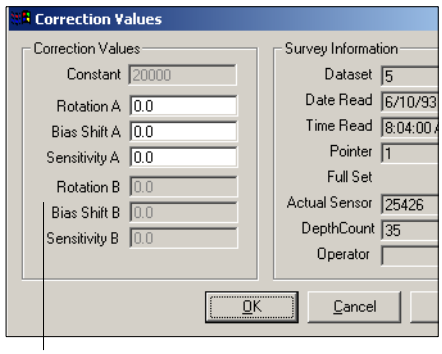
DigiPro automatically recognizes the spiral survey if it is present. If DigiPro cannot find a spiral survey, the checkbox is grayed out and cannot be enabled.

Corrections for Sensors

These corrections must be entered for each survey.

1. Enable the correction.
2. Click on the Surveys tab.
3. Right click on the survey that requires correction. A dialog appears.
4. Choose Enter Correction Values. The Correction Values dialog appears.
5. Enter a value in the appropriate field.
6. Click Apply to see the effect on the graph.
7. Repeat steps 5 and 6 until the correction value is correct.





To enter values for the B axis, you must click on the B-axis graph.

Bias-Shift Error

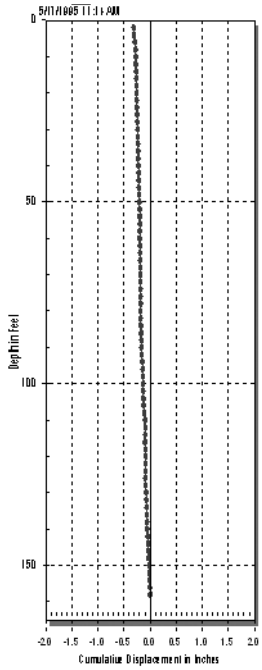
Bias shift values are entered in reading units. Here is a simple introduction to bias shift error. More information can be found in the "Training" section of www.slopeindicator.com.

What is Bias Shift

Bias: If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value. This is the probe's bias. The bias value is normally eliminated in the data reduction process when the 0 readings are combined with the 180 readings.

Bias-Shift Error: If the bias value changes during a survey, the data reduction process cannot eliminate all of the bias. The remaining value is error that is embedded in the reduced data.

The straight, but leaning plot at right is the result of bias-shift error.



Identifying Bias Shift Error

Appearance: A straightened, but leaning cumulative displacement plot is a signature of bias shift error. The embedded error grows larger at each interval, so the plot leans to the left or right.

Unlikely Behavior: The graph above shows rotation of the entire 150 foot span of soil or rock. This unlikely behavior suggests error in the data.

Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error. In our example, we know that the casing entered rock below 80 feet, and that no movement has occurred from 80 feet downwards. This again suggests error in the data.

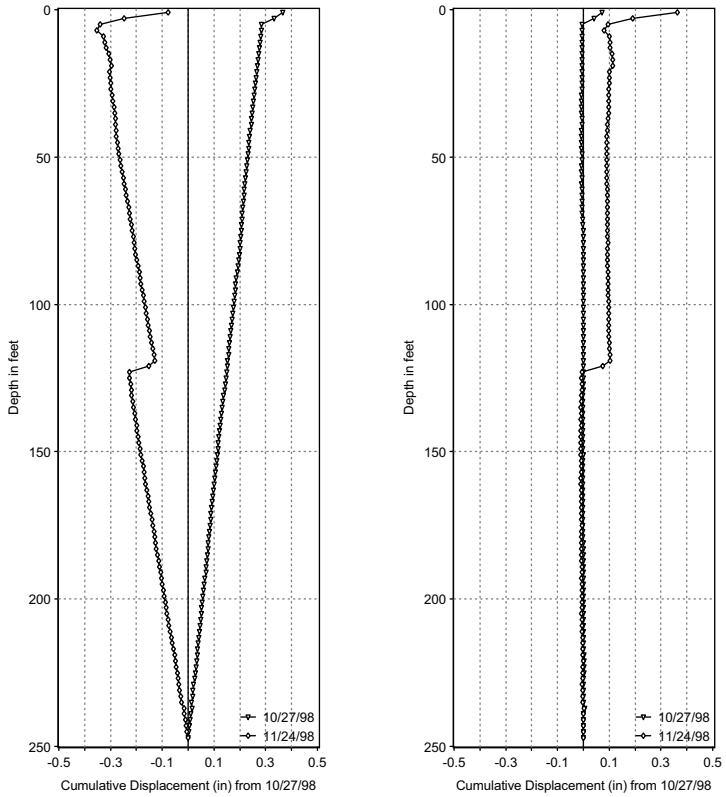
Quantifying Bias Shift Error

DMM for Windows has a routine for quantifying bias shift error. It suggests an value that you can enter in DigiPro's correction routine. Refer to the DMM manual for details.

Visual Correction

You can also arrive at an correction value visually.

1. Display a cumulative displacement graph.
2. Identify displacements that are produced by bias-shift error. For example, if you know that the bottom 20 feet of the casing are installed in rock, then any displacement seen there is probably error. If the error appears as a straight line tilted away from vertical, then it is probably due to bias-shift.
3. Enable bias-shift corrections. Then right click on one of the surveys, and choose Enter Correction Values.
4. In the Corrections Value dialog, enter a value, typically less than 20. If the tilt is to the right, enter a positive value. If the tilt is to the left, enter a negative value.
5. Click Apply and observe the graph. The tilted line should be vertical when the error has been corrected. Experiment with different values until you have found the correct one.



This example shows uncorrected and corrected graphs. You can see the typical linear pattern of bias-shift error. The second survey was obtained on the same day as the initial survey, so any movement is certainly false. The second survey was taken a month later and apparent displacement is in the wrong direction. When corrected, both surveys make sense and we can see that some real movement has occurred at about 125 feet.

Rotation

Rotation corrections are entered in radians. Here is a simple introduction to "rotation" error. More information can be found in the "Training" section of www.slopeindicator.com.

What is Rotation Error?

Rotation is a small change in the alignment of the measurement axis of the inclinometer probe. The change is usually less than one degree.

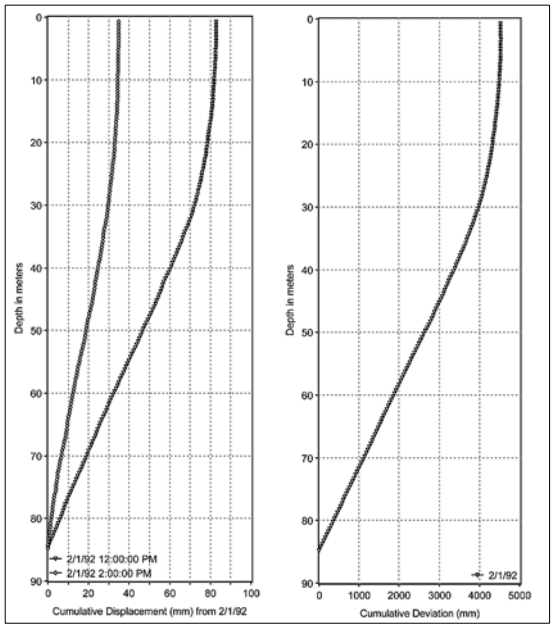
Ideally, the mechanicals of the probe are aligned so that the A-axis accelerometer measures tilt only in the A-plane. If the mechanicals of the probe are rotated slightly towards the B-plane, the A-axis accelerometer becomes slightly sensitive to tilts in the B-plane, too.

Rotation error is the cross-axis component in a reading, for example, the B-axis tilt in the A-axis reading. Rotation error becomes noticeable when two conditions combine:

- There is significant inclination in the cross axis.
- The change in the alignment of the probe occurs after the initial set was taken.

Identifying Rotation Error

- The cumulative displacement plot shows a curved line, when the line should really be straight.
- The cumulative deviation plot shows significant tilt in the cross axis.
- The two plots have a similar shape, as shown below.

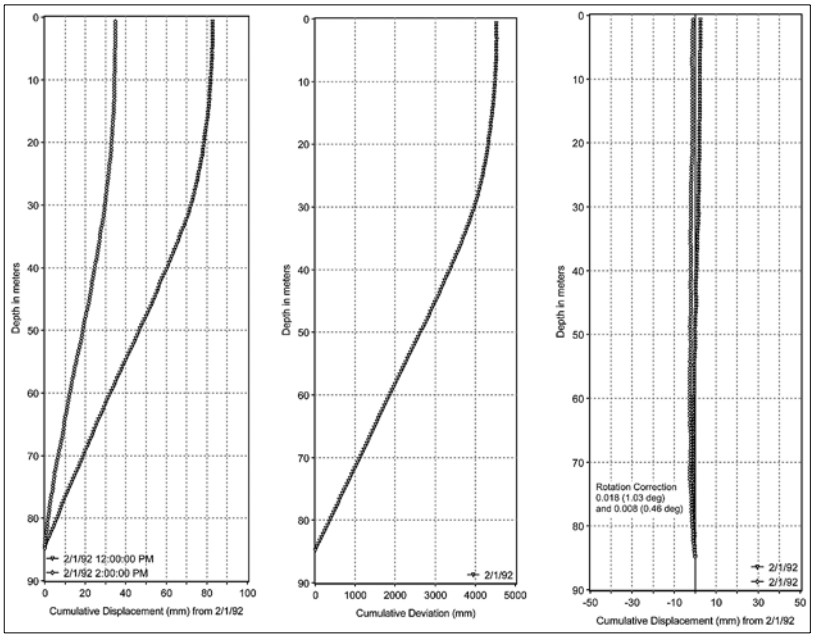


Cumulative Displacement A-Axis

Cumulative Deviation B-Axis

Correcting Rotation Error

1. Display a cumulative displacement graph. Use surveys that contain the error.
2. Identify displacements that are produced by rotation error. Find the depth of the maximum error.
3. Display a cumulative deviation plot of the cross axis. Find the deviation value at the same depth noted above.
4. Divide the displacement value by the deviation value. The result is a starting value for correcting rotation.
5. In DigiPro, enable rotation corrections and enter the rotation value.
6. Apply the correction and inspect the redrawn plot. The curve in the line should straighten..



Cumulative Displacement A-Axis

Cumulative Deviation B-Axis

Cumulative Displacement Corrected

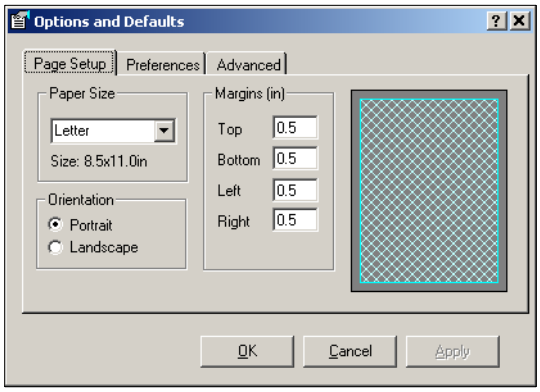
This example was a comparison test of three inclinometer probes. Readings from two probes are plotted against the third probe. All readings were taken on the same day. The casing was tilted about 4 degrees in the B-axis. The similarity between the A displacements and the B profile signals rotation error. The corrected displacement are shown at right.

Options and Defaults

Overview

Some of DigiPro's default settings can be changed by using options and defaults dialog: File > Options and Defaults.

Page Setup



Paper Size

Set the default paper size for all new reports.

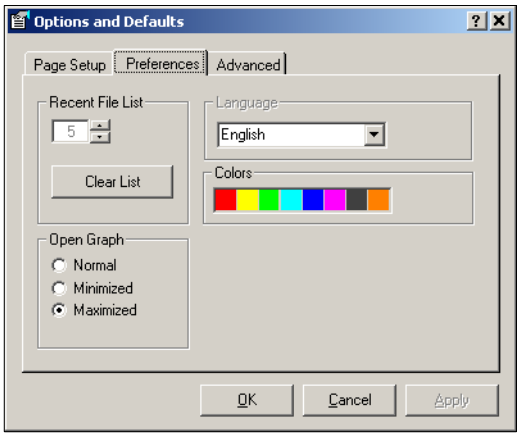
Orientation

Normally, you will allow report templates to take care of this.

Margins

Set page margins. Choose paper size first.

Preferences



Recent File List

Sets the number of recent files displayed on the File menu.

Language

Currently, the only choice is English. Sorry.

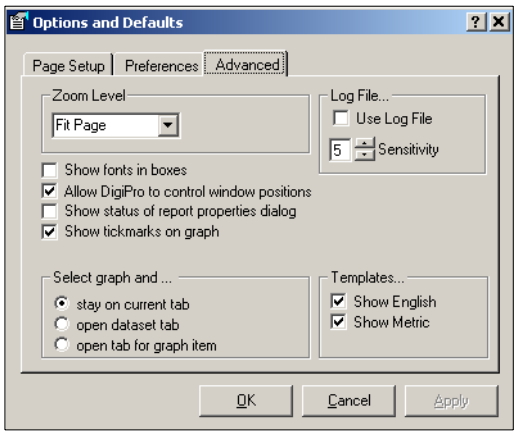
Colors

Set colors for DigiPro graphs by clicking on a color patch and choosing a different color from the pop-up pallet.

Open Graph

Sets DigiPro's window: normal is resizable, minimized is a task on the task bar, maximized is full screen.

Advanced Tab



Zoom Level

Sets the initial size of all displayed reports. We recommend using the default "Fit Page."

Show Fonts in Boxes

If unchecked, the text fields in the Title Block and Labels tabs will display text in DigiPro's default display font (Arial 10). If the box is checked, the text fields will display text in the font you select using the A button.

Allow DigiPro to Control Window Positions

Starts the report window in the upper left corner of the screen and the Report Properties dialog to the top edge of the screen.

If the box is not checked, the Windows system controls placement. This may be the preferred setting if you open multiple windows.

Show Status of Report Properties

If this box is checked, a grid appears at the bottom of the Report Properties dialog. The grid lists the tabs in which changes have been made. When you click Apply, the grid resets.

Show Tickmarks on Graph

When this box is checked, DigiPro displays tick marks on the borders of the graphs. When the box is unchecked, the tick marks do not appear. You can set the tick mark positions in the Data Units and Depth Units tabs of the Report Properties dialog.

Select Graph and...

Sets what happens when report properties dialog is closed and then reopened.

- Stay on Current Tab: This is the default. Report Properties displays the same tab as you switch back and forth between graphs.
- Open Survey Tab: Report Properties shows the Survey tab each time you switch between graphs.

Open Tab for Graph Item: Report Properties opens to the tab that corresponds to the part of the graph that you clicked on.

Appendix A: Project Databases

What is a Project Database?

Slope Indicator's project databases contain:

- Information about inclinometer installations, such as their ID and depth. The database can contain any number of installations.
- Surveys of the installations above. The database can contain any number of surveys.
- Reports created by DigiPro. A report is a collection of parameters that tell DigiPro how to create a graph. The database can contain any number of reports.

Use DMM to Create the Database

Project databases are created by DMM for Windows. DMM also imports or converts older data formats. DigiPro simply uses the data in the database.

If you don't have DMM for Windows, you can download it from Slope Indicator's website: www.slopeindicator.com or install it from Slope Indicator's Resource CD. DMM for Windows is free.

Use DMM to Convert or Import Data

Project databases created by DMM for Windows have a ".mdb" extension. If you have been using the Windows version of DMM, your data are already in this format, so no conversion is necessary.

Converting .hdr Databases

Project databases created by DMM for DOS consisted of a number of files. The main file had an ".hdr" extension. DMM for Windows provides a utility to quickly convert any of your old .hdr files to the .mdb Windows format. See Appendix 3 of the DMM manual: "Converting DOS DMM databases."

Importing GTilt, RPP, and PCSLIN Files

DMM for Windows can import RPP, PCSLIN, or GTilt files. It will also accept manually-entered data. See Appendix 5 and 6, "Importing Data" and "Manual Entry of Data."

If you are switching from some other inclinometer system to Slope Indicator's system, you can usually export your data in one of these formats.

Note: DMM does not import spreadsheet files.

Appendix A7 - DigiPro2 for Windows

DigiPro2

User Manual

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Introduction

About DigiPro

DigiPro2 creates databases, manages inclinometer data, and generates plots and reports. It also provides advanced routines for identifying and correcting systematic errors.

DigiPro2 works with both the Digitilt Classic system and the Digitilt AT system. It replaces the original DigiPro for Windows and it also replaces DMM, since it can retrieve surveys from the DataMate directly.

Compatibility

DigiPro2 runs on XP and later versions of Windows. It features a new database engine and a new database format. It can import surveys from the mdb databases created by DMM, so there is no loss of data when you switch to DigiPro2. However, plots and reports must be recreated because DigiPro2 uses a new graphics library with support for many more features.

DigiPro 2 can also import import surveys from GTILT and other formats and export processed data in several formats.

Installing DigiPro2

1. Direct your browser to www.slopeindicator.com.
2. Click Downloads > Software > DigiPro2.
3. Run the "digipro2setup.exe" program after it downloads.

About DigiPro2 Licenses

DigiPro2 starts with advanced features enabled for 45 days. After 45 days, it reverts to a basic version, unless a license is purchased. See Appendix 1 for information about purchasing and installing a license.

The basic version has no time limits and is free to use.

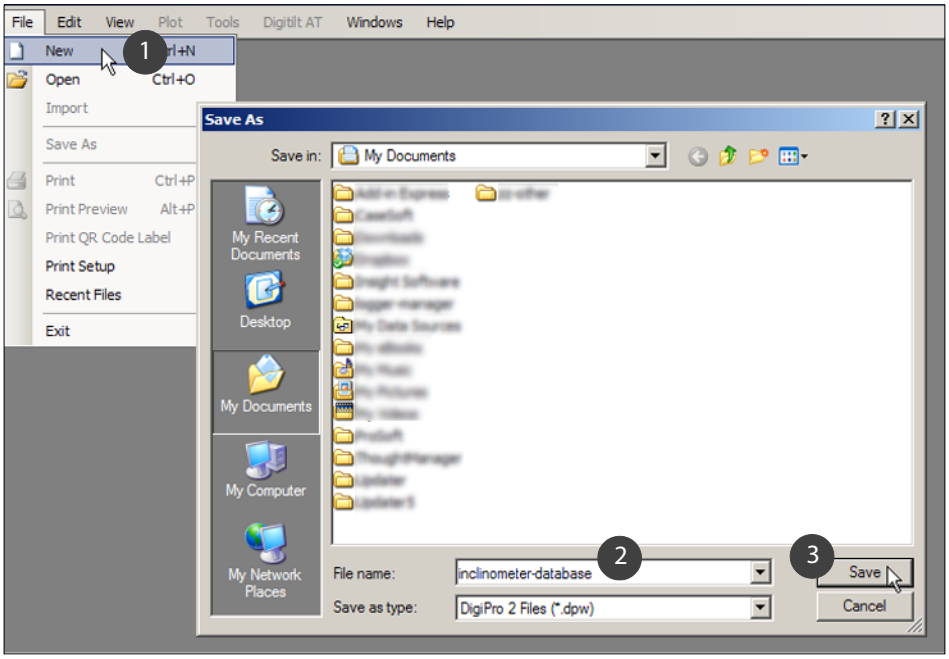
Creating a Database

Introduction

DigiPro2 creates a database to keep inclinometer surveys neatly indexed by name and date.

Creating a Database

1. Start DigiPro. The File menu appears.
2. Click New.
3. Enter a name for the database.
4. Click Save.



Notes

- The default folder is “My Documents” or “Documents.”

  To set a different default folder, click Edit > Preferences > Database Folder. Be sure to create your new database in that folder.
- Choose your own filename for the database. All DigiPro2 databases have a .dpw extension.

Next Steps

The new database is empty. To fill it, you can:

- Import DMM data.
- Retrieve surveys from a Digitilt DataMate readout.
- Import dux files from the Digitilt AT system.
- Import inclinometer data from other formats.

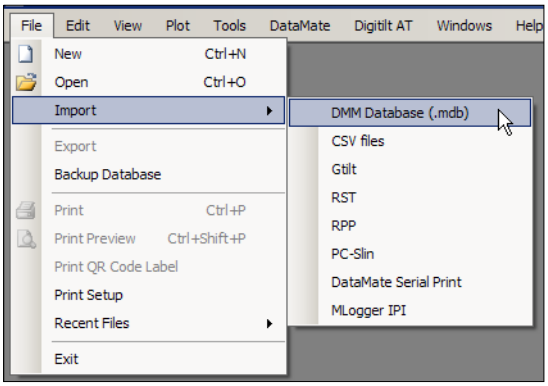
Importing DMM Data

Importing DMM Data

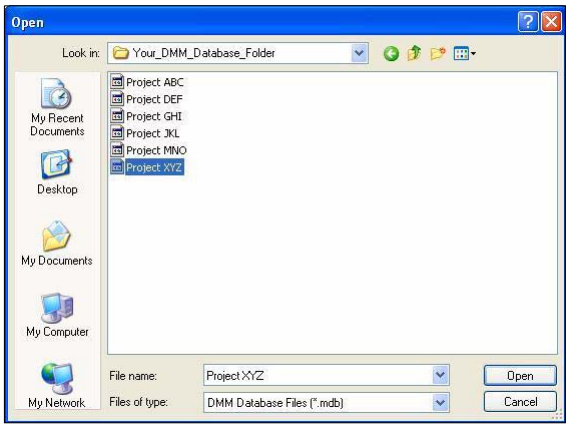
DigiPro2 can import surveys from .mdb databases created by DMM. Note that plots and reports must be recreated.

1. Create a database to hold the DMM data.

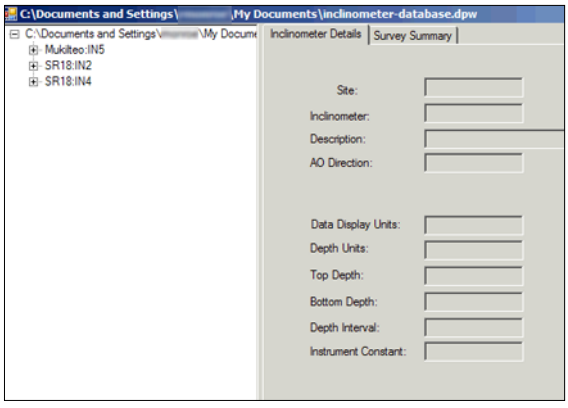
2. Click File > Import > DMM database (.mdb).



3. Navigate to the mdb file, select it, and click Open.



4. The screen refreshes to show the imported inclinometers and surveys



Inspecting a Database

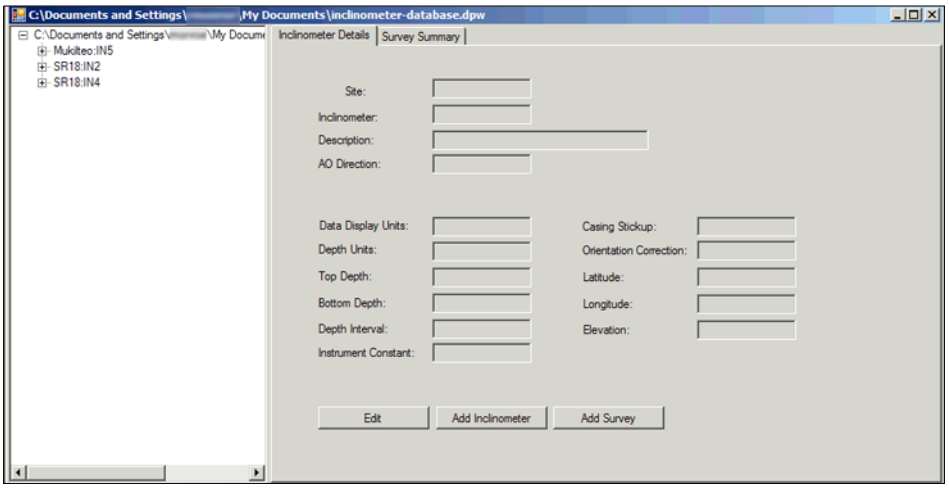
Opening a Database

Open the dpw database that you just created. Or, if you have no data yet, open the sample database, as explained below.

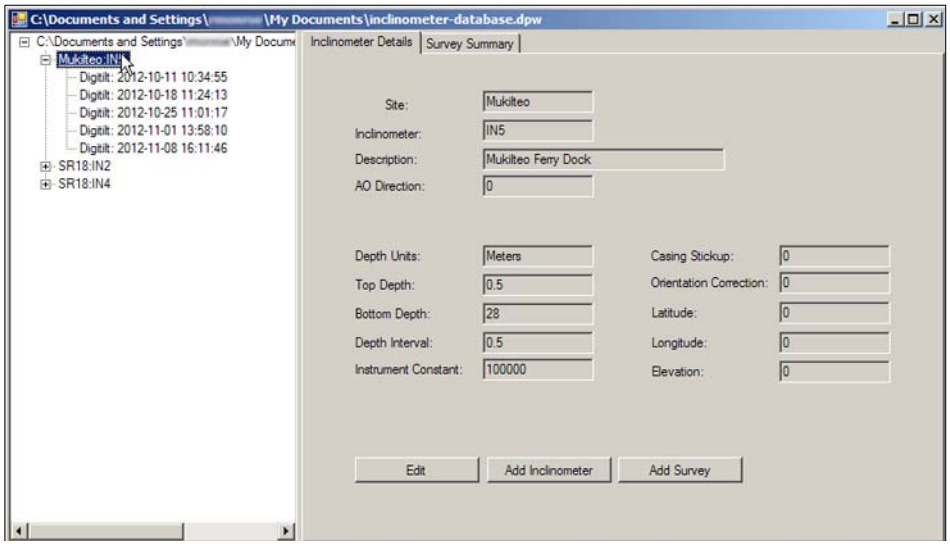
1. Start DigiPro2 from the desktop icon or the start menu.
2. The File menu appears. Choose Open.
3. Click My Documents (left side) or navigate to My Documents.
4. Double-click the folder named "Inclinometer-Data."
5. Choose "sample.dpw."

Inclinometer List

A list of inclinometers appears on the left.

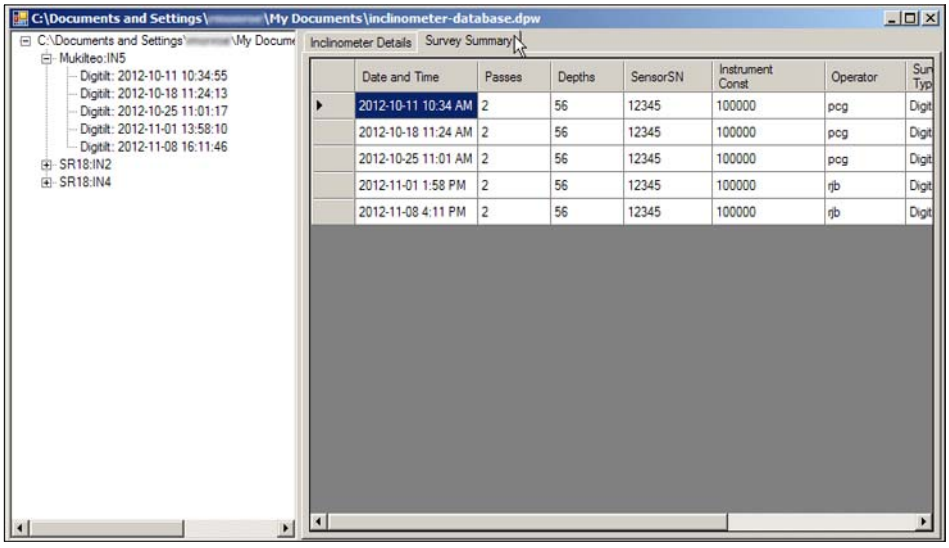


Double-click any inclinometer to see its details on the right. To modify any of the details, click the Edit button.



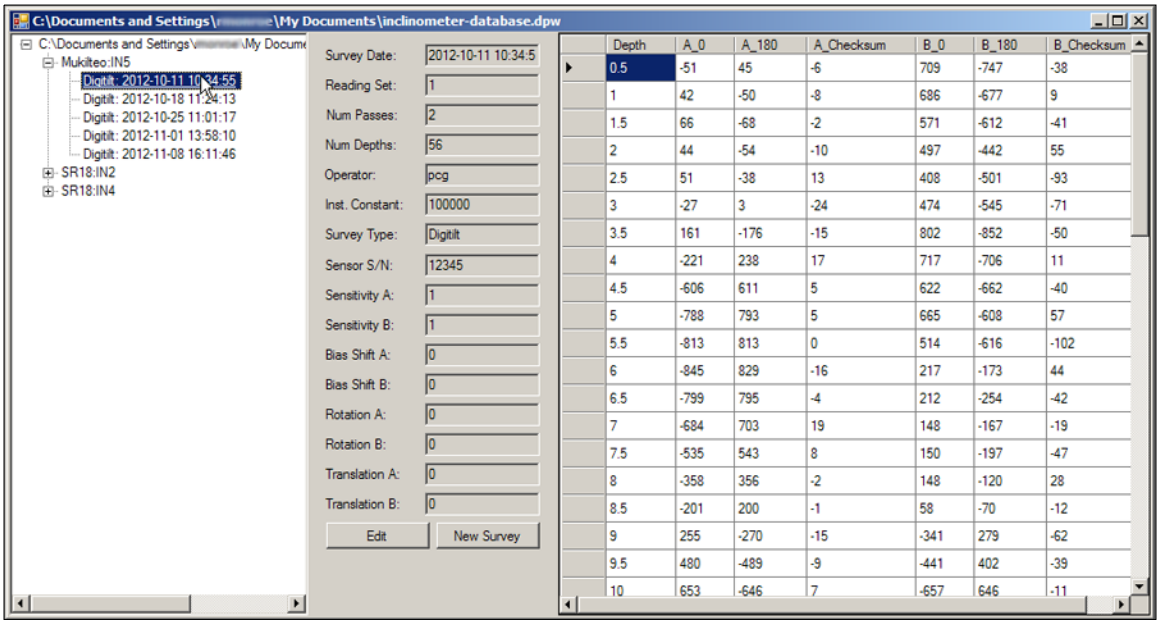
Survey Summary

Click the survey summary tab to see a summary of the surveys for this inclinometer. Double-click any date (left side or right side) to see data values, as shown in the next screen shot.



Survey Data

Double-click a survey (date) to see readings and checksums. Readings from the Classic system are shown in the traditional sine units. Readings from the AT system are shown in the units set by the AT Reader.



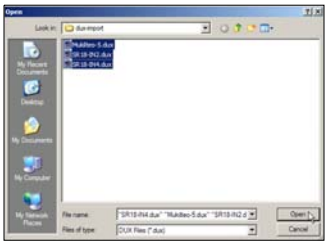
Working with the DataMate

System Workflow

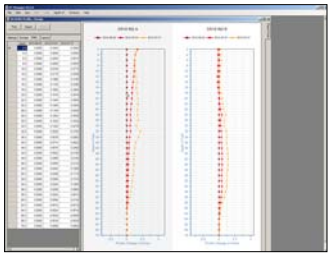
1. Survey the inclinometers with the Digitilt Classic system. The Digitilt DataMate readout stores the surveys in memory.

2. Connect the DataMate to a PC.

3. Open a database (.dpw only), establish a connection with the DataMate, and then retrieve surveys from the DataMate.



4. Use DigiPro2 to display and print inclinometer plots.

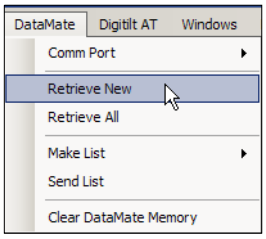


Terminology

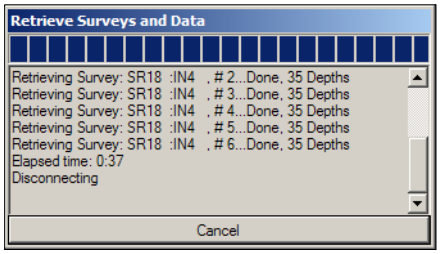
DigiPro2 uses “inclinometer” to refer to the installed portion of the inclinometer system. The DataMate, DMM, and the previous DigiPro use “installation” to refer to the same thing.

Retrieving Surveys

1. Connect the Datamate to the PC.
2. Switch on the DataMate.
3. Choose “Comm.” The DataMate displays “Waiting for PC.”
4. Start DigiPro2 and open the appropriate database.
5. Click DataMate > “Retrieve All” or “Retrieve New.”



6. DigiPro2 shows a progress bar as it imports data.



Communications Problems

1. If DigiPro reports a communications problem, click DataMate > Comm Port to choose a different comm port.
2. Additional help is available at www.slopeindicator.com. Go to: Support > Tech Notes > DataMate Communications FAQ.

Managing the DataMate

The DataMate holds a list of installations. It is convenient to create the list in DigiPro2 and send it to the DataMate. Please remember the following:

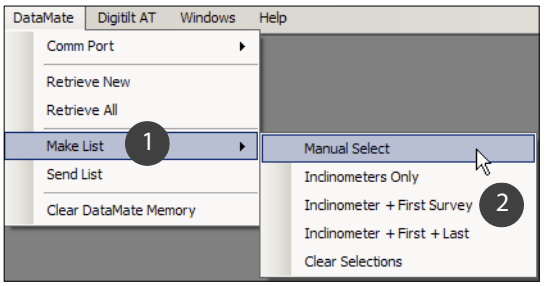
- DigiPro2 completely replaces the list held in the DataMate and also clears all surveys from the DataMate's memory.
- First you create the list. Then you send the list.

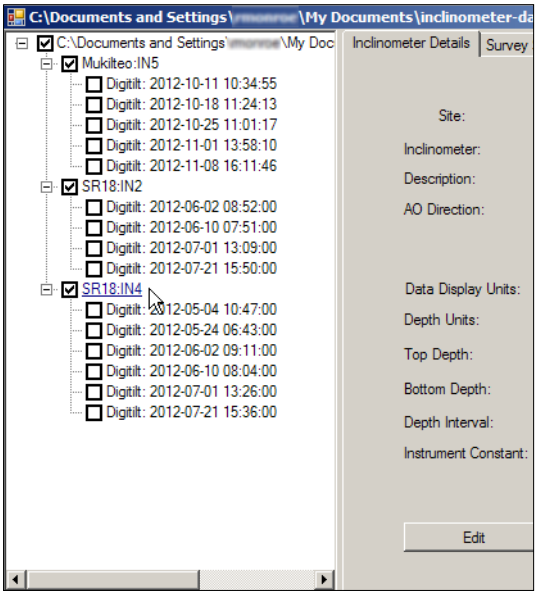
Create the List

1. Open a database and click DataMate > Make List.
2. Choose one of the options. DigiPro2 places checks next to the items selected for the list. In the example at right, only inclinometers were selected for the list.

   The original DataMate has room for 40 inclinometers. Keep as memory free for new surveys.

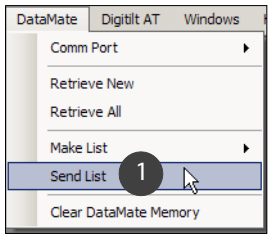
   The DataMate II has room for 160 installations and 320 surveys.

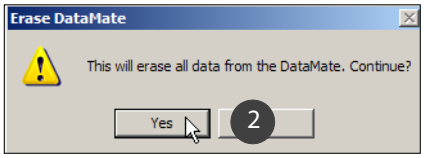




Send the List

1. Click DataMate > Send List.
2. DigiPro shows a warning. This is normal. Click Yes to continue.

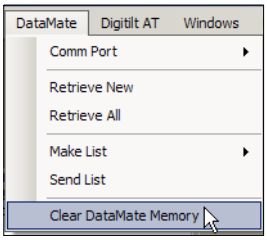




Clearing Memory

DigiPro2 offers an erase command that can clear the memory of the DataMate, if necessary. This erases all installations and surveys.

Click DataMate > Erase Memory.

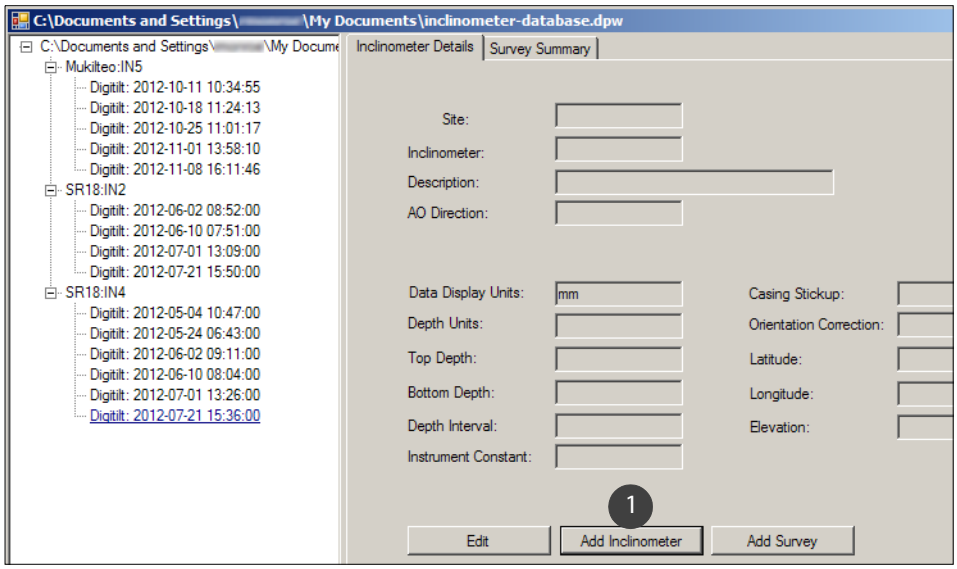


Adding Inclinometers to the Database

If you are in the field, you can create a new "installation" on the DataMate. Then, when you retrieve surveys with DigiPro2, the new installation will appear as an inclinometer in the database.

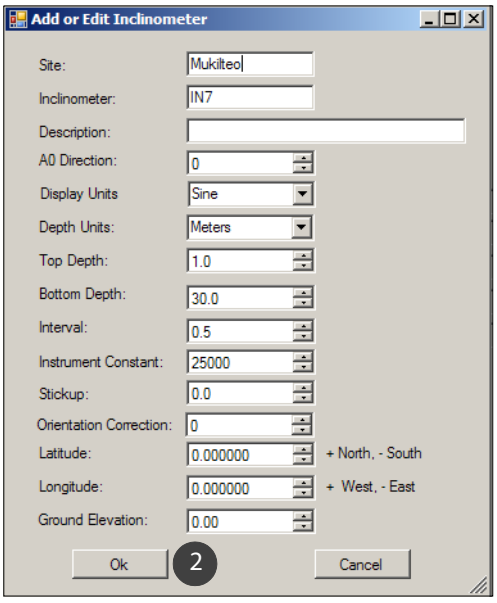
If you are in the office, you can use DigiPro2 to create new inclinometers. Afterwards, you make a list that includes the new inclinometers and send the list to the DataMate, as explained above. Here are instructions for creating an inclinometer in the database:

1. Open the database and click "Add Inclinometer." DigiPro2 clears the fields and starts a new inclinometer



Adding Inclinometers continued

2. Enter the information. Starred fields are required.



***Site:** The Site and Inclinometer fields together make a unique ID for the inclinometer. DigiPro2 allows 12 characters for the Site ID but sends only 6 characters to the DataMate.

***Inclinometer:** Enter an ID for the inclinometer. Again DigiPro2 allows up to 12 characters (for the Digitilt AT system) but sends only 6 to the DataMate.

Description: Optional field that does not appear in the DataMate. Accepts up to 35 characters.

AO Direction Optional field for the compass heading (0-359) of the inclinometer "A" grooves. Not used in calculations.

Display Units: Choose sine, mm, or inches. Sine refers to the units displayed by the DataMate readout. Millimeters assumes a .5m gauge length. Inches assumes a 2-foot gauge length. Default is sine units.

***Depth units:** Choose feet or meters.

***Top Depth:** Typically 0.5 for metric-unit systems or 2 for English-unit systems.

***Bottom Depth:** Depth of deepest reading. With English-unit systems, use an even number to match the two-foot cable graduations.

***Depth Interval:** Typically 0.5 for metric-unit systems or 2 for English-unit systems.

***Instrument Constant:** Enter 25000 for metric-unit systems , 20000 for English unit systems, 100000 for AT system.

Reserved Fields

Casing Stickup: Distance from the top of the casing to ground level. Allowed values from -10 to + 10. Used by DigiPro.

Elevation: The elevation of the ground surface. Used by DigiPro.

Orientation Correction: Range is -180 to +360. Used by DigiPro.

Latitude, Longitude: Information field not used by DataMate.

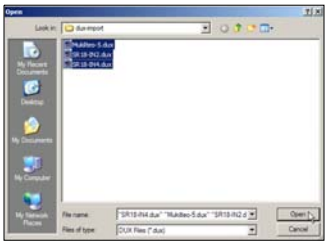
Working with the Digitilt AT

System Workflow

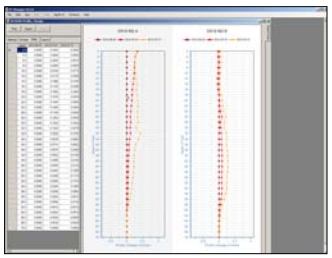
1. Use the Digitilt AT system to to survey the inclinometers. The Reader stores the surveys in inclinometer files.

2. Use the Reader to send the inclinometer files to the PC, where they are saved in an import folder for easy access by DigiPro2.

3. Use DigiPro2 to import the inclinometer surveys.



4. Use DigiPro2 to display and print inclinometer plots.

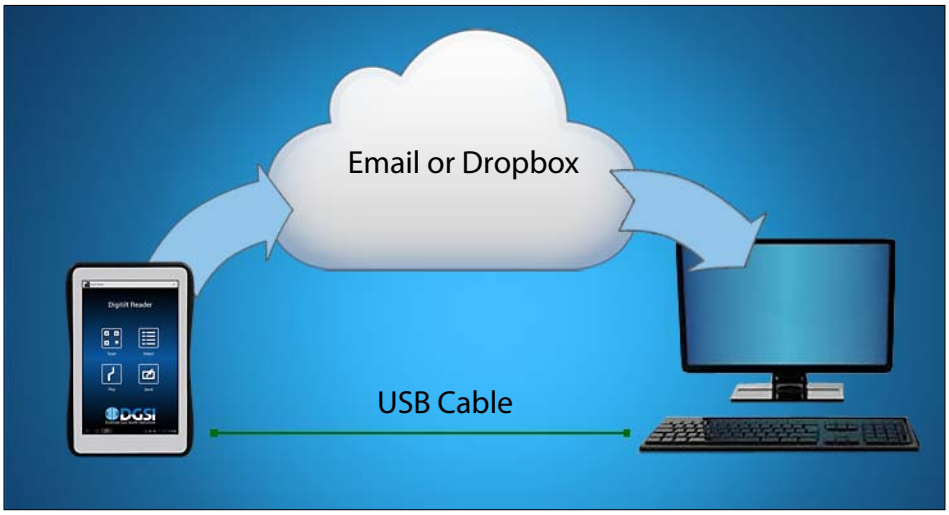


Transfer of Dux Files

The Reader stores surveys in inclinometer files. For convenience, we call these “dux” files because they have a .dux extension. (dux mean DigiPro Uniform eXchange).

Transfer Methods

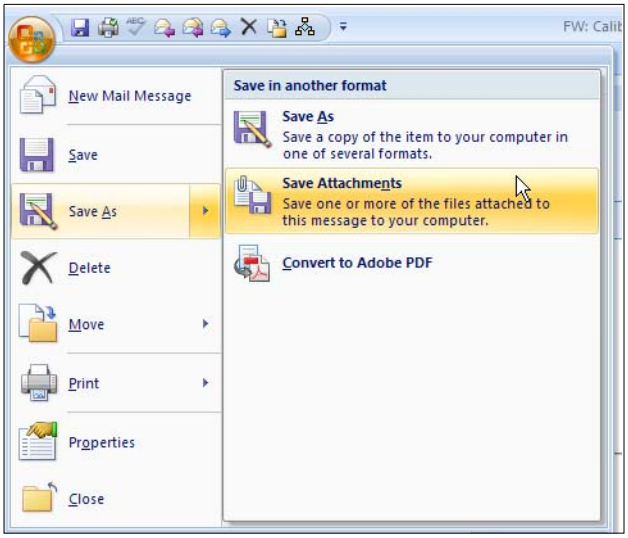
The Reader can send dux files to the PC by email or Dropbox. If the internet is not available, you can use a USB cable and the Windows file manager to copy files from the Reader to the PC.



Email Transfers

The Reader sends dux files as attachments to an email message.

1. Use Outlook, Gmail, or some other email program to open the email message.
2. Save the attached dux files into the import folder. (The import folder is explained in the next chapter.)



Dropbox Transfers

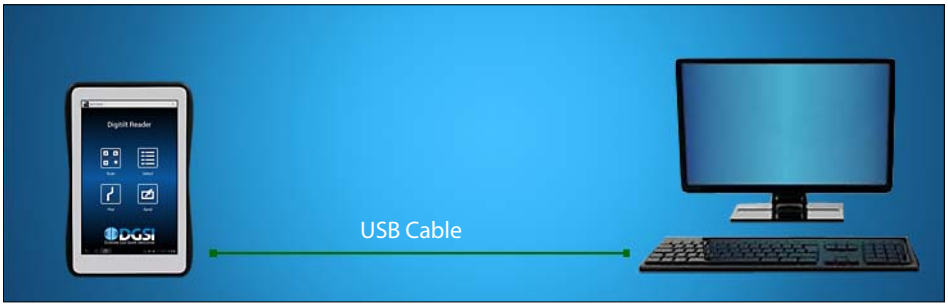
The Reader sends dux files to Dropbox. A few minutes (or seconds) later, the files appear in the Dropbox folder on the PC. No user actions are required.

The convenience of Dropbox is well worth the time that it takes to set up. Other cloud services such as Google Drive can be set up in a similar way.

1. Visit Dropbox.com using your web browser. Create a free Dropbox account. Enter an email address for the User ID, then create a Dropbox password. User ID and password are used again in the next steps
2. Download Dropbox for Windows. Run the setup program and then log in to Dropbox, using your User ID and password. Now your PC is linked to Dropbox in the cloud.
3. Start DigiPro2 and create a default import folder in Dropbox, as explained in the next chapter.
4. Visit the Google Play store using your Android device. Search for Dropbox and install it. You already have a Dropbox account, so login using your User ID and password. Now the Android device is linked to Dropbox, too.
5. The Dropbox listing on your Android device now shows the default import folder. That is where the Reader app will send dux files.

USB Transfers

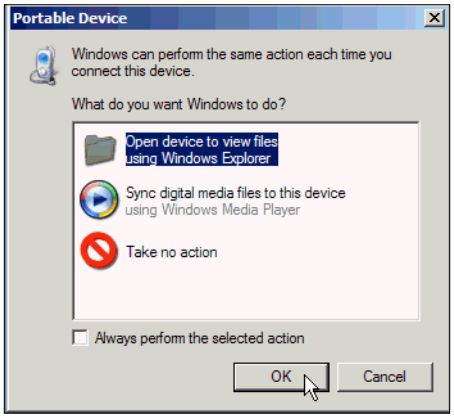
Use the Windows file manager and the USB cable supplied with your Android device. No USB drivers are required.



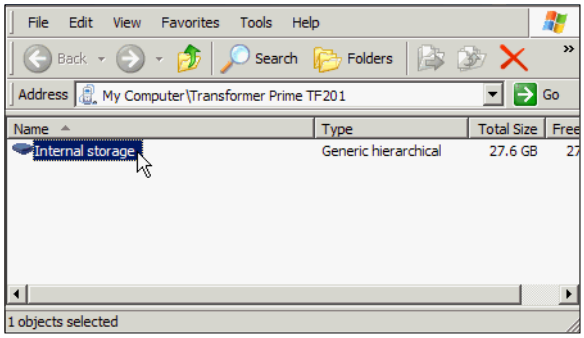
1. Connect the Reader to the PC using the USB cable.

   Switch on the Reader.

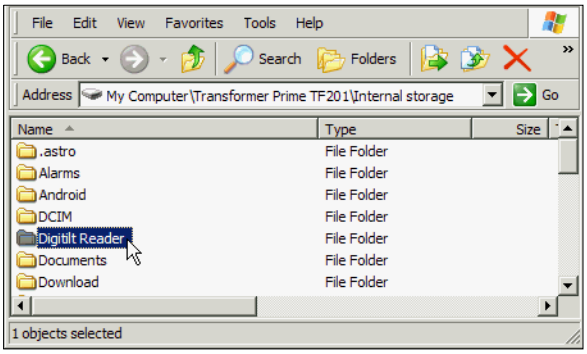
   A dialog appears on your PC. Choose “Open device ...”



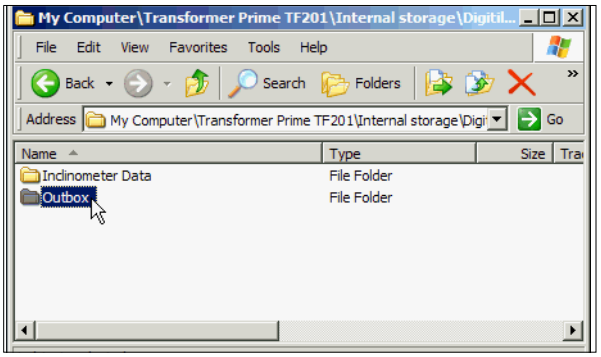
2. Windows opens the device. Click on “Internal storage.”



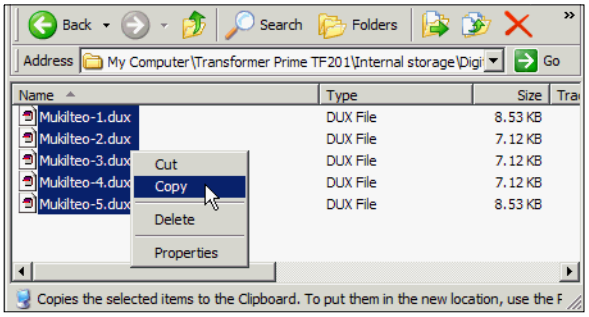
3. .Windows displays list of folders. Click on the “Digitilt Reader” folder.



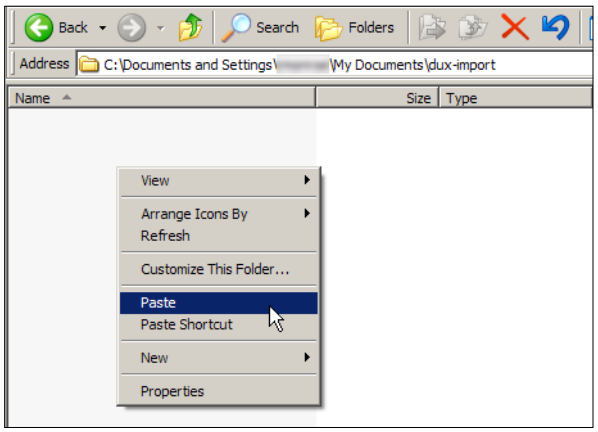
4. Click on the Outbox folder. This folder holds the dux files that should be transferred.



5. Select all the dux files in the Outbox, then right-click, and choose Copy.



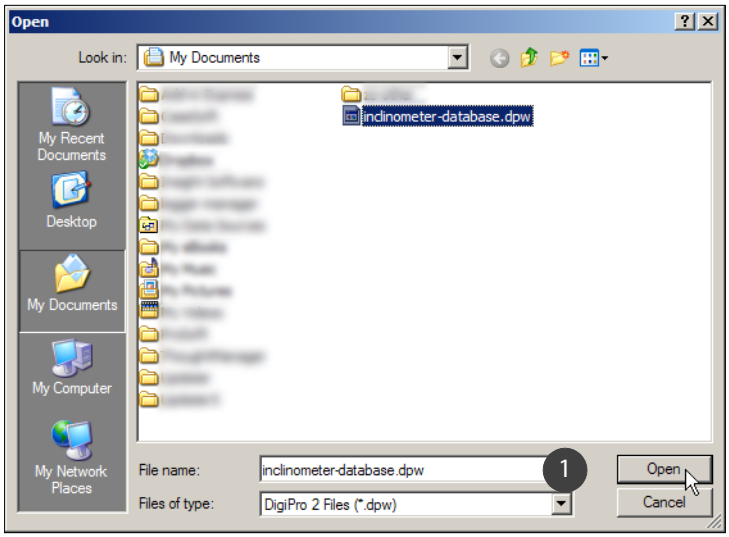
6. Now paste the dux files into the default import folder (which is explained in the next chapter).



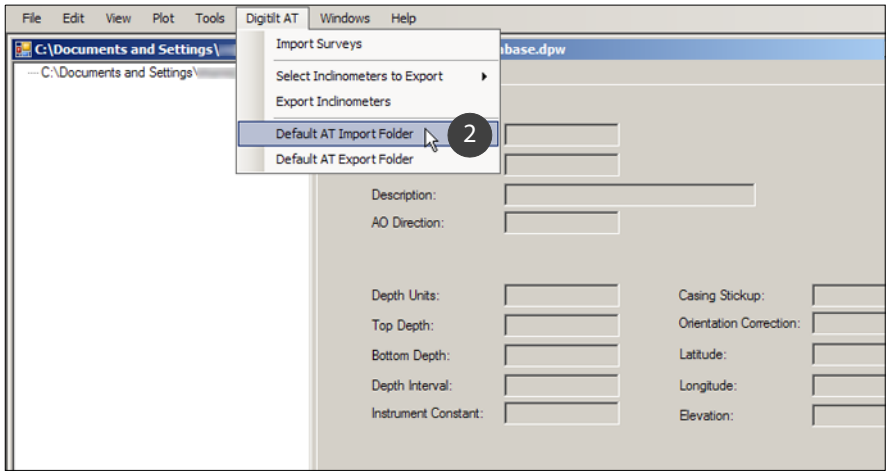
Create an Import Folder

Use DigiPro2 to create an import folder for dux files transferred from the Digitilt Reader. That will simplify importing the data into DigiPro.

1. Start DigiPro. Open the database that you just created.



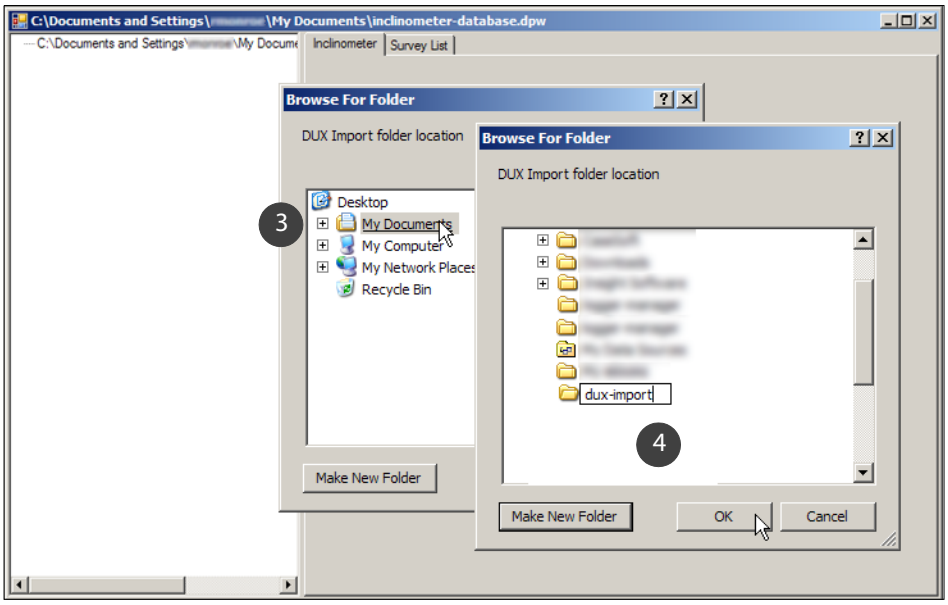
2. Click Digitilt AT > Default Import Folder.



...for Email or USB Transfers

3. Click “My Documents” (XP) or “Documents” (Win 7 & 8).

4. Click “Make New Folder,” enter a name for the folder, and click OK. In the example below, the folder is named “dux-import,” but you can choose your own name.



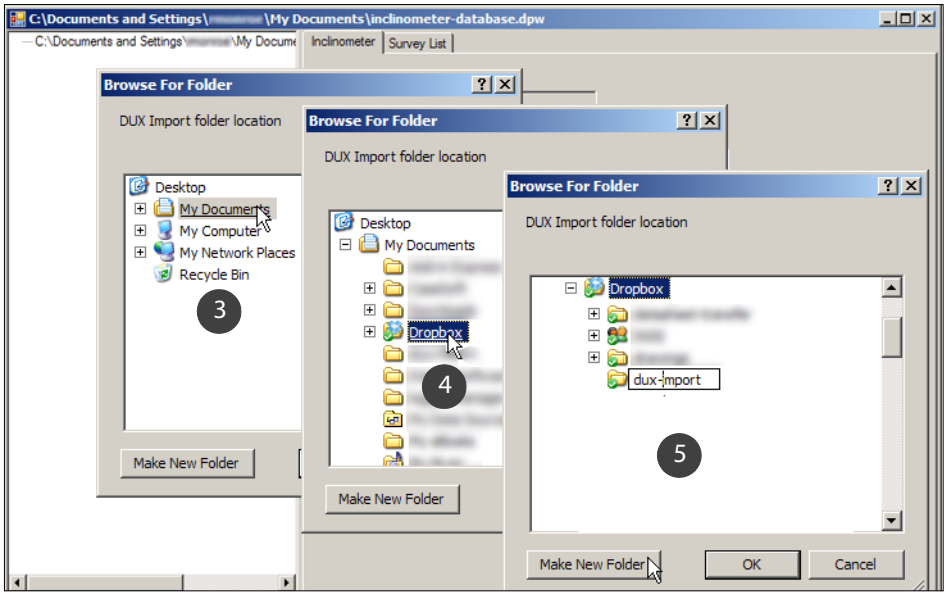
... or for Dropbox Transfers

After you install Dropbox, you can see a Dropbox folder in My Documents.

3. Click My Documents.

4. Click the Dropbox Folder.

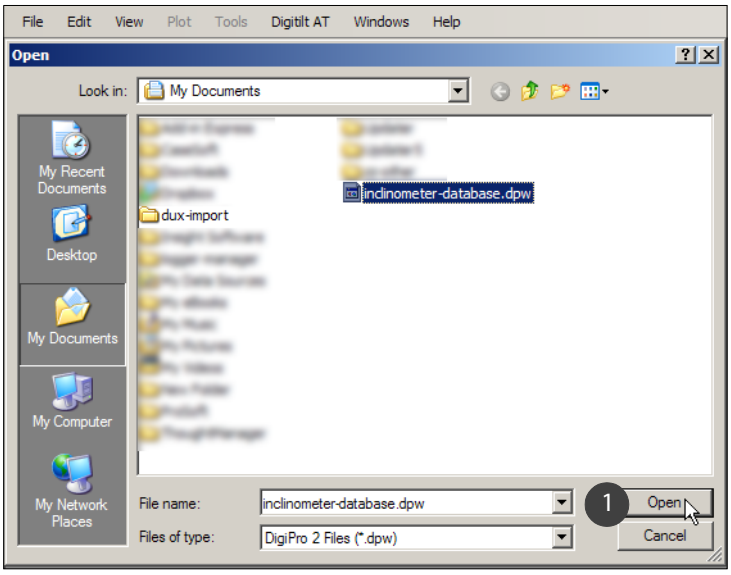
5. Click “Make New Folder,” enter a name for the folder, and click OK. In the example, the folder is named “dux-import,” but you can choose your own name.



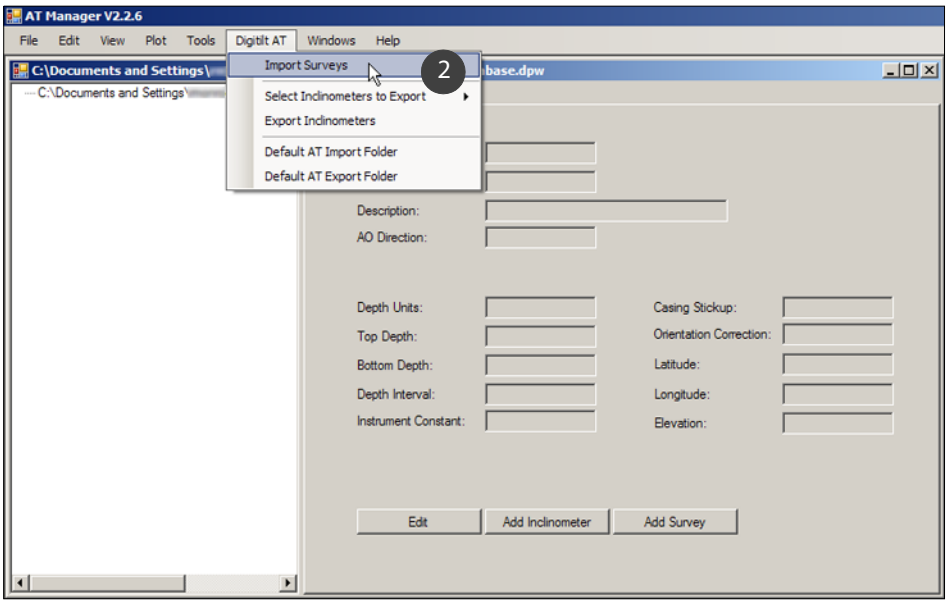
Import AT Surveys

Now it is time to import data from the dux files.

1. Open the .dpw database.



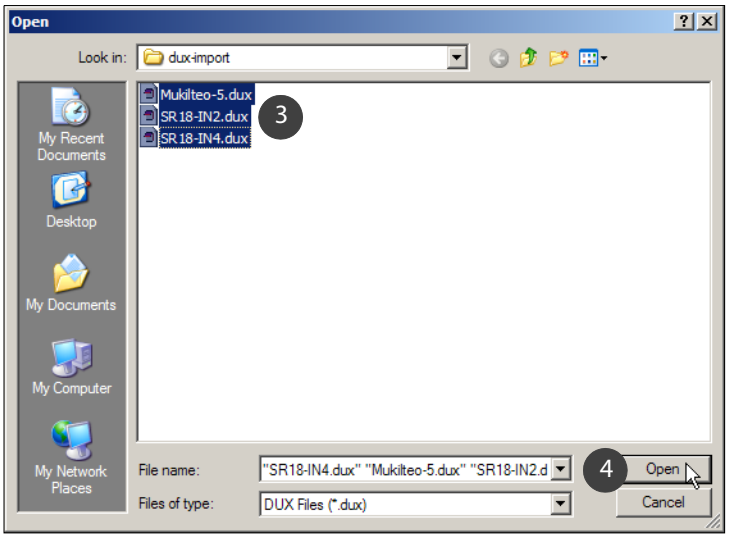
2. Click Digitilt AT > Import Surveys. DigiPro2 opens the default import folder.



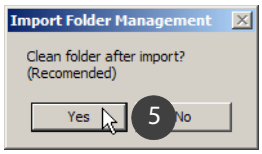
Import continued

3. Select the dux files that you want to import (Ctrl-A for All).

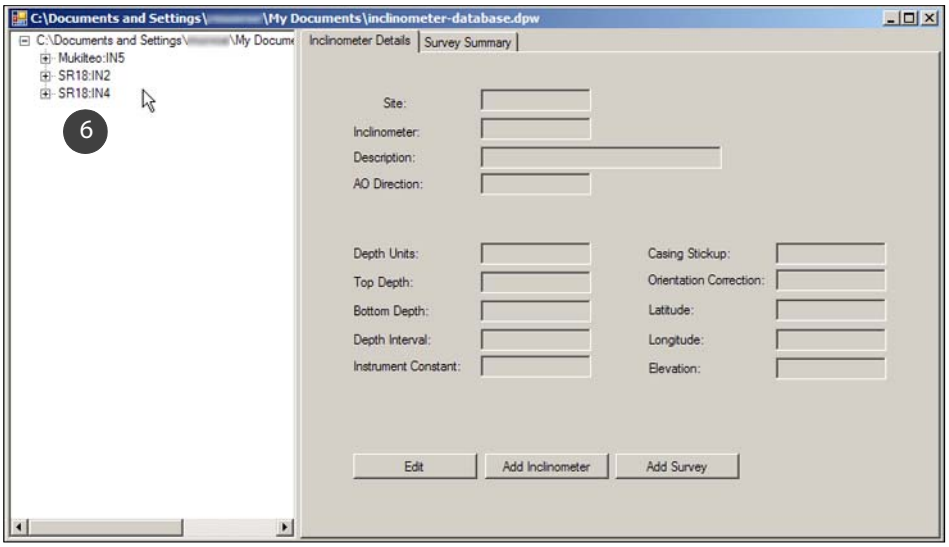
4. Click Open.



5. Click "Yes" to allow DigiPro2 to delete dux files that are imported successfully. These are no longer needed. The Reader keeps the original files and the database has the transferred readings.



6. DigiPro2 imports the surveys and clears the imported files from the folder.



Generating Plots

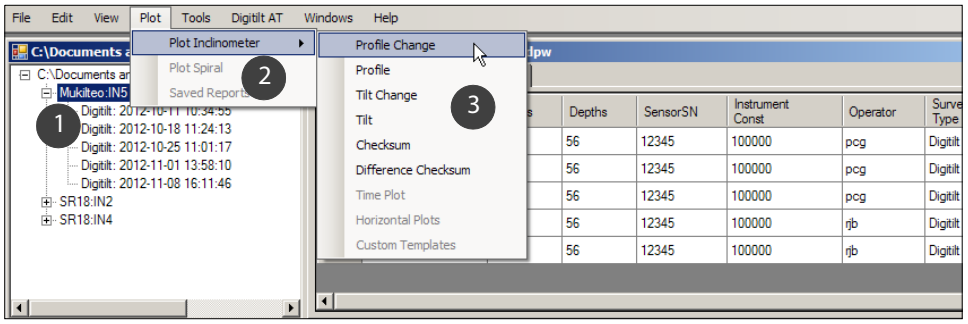
Overview

DigiPro2 can generate, print, and export a variety of plots. Plots can be saved as reports and reused with new surveys. DigiPro2 can also apply a variety of corrections to inclinometer data.

Some features explained below exist only in the Advanced version of DigiPro2, which requires purchase of a license key. The appendix presents a comparison of features available in the basic and advanced versions.

Plotting

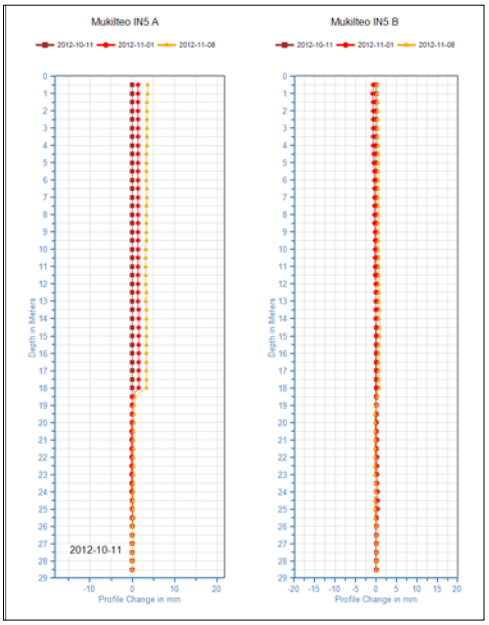
1. Click on an inclinometer
2. Click Plots
3. Choose a plot. Plot types are discussed below.



Profile Change Plot

This change plot is most common way to present inclinometer data. The plot compares compares the current profile to the initial profile. Changes are understood to be movement (displacement).

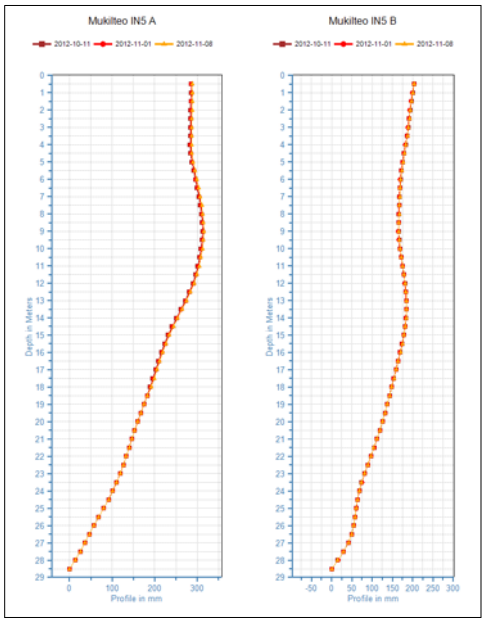
The previous name for this plot was "Cumulative Displacement."



Profile Plot

This is a diagnostic plot. It accumulates tilt readings (in mm or inches) to show the profile of the installed casing. The plot is used to evaluate borehole verticality and is also used in diagnosing and correcting error.

The previous name for this plot was “Cumulative Deviation.” It is also known as an “absolute position” plot.

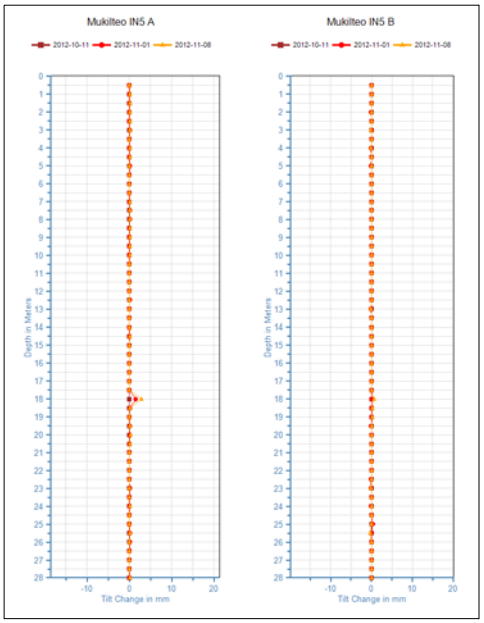


Tilt Change Plot

This change plot compares the current tilt reading at a given depth to the initial reading at the same depth. Changes are understood to be movements (displacement).

Tilt change plots do not accumulate values, so are immune to systematic error. Movement appears as a growing spike, typically centered on one or two depths.

The previous name for this plot was “incremental deviation.”

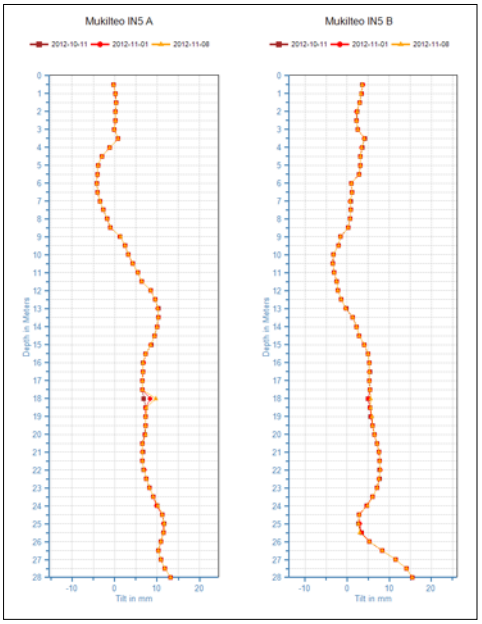


Tilt Plot

This is a diagnostic plot that shows tilt in mm or inches at each depth.

It can be used to evaluate the installed "straightness" of an inclinometer and the potential for depth control errors.

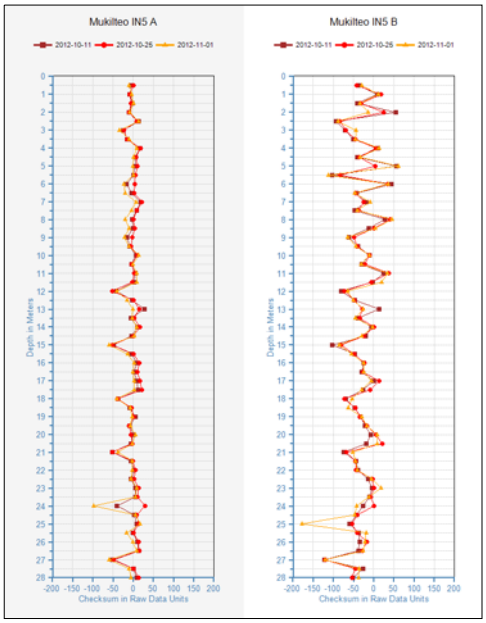
The previous name for this plot was "Incremental Deviation."



Checksum Plot

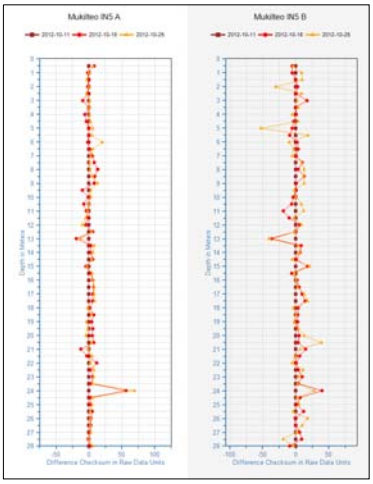
This is a diagnostic plot that shows the checksum at each depth. A checksum is the sum of the 0 and 180 readings.

Generally speaking, the magnitude of the checksums is less important than the uniformity of checksums within a survey. In that regard, you would hope to see plots that are straight and vertical rather than curved and off vertical.



Difference Checksum Plot

This is a diagnostic plot that attempts to remove casing irregularities from the analysis of checksums. The initial checksum is subtracted from the current checksum. This eliminates variations that are due to characteristics of the casing, such as telescoping couplings.

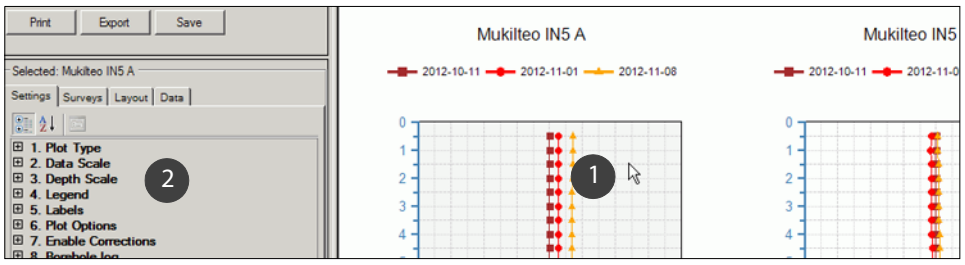


Modifying Plots

Overview

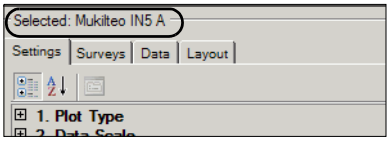
A tabbed control panel provides access to settings, surveys, and layout.

1. Click to select a plot. The plot background turns gray.
2. Double-click to open a settings.

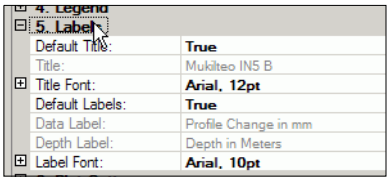


Helpful Hints

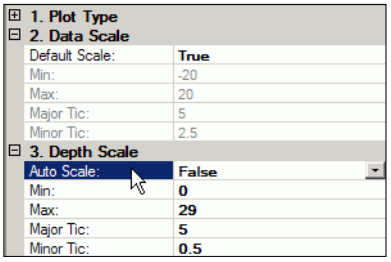
- The name of the selected plot appears above the settings tab.



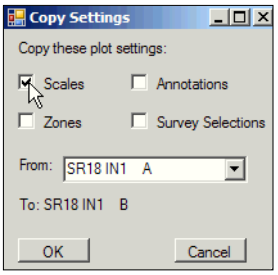
- To open a settings group, double-click on the name of the setting. You can also click the + mark.



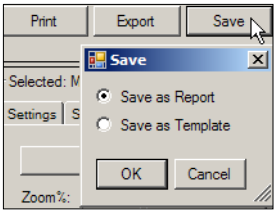
- To change default or automatic settings, first double-click the label to turn off the automation (false = off). Then you can edit the settings.



- To copy plot A settings to plot B, right-click on the B plot and choose “copy settings.” Then choose which settings to copy.



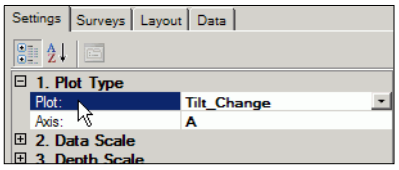
- To save settings, click the “Save” button and choose Save as Report. When you have new surveys, choose “Saved Reports” to plot the new surveys with all the same settings



Settings Tab

Use the Settings tab to control the appearance of the plots.

Plot Type



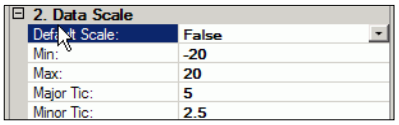
DigiPro normally plots A and B using the same type of plot. Use this setting if you want a different type for one of the plots.

Plot: Double-click on "Plot" to iterate through the available plot types.

Axis: Double-click on "Axis" to iterate through the following choices:

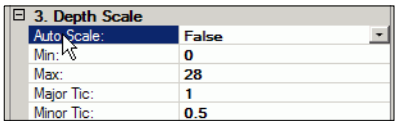
- A shows tilt in the plane of the wheels.
- B shows tilt in the plane rotated 90 degrees to the wheels.
- Magnitude shows the magnitude of the tilt vector: sqrt(A^2 + B^2).
- Angle shows the direction of the tilt vector: arctan(B/A).

Data Scale



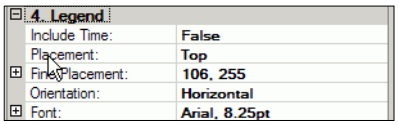
DigiPro2 sets default scale according to the depth of the inclinometer. To enter your own scales, turn off the default scale by double-clicking "Default Scale."

Depth Scale



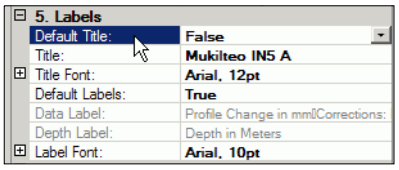
DigiPro2 sets depth scales automatically. To enter your own depth scales, turn off the autoscaling by double-clicking "Auto Scale."

Legend



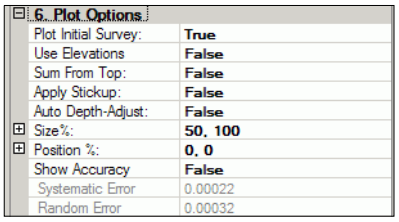
Legends usually show a date only. If time is important, double-click "Include Time." Double-click "Placement" to view available locations for the legend. Fine Placement adjusts X Y placement of the plot starting from top left corner of the page. This adjustment is useful for printed plots. Double-click "Orientation" to place dates vertically or horizontally.

Labels



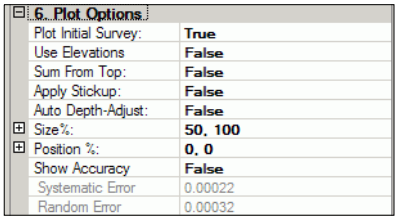
DigiPro2 automatically generates titles and labels.To turn off automation, double-click "Default Title" or "Default Labels," and then enter your own text.

Plot Options



Plot Initial Survey: DigiPro2 automatically shows the initial survey in all plots. Double-click if you want to hide the initial survey.

Use Elevations: DigiPro2 shows depths by default. If you have entered elevation in the inclinometer header, double-click to show elevations.



Sum from Top: Profile plots are created by summing values. Summing from bottom is the default, since the bottom is normally assumed to be stable. To sum from top, double-click to change the value to "true."

Apply Stickup: Double-click to enable or disable. When enabled, and a stickup value has been entered in the inclinometer header, DigiPro2 plots values at their real depths (or elevations) rather than at cable depths.

We record readings at depths indicated by depth marks on the cable. We align depth marks to an index, such as the top of the casing or the top of a pulley assembly. Stickup is the distance from the index to the surface of the ground. If the index is 0.5m above the ground, the real depth of the probe is 0.5m shallower than the depth indicated by the cable. Applying a stickup of 0.5m will cause values to be plotted at their real depth (or elevation).

Auto Depth-Adjust: This adjustment is sometimes used with Classic systems, which have cabled marked from the middle of the probe. When turned on, readings are plotted at the depth of the top wheels rather than at cable depth. Auto depth-adjust should be off (false) for AT systems.

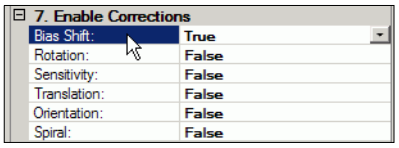
Size: This setting controls the width and height of the chart area (the area including the white space around the plot). It may be useful when you display only one plot. Double-click to make entries. Value are percent of page.

Position: This setting moves the chart area. It may be useful when you display only one plot. Double-click to make entries. Value are percent of page.

Show Accuracy: Field accuracy generates lines showing the approximate "Field Accuracy" of profile change plots, assuming systematic error increasing with the number of readings and random error increasing with the square-root of the number of readings. Double-click to toggle the accuracy lines on and off.

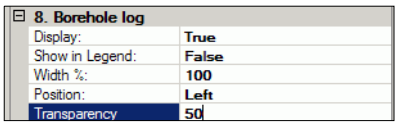
Enable Corrections

This settings group allows corrections to be double-clicked on and off. True is on, False if off. Corrections are discussed in a later chapter.



Boring Log

This settings group shows or hides a graphic representing a boring log. The graphic appears in the background of the plot.



Display: Double-click to show or hide the boring log graphic. Note that the details of the boring log are entered elsewhere: Edit>Add/Edit Boring Log.

Show in Legend: Double-click to show or hide boring log labels in the legend area.

Width: Set width of the graphic. 100% is the full width of the plot. Try 10 for a narrow graphic.

Position: Move the graphic to the right side or left side of the plot.

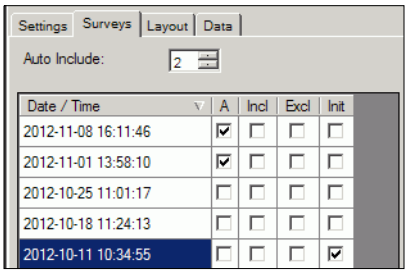
Transparency: Make the graphic more transparent with a smaller number.

Survey Tab

Click the "Surveys" tab to select surveys to include in the plot.

Auto-Include: Automatically includes this number of recent surveys in the plot.

A: Shows which surveys are included by the Auto-Include setting.



Inc (Include): Check the box to always include this survey in the plot.

Exc (Exclude): Check the box to always exclude this survey.

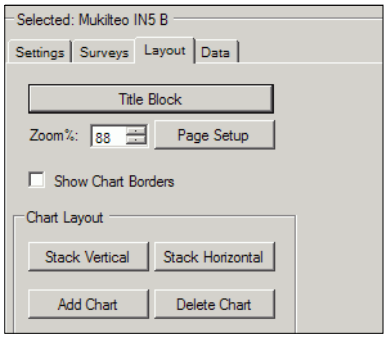
Init (Initial): Check this box to choose the initial survey.

Note

DigiPro2 Basic is limited to three surveys: the initial plus two others.

Layout Tab

The layout tab provides mostly page-related settings.



Title Block: Click to add a title block. Details are explained below.

Zoom: This is a display setting. DigiPro2 sizes plots for your display automatically. Use zoom to adjust, if necessary.

Page Setup: DigiPro2 displays settings related to printing, such as paper size and margins. These are discussed in the next chapter.

Show Chart Borders: Check the box to draw borders around each chart. A chart includes the white space around each plot.

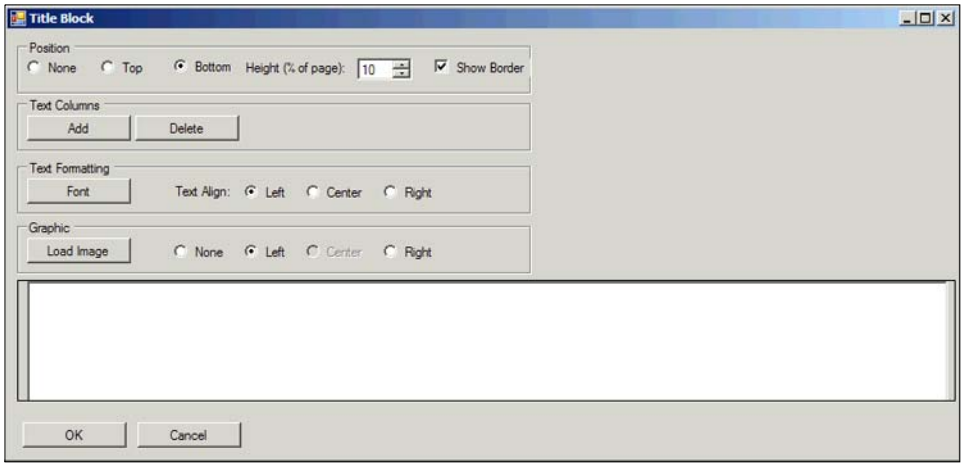
Stack Vertical / Stack Horizontal: Controls layout of charts. Click to see the effect. Horizontal is the default. Vertical may be useful for horizontal inclinometers.

Add Chart: Click to add an additional chart (and plot) to the page. It is not possible to add plots from other inclinometers.

Delete Chart: Removes a chart from the page.

Title Block Details

The title block dialog lets you add a logo and descriptive text to the plot.

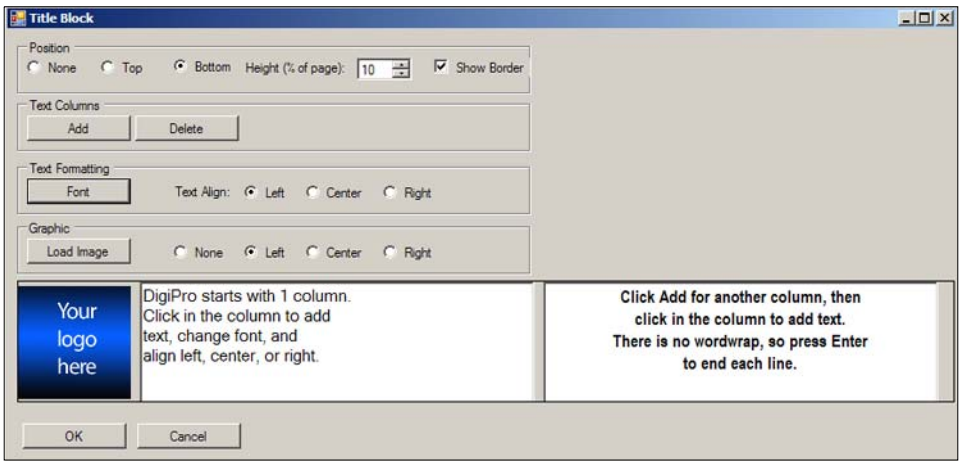


Position: Controls visibility, location, and size of the title block:

- None hides the title block but does not delete it. You can set the title block to none while inspect the plots and then set to top or bottom before you print.
- Top places the title block at the top of the page.
- Bottom places the title block at the bottom of the page.
- Height sets the vertical size of the title block.
- Show Border draws a line around the title block, if checked.

Title Block Details continued

Add columns, text, and a graphic:



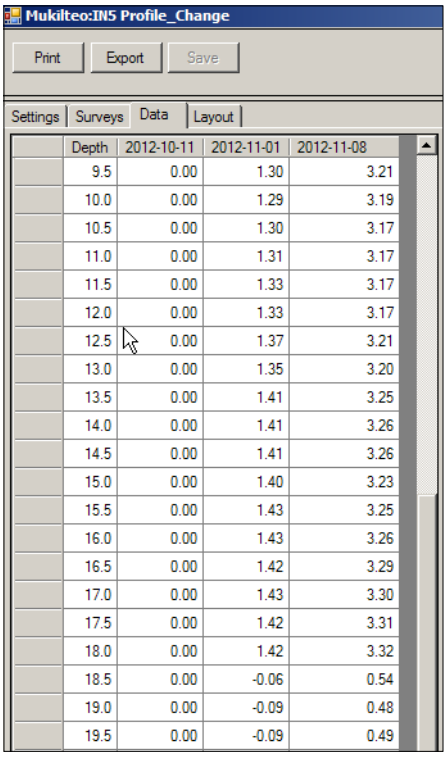
Text Columns: DigiPro starts with one column. Click in the column to enter text. Press Enter to end each line. There is no wordwrap. Click Add if you want more columns.

Text Formatting: Click in a column first, then adjust the font and alignment of the text. You cannot adjust individual lines within a column. The printed page is not the same as the displayed page, so you may need to experiment with line lengths and font sizes for a good appearance.

Graphic: Click the Load Image button to browse for a jpeg, gif, png, emf, or bmp graphic file. DigiPro resizes the graphic to fit the vertical space. You can choose left, center, or right alignment.

Data Tab

Click the "Data" tab to display values used in the plot. Survey dates appear at the top of each column. Use the scroll bar to see other depths.

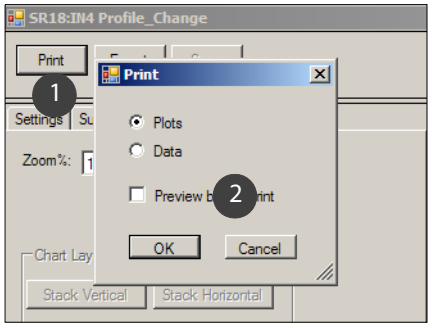


Depth	2012-10-11	2012-11-01	2012-11-08
9.5	0.00	1.30	3.21
10.0	0.00	1.29	3.19
10.5	0.00	1.30	3.17
11.0	0.00	1.31	3.17
11.5	0.00	1.33	3.17
12.0	0.00	1.33	3.17
12.5	0.00	1.37	3.21
13.0	0.00	1.35	3.20
13.5	0.00	1.41	3.25
14.0	0.00	1.41	3.26
14.5	0.00	1.41	3.26
15.0	0.00	1.40	3.23
15.5	0.00	1.43	3.25
16.0	0.00	1.43	3.26
16.5	0.00	1.42	3.29
17.0	0.00	1.43	3.30
17.5	0.00	1.42	3.31
18.0	0.00	1.42	3.32
18.5	0.00	-0.06	0.54
19.0	0.00	-0.09	0.48
19.5	0.00	-0.09	0.49

Printing & Exporting Plots

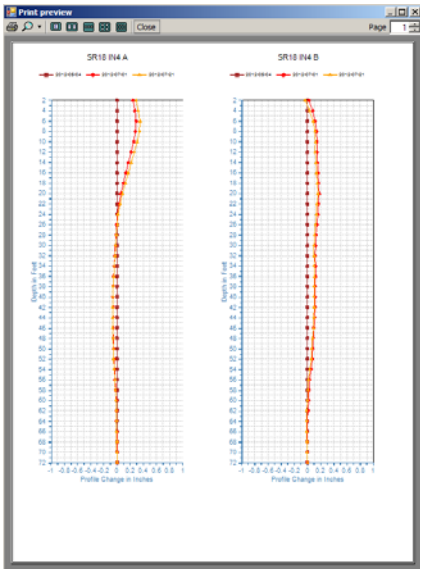
Printing Plots

1. Click the “Print” button.
2. Choose “Plots” or “Data.” Click the checkbox for a print preview. Then click OK.



Preview

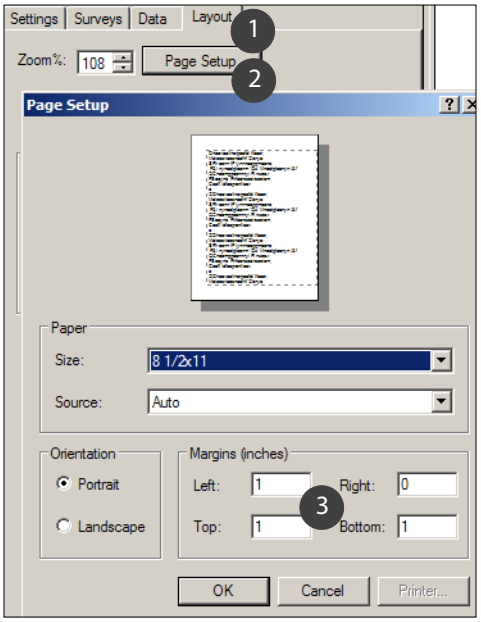
Print preview lets you inspect the page before you print it. Click the print button to print.



Page Layout

To adjust page margins:

1. Click the “Layout” tab.
2. Click the “Page Setup” button.
3. Adjust margins as required, then click OK.

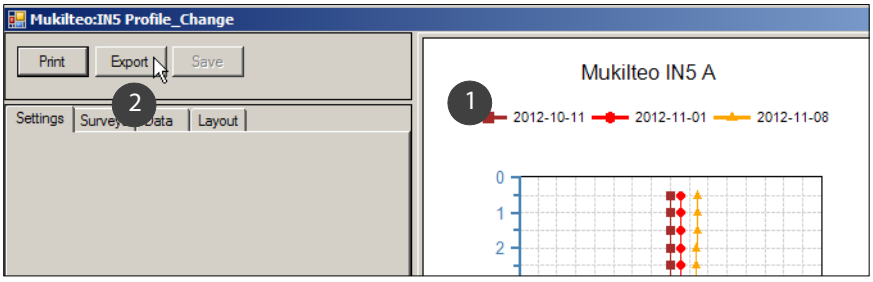


Exporting Plots

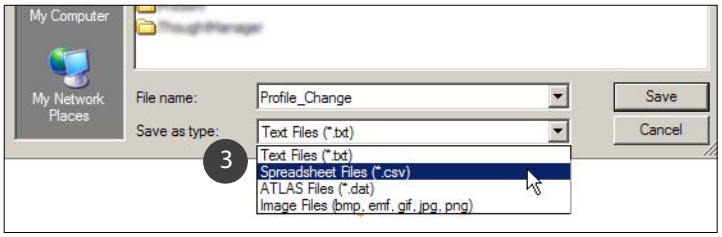
DigiPro2 can export plots as text files or graphic files.

1. Generate the plot.

2. Click the Export button.



3. The Save-As dialog appears. Choose a file type from the drop menu.

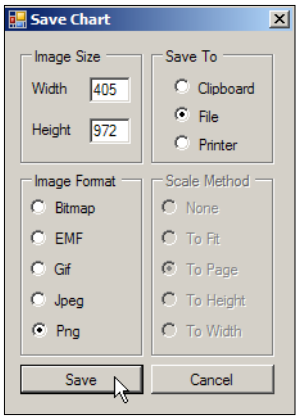


Text File: Printable file with tab separated values.

Spreadsheet File: Spreadsheet-ready file with regionalized field separators and decimals.

Atlas File: Data arrays formatted for Atlas. Each array has a date stamp followed by depth-value pairs. A values first, then B values.

Image File: First select the A or B plot, and then click Export. Choose an image format and click save. PNG and GIF provide the sharpest results.



Using Reports & Templates

What is a Report?

Reports are customized plots that are saved for reuse. You create a plot, modify scales, labels, title blocks, survey selections, etc. as needed, and then save it. Each inclinometer can have any number of reports.

When you have new surveys, you open the report rather than create a new plot. When the report is displayed, the new surveys are automatically included (according to the auto-select setting) and the plots are generated with all the saved settings.

Creating a Report

Modify the plot as needed, then click Save, enter a name, and click OK.

Using a Report

Open: Choose the inclinometer. Click Plot>Saved Reports. Select the report and click OK.

Modify: You can modify a report if necessary. Click Save when you are done.

Delete: The report dialog provides a delete button. Select the report that is no longer needed, then click "Delete."

What is a Template?

A template is similar to a report, in that it saves certain settings, but it is not dedicated to a particular installation.

- You may want all of your plots to include a standardized title block with the company logo.
- You may want a different combination of plots on the page.

Creating a Template

Generate a plot. Modify the plot as necessary and then click Save. Choose "Save as Template" and click OK.

Using a Template

1. Choose an inclinometer.
2. Click Plot > Plot Inclinometer >Custom Templates.
3. Choose a template and click OK.
4. After the template loads, make any extra modifications needed and save as a report.

Applying Corrections

Introduction

DigiPro2 provides correction routines that can improve the presentation and understanding of data. There are two categories of routines: those that apply to single surveys, and those that apply to all surveys of a particular inclinometer.

- Routines that affect single surveys are bias-shift, rotation, and sensitivity corrections, which are related to the inclinometer probe, and translation corrections, which are related to the inclinometer casing.
- Routines that affect all surveys are orientation correction and spiral correction. Orientation correction can help when casing grooves are not aligned with the real direction of movement. Spiral correction can help when casing was twisted during installation.

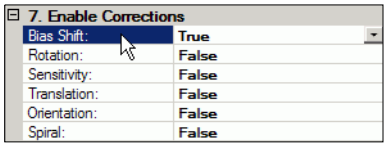
Most corrections routines involve a minimum of three steps:

1. Generate a plot.
2. Enable corrections in the plot settings panel.
3. Enter a correction value and check the result. This may be an interative process with different values entered until a satisfactory plot is generated.

Enabling Corrections

DigiPro2 stores correction values separately from readings. Correction routines apply these values on-the-fly when plots are graphs are generated. Thus corrections can be enabled and disabled at any time. To enable correction routines.

1. Generate a plot.
2. Double-click to open Enable Corrections.



3. Double-click on the particular correction that you want to enable. In the example, Bias-Shift correction has been enabled.
4. To disable a correction, double-click to toggle the value to false..

Bias-Shift Error

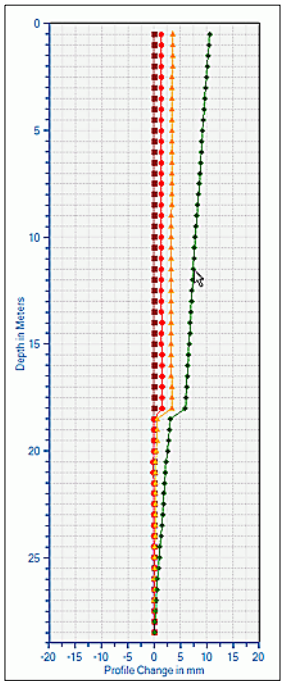
Here is a simple introduction to bias shift error. Refer to the support pages of www.slopeindicator.com for more information.

What is Bias Shift?

Bias: Bias is the value returned by the probe when it is held absolutely vertical. In theory, the value should be zero, but in practice, the value is non-zero. This non-zero value is embedded in every reading.

Bias Shift: It is normal for the bias of the probe to change from time to time. This is not a problem because the bias value is normally eliminated in the data reduction process, when 0 readings are combined with 180 readings.

Bias-Shift Error: If the bias shifts during a survey, the data reduction process cannot competely eliminate the bias. The remaining value is bias shift error. The error becomes visible when readings are accumulated, as in the profile change plot at right.



Identifying Bias-Shift Error

Appearance: The plot above shows the typical appearance of a bias-shift error: a straight-line that is tilted away from vertical. The tilt may be in either direction.

Unlikely Behavior: The plots above shows tilt over the entire span of the inclinometer. This unlikely behavior suggests error in the data.

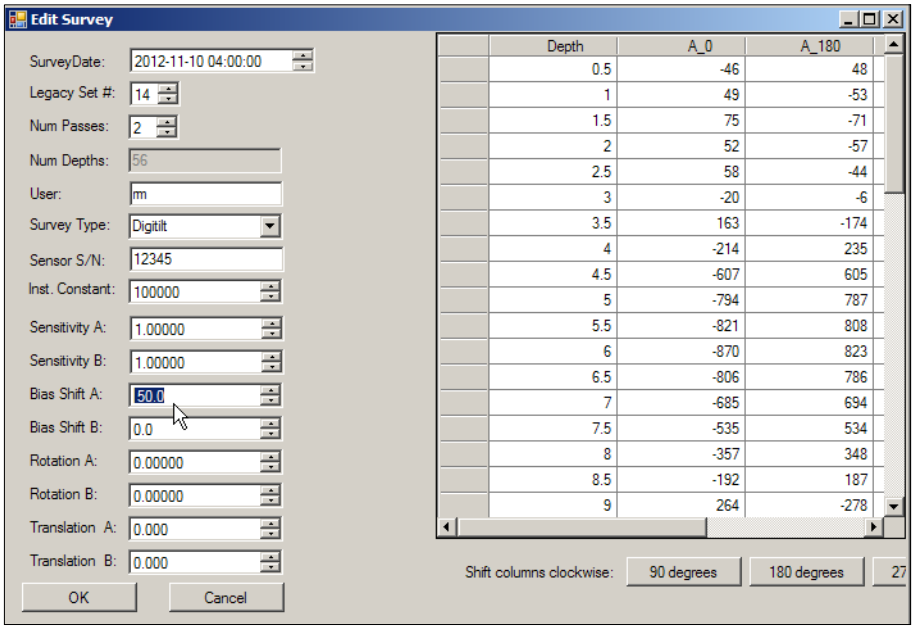
Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error in the data.

Checksum Plots: Checksum plots show that a bias-shift has occurred.

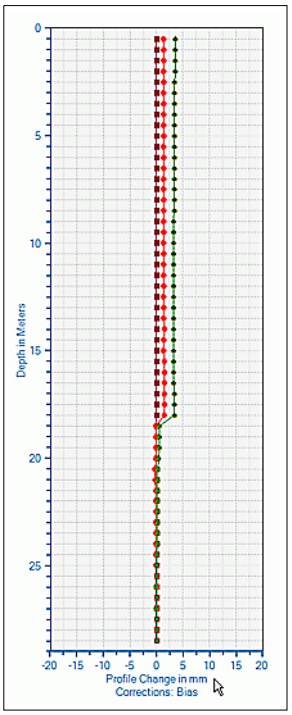
Correcting Bias-Shift Error

You identified bias-shift error in a profile change plot. Then you verified that a bias shift occured by plotting checksums. Now you want to correct for bias shift.

1. Generate the profile change plot again.
2. Enable bias-shift corrections in the settings panel.
3. Double-click the survey (the plot of the survey) that you want to correct.
4. DigiPro2 displays the Edit Survey dialog. Find the Bias-Shift field.



5. Enter a value. If the plotted survey was tilted to the right, try a positive value. If the tilt was to the left, try a negative value. The exact value doesn't matter yet. Click OK.
6. DigiPro2 redraws the plot. Inspect zones were no movement should have occurred (the bottom, for example). Have you eliminated the tilt in those zones?If necessary, double click the survey again and enter a different value. Continue until the tilt is eliminated.
7. The bias-shift error has been removed from the offending survey. The label for the data axis shows the type of correction that was applied.



Rotation

Here is a simple introduction to “rotation” error.

What is Rotation Error?

Rotation is a small change in the alignment of the measurement axis of the inclinometer probe. The change is usually less than one degree.

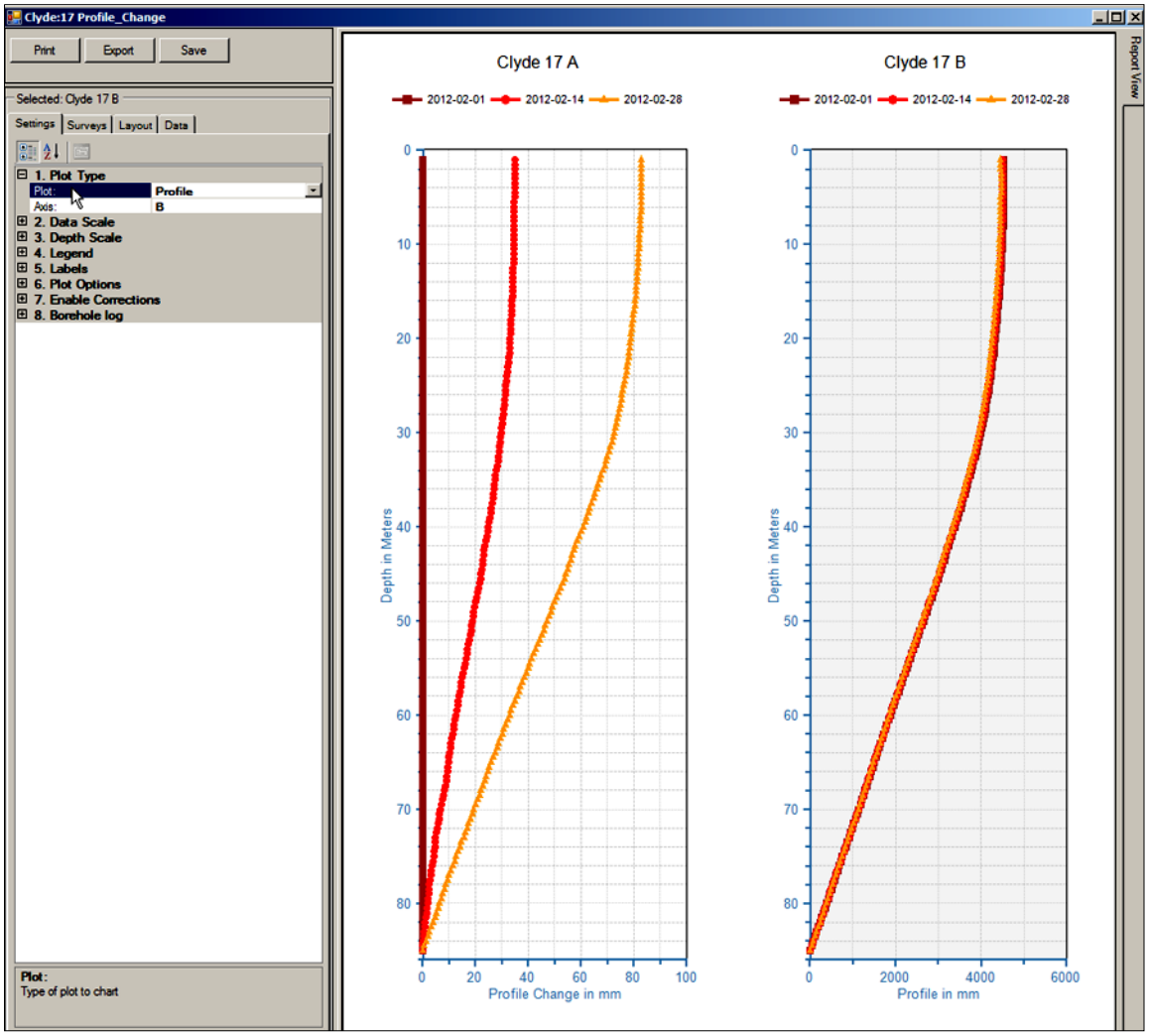
Ideally, each sensor is aligned to measure tilt in only one plane. If the mechanicals of the probe are rotated slightly towards the cross-axis plane, the A-axis sensor also measures some of the tilt in B and vice versa.

Rotation Error is the cross-axis component in a reading: for example, the B-axis tilt value that is embedded in the A-axis tilt reading. Rotation error becomes visibile when when two conditions combine:

- There is significant inclination in the cross axis.
- The change in the alignment of the probe occurs after the initial set was taken.

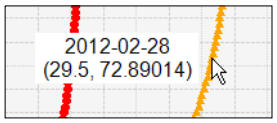
Identifying Rotation Error

- The profile-change plot is curved.
- The profile plot of the cross axis shows significant tilt.
- The two plots have a similar shape, as shown below.

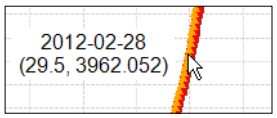


Correcting Rotation Error

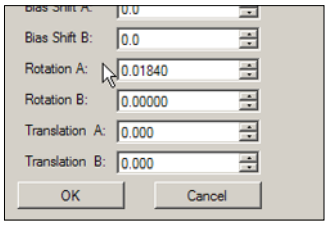
In the example on the previous page, a rotation error was identified in the profile change plot for A axis. To check, we selected the B plot and changed its plot type from profile change to profile. We saw that the A change plot looked similar to the B profile plot. Now we want to apply a correction.



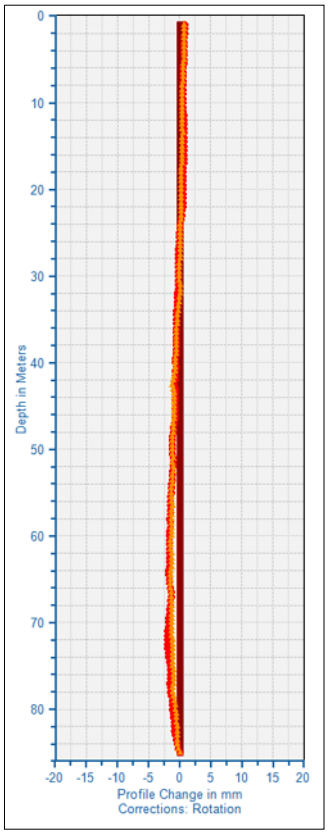
1. Enable rotation correction in the settings panel.
2. Move the cursor to the maximum profile change value in the A-axis plot. Note the depth and value that DigiPro displays: 29.5m and 73mm.



3. Move the cursor to the same depth on the B-axis plot. Note the profile value.
4. Find a starting correction value by dividing the the A profile-change value by the B profile value: 73 / 3962 = 0.0184. (Normally values are smaller than the sine of 1 degree: 0.01745).



5. Double-click the offending survey on the A plot. DigiPro2 displays the Edit Survey dialog. Enter the value into Rotation A field. Click OK.
6. Inspect the plot, and double-click to reopen the edit dialog as necessary.
7. Repeat these steps for any other surveys that show rotation error. The plots become useable, if not perfect.



Sensitivity Correction

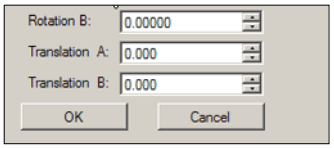
Sensitivity drift is not easy to recognize. It can easily be detected by the factory and is a reason for sending probes in for calibration at regular intervals. An example will appear in a future edition of this manual.

The error is directly proportional to reading magnitudes. Typical errors are 1 to 2 percent. Correction involves the same steps as others:

1. Generate a plot.
2. Click on a survey to call up the Edit Survey dialog.
3. Enter the sensitivity value and check the resulting plot.

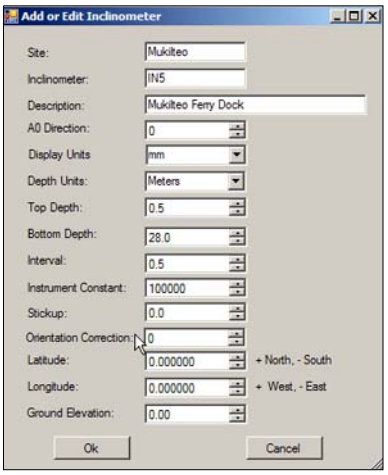
Translation Correction

This correction can be applied to shift all plotted values in the A or B direction. Values in inches or mm are determined by survey or other means and entered in the Edit Survey dialog.



Orientation Correction

Inclinometer casing is installed so that one set of grooves is aligned with the expected direction of movement. If the real direction of movement is some other direction, DigiPro2 can mathematically rotate the orientation of the measurement axes into the direction of interest.

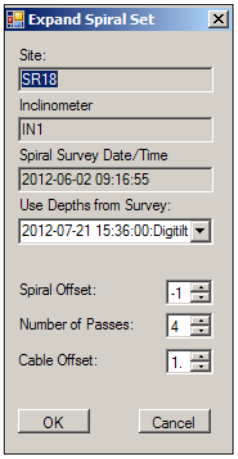


1. Select the inclinometer.
2. Click the Edit button to display the Edit Inclinometer dialog.
3. Enter a value in degrees into the Orientation Correction field. Enter a positive value to rotate orientation clockwise. Enter a negative value to rotate the orientation counter-clockwise.
4. When you plot the inclinometer, enable the Orientation Correction in the settings panel.

Spiral Correction

A spiral survey, obtained with a spiral sensor, provides measurements that can be used to correct for spiraled (twisted) casing. DigiPro2 retrieves the spiral survey from the DataMate.

Readings in the spiral survey are taken at 5 foot or 1.5m intervals. Readings in an inclinometer survey are taken at 2 foot or 0.5m intervals. DigiPro must "expand" the spiral survey to provide a correction value to be used with each inclinometer reading.



1. Select the inclinometer.
2. Select the spiral survey.
3. Click Tools > Expand Spiral Survey.
4. Enter the spiral offset, cable offset, and passes. The recommended number of passes is 4.

   The two offset values are important for calculations. This information must be obtained from the person who took the spiral survey.
5. DigiPro2 expands the spiral set.
6. Enable Spiral Correction in the settings panel. DigiPro will then automatically apply the spiral corrections to any surveys that you plot.

DigiPro2: Basic vs Advanced

DigiPro 2

DigiPro2 is distributed as a trial version with all the advanced features enabled. After 45 days, the advanced features are disabled and DigiPro reverts to a “basic” version unless you purchase and install a license key. The "basic" version is free to use and can be converted to the advanced version at any time. The table below provides a comparison between basic and advanced versions.

DigiPro2 Features	Basic	Advanced
Create dpw databases	●	●
Import dux files from Digitilt AT system	●	●
Retrieve surveys directly from Digitilt DataMate	●	●
Import mdb databases created by DMM	●	●
Import Gtilt and other file formats	●	●
Export surveys data to many formats	●	●
Export processed data to txt, csv, dat, and image file	●	●
Standard vertical plots	●	●
Surveys per plot	3	Unlimited
Spiral plot	●	●
Title block with multiple columns, graphic logo		●
Time displacement plot, Resultant plot		●
Horizontal plots		●
Copy settings from one plot to another		●
Mixed plot types, additional plots on page		●
Field Accuracy Indicator		●
Represent boring log on plot		●
Corrections for Inclinometer: Orientation, Spiral		●
Corrections for Surveys: bias shift, rotation, sensitivity, xy translation, settlement		●
Save plots for reuse on new surveys		●
Save plots as templates for use with other inclinometers		●

Licensing DigiPro2

Overview

DigiPro2 is distributed as a trial version with all the advanced features enabled. After 45 days, the advanced features are disabled unless you purchase and install a license key.

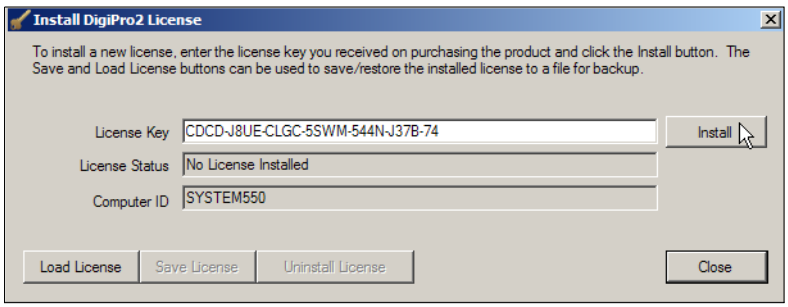
When you purchase DigiPro2, we make an entry in the license database and email the required number of keys to you. If you purchased DigiPro2 through a distributor, we typically email the keys to the distributor.

Installing a Key

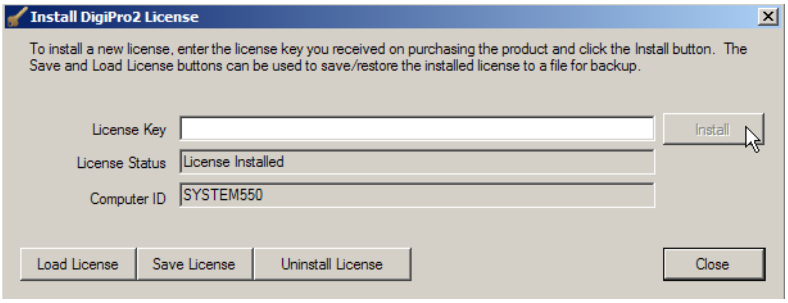
1. Start DigiPro2 and click "License."

   In the example at right, DigiPro2 has reverted to the basic version.

2. DigiPro2 displays the license dialog. Cut and paste the key from your email into the License Key field. Then click "Install.

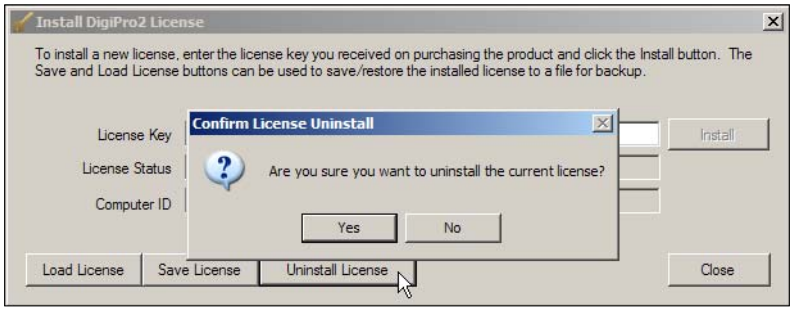


3. DigiPro2 activates the license via the internet. When the activation is successful, the License Key field goes blank, but the License Status field shows "License Installed." Click "Close" to complete the process.



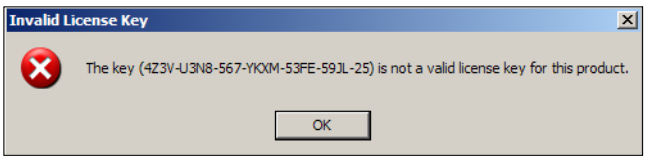
Uninstalling a Key

If you wish to move a key from one computer to another, you can uninstall a key and reinstall it on another computer. Click “Uninstall License” and then click “Yes.” DigiPro2 then reverts to the basic version .



Invalid Key

If DigiPro2 cannot activate a key, it displays this message:.



Possible reasons for this message:

- The key has been used too many times. Perhaps the key was not uninstalled before it was reused on this PC.
- The internet connection was bad.

Contact DGSI or your distributor to correct the situation.

No Internet

If it is not possible to activate DigiPro via the internet, contact DGSI or your distributor. Other solutions are available.

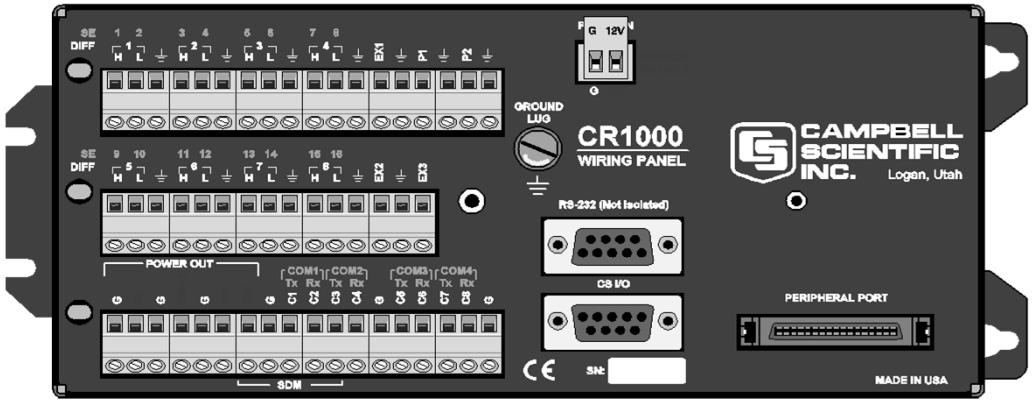
Appendix B - Wiring Diagrams

Appendix B1 - Datalogger Diagrams

CR1000 Wiring Diagram

Company:	Nuna Contracting / SRK Consulting
Project:	Hope Bay Dam project
Documented By:	Mike Ryder - Campbell Scientific Canada Corp.

CR1000 #1 Located in Node B



Ground	Black
12V	Red
Reset	White
Clock	Green
COM H (ODD)	White
COM L (ODD)	Green
COM H (EVEN)	Red
COM L (EVEN)	Black

	G
	5V
	G
	SW-12
AM16/32B #1,#2,#3 - G	**G**
AM16/32B #1,#2,#3 - 12V	**12V**
AM16/32B #4, #5, - 12V	**12V**
AM16/32B #4, #5 - G	**G**
AM16/32B#1, #5 Res	**C1 (COM1 Tx)**
AM16/32B#1, #5 Clk	**C2 (COM1 Rx)**
AM16/32B#2 Res	**C3 (COM2 Tx)**
AM16/32B#2 Clk	**C4 (COM2 Rx)**
	G
AM16/32B#3 Res	**C5 (COM3 Tx)**
AM16/32B#3 Clk	**C6 (COM3 Rx)**
AM16/32B#4 Res	**C7 (COM4 Tx)**
AM16/32B#4 Clk	**C8 (COM4 Rx)**
	G

Battery 12V (Red)	**12V**
Battery G (Black)	**G**

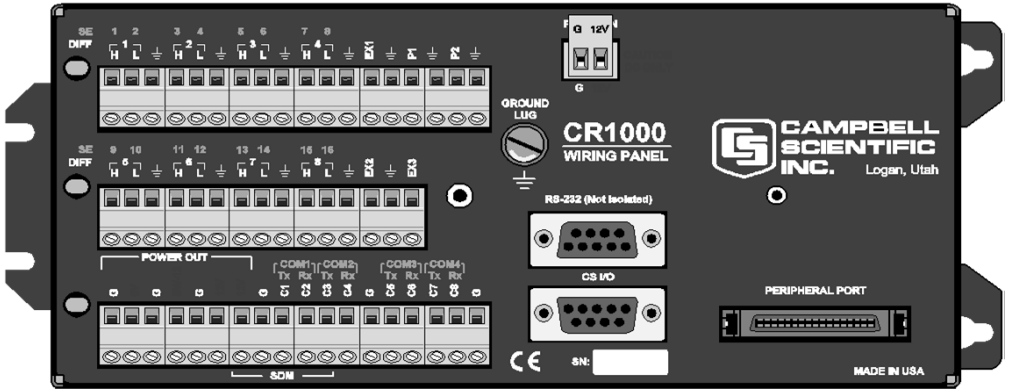
AM16/32B#3 COM L(EVEN) - RES to ⏚	**5H (SE9)**
AM16/32B#4 COM L(ODD) - RES to ⏚	**5L (SE10)**
RES to SE10, SE11, SE12	⏚
AM16/32B#4 COM H(EVEN) - RES to ⏚	**6H (SE11)**
AM16/32B#4 COM L(EVEN) - RES to ⏚	**6L (SE12)**
	⏚
AM16/32B#5 COM L(ODD) - RES to ⏚	**7H (SE13)**
AM16/32B#5 COM H(EVEN) - RES to ⏚	**7L (SE14)**
RES to SE13, SE14, SE15	⏚
AM16/32B#5 COM L(EVEN) - RES to ⏚	**8H (SE15)**
	8L (SE16)
	⏚
AM16/32B #3,#4 COM H(ODD)	**EX2**
	⏚
AM16/32B #5 COM H(ODD)	**EX3**

AM16/32B#1 COM L(ODD) - RES to ⏚	**1H (SE1)**
AM16/32B#1 COM H(EVEN) - RES to ⏚	**1L (SE2)**
RES to SE1, SE2, SE3	⏚
AM16/32B#1 COM L(EVEN) - RES to ⏚	**2H (SE3)**
AM16/32B#2 COM L(ODD) - RES to ⏚	**2L (SE4)**
RES to SE4, SE5, SE6	⏚
AM16/32B#2 COM H(EVEN) - RES to ⏚	**3H (SE5)**
AM16/32B#2 COM L(EVEN) - RES to ⏚	**3L (SE6)**
RES to SE7, SE8, SE9	⏚
AM16/32B#3 COM L(ODD) - RES to ⏚	**4H (SE7)**
AM16/32B#3 COM H(EVEN) - RES to ⏚	**4L (SE8)**
	⏚
AM16/32B#1,#2 COM H(ODD)	**EX1**
	⏚
	P1
	⏚
	P2
	⏚

CR1000 Wiring Diagram

Company:	Nuna Contracting / SRK Consulting
Project:	Hope Bay Dam project
Documented By:	Mike Ryder - Campbell Scientific Canada Corp.

CR1000 #2 Located in Node D



Ground	Black
12V	Red
Reset	White
Clock	Green
COM H (ODD)	White
COM L (ODD)	Green
COM H (EVEN)	Red
COM L (EVEN)	Black

	G
	5V
	G
	SW-12
AM16/32B #8, #9 - G	**G**
AM16/32B #8, #9 - 12V	**12V**
AM16/32B #6, #7 - 12V	**12V**
AM16/32B #6, #7 - G	**G**
AM16/32B #6 Res	**C1 (COM1 Tx)**
AM16/32B #6 Clk	**C2 (COM1 Rx)**
AM16/32B #7 Res	**C3 (COM2 Tx)**
AM16/32B #7 Clk	**C4 (COM2 Rx)**
	G
AM16/32B #8 Res	**C5 (COM3 Tx)**
AM16/32B #8 Clk	**C6 (COM3 Rx)**
AM16/32B #9 Res	**C7 (COM4 Tx)**
AM16/32B #9 Clk	**C8 (COM4 Rx)**
	G

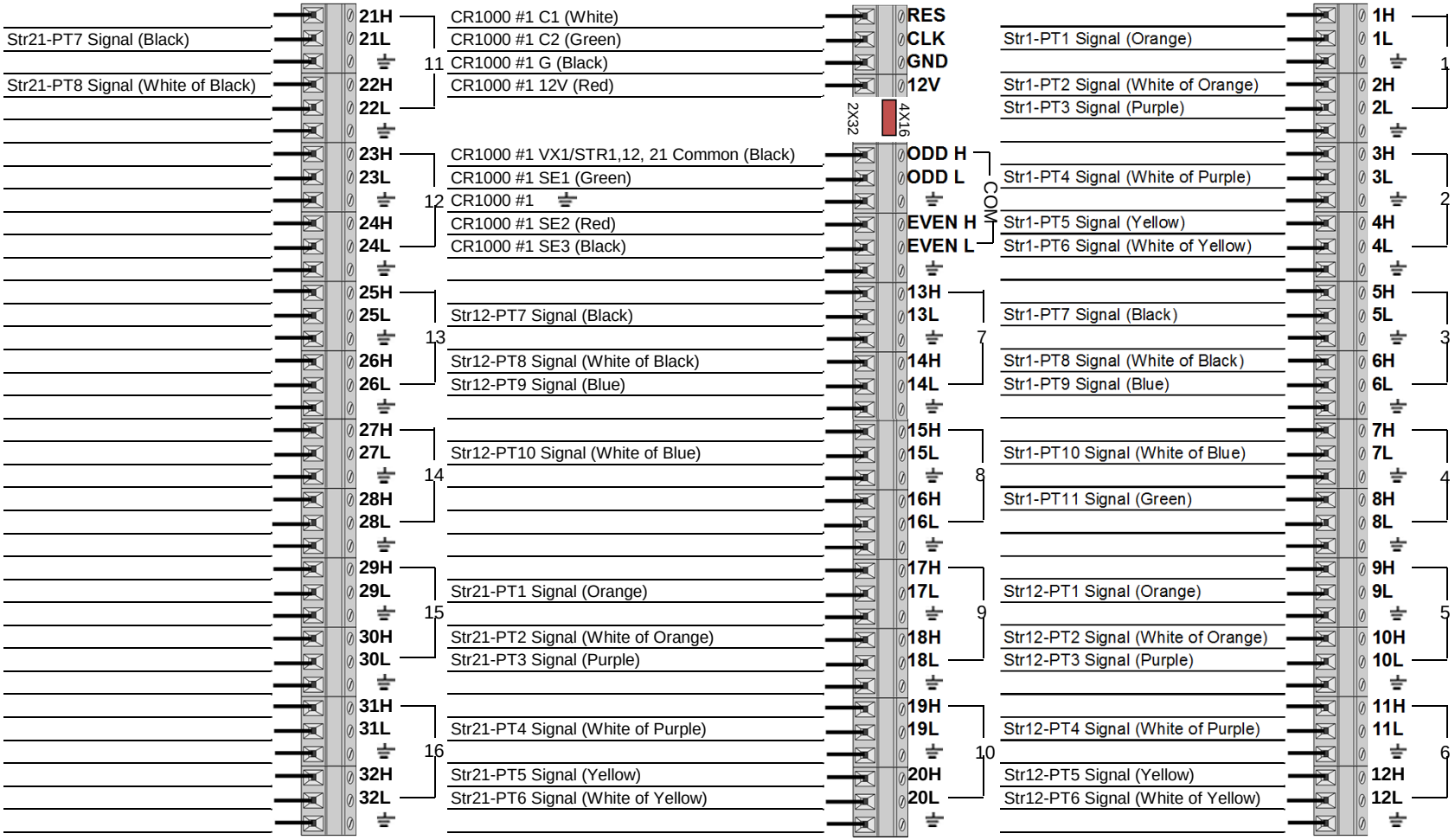
Battery 12V (Red)	**12V**
Battery G (Black)	**G**

AM16/32B#8 COM L(EVEN) - RES to ⏚	**5H (SE9)**
AM16/32B#9 COM L(ODD) - RES24.9 to ⏚	**5L (SE10)**
RES to SE10	⏚
	6H (SE11)
	6L (SE12)
	⏚
	7H (SE13)
	7L (SE14)
	⏚
	8H (SE15)
	8L (SE16)
	⏚
AM16/32B #8 COM H(ODD)	**EX2**
	⏚
AM16/32B #9 COM H (ODD)	**EX3**

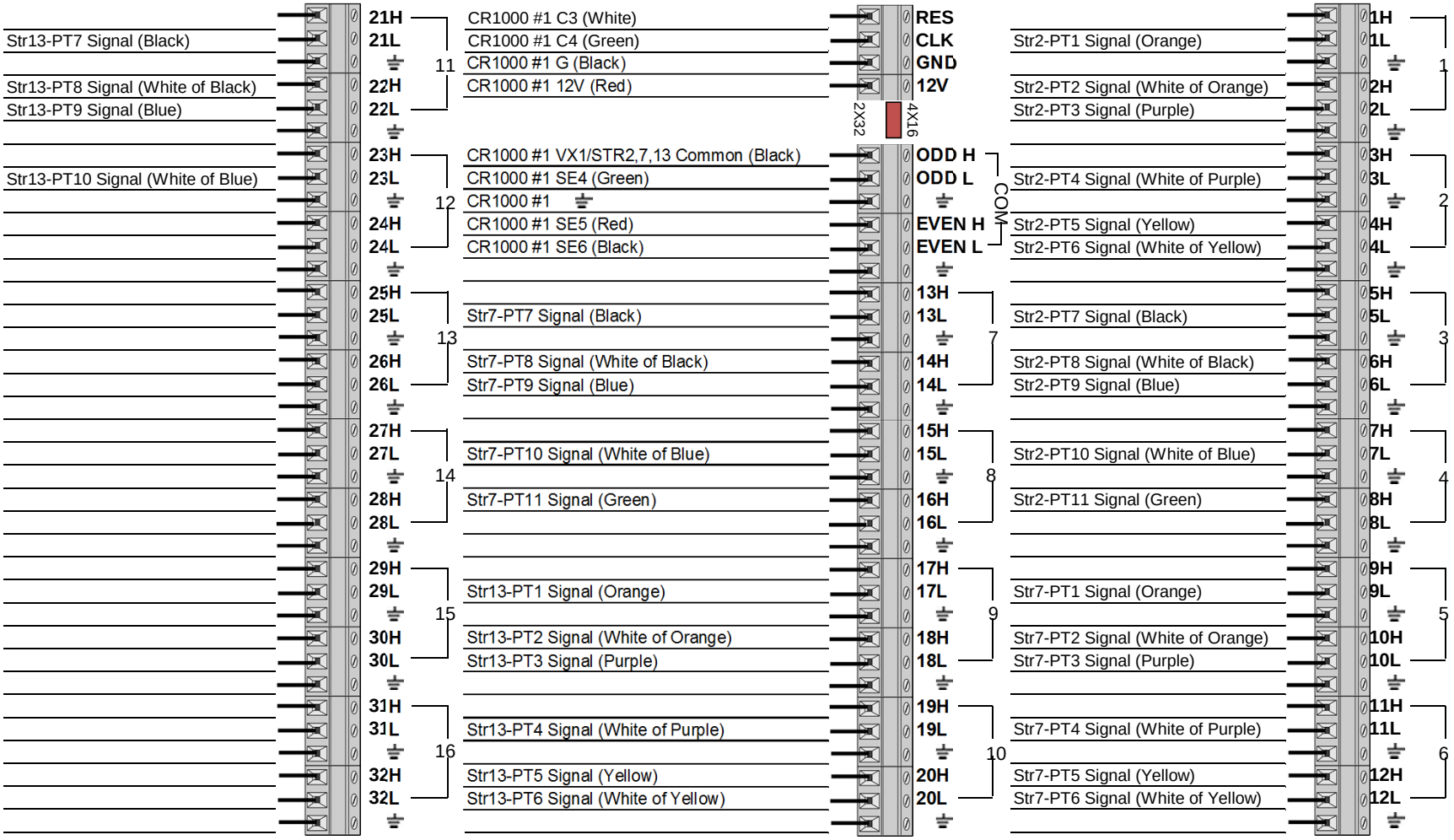
AM16/32B#6 COM L(ODD) - RES to ⏚	**1H (SE1)**
AM16/32B#6 COM H(EVEN) - RES to ⏚	**1L (SE2)**
RES to SE1, SE2, SE3	⏚
AM16/32B#6 COM L(EVEN) - RES to ⏚	**2H (SE3)**
AM16/32B#7 COM L(ODD) - RES to ⏚	**2L (SE4)**
RES to SE4, SE5, SE6	⏚
AM16/32B#7 COM H(EVEN) - RES to ⏚	**3H (SE5)**
AM16/32B#7 COM L(EVEN) - RES to ⏚	**3L (SE6)**
RES to SE7, SE8, SE9	⏚
AM16/32B#8 COM L(ODD) - RES to ⏚	**4H (SE7)**
AM16/32B#8 COM H(EVEN) - RES to ⏚	**4L (SE8)**
	⏚
AM16/32B #6, #7 COM H(ODD)	**EX1**
	⏚
	P1
	⏚
	P2
	⏚

Appendix B2 - Multiplexer Diagrams

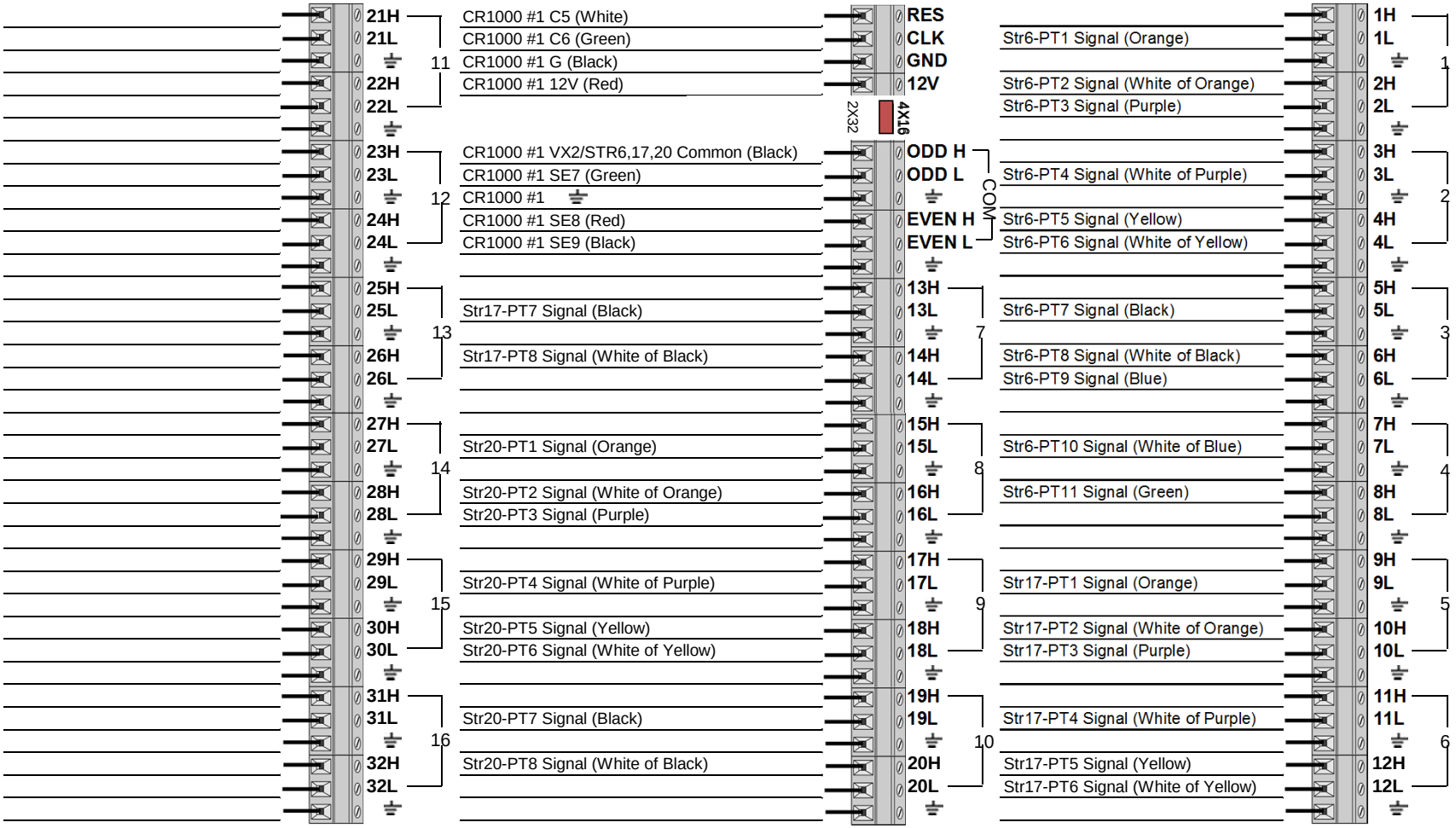
AM16/32 WIRING DIAGRAM	NODE A - Multiplexer #1
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



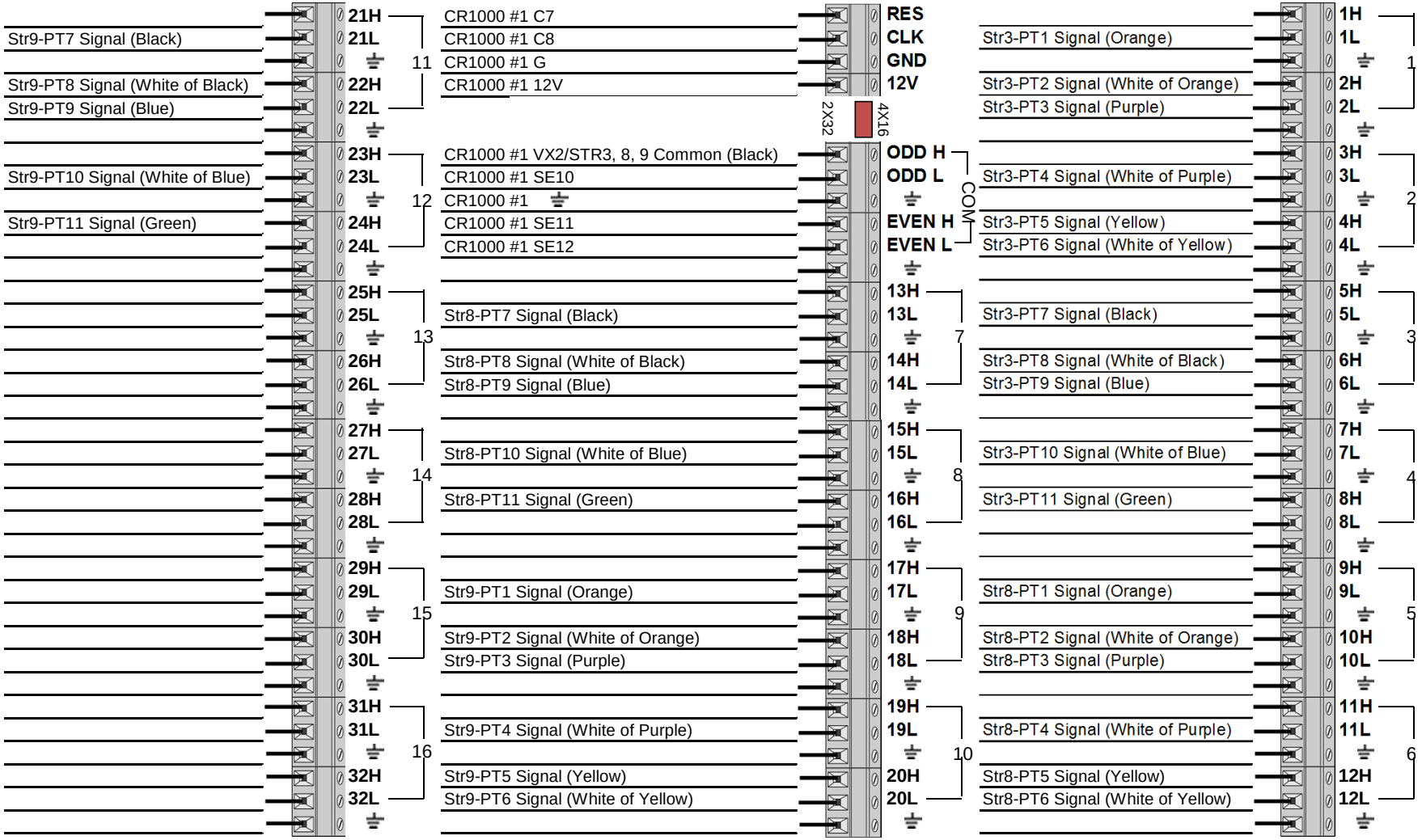
AM16/32 WIRING DIAGRAM	NODE B - Multiplexer #2
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



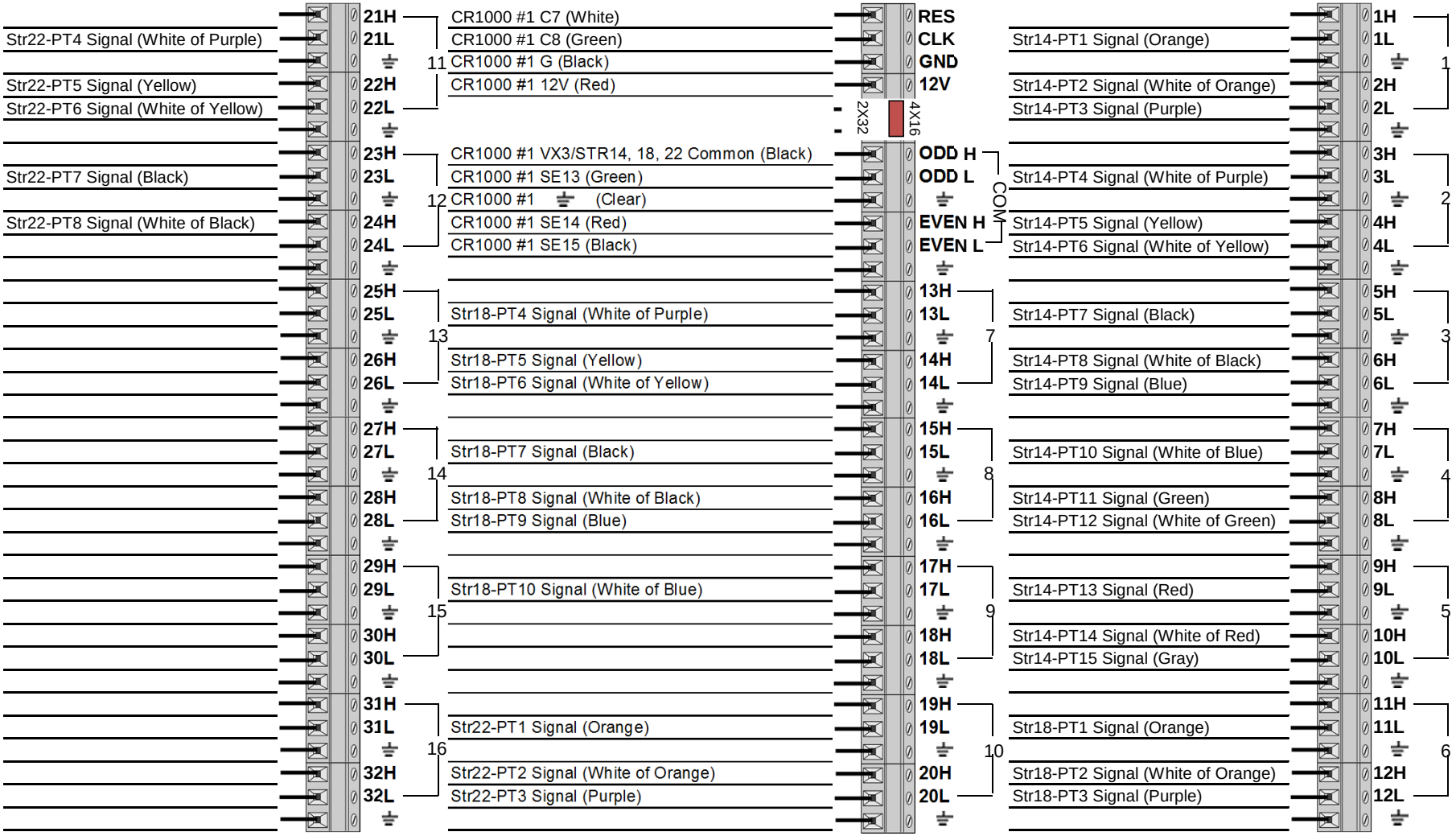
AM16/32 WIRING DIAGRAM	NODE B - Multiplexer #3
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



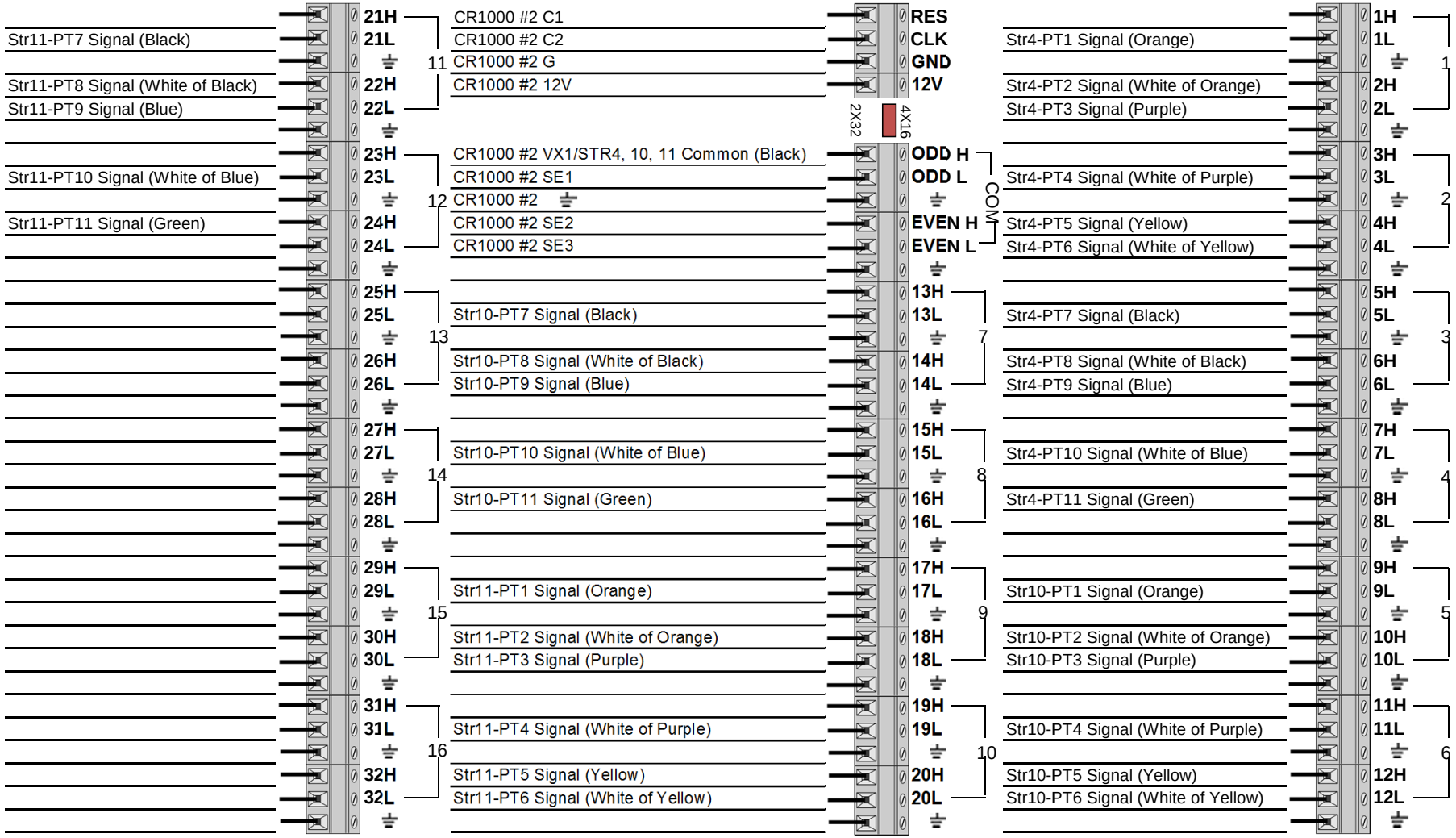
AM16/32 WIRING DIAGRAM	NODE C - Multiplexer #4
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



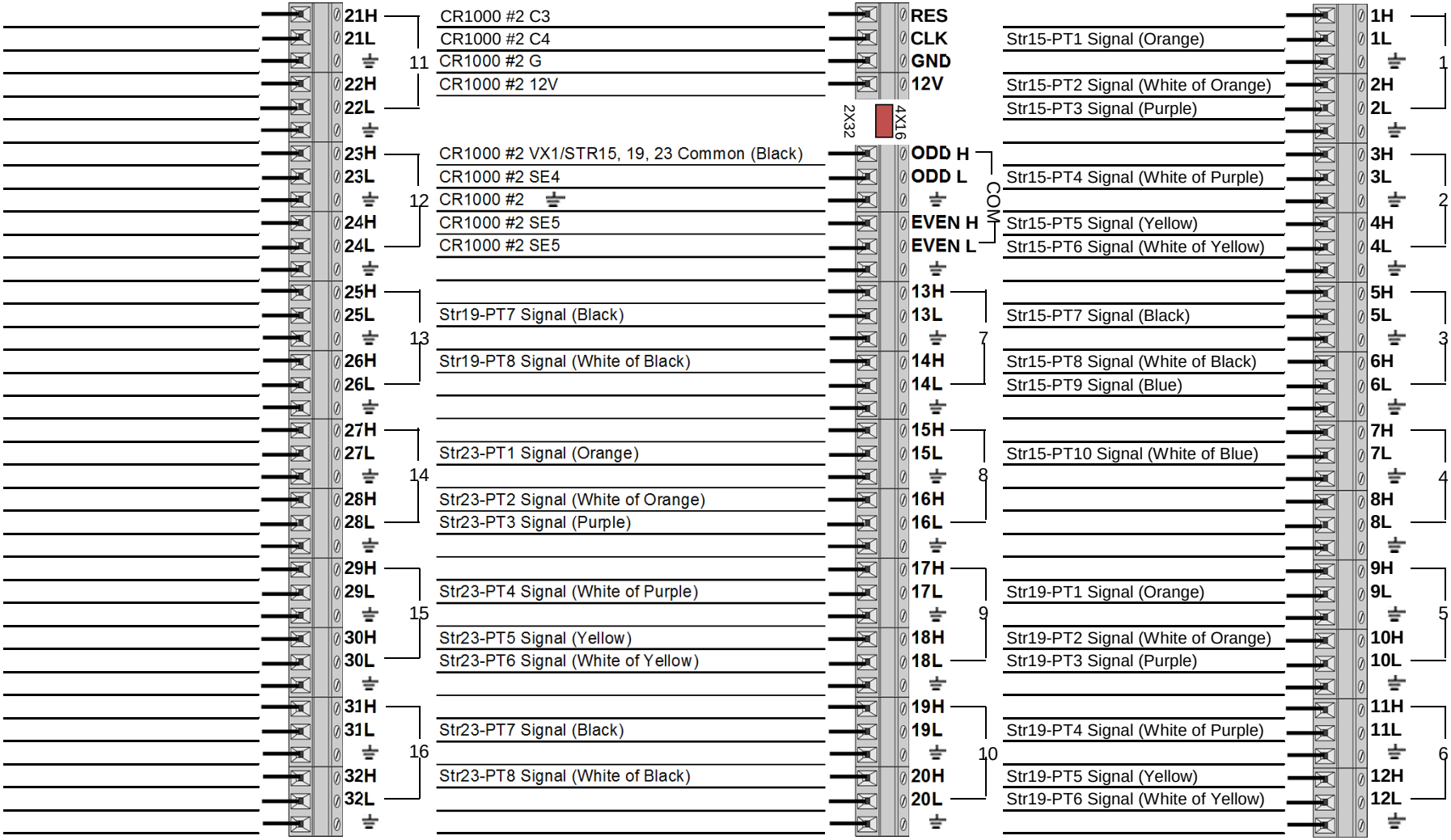
AM16/32 WIRING DIAGRAM	NODE C - Multiplexer #5
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



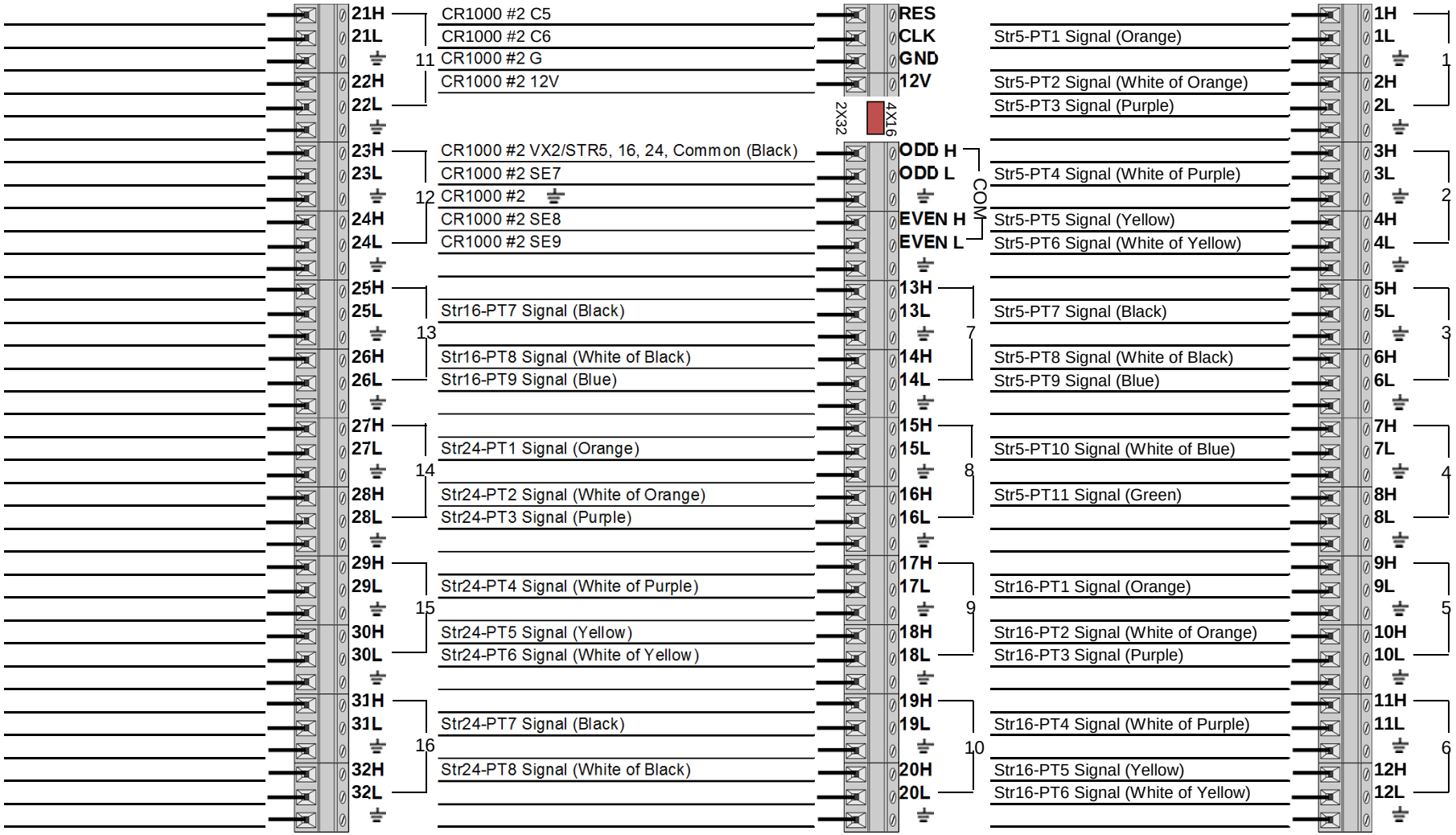
AM16/32 WIRING DIAGRAM	NODE D - Multiplexer #6
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



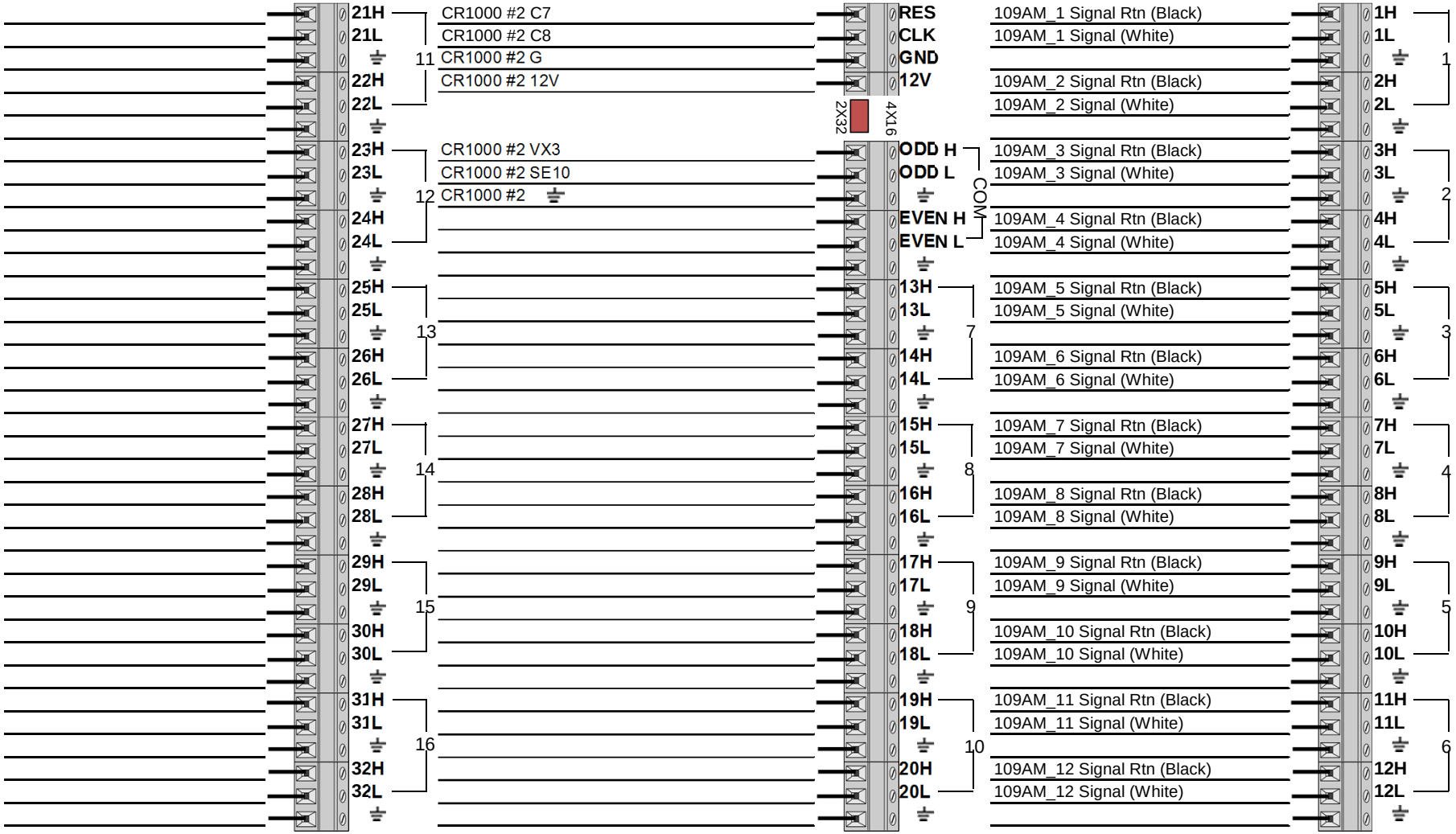
AM16/32 WIRING DIAGRAM	NODE D - Multiplexer #7
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



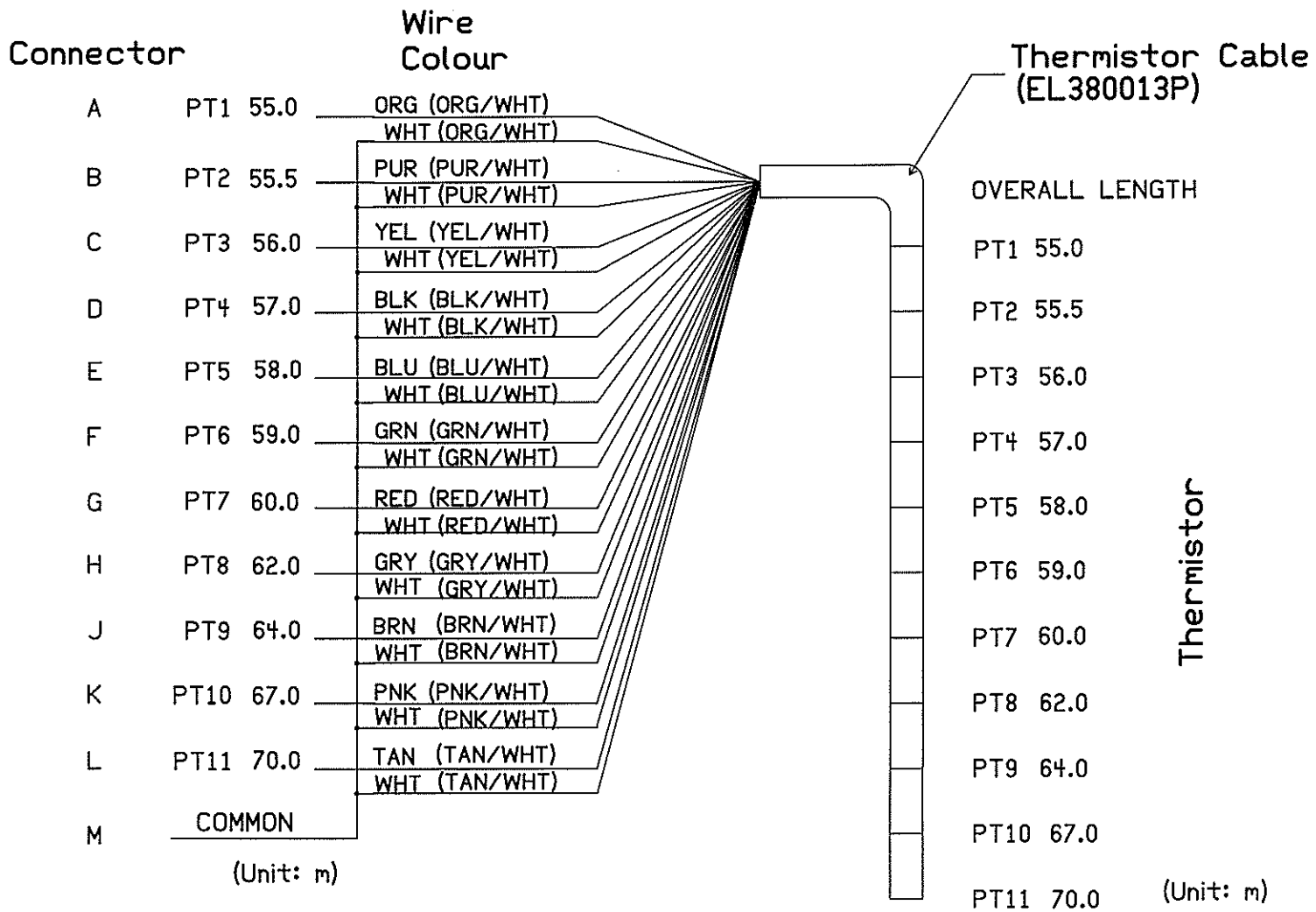
AM16/32 WIRING DIAGRAM	NODE E - Multiplexer #8
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



AM16/32 WIRING DIAGRAM	NODE E - Multiplexer # 9
COMPANY:	Nuna Contracting / SRK Consulting
PROJECT:	Hope Bay Dam project
documented by:	Mike Ryder - Campbell Scientific Canada Corp.



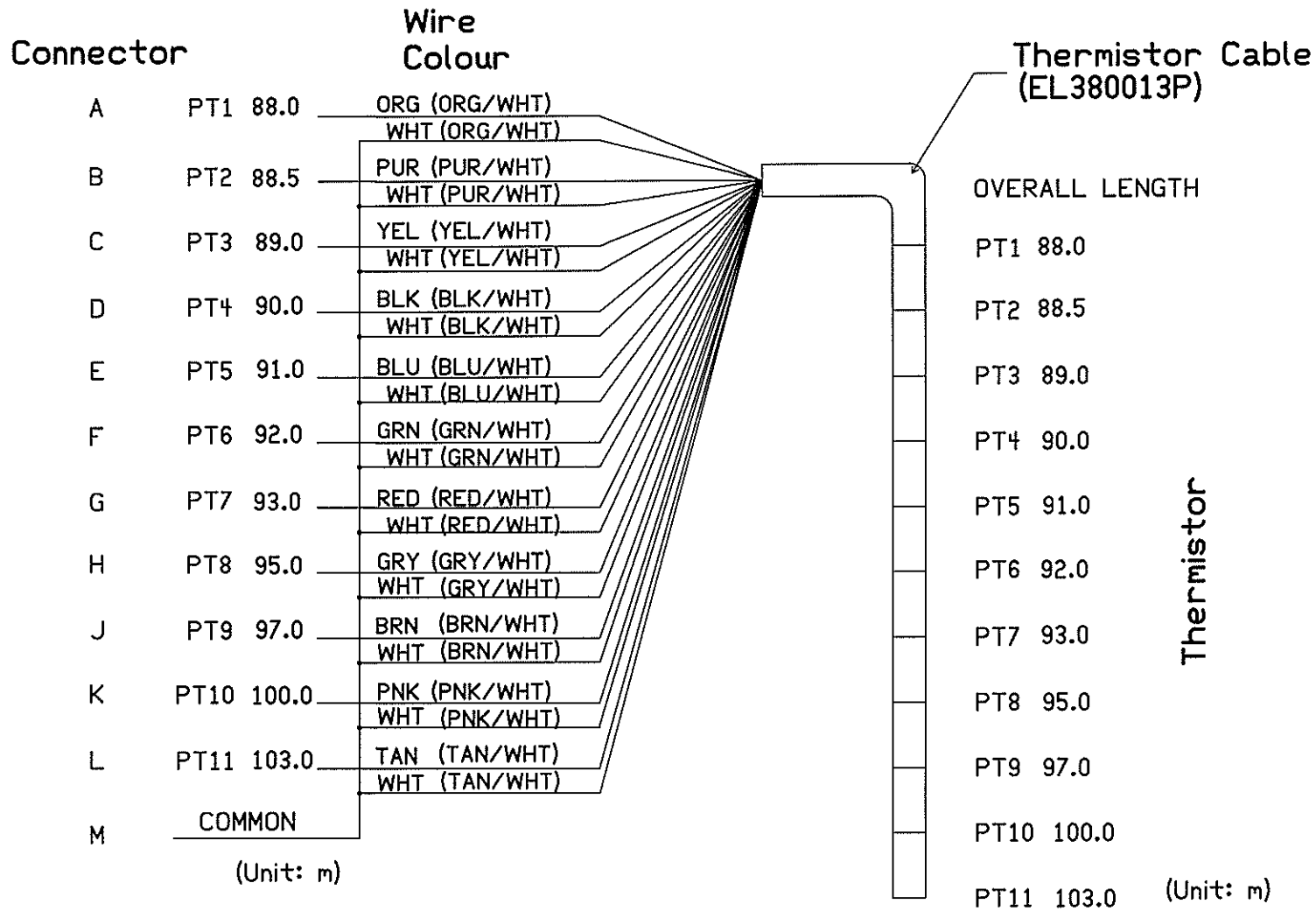
Appendix B3 - Thermistor Cable Diagrams



Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-1 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3080

ID: ND-VTS-040-KT



S/N: TS3081

ID: ND-VTS-060-KT

Co:	RST INSTRUMENTS LTD
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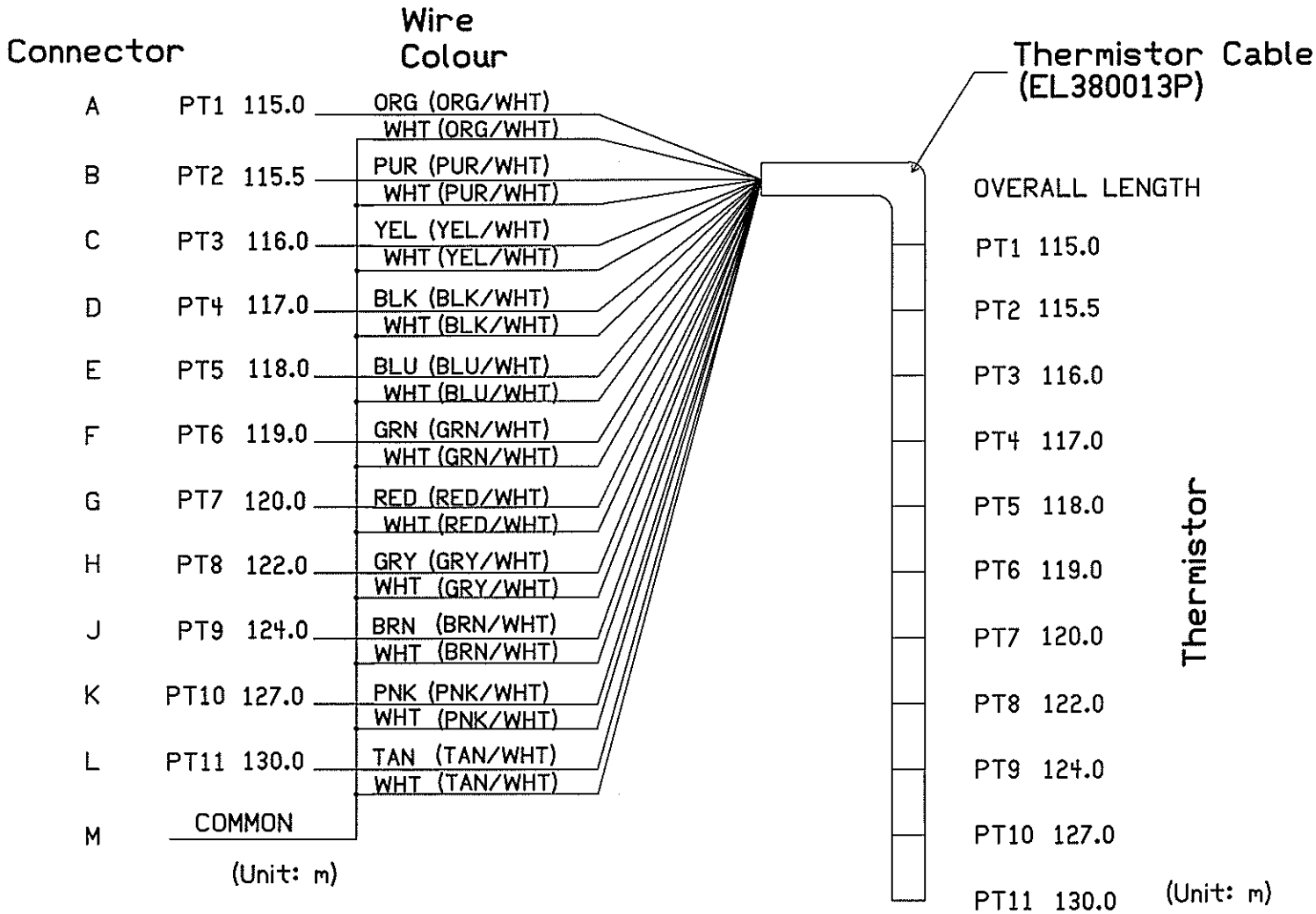
J/N:	WOQ018560-2 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



Co:	RST INSTRUMENTS LTD
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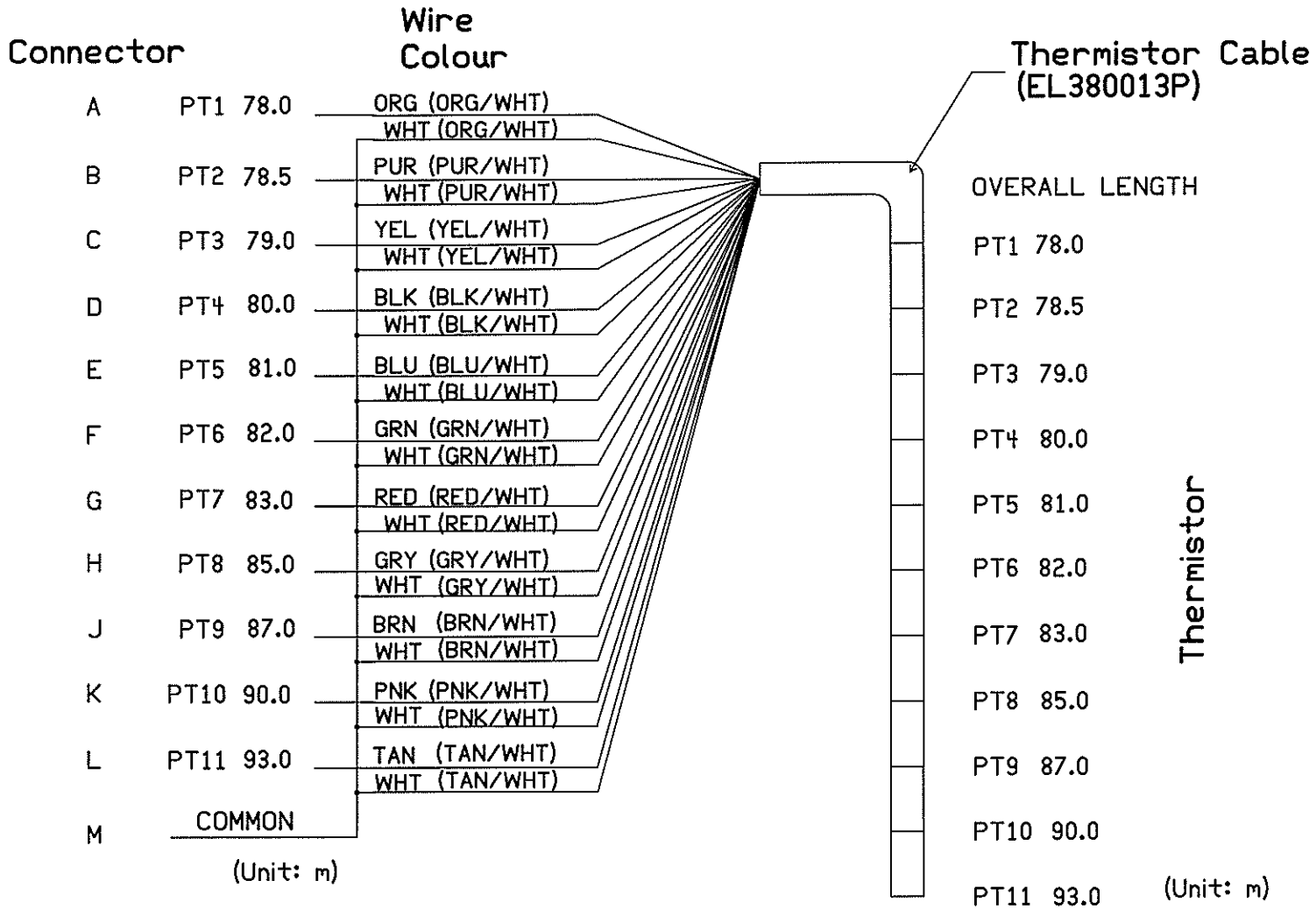
J/N:	WOQ018560-3 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3082

ID: ND-VTS-085-KT



S/N: TS3083

ID: ND-VTS-130-KT

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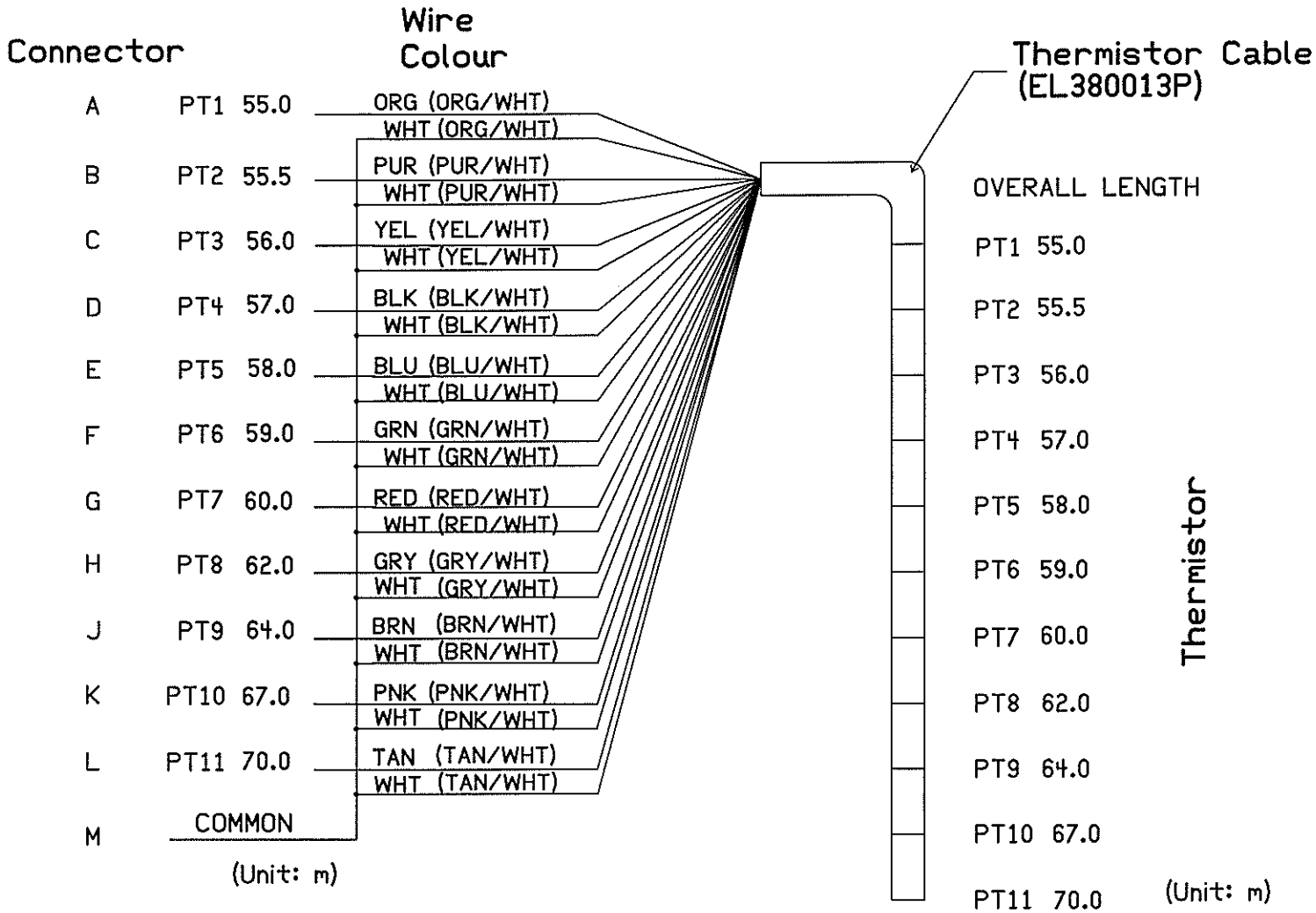
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



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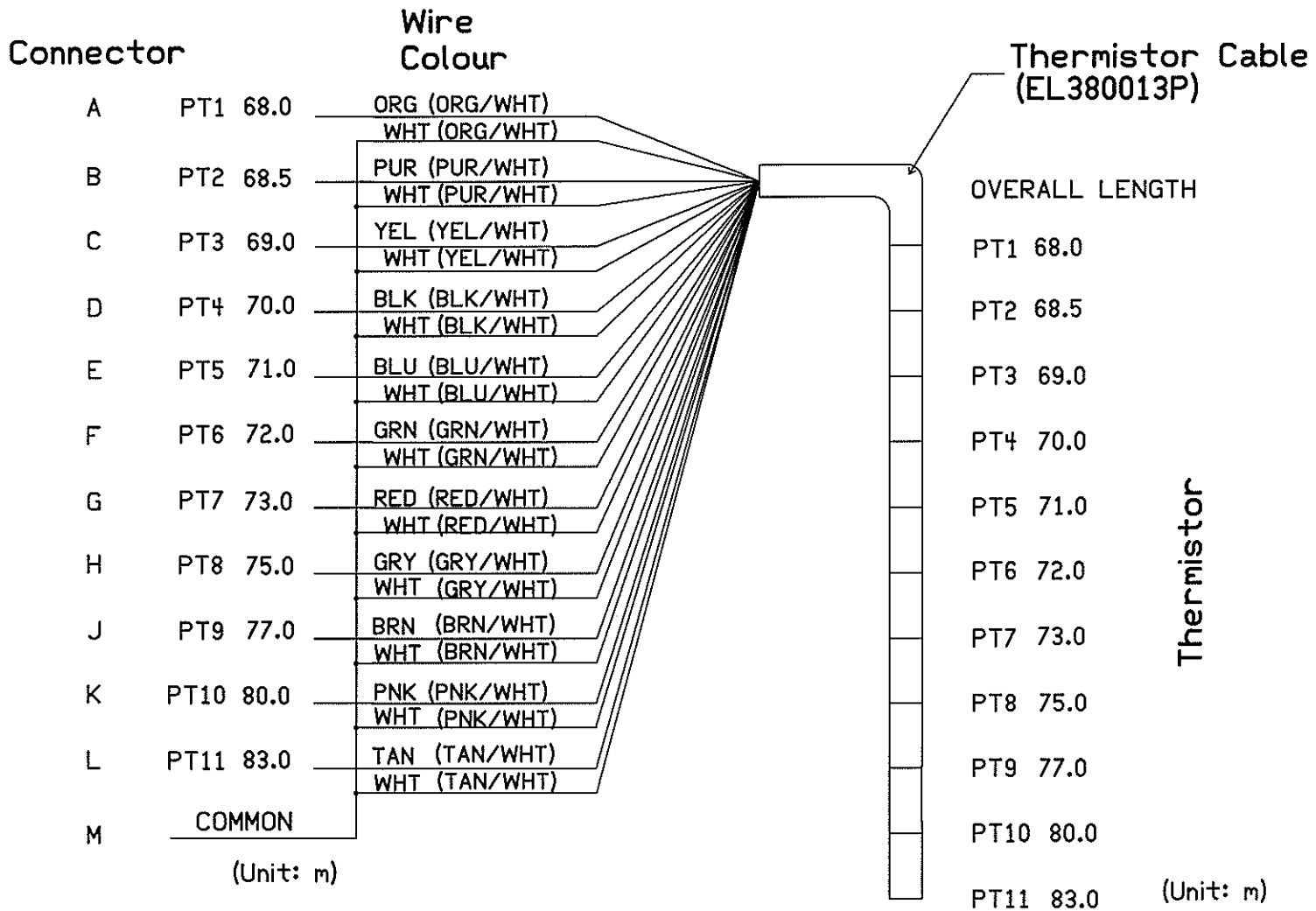
J/N:	WOQ018560-5
Revision:	A
Author:	CB
Size:	A
Date:	2010/10/12
Sheet	1 of 1

S/N: TS3084

ID: ND-VTS-175-KT



S/N: TS3085

ID: ND-VTS-060-US

Co:	RST INSTRUMENTS LTD
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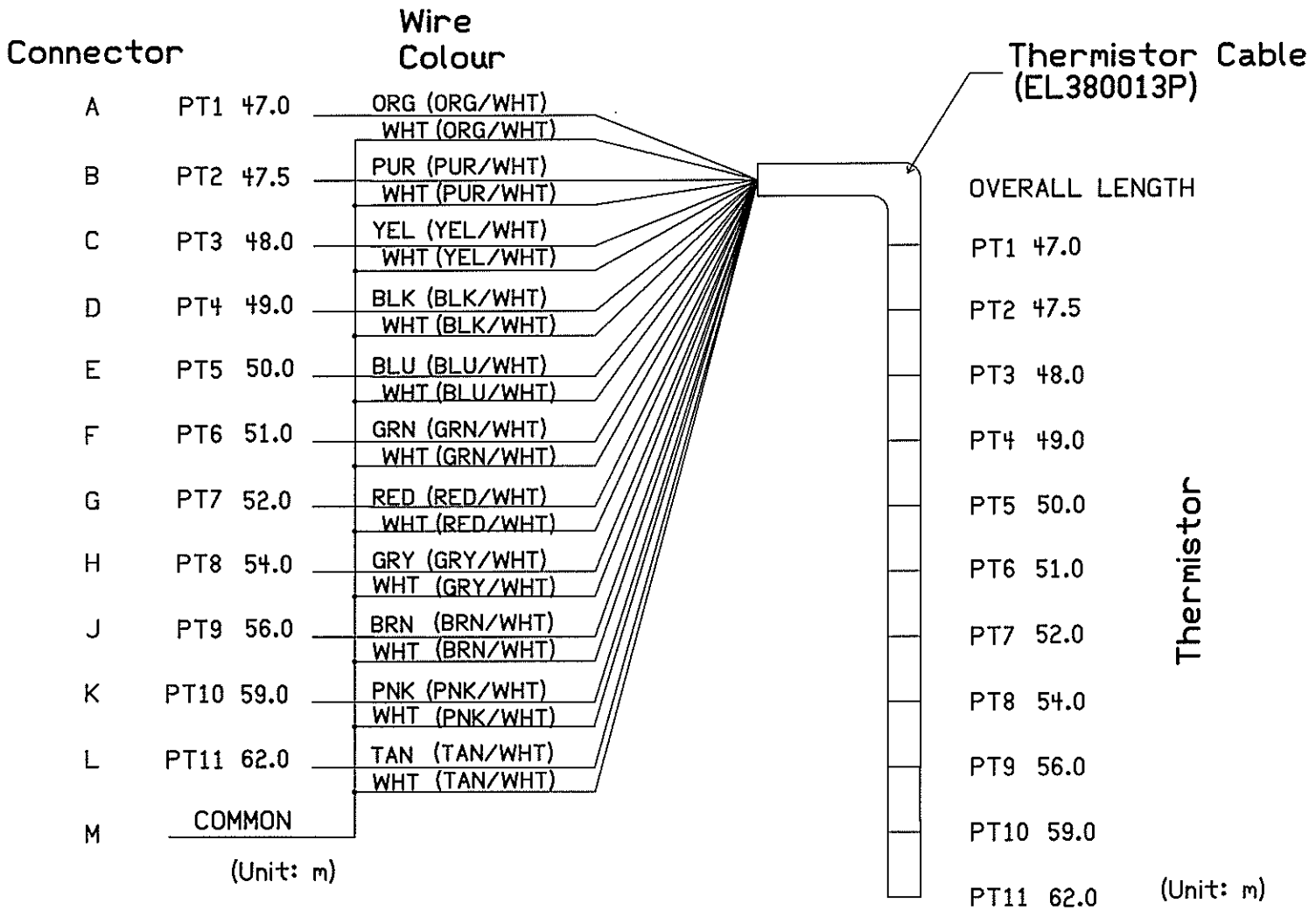
J/N:	WOQ018560-6 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



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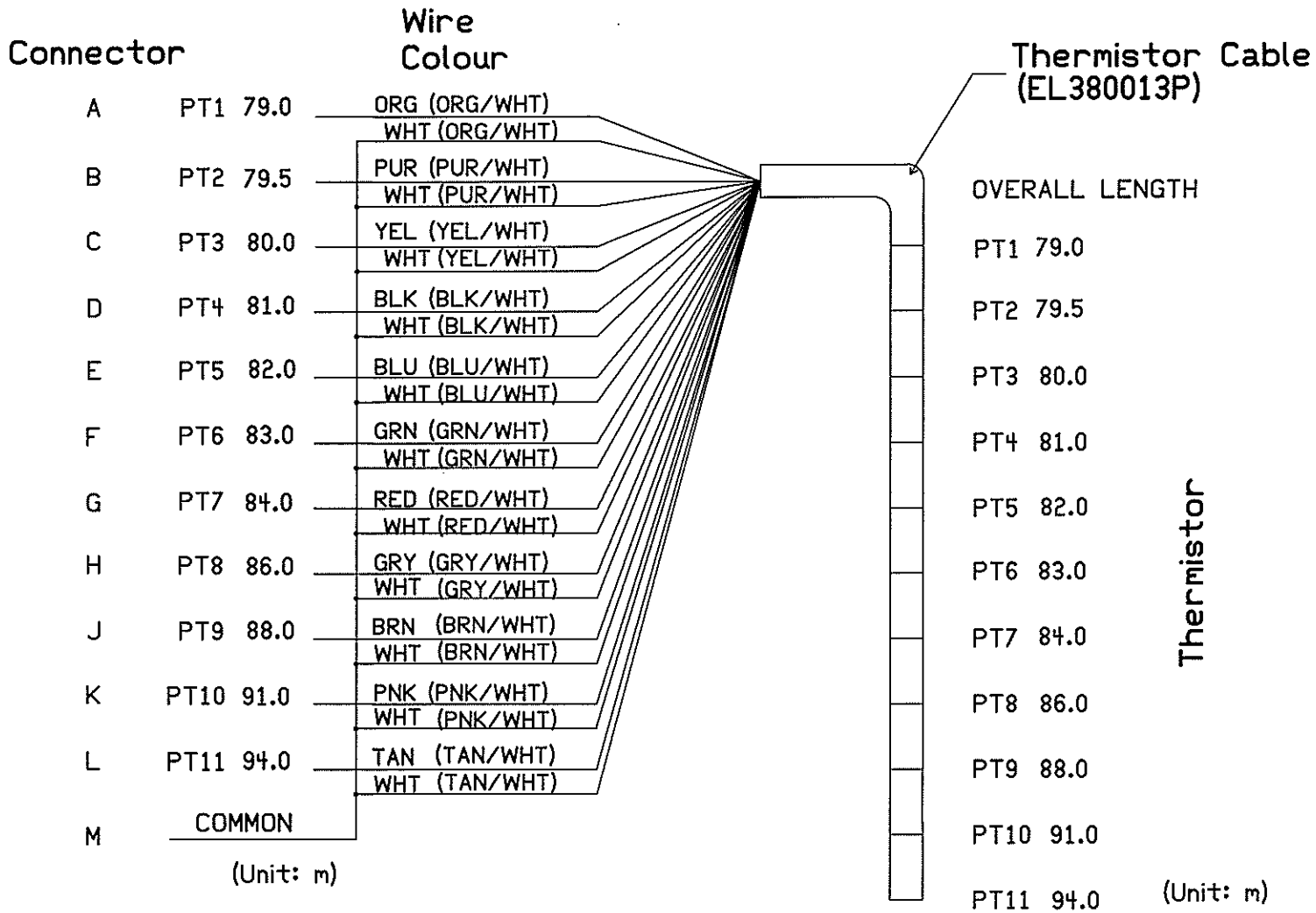
J/N:	WOQ018560-7 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3086

ID: ND-VTS-060-DS



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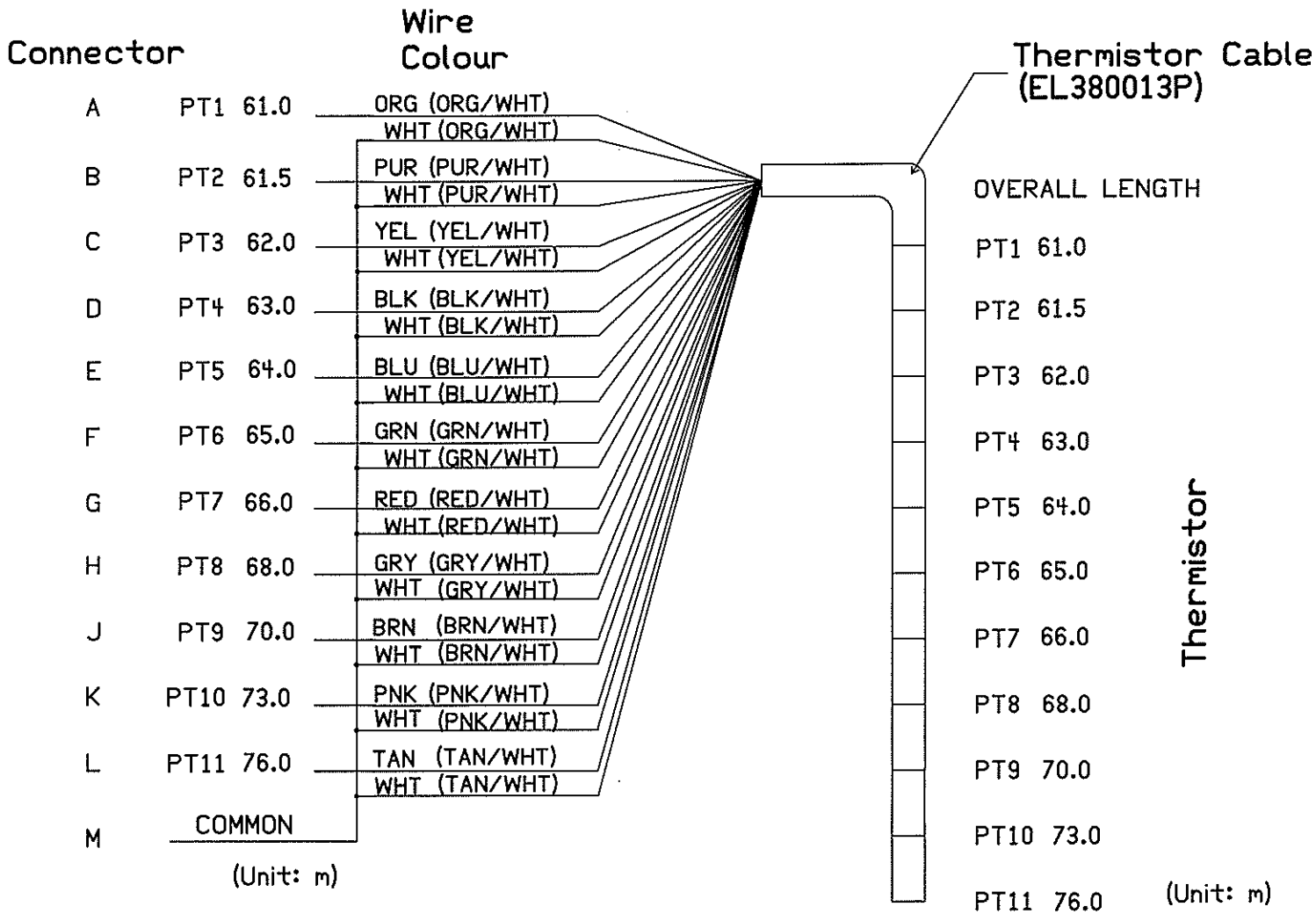
J/N:	WOQ018560-8
Revision:	A
Author:	CB
Size:	A
Date:	2010/10/12
Sheet	1 of 1

S/N: TS3087

ID: ND-VTS-085-US



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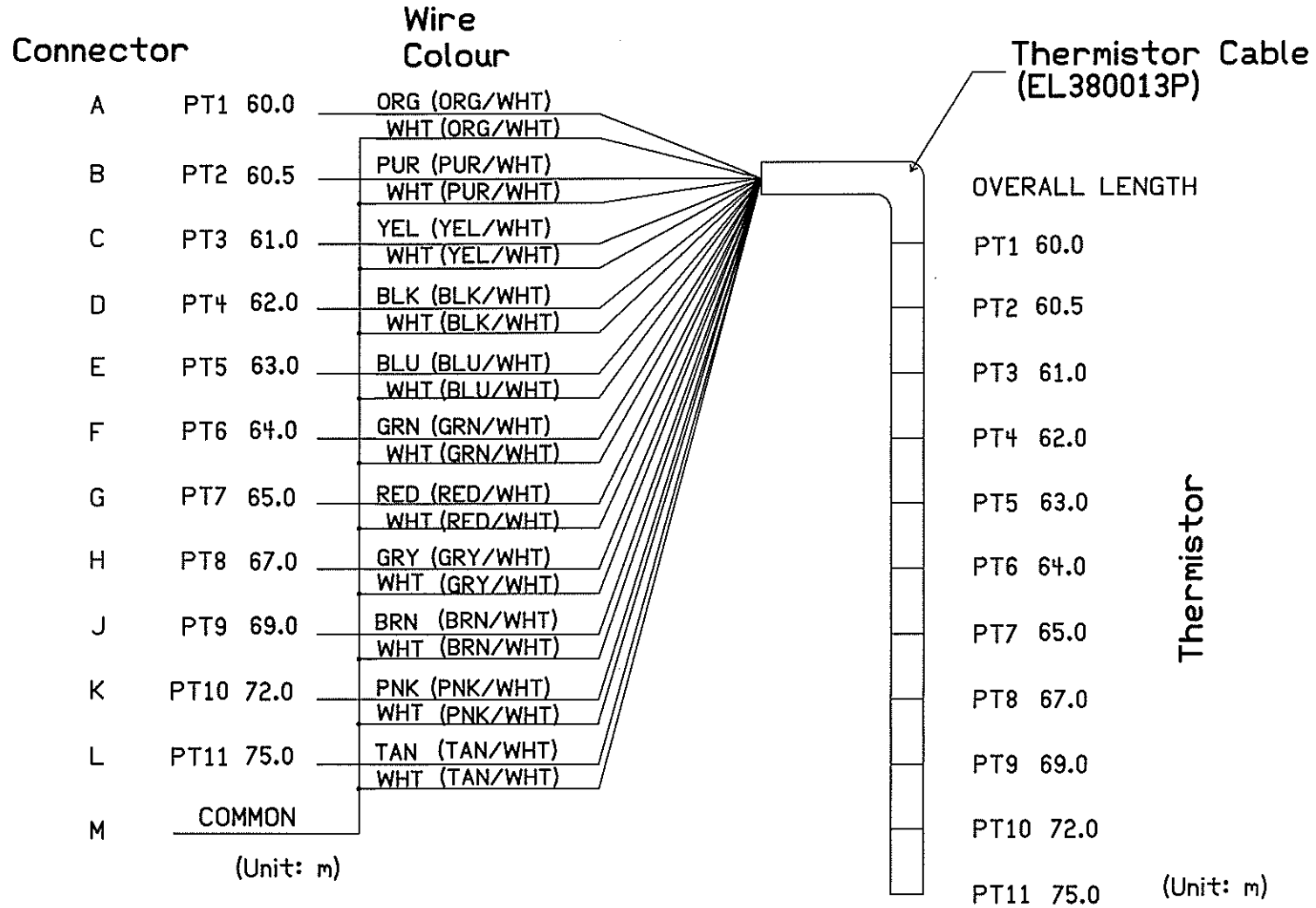
J/N:	WOQ018560-9 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3088

ID: ND-VTS-085-DS



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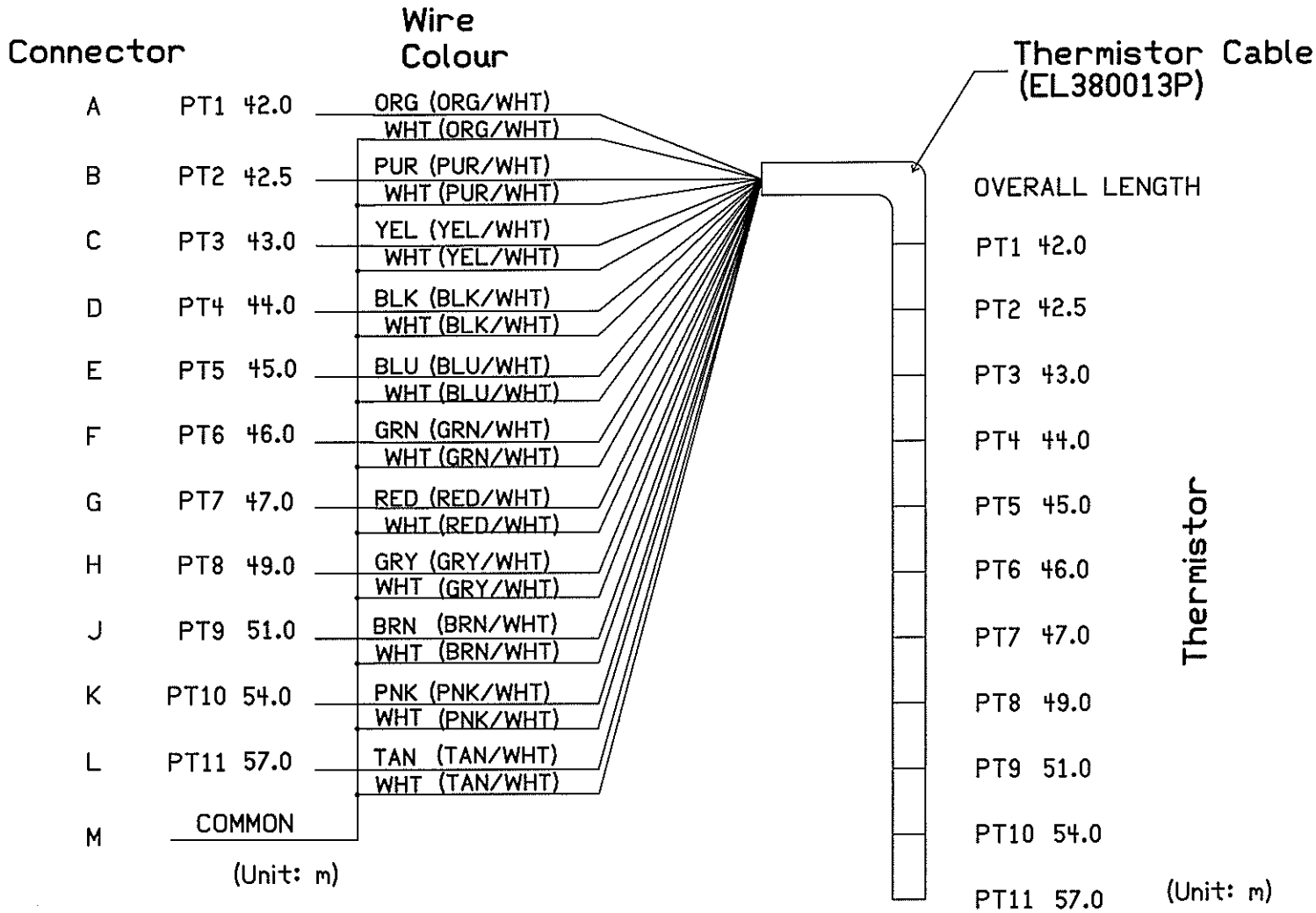
J/N:	WOQ018560-10 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3089

ID: ND-VTS-130-US



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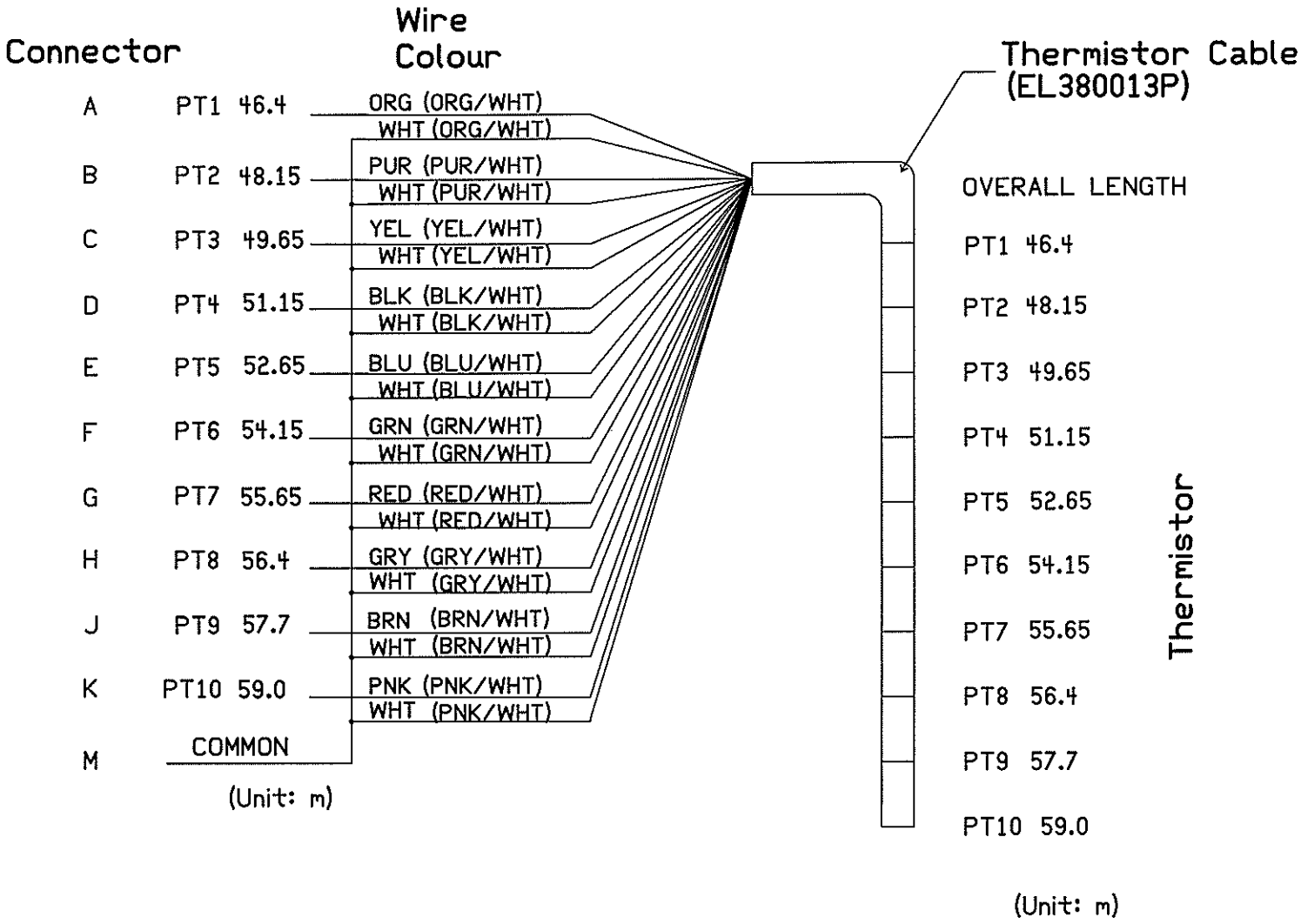
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3090

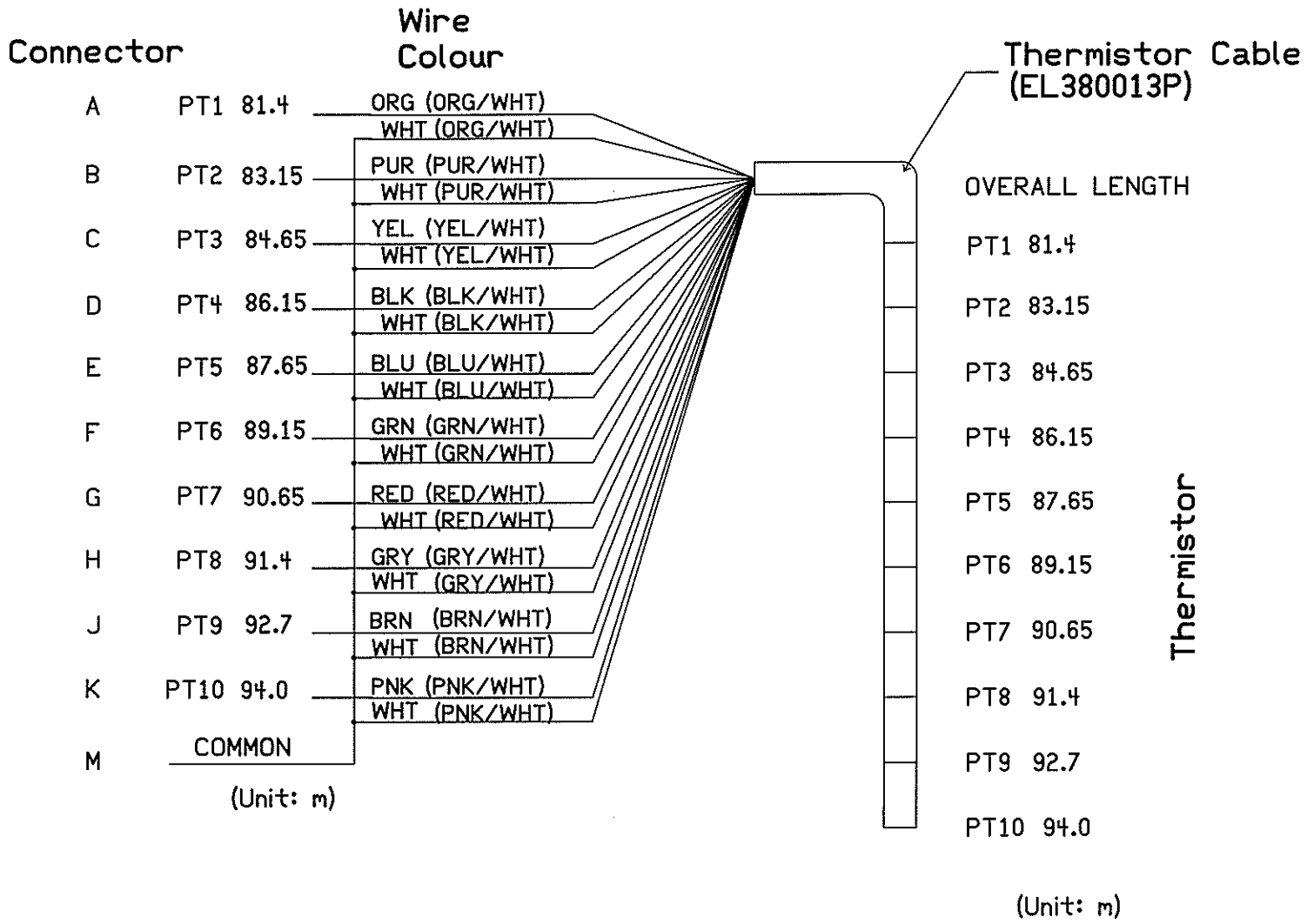
ID: ND-VTS-130-DS



Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-12 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3091

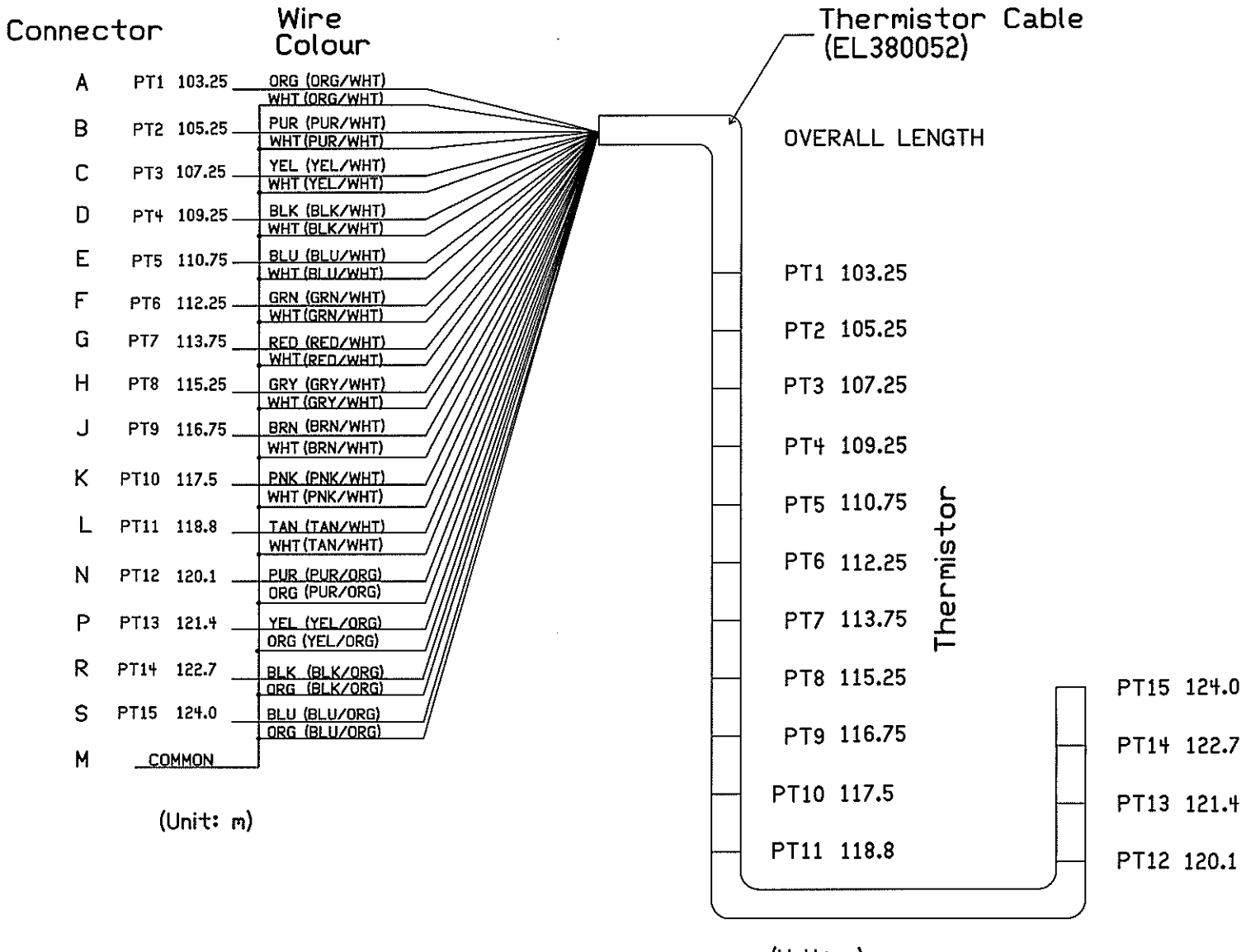
ID: ND-HTS-040-31.5



S/N: TS3092

ID: ND-HTS-060-28.8

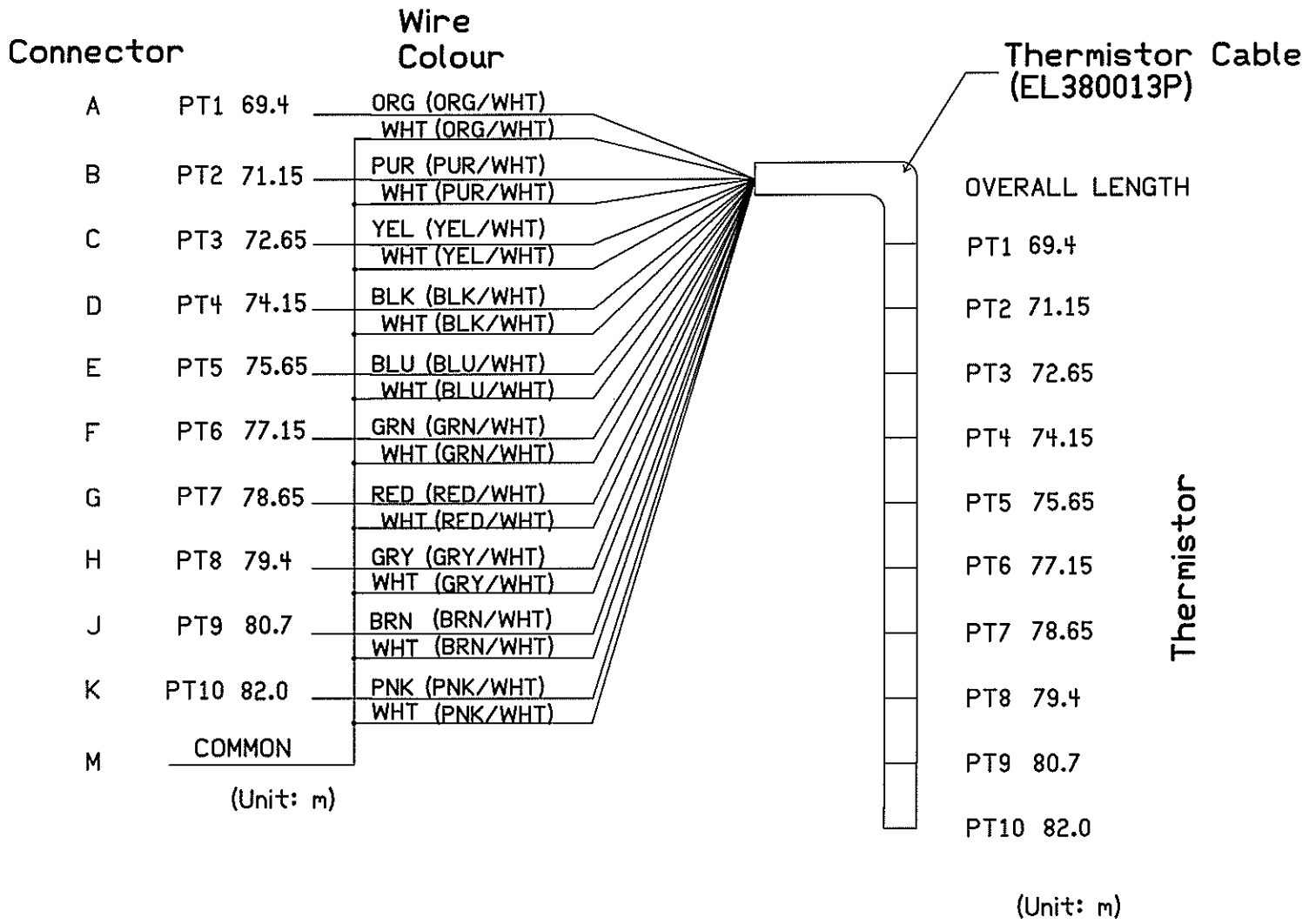
Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-13 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-14 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3093

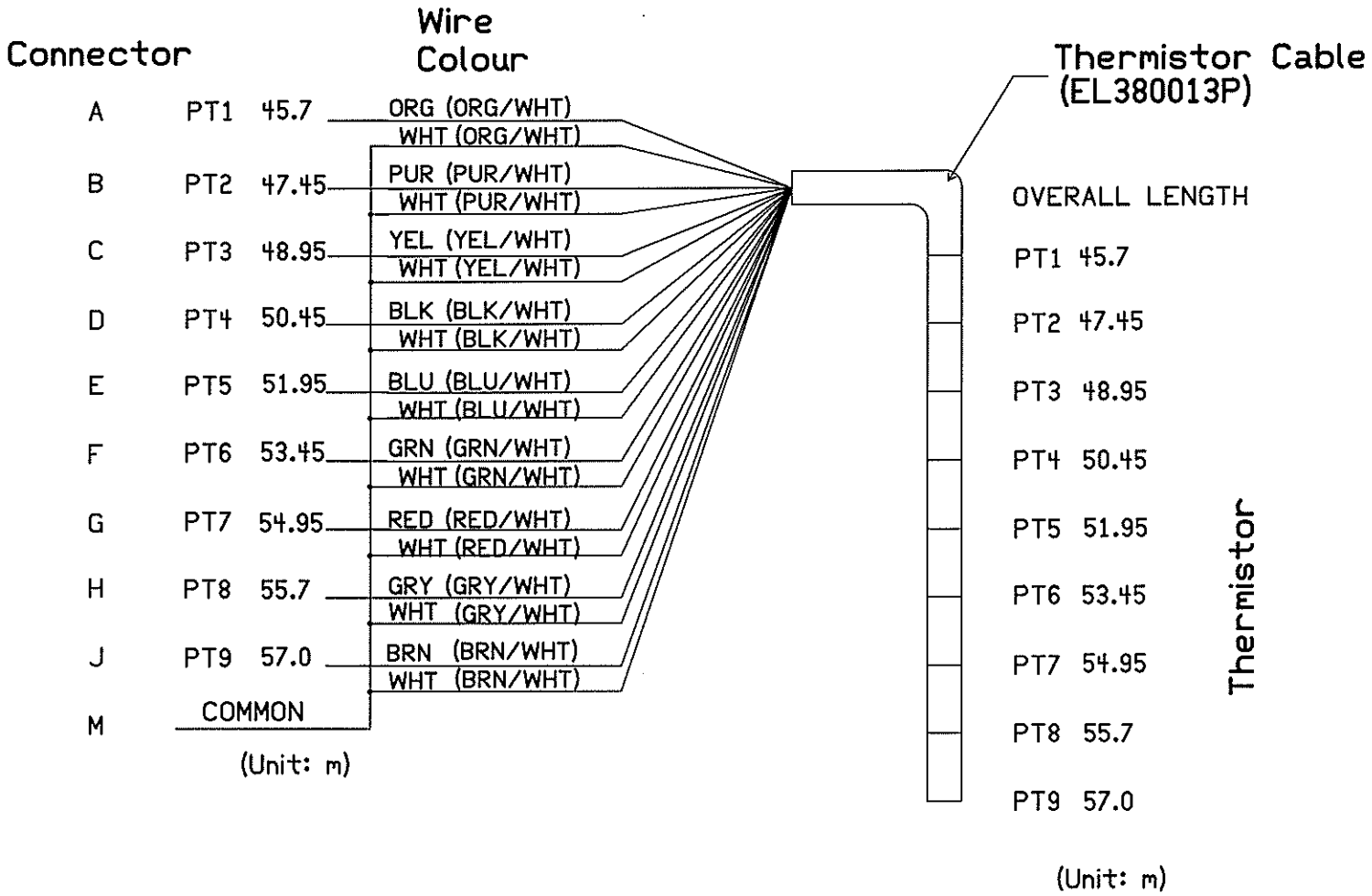
ID: ND-HTS-085-25.3



S/N: TS3094

ID: ND-HTS-130-28.8

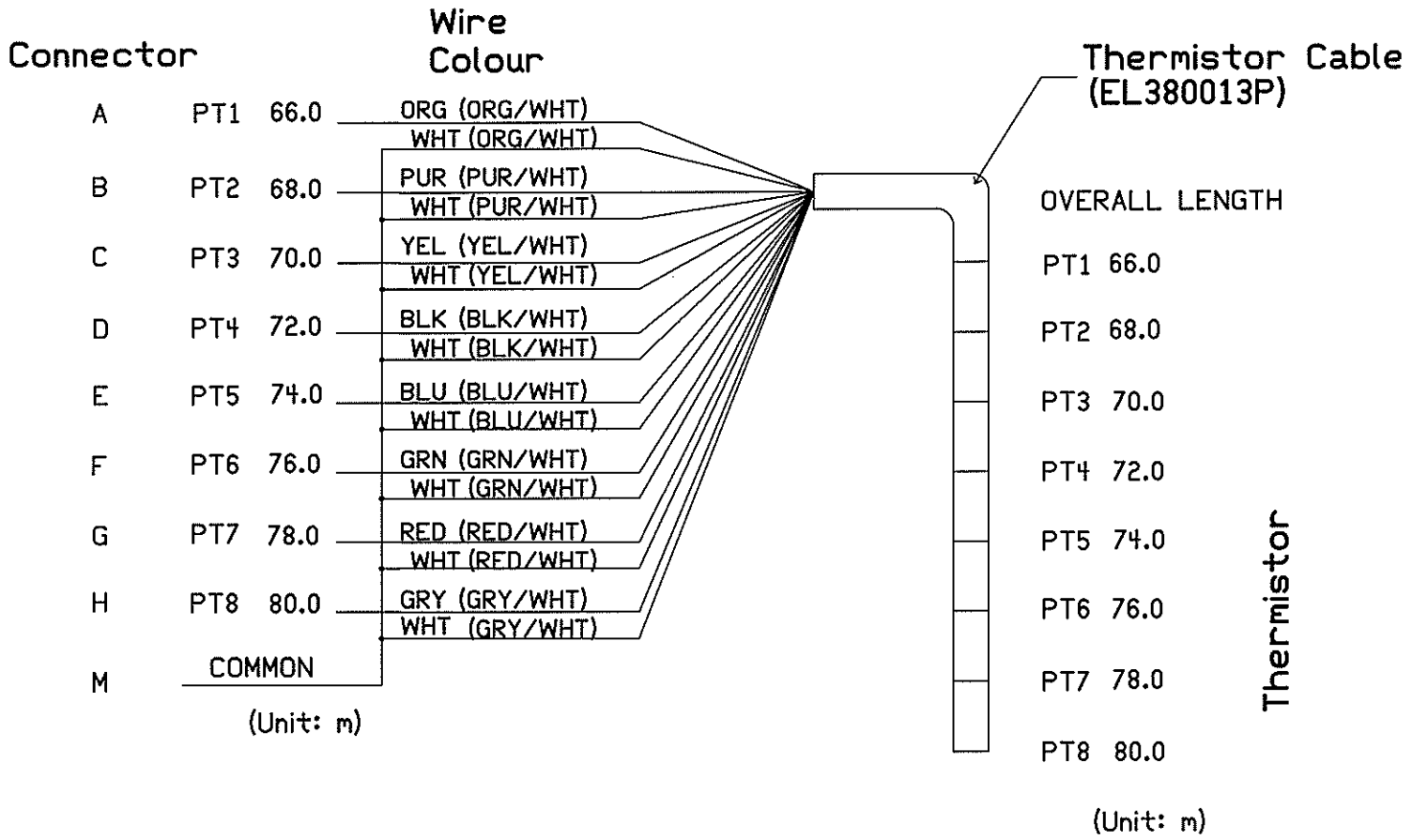
Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	WOQ018560-15	Revision:	A
Author:	CB	Size:	A
Date:	2010/10/12	Sheet	1 of 1



S/N: TS3095

ID: ND-HTS-175-32.5

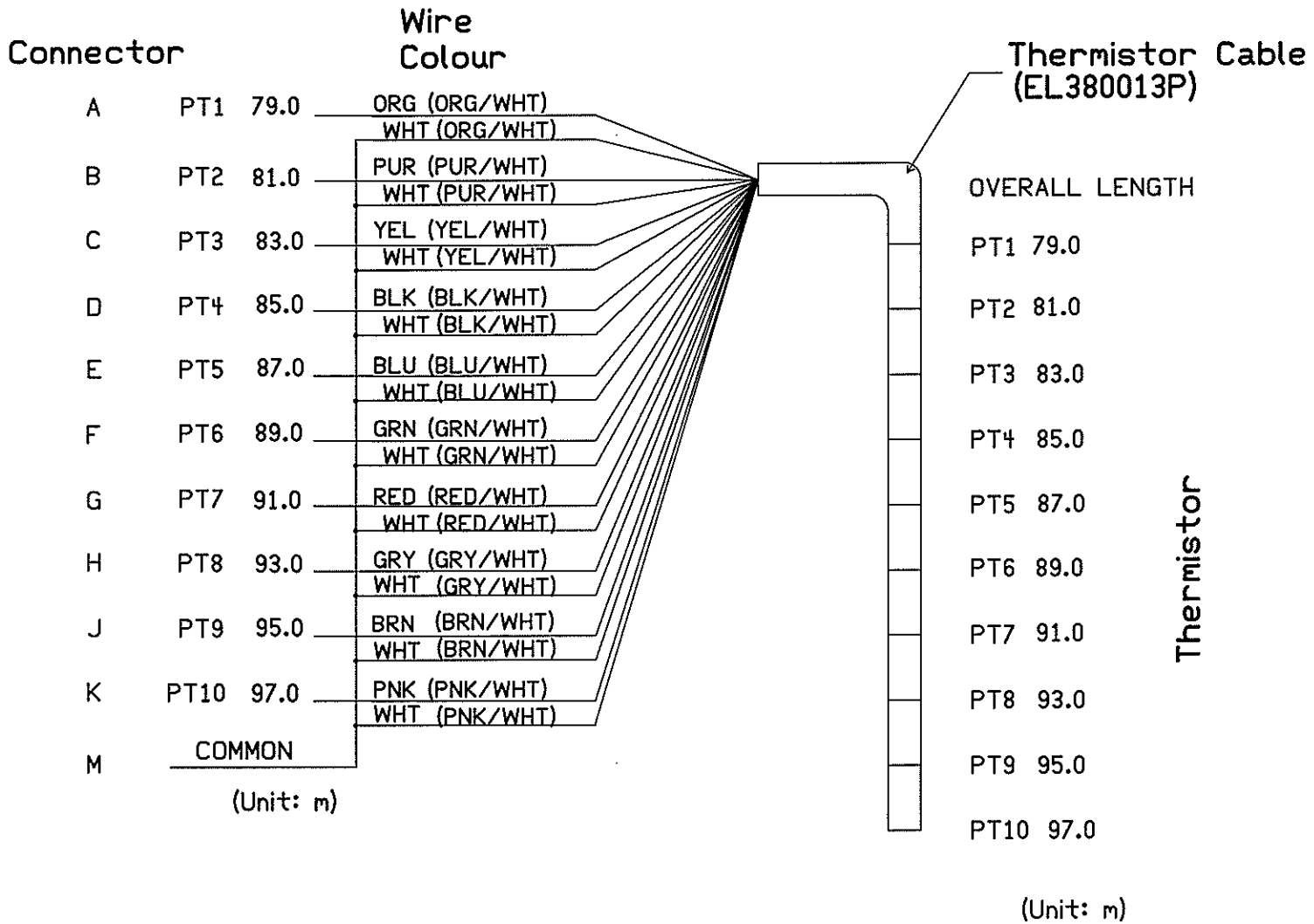
Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	WOQ018560-16	Revision:	A
Author:	CB	Size:	A
Date:	2010/10/12	Sheet	1 of 1



S/N: TS3096

ID: ND-HTS-060-31.0

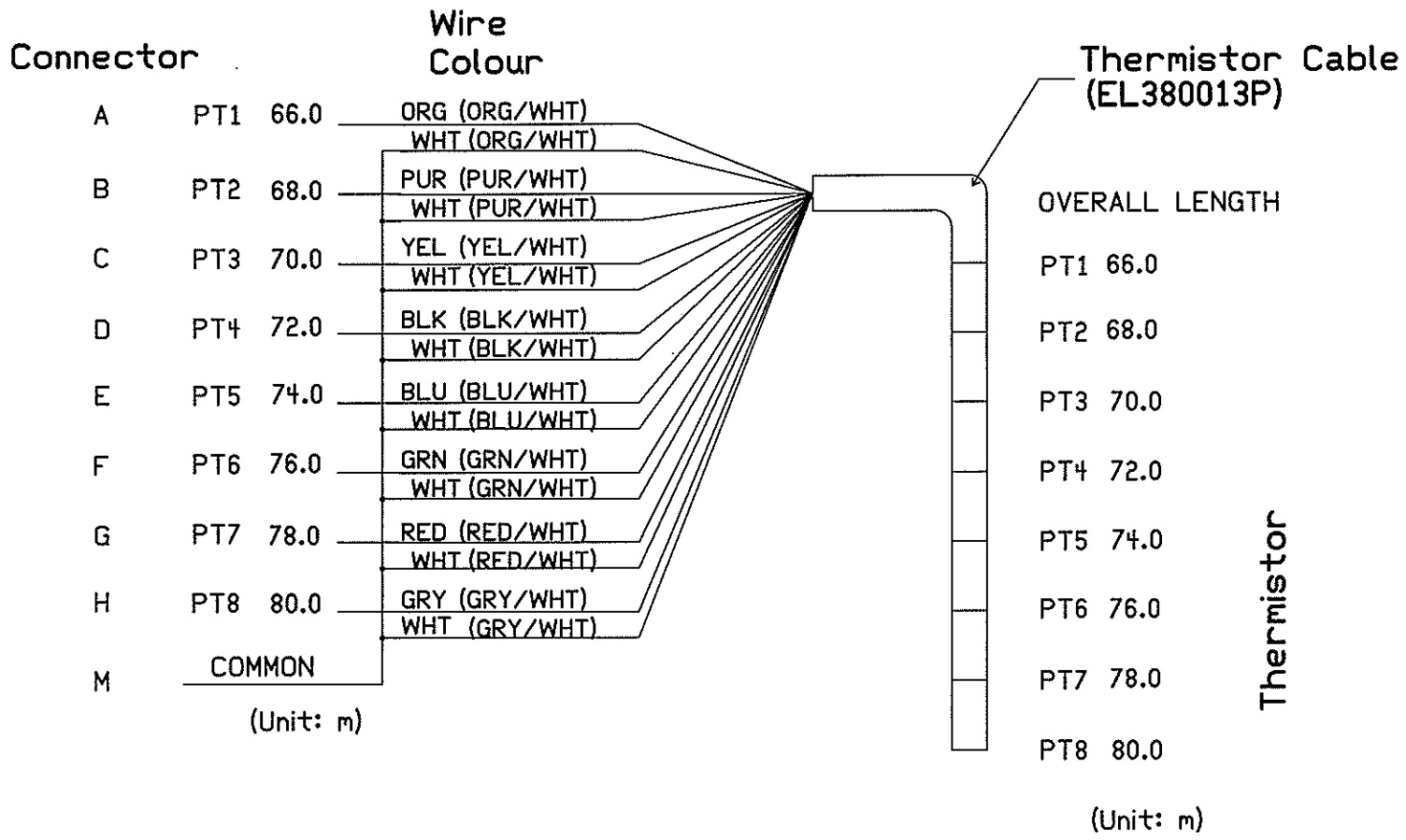
Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	WOQ018560-17	Revision:	A
Author:	CB	Size:	A
Date:	2010/10/12	Sheet	1 of 1



Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-18 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1

S/N: TS3097

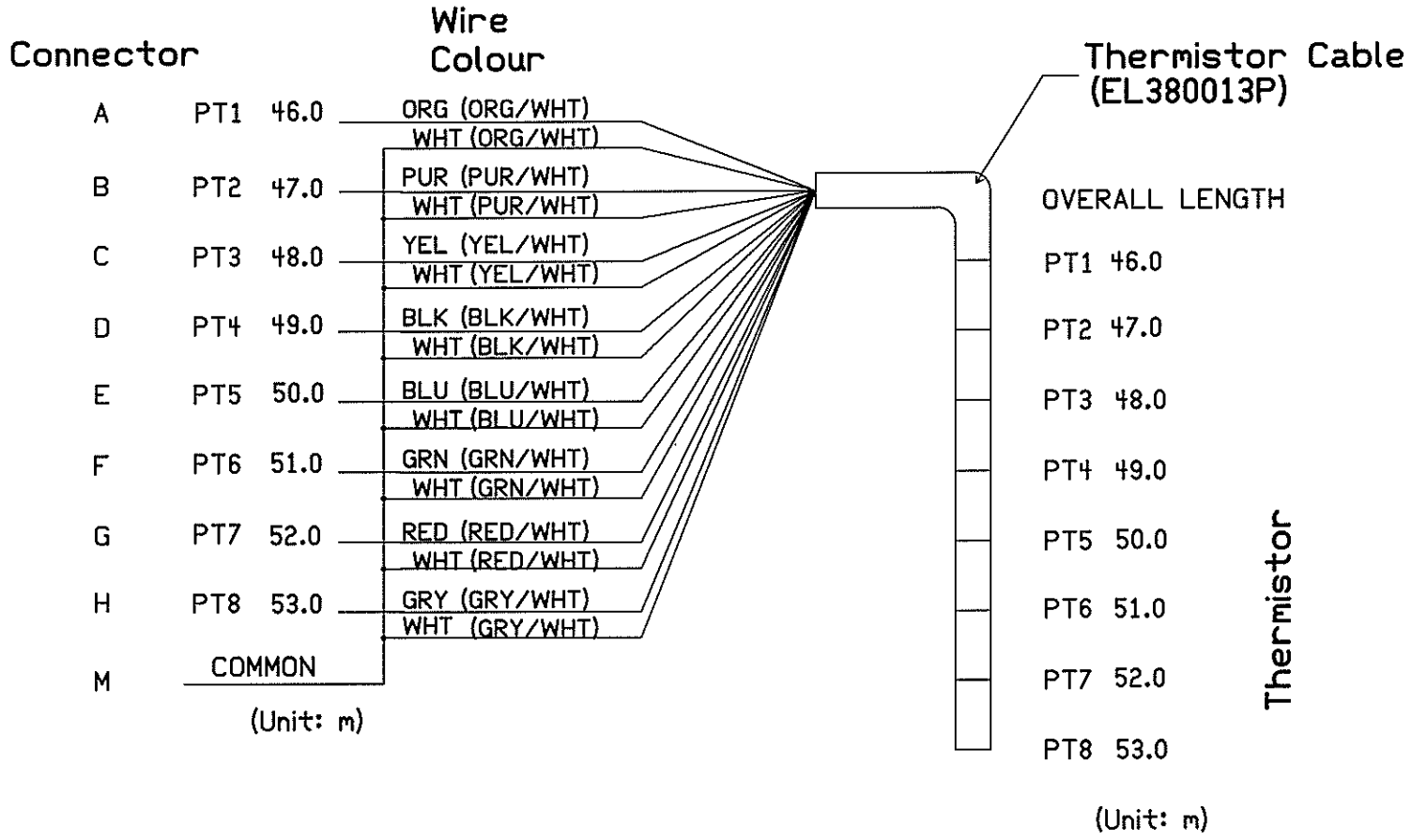
ID: ND-HTS-085-29.4



S/N: TS3098

ID: ND-HTS-130-31.0

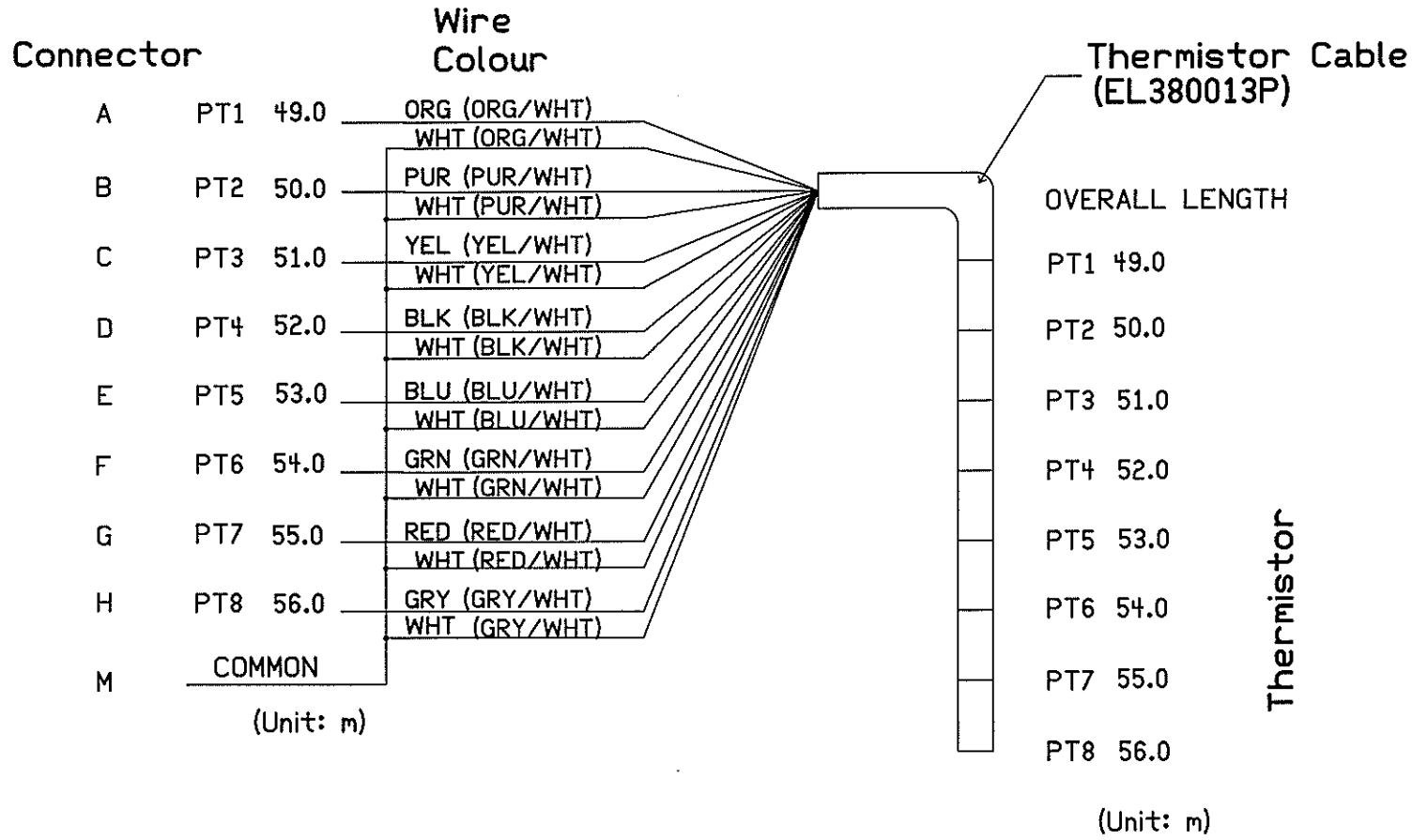
Co:	RST INSTRUMENTS LTD	
Title:	THERMISTOR CABLE	
J/N:	WOQ018560-19	Revision: A
Author:	CB	Size: A
Date:	2010/10/12	Sheet 1 of 1



S/N: TS3099

ID: ND-HTS-060-33.5

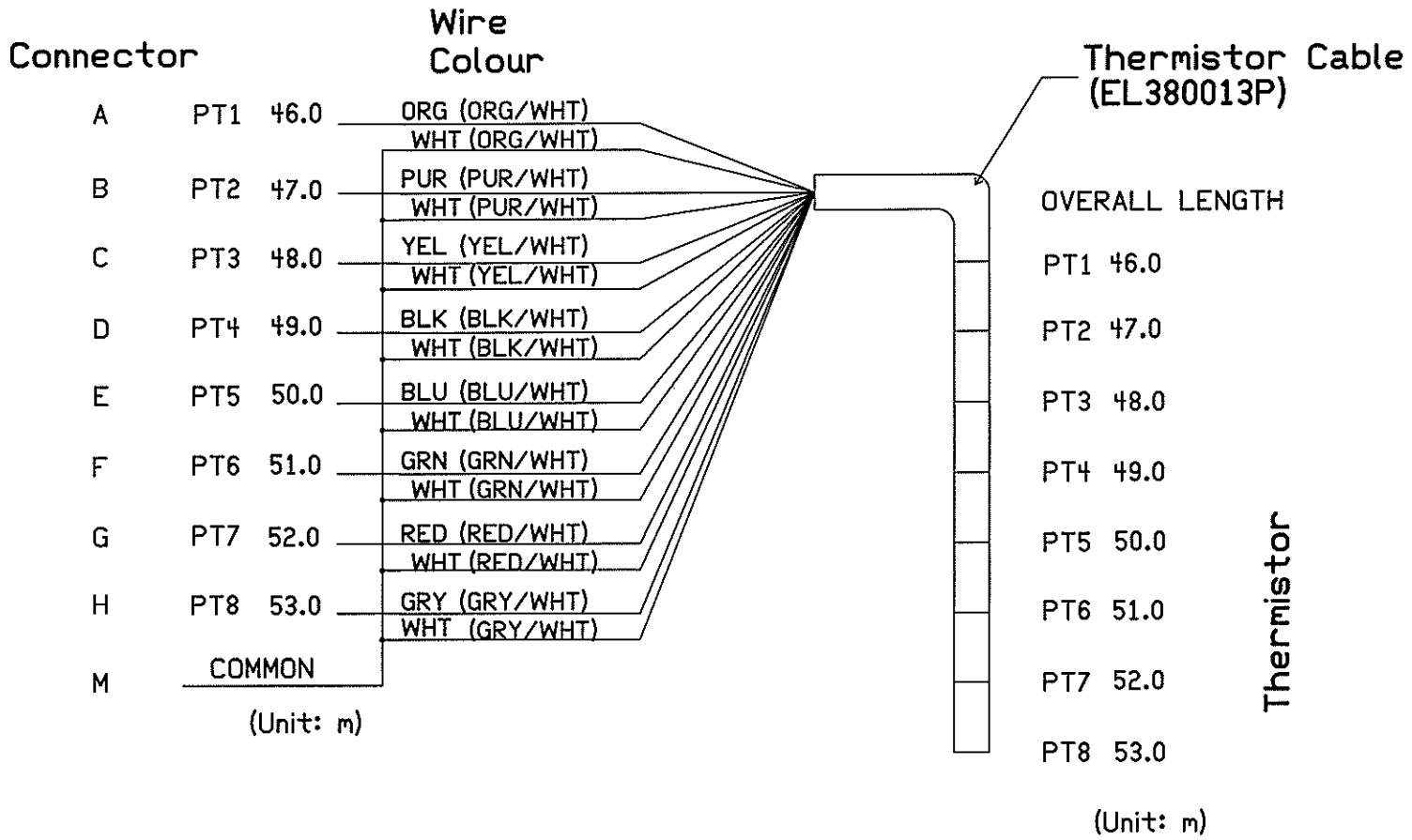
Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-20 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



S/N: TS3102

ID: ND-HTS-040-33.5

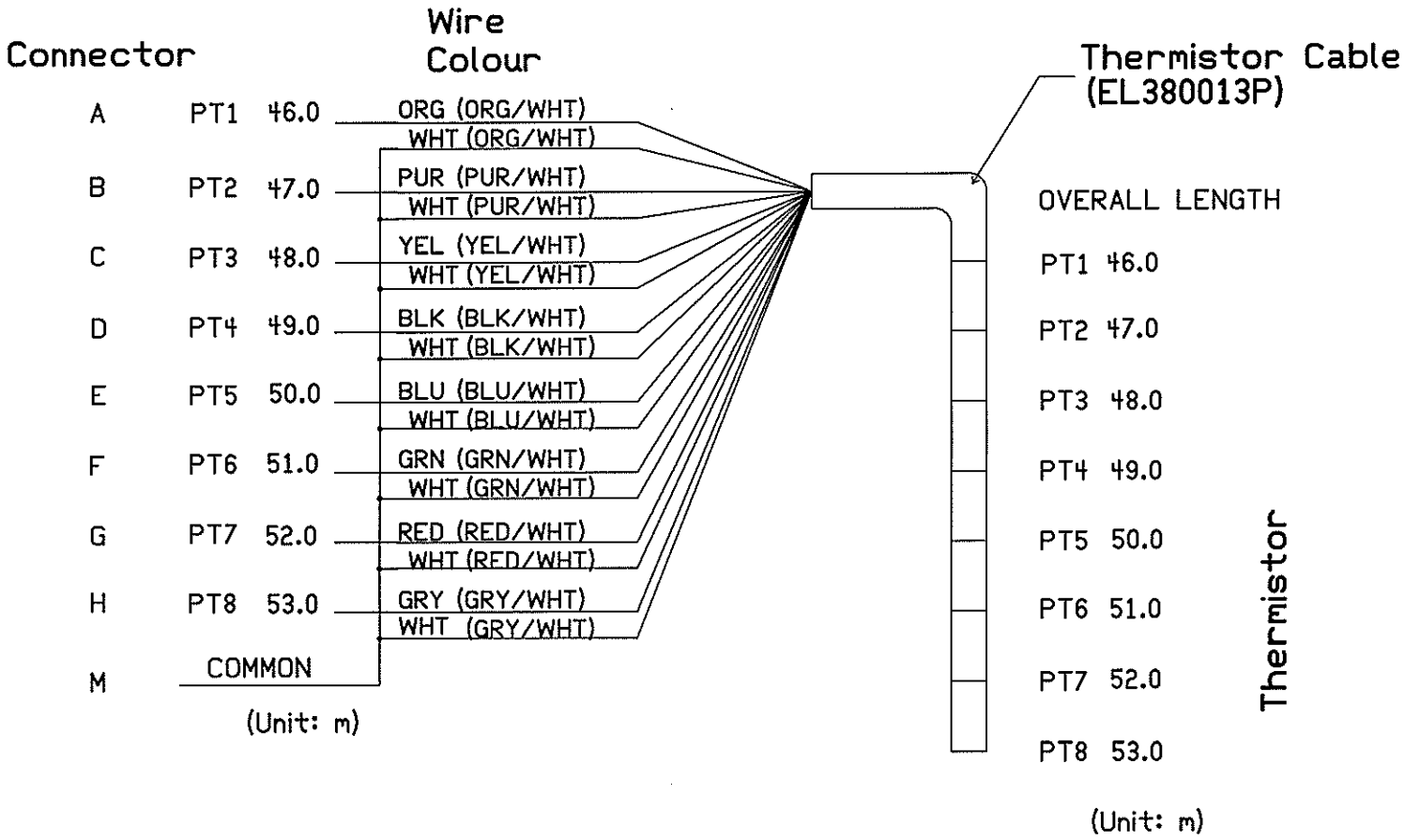
Co:	RST INSTRUMENTS LTD	
Title:	THERMISTOR CABLE	
J/N:	WOQ018560-21	Revision: A
Author:	CB	Size: A
Date:	2010/10/12	Sheet 1 of 1



S/N: TS3100

ID: ND-HTS-085-33.5

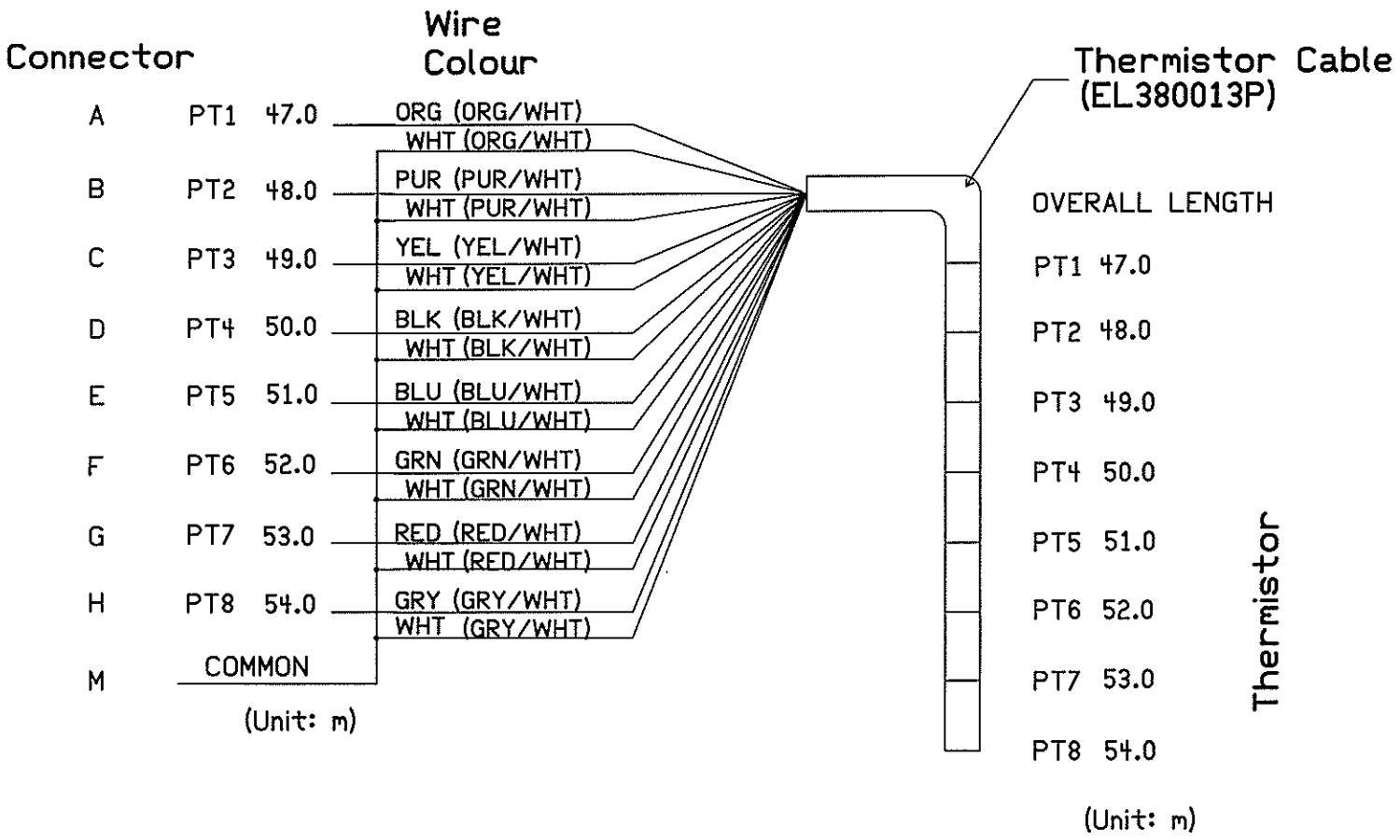
Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	WOQ018560-22 Revision: A
Author:	CB Size: A
Date:	2010/10/12 Sheet 1 of 1



S/N: TS3101

ID: ND-HTS-130-33.5

Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	WOQ018560-23	Revision:	A
Author:	CB	Size:	A
Date:	2010/10/12	Sheet	1 of 1



S/N: TS3103

ID: ND-HTS-175-33.5

Co:	RST INSTRUMENTS LTD	
Title:	THERMISTOR CABLE	
J/N:	WOQ018560-24	Revision: A
Author:	CB	Size: A
Date:	2010/10/12	Sheet 1 of 1

Appendix C - CR1000 Program Listing Overview

```
'CR1000 Series Datalogger


'Contact: Iozsef Miskolczi
'SRK Consulting
'2200-1066 West Hastings Street
'Vancouver, BC, V6E 3X2
'Canada

'Phone: 604-681-4196
'Direct Number: 778-785-8460
'email: IMiskolczi@srk.com



'Program overview: CR1000 #1 Station Program
'This program will take themperature measurements on a dam located
'on Hope bay, Nunavut.
' Data will be stored on a compact flash card once every 6 hours

'*****************************************************
'Program author: Mike Ryder - Sales & Technical Support
' modified by Iozsef Miskolczi on August 11, 2012

'Campbell Scientific (Canada) Corp.
'11564 - 149 Street NW
'Edmonton, AB T5M 1W7
'Canada

'Main Phone: 780-454-2505
'Direct Number: 780-733-8214
'Fax: 780-454-2655
'Email: Mike.Ryder@campbellsci.ca
'General Email: dataloggers@campbellsci.ca
'Web Site: www.campbellsci.ca
'*****************************************************
'=============================================================================
'- - - - - - - - - - - - - - - CR1000 Wiring - - - - - - - - - - - - - - - -
'=============================================================================

'=============================================================================
'- - - - - - - - - - - - - - - Variables - - - - - - - - - - - - - - - - - -
'=============================================================================

Public PTemp
Public batt_volt

Public Therm_ResA_1 (34)
Public Therm_mV_A_1 (34)
Public Therm_TempA_1 (34)

Public Therm_ResB_2 (36)
Public Therm_mV_B_2 (36)
Public Therm_TempB_2 (36)

Public Therm_ResB_3 (30)
```

```
Public Therm_mV_B_3 (30)
Public Therm_TempB_3 (30)

Public Therm_ResC_4 (36)
Public Therm_mV_C_4 (36)
Public Therm_TempC_4 (36)

Public Therm_ResC_5 (36)
Public Therm_mV_C_5 (36)
Public Therm_TempC_5 (36)

Dim Index
Dim Index2
Dim Index3
Dim Index4
Dim Index5

StationName (HB_NorthDam_CR1000_#1)

'================================================================================
'- - - - - - - - - - - - - - Variable aliases - - - - - - - - - - - - - -
'================================================================================

Alias Therm_TempA_1 (1) = ND_VTS_040_KT_PT1
Alias Therm_TempA_1 (2) = ND_VTS_040_KT_PT2
Alias Therm_TempA_1 (3) = ND_VTS_040_KT_PT3
Alias Therm_TempA_1 (4) = ND_VTS_040_KT_PT4
Alias Therm_TempA_1 (5) = ND_VTS_040_KT_PT5
Alias Therm_TempA_1 (6) = ND_VTS_040_KT_PT6
Alias Therm_TempA_1 (7) = ND_VTS_040_KT_PT7
Alias Therm_TempA_1 (8) = ND_VTS_040_KT_PT8
Alias Therm_TempA_1 (9) = ND_VTS_040_KT_PT9
Alias Therm_TempA_1 (10) = ND_VTS_040_KT_PT10
Alias Therm_TempA_1 (11) = ND_VTS_040_KT_PT11

Alias Therm_TempA_1 (13) = ND_HTS_040_315_PT1
Alias Therm_TempA_1 (14) = ND_HTS_040_315_PT2
Alias Therm_TempA_1 (15) = ND_HTS_040_315_PT3
Alias Therm_TempA_1 (16) = ND_HTS_040_315_PT4
Alias Therm_TempA_1 (17) = ND_HTS_040_315_PT5
Alias Therm_TempA_1 (18) = ND_HTS_040_315_PT6
Alias Therm_TempA_1 (19) = ND_HTS_040_315_PT7
Alias Therm_TempA_1 (20) = ND_HTS_040_315_PT8
Alias Therm_TempA_1 (21) = ND_HTS_040_315_PT9
Alias Therm_TempA_1 (22) = ND_HTS_040_315_PT10

Alias Therm_TempA_1 (25) = ND_HTS_040_335_PT1
Alias Therm_TempA_1 (26) = ND_HTS_040_335_PT2
Alias Therm_TempA_1 (27) = ND_HTS_040_335_PT3
Alias Therm_TempA_1 (28) = ND_HTS_040_335_PT4
Alias Therm_TempA_1 (29) = ND_HTS_040_335_PT5
Alias Therm_TempA_1 (30) = ND_HTS_040_335_PT6
Alias Therm_TempA_1 (31) = ND_HTS_040_335_PT7
Alias Therm_TempA_1 (32) = ND_HTS_040_335_PT8

Alias Therm_TempB_2 (1) = ND_VTS_060_KT_PT1
```

Alias Therm_TempB_2 (2) = ND_VTS_060_KT_PT2
Alias Therm_TempB_2 (3) = ND_VTS_060_KT_PT3
Alias Therm_TempB_2 (4) = ND_VTS_060_KT_PT4
Alias Therm_TempB_2 (5) = ND_VTS_060_KT_PT5
Alias Therm_TempB_2 (6) = ND_VTS_060_KT_PT6
Alias Therm_TempB_2 (7) = ND_VTS_060_KT_PT7
Alias Therm_TempB_2 (8) = ND_VTS_060_KT_PT8
Alias Therm_TempB_2 (9) = ND_VTS_060_KT_PT9
Alias Therm_TempB_2 (10) = ND_VTS_060_KT_PT10
Alias Therm_TempB_2 (11) = ND_VTS_060_KT_PT11

Alias Therm_TempB_2 (13) = ND_VTS_060_DS_PT1
Alias Therm_TempB_2 (14) = ND_VTS_060_DS_PT2
Alias Therm_TempB_2 (15) = ND_VTS_060_DS_PT3
Alias Therm_TempB_2 (16) = ND_VTS_060_DS_PT4
Alias Therm_TempB_2 (17) = ND_VTS_060_DS_PT5
Alias Therm_TempB_2 (18) = ND_VTS_060_DS_PT6
Alias Therm_TempB_2 (19) = ND_VTS_060_DS_PT7
Alias Therm_TempB_2 (20) = ND_VTS_060_DS_PT8
Alias Therm_TempB_2 (21) = ND_VTS_060_DS_PT9
Alias Therm_TempB_2 (22) = ND_VTS_060_DS_PT10
Alias Therm_TempB_2 (23) = ND_VTS_060_DS_PT11

Alias Therm_TempB_2 (25) = ND_HTS_060_288_PT1
Alias Therm_TempB_2 (26) = ND_HTS_060_288_PT2
Alias Therm_TempB_2 (27) = ND_HTS_060_288_PT3
Alias Therm_TempB_2 (28) = ND_HTS_060_288_PT4
Alias Therm_TempB_2 (29) = ND_HTS_060_288_PT5
Alias Therm_TempB_2 (30) = ND_HTS_060_288_PT6
Alias Therm_TempB_2 (31) = ND_HTS_060_288_PT7
Alias Therm_TempB_2 (32) = ND_HTS_060_288_PT8
Alias Therm_TempB_2 (33) = ND_HTS_060_288_PT9
Alias Therm_TempB_2 (34) = ND_HTS_060_288_PT10

Alias Therm_TempB_3 (1) = ND_VTS_060_US_PT1
Alias Therm_TempB_3 (2) = ND_VTS_060_US_PT2
Alias Therm_TempB_3 (3) = ND_VTS_060_US_PT3
Alias Therm_TempB_3 (4) = ND_VTS_060_US_PT4
Alias Therm_TempB_3 (5) = ND_VTS_060_US_PT5
Alias Therm_TempB_3 (6) = ND_VTS_060_US_PT6
Alias Therm_TempB_3 (7) = ND_VTS_060_US_PT7
Alias Therm_TempB_3 (8) = ND_VTS_060_US_PT8
Alias Therm_TempB_3 (9) = ND_VTS_060_US_PT9
Alias Therm_TempB_3 (10) = ND_VTS_060_US_PT10
Alias Therm_TempB_3 (11) = ND_VTS_060_US_PT11

Alias Therm_TempB_3 (13) = ND_HTS_060_310_PT1
Alias Therm_TempB_3 (14) = ND_HTS_060_310_PT2
Alias Therm_TempB_3 (15) = ND_HTS_060_310_PT3
Alias Therm_TempB_3 (16) = ND_HTS_060_310_PT4
Alias Therm_TempB_3 (17) = ND_HTS_060_310_PT5
Alias Therm_TempB_3 (18) = ND_HTS_060_310_PT6
Alias Therm_TempB_3 (19) = ND_HTS_060_310_PT7
Alias Therm_TempB_3 (20) = ND_HTS_060_310_PT8

Alias Therm_TempB_3 (22) = ND_HTS_060_335_PT1

Alias Therm_TempB_3 (23) = ND_HTS_060_335_PT2
Alias Therm_TempB_3 (24) = ND_HTS_060_335_PT3
Alias Therm_TempB_3 (25) = ND_HTS_060_335_PT4
Alias Therm_TempB_3 (26) = ND_HTS_060_335_PT5
Alias Therm_TempB_3 (27) = ND_HTS_060_335_PT6
Alias Therm_TempB_3 (28) = ND_HTS_060_335_PT7
Alias Therm_TempB_3 (29) = ND_HTS_060_335_PT8

Alias Therm_TempC_4 (1) = ND_VTS_085_KT_PT1
Alias Therm_TempC_4 (2) = ND_VTS_085_KT_PT2
Alias Therm_TempC_4 (3) = ND_VTS_085_KT_PT3
Alias Therm_TempC_4 (4) = ND_VTS_085_KT_PT4
Alias Therm_TempC_4 (5) = ND_VTS_085_KT_PT5
Alias Therm_TempC_4 (6) = ND_VTS_085_KT_PT6
Alias Therm_TempC_4 (7) = ND_VTS_085_KT_PT7
Alias Therm_TempC_4 (8) = ND_VTS_085_KT_PT8
Alias Therm_TempC_4 (9) = ND_VTS_085_KT_PT9
Alias Therm_TempC_4 (10) = ND_VTS_085_KT_PT10
Alias Therm_TempC_4 (11) = ND_VTS_085_KT_PT11

Alias Therm_TempC_4 (13) = ND_VTS_085_US_PT1
Alias Therm_TempC_4 (14) = ND_VTS_085_US_PT2
Alias Therm_TempC_4 (15) = ND_VTS_085_US_PT3
Alias Therm_TempC_4 (16) = ND_VTS_085_US_PT4
Alias Therm_TempC_4 (17) = ND_VTS_085_US_PT5
Alias Therm_TempC_4 (18) = ND_VTS_085_US_PT6
Alias Therm_TempC_4 (19) = ND_VTS_085_US_PT7
Alias Therm_TempC_4 (20) = ND_VTS_085_US_PT8
Alias Therm_TempC_4 (21) = ND_VTS_085_US_PT9
Alias Therm_TempC_4 (22) = ND_VTS_085_US_PT10
Alias Therm_TempC_4 (23) = ND_VTS_085_US_PT11

Alias Therm_TempC_4 (25) = ND_VTS_085_DS_PT1
Alias Therm_TempC_4 (26) = ND_VTS_085_DS_PT2
Alias Therm_TempC_4 (27) = ND_VTS_085_DS_PT3
Alias Therm_TempC_4 (28) = ND_VTS_085_DS_PT4
Alias Therm_TempC_4 (29) = ND_VTS_085_DS_PT5
Alias Therm_TempC_4 (30) = ND_VTS_085_DS_PT6
Alias Therm_TempC_4 (31) = ND_VTS_085_DS_PT7
Alias Therm_TempC_4 (32) = ND_VTS_085_DS_PT8
Alias Therm_TempC_4 (33) = ND_VTS_085_DS_PT9
Alias Therm_TempC_4 (34) = ND_VTS_085_DS_PT10
Alias Therm_TempC_4 (35) = ND_VTS_085_DS_PT11

Alias Therm_TempC_5 (1) = ND_HTS_085_253_PT1
Alias Therm_TempC_5 (2) = ND_HTS_085_253_PT2
Alias Therm_TempC_5 (3) = ND_HTS_085_253_PT3
Alias Therm_TempC_5 (4) = ND_HTS_085_253_PT4
Alias Therm_TempC_5 (5) = ND_HTS_085_253_PT5
Alias Therm_TempC_5 (6) = ND_HTS_085_253_PT6
Alias Therm_TempC_5 (7) = ND_HTS_085_253_PT7
Alias Therm_TempC_5 (8) = ND_HTS_085_253_PT8
Alias Therm_TempC_5 (9) = ND_HTS_085_253_PT9
Alias Therm_TempC_5 (10) = ND_HTS_085_253_PT10
Alias Therm_TempC_5 (11) = ND_HTS_085_253_PT11
Alias Therm_TempC_5 (12) = ND_HTS_085_253_PT12

```
Alias Therm_TempC_5 (13) = ND_HTS_085_253_PT13
Alias Therm_TempC_5 (14) = ND_HTS_085_253_PT14
Alias Therm_TempC_5 (15) = ND_HTS_085_253_PT15

Alias Therm_TempC_5 (16) = ND_HTS_085_294_PT1
Alias Therm_TempC_5 (17) = ND_HTS_085_294_PT2
Alias Therm_TempC_5 (18) = ND_HTS_085_294_PT3
Alias Therm_TempC_5 (19) = ND_HTS_085_294_PT4
Alias Therm_TempC_5 (20) = ND_HTS_085_294_PT5
Alias Therm_TempC_5 (21) = ND_HTS_085_294_PT6
Alias Therm_TempC_5 (22) = ND_HTS_085_294_PT7
Alias Therm_TempC_5 (23) = ND_HTS_085_294_PT8
Alias Therm_TempC_5 (24) = ND_HTS_085_294_PT9
Alias Therm_TempC_5 (25) = ND_HTS_085_294_PT10

Alias Therm_TempC_5 (28) = ND_HTS_085_335_PT1
Alias Therm_TempC_5 (29) = ND_HTS_085_335_PT2
Alias Therm_TempC_5 (30) = ND_HTS_085_335_PT3
Alias Therm_TempC_5 (31) = ND_HTS_085_335_PT4
Alias Therm_TempC_5 (32) = ND_HTS_085_335_PT5
Alias Therm_TempC_5 (33) = ND_HTS_085_335_PT6
Alias Therm_TempC_5 (34) = ND_HTS_085_335_PT7
Alias Therm_TempC_5 (35) = ND_HTS_085_335_PT8

'================================================================================
'- - - - - - - - - - - - - - Declare Constants - - - - - - - - - - - - - -
'================================================================================

' Thermistor constants 3000Ohm @ 25C thermistor
Const ConstC0 = 0.0014051
Const ConstC1 = 0.0002369
Const ConstC2 = 0.0000001019

'================================================================================
'- - - - - - - - - - - - - - Data Tables - - - - - - - - - - - - - - - -
'================================================================================
'Define Data Tables

DataTable (StationStatus,1,-1)
  DataInterval (0,6,hr,10)
  CardOut (0, -1000)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,PTemp,FP2)
EndTable

DataTable (Daily_Samples,1,-1)
  DataInterval (0,6,hr,10)
  CardOut (0,-1000)

  Sample (11,ND_VTS_040_KT_PT1,FP2)
  Sample (10,ND_HTS_040_315_PT1,FP2)
  Sample (8,ND_HTS_040_335_PT1,FP2)

  Sample (11,ND_VTS_060_KT_PT1,FP2)
  Sample (11,ND_VTS_060_DS_PT1,FP2)
  Sample (10,ND_HTS_060_288_PT1,FP2)
```

```
  Sample (11,ND_VTS_060_US_PT1,FP2)
  Sample (8,ND_HTS_060_310_PT1,FP2)
  Sample (8,ND_HTS_060_335_PT1,FP2)

  Sample (11,ND_VTS_085_KT_PT1,FP2)
  Sample (11,ND_VTS_085_US_PT1,FP2)
  Sample (11,ND_VTS_085_DS_PT1,FP2)

  Sample (15,ND_HTS_085_253_PT1,FP2)
  Sample (10,ND_HTS_085_294_PT1,FP2)
  Sample (8,ND_HTS_085_335_PT1,FP2)

EndTable


'================================================================================
'- - - - - - - - - - - - - - - Main Program - - - - - - - - - - - - - - -
'================================================================================
BeginProg
  Scan (6,hr,0,0)' 4 times daily, at midnight, 6AM, noon, 6PM
    PanelTemp (PTemp,_60Hz)
    Battery (batt_volt)
    If TimeIntoInterval (0,6,hr)
      '----------------------
      PortSet (1,1)'Turn On Node A_1 Multiplexer
      Delay (0,150,msec)
      PulsePort (2,10000)
      'Multiplexer A_1
      'Measurement conversions for Multiplexer A_1
      'Calculate resistance for 32 thermistors
      For Index = 1 To 36
        BrHalf (Therm_mV_A_1(Index),3,mv2500C,1,Vx1,3,2500,True ,20000,_60Hz,1.0,0)
        Index=Index+2
        PulsePort (2,10000)
      Next
      PortSet (1,0)
      'Multiplexer C_5
      'Measurement conversions for Multiplexer C_5
      'Calculate resistance for 35 thermistors
      PortSet (1,1)'Turn On Node Node C_5 Multiplexer
      Delay (0,150,msec)
      PulsePort (2,10000)
      For Index5 = 1 To 36
        BrHalf (Therm_mV_C_5(Index5),3,mv2500C,13,Vx3,3,2500,True ,20000,_60Hz,1.0,0)
        Index5=Index5+2
        PulsePort (2,10000)
      Next
      PortSet (1,0)
      'Turn Off Node A_1 and Node C_5 Multiplexer
      '----------------------
      PortSet (3,1)'Turn On Node B_2 Multiplexer
      Delay (0,150,msec)
      PulsePort (4,10000)
      'Multiplexer B_2
      'Measurement conversions for Multiplexer B_2
```

```
    'Calculate resistance for 33 thermistors
    For Index2 = 1 To 36
      BrHalf (Therm_mV_B_2(Index2),3,mv2500C,4,Vx1,3,2500,True ,20000,_60Hz,1.0,0)
      Index2=Index2+2
      PulsePort (4,10000)
    Next
    PortSet (3,0)'Turn Off Node B_2 Multiplexer
    '---------------------
    PortSet (5,1)'Turn On Node B_3 Multiplexer
    Delay (0,150,msec)
    PulsePort (6,10000)
    'Multiplexer B_3
    'Measurement conversions for Multiplexer B_3
    'Calculate resistance for 33 thermistors
    For Index3 = 1 To 30
      BrHalf (Therm_mV_B_3(Index3),3,mv2500C,7,Vx2,3,2500,True ,20000,_60Hz,1.0,0)
      Index3=Index3+2
      PulsePort (6,10000)
    Next
    PortSet (5,0)'Turn Off Node B_3 Multiplexer
    '---------------------
    PortSet (7,1)'Turn On Node C_4 Multiplexer
    Delay (0,150,msec)
    PulsePort (8,10000)
    'Multiplexer B_3
    'Measurement conversions for Multiplexer B_3
    'Calculate resistance for 33 thermistors
    For Index4 = 1 To 36
      BrHalf (Therm_mV_C_4(Index4),3,mv2500C,10,Vx2,3,2500,True ,20000,_60Hz,1.0,0)
      Index4=Index4+2
      PulsePort (8,10000)
    Next
    PortSet (7,0)'Turn Off Node C_4 Multiplexer

    '-----------------------------------------

    'Measurement conversions for Multiplexer A_1
    For Index = 1 To 32
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResA_1(Index) = 10000*(1-Therm_mV_A_1(Index))/Therm_mV_A_1(Index)
      If Therm_ResA_1(Index) > 1000000 OR Therm_ResA_1(Index) <0 Then Therm_ResA_1(Index) = 0
      'Calculate temperature of 35 thermistors using the steinhart-hart equation
      Therm_TempA_1(Index) =
1/(ConstC0+ConstC1*LN(Therm_ResA_1(Index))+ConstC2*(LN(Therm_ResA_1(Index))^3))-273.15
    Next

    'Measurement conversions for Multiplexer B_2
    For Index2 = 1 To 34
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResB_2(Index2) = 10000*(1-Therm_mV_B_2(Index2))/Therm_mV_B_2(Index2)
      If Therm_ResB_2(Index2) > 1000000 OR Therm_ResB_2(Index2) < 0 Then Therm_ResB_2(Index2) = 0
      'Calculate temperature of 35 thermistors using the steinhart-hart equation
      Therm_TempB_2(Index2) =
1/(ConstC0+ConstC1*LN(Therm_ResB_2(Index2))+ConstC2*(LN(Therm_ResB_2(Index2))^3))-273.15
    Next
```

```
    'Measurement conversions for Multiplexer B_3
    For Index3 = 1 To 29
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResB_3(Index3) = 10000*(1-Therm_mV_B_3(Index3))/Therm_mV_B_3(Index3)
      If Therm_ResB_3(Index3) > 1000000 OR Therm_ResB_3(Index3) < 0 Then Therm_ResB_3(Index3) = 0

      'Calculate temperature of 35 thermistors using the steinhart-hart equation
      Therm_TempB_3(Index3) =
1/(ConstC0+ConstC1*LN(Therm_ResB_3(Index3))+ConstC2*(LN(Therm_ResB_3(Index3))^3))-273.15
    Next

    'Measurement conversions for Multiplexer C_4
    For Index4 = 1 To 35
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResC_4(Index4) = 10000*(1-Therm_mV_C_4(Index4))/Therm_mV_C_4(Index4)
      If Therm_ResC_4(Index4) > 1000000 OR Therm_ResC_4(Index4) < 0 Then Therm_ResC_4(Index4) = 0
      'Calculate temperature of 35 thermistors using the steinhart-hart equation
      Therm_TempC_4(Index4) =
1/(ConstC0+ConstC1*LN(Therm_ResC_4(Index4))+ConstC2*(LN(Therm_ResC_4(Index4))^3))-273.15
    Next

    'Measurement conversions for Multiplexer C_5
    For Index5 = 1 To 35
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResC_5(Index5) = 10000*(1-Therm_mV_C_5(Index5))/Therm_mV_C_5(Index5)
      If Therm_ResC_5(Index5) > 1000000 OR Therm_ResC_5(Index5) < 0 Then Therm_ResC_5(Index5) = 0
      'Calculate temperature of 35 thermistors using the steinhart-hart equation
      Therm_TempC_5(Index5) =
1/(ConstC0+ConstC1*LN(Therm_ResC_5(Index5))+ConstC2*(LN(Therm_ResC_5(Index5))^3))-273.15
    Next

    CallTable (Daily_Samples)
    CallTable (StationStatus)
  EndIf
 NextScan
EndProg
```

```
'CR1000 Series Datalogger

'Company: SRK Consulting / Nuna Logistics
'Contact: SRK: Iozsef Miskolczi

'Program overview: CR1000 #2 Station program
'This program will take themperature measurements on a dam located
'on Hope bay, Nunavut.
' Data will be stored on a compact flash card once every 6 hours

'*****************************************************
'Program author: Mike Ryder - Sales & Technical Support

'Campbell Scientific (Canada) Corp.
'11564 - 149 Street NW
'Edmonton, AB T5M 1W7
'Canada

'Main Phone: 780-454-2505
'Direct Number: 780-733-8214
'Fax: 780-454-2655
'Email: Mike.Ryder@campbellsci.ca
'General Email: dataloggers@campbellsci.ca
'Web Site: www.campbellsci.ca
'*****************************************************
'=================================================================================
'- - - - - - - - - - - - - - - CR1000 Wiring - - - - - - - - - - - - - - - -
'=================================================================================

'=================================================================================
'- - - - - - - - - - - - - - - Variables - - - - - - - - - - - - - - - - - -
'=================================================================================

Public PTemp
Public batt_volt

Public Therm_ResD_6 (36)
Public Therm_mV_D_6 (36)
Public Therm_TempD_6 (36)

Public Therm_ResD_7 (30)
Public Therm_mV_D_7 (30)
Public Therm_TempD_7 (30)

Public Therm_ResE_8 (30)
Public Therm_mV_E_8 (30)
Public Therm_TempE_8 (30)

Public Therm_109 (12)

Dim Index
Dim Index2
Dim Index3
Dim Index4

StationName (HB_NorthDam_CR1000_#2)
```

'==
'- - - - - - - - - - - - - - Variable aliases - - - - - - - - - - - - - -
'==

Alias Therm_TempD_6 (1) = ND_VTS_130_KT_PT1
Alias Therm_TempD_6 (2) = ND_VTS_130_KT_PT2
Alias Therm_TempD_6 (3) = ND_VTS_130_KT_PT3
Alias Therm_TempD_6 (4) = ND_VTS_130_KT_PT4
Alias Therm_TempD_6 (5) = ND_VTS_130_KT_PT5
Alias Therm_TempD_6 (6) = ND_VTS_130_KT_PT6
Alias Therm_TempD_6 (7) = ND_VTS_130_KT_PT7
Alias Therm_TempD_6 (8) = ND_VTS_130_KT_PT8
Alias Therm_TempD_6 (9) = ND_VTS_130_KT_PT9
Alias Therm_TempD_6 (10) = ND_VTS_130_KT_PT10
Alias Therm_TempD_6 (11) = ND_VTS_130_KT_PT11

Alias Therm_TempD_6 (13) = ND_VTS_130_US_PT1
Alias Therm_TempD_6 (14) = ND_VTS_130_US_PT2
Alias Therm_TempD_6 (15) = ND_VTS_130_US_PT3
Alias Therm_TempD_6 (16) = ND_VTS_130_US_PT4
Alias Therm_TempD_6 (17) = ND_VTS_130_US_PT5
Alias Therm_TempD_6 (18) = ND_VTS_130_US_PT6
Alias Therm_TempD_6 (19) = ND_VTS_130_US_PT7
Alias Therm_TempD_6 (20) = ND_VTS_130_US_PT8
Alias Therm_TempD_6 (21) = ND_VTS_130_US_PT9
Alias Therm_TempD_6 (22) = ND_VTS_130_US_PT10
Alias Therm_TempD_6 (23) = ND_VTS_130_US_PT11

Alias Therm_TempD_6 (25) = ND_VTS_130_DS_PT1
Alias Therm_TempD_6 (26) = ND_VTS_130_DS_PT2
Alias Therm_TempD_6 (27) = ND_VTS_130_DS_PT3
Alias Therm_TempD_6 (28) = ND_VTS_130_DS_PT4
Alias Therm_TempD_6 (29) = ND_VTS_130_DS_PT5
Alias Therm_TempD_6 (30) = ND_VTS_130_DS_PT6
Alias Therm_TempD_6 (31) = ND_VTS_130_DS_PT7
Alias Therm_TempD_6 (32) = ND_VTS_130_DS_PT8
Alias Therm_TempD_6 (33) = ND_VTS_130_DS_PT9
Alias Therm_TempD_6 (34) = ND_VTS_130_DS_PT10
Alias Therm_TempD_6 (35) = ND_VTS_130_DS_PT11

Alias Therm_TempD_7 (1) = ND_HTS_130_288_PT1
Alias Therm_TempD_7 (2) = ND_HTS_130_288_PT2
Alias Therm_TempD_7 (3) = ND_HTS_130_288_PT3
Alias Therm_TempD_7 (4) = ND_HTS_130_288_PT4
Alias Therm_TempD_7 (5) = ND_HTS_130_288_PT5
Alias Therm_TempD_7 (6) = ND_HTS_130_288_PT6
Alias Therm_TempD_7 (7) = ND_HTS_130_288_PT7
Alias Therm_TempD_7 (8) = ND_HTS_130_288_PT8
Alias Therm_TempD_7 (9) = ND_HTS_130_288_PT9
Alias Therm_TempD_7 (10) = ND_HTS_130_288_PT10

Alias Therm_TempD_7 (13) = ND_HTS_130_310_PT1
Alias Therm_TempD_7 (14) = ND_HTS_130_310_PT2
Alias Therm_TempD_7 (15) = ND_HTS_130_310_PT3
Alias Therm_TempD_7 (16) = ND_HTS_130_310_PT4

Alias Therm_TempD_7 (17) = ND_HTS_130_310_PT5
Alias Therm_TempD_7 (18) = ND_HTS_130_310_PT6
Alias Therm_TempD_7 (19) = ND_HTS_130_310_PT7
Alias Therm_TempD_7 (20) = ND_HTS_130_310_PT8

Alias Therm_TempD_7 (22) = ND_HTS_130_335_PT1
Alias Therm_TempD_7 (23) = ND_HTS_130_335_PT2
Alias Therm_TempD_7 (24) = ND_HTS_130_335_PT3
Alias Therm_TempD_7 (25) = ND_HTS_130_335_PT4
Alias Therm_TempD_7 (26) = ND_HTS_130_335_PT5
Alias Therm_TempD_7 (27) = ND_HTS_130_335_PT6
Alias Therm_TempD_7 (28) = ND_HTS_130_335_PT7
Alias Therm_TempD_7 (29) = ND_HTS_130_335_PT8

Alias Therm_TempE_8 (1) = ND_VTS_175_KT_PT1
Alias Therm_TempE_8 (2) = ND_VTS_175_KT_PT2
Alias Therm_TempE_8 (3) = ND_VTS_175_KT_PT3
Alias Therm_TempE_8 (4) = ND_VTS_175_KT_PT4
Alias Therm_TempE_8 (5) = ND_VTS_175_KT_PT5
Alias Therm_TempE_8 (6) = ND_VTS_175_KT_PT6
Alias Therm_TempE_8 (7) = ND_VTS_175_KT_PT7
Alias Therm_TempE_8 (8) = ND_VTS_175_KT_PT8
Alias Therm_TempE_8 (9) = ND_VTS_175_KT_PT9
Alias Therm_TempE_8 (10) = ND_VTS_175_KT_PT10
Alias Therm_TempE_8 (11) = ND_VTS_175_KT_PT11

Alias Therm_TempE_8 (13) = ND_HTS_175_325_PT1
Alias Therm_TempE_8 (14) = ND_HTS_175_325_PT2
Alias Therm_TempE_8 (15) = ND_HTS_175_325_PT3
Alias Therm_TempE_8 (16) = ND_HTS_175_325_PT4
Alias Therm_TempE_8 (17) = ND_HTS_175_325_PT5
Alias Therm_TempE_8 (18) = ND_HTS_175_325_PT6
Alias Therm_TempE_8 (19) = ND_HTS_175_325_PT7
Alias Therm_TempE_8 (20) = ND_HTS_175_325_PT8
Alias Therm_TempE_8 (21) = ND_HTS_175_325_PT9

Alias Therm_TempE_8 (22) = ND_HTS_175_335_PT1
Alias Therm_TempE_8 (23) = ND_HTS_175_335_PT2
Alias Therm_TempE_8 (24) = ND_HTS_175_335_PT3
Alias Therm_TempE_8 (25) = ND_HTS_175_335_PT4
Alias Therm_TempE_8 (26) = ND_HTS_175_335_PT5
Alias Therm_TempE_8 (27) = ND_HTS_175_335_PT6
Alias Therm_TempE_8 (28) = ND_HTS_175_335_PT7
Alias Therm_TempE_8 (29) = ND_HTS_175_335_PT8

Alias Therm_109 (1)= South_31
Alias Therm_109 (2)= South_32
Alias Therm_109 (3)= South_33
Alias Therm_109 (4)= South_34
Alias Therm_109 (5)= South_35
Alias Therm_109 (6)= South_36
Alias Therm_109 (7)= North_1
Alias Therm_109 (8)= North_2
Alias Therm_109 (9)= North_3
Alias Therm_109 (10)= North_4
Alias Therm_109 (11)= North_5

```
Alias  Therm_109 (12)= North_6
'=============================================================================
'- - - - - - - - - - - - - - - Units - - - - - - - - - - - - - - - - - -
'=============================================================================

'=============================================================================
'- - - - - - - - - - - - - - - Declare Constants - - - - - - - - - - - - -
'=============================================================================

' Thermistor constants 3000Ohm @ 25C thermistor
Const ConstC0 = 0.0014051
Const ConstC1 = 0.0002369
Const ConstC2 = 0.0000001019

'=============================================================================
'- - - - - - - - - - - - - - - Data Tables - - - - - - - - - - - - - - - -
'=============================================================================
'Define Data Tables

DataTable (StationStatus,1,-1)
 DataInterval (0,6,Hr,10)
  CardOut (0 ,-1000)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,PTemp,FP2)
EndTable

DataTable (Daily_Samples,1,-1)
  DataInterval (0,6,Hr,10)
  CardOut (0, -1000)

  Sample (11,ND_VTS_130_KT_PT1,FP2)
  Sample (11,ND_VTS_130_US_PT1,FP2)
  Sample (11,ND_VTS_130_DS_PT1,FP2)

  Sample (10,ND_HTS_130_288_PT1,FP2)
  Sample (8,ND_HTS_130_310_PT1,FP2)
  Sample (8,ND_HTS_130_335_PT1,FP2)

  Sample (11,ND_VTS_175_KT_PT1,FP2)
  Sample (9,ND_HTS_175_325_PT1,FP2)
  Sample (8,ND_HTS_175_335_PT1,FP2)

  Sample (12,Therm_109(),FP2)
EndTable


'=============================================================================
'- - - - - - - - - - - - - - - Main Program - - - - - - - - - - - - - - - -
'=============================================================================
BeginProg
  Scan (6,hr,0,0)' 4 times daily at midnight, 6AM, noon, 6 PM
    PanelTemp (PTemp,_60Hz)
    Battery (batt_volt)
   If TimeIntoInterval(0,6,hr)
      'Mutliplexer in 4x16 mode
      'Turn on all AM16/32B-XT multiplexers
```

```
PortSet (1,1)'Node D_6

Delay (0,150,msec)
PulsePort (2,10000)
'Multiplexer D_6
' measurement conversions for Multiplexer D_6
'Calculate resistance for 33 thermistors
For Index = 1 To 36
  BrHalf (Therm_mV_D_6(Index),3,mv2500C,1,Vx1,3,2500,True ,20000,_60Hz,1.0,0)
  Index=Index+2
  PulsePort (2,10000)
Next
PortSet (1,0)

'Multiplexer D_7
PortSet (3,1) 'Node D_7
Delay (0,150,msec)
PulsePort (4,10000)
For Index2 = 1 To 30
  BrHalf (Therm_mV_D_7(Index2),3,mv2500C,4,Vx1,3,2500,True ,20000,_60Hz,1.0,0)
  Index2=Index2+2
  PulsePort (4,10000)
Next
PortSet (3,0)

'Multiplexer E_8
PortSet (5,1) 'Node E_8
Delay (0,150,msec)
PulsePort (6,10000)
For Index3 = 1 To 30
  BrHalf (Therm_mV_E_8(Index3),3,mv2500C,7,Vx2,3,2500,True ,20000,_60Hz,1.0,0)
  Index3=Index3+2
  PulsePort (6,10000)
Next
PortSet (5,0)

'Multiplexer E_9 (109 thermistors)
PortSet (7,1) ' Node E_9
Delay (0,150,msec)
PulsePort (8,10000)
For Index4 = 1 To 12
  Therm109 (Therm_109 (Index4),1,10,Vx3,20000,_60Hz,1.0,0)
  PulsePort (8,10000)
Next
PortSet (7,0)


For Index = 1 To 35
  ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
  Therm_ResD_6(Index) = 10000*(1-Therm_mV_D_6(Index))/Therm_mV_D_6(Index)
  If Therm_ResD_6(Index) > 1000000 OR Therm_ResD_6(Index) <0 Then Therm_ResD_6(Index) = 0
  Therm_TempD_6(Index) =
1/(ConstC0+ConstC1*LN(Therm_ResD_6(Index))+ConstC2*(LN(Therm_ResD_6(Index))^3))-273.15
Next

' Measurement conversions for Multiplexer D_7
```

```
    For Index2 = 1 To 29
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResD_7(Index2) = 10000*(1-Therm_mV_D_7(Index2))/Therm_mV_D_7(Index2)
      If Therm_ResD_7(Index2) > 1000000 OR Therm_ResD_7(Index2) < 0 Then
Therm_ResD_7(Index2) = 0
      Therm_TempD_7(Index2) =
1/(ConstC0+ConstC1*LN(Therm_ResD_7(Index2))+ConstC2*(LN(Therm_ResD_7(Index2))^3))-273.15
    Next

    ' Measurement conversions for Multiplexer E_8
    For Index3 = 1 To 29
      ' Calculate resistance using equation : Rt = 10000*(1-Therm_mV(n))/Therm_mV(n)
      Therm_ResE_8(Index3) = 10000*(1-Therm_mV_E_8(Index3))/Therm_mV_E_8(Index3)
      If Therm_ResE_8(Index3) > 1000000 OR Therm_ResE_8(Index3) < 0 Then Therm_ResE_8(Index3)
= 0
      Therm_TempE_8(Index3) =
1/(ConstC0+ConstC1*LN(Therm_ResE_8(Index3))+ConstC2*(LN(Therm_ResE_8(Index3))^3))-273.15
    Next


    CallTable (Daily_Samples)
    CallTable (StationStatus)

  EndIf
 NextScan
EndProg
```

Appendix D - Suggested Guidelines for Surveying at the North Dam

Suggested guidelines for surveying at the North Dam

Introduction

In the upcoming years, it is expected that at regular interval, monitoring surveys will take place at the North Dam. Various surveyors may be called up to do the work. Following those suggested guidelines will provide consistency in the data acquisition process.

Manpower & Time allocation

If the surveyor is flying to the mine site for the work, three days should be allocated for this work.

- Day one: Fly to site, orientation, equipment testing and calibration.
- Day two: Surveying, data processing.
- Day three: Final data preparation, packing of equipment and fly out.

Equipment and accessories

- Robotic total station and accessories, including barometer and thermometer.
- Back sight kit.
- Extensions for the mini prism for the surveying of the crest monitoring points.
- A source of light to shine into the casing for the surveying of the crest monitoring points.
- A transparent template with circles at 5mm increment to pin point exactly the center of the deep settlement points.

Metadata

There are five control points: ND1, ND2, ND3, ND4 and ND5. Each control point consists of 1 inch Hilti bolt with an approximate height of 15 centimeters (~ 6 inch) from ground. The control points at the North Dam were originally surveyed by GNSS method. Closed leveling loops were performed in 2012 (ND3-ND2) and 2013 (ND3-ND2-ND1). ND5 appears to be weak, being located on a large flat boulder, 2013 survey indicates that it could have shifted.

The data is grid. Scale factor at DN1 is 0.99965099.

Station set-up

For consistency from one survey to the next, the total station should set-up at control point ND1. From this station, all points to be surveyed are visible. Back sight point is ND4. Once the station set-up is

completed, it is suggested to transfer the elevation to the total station from ND3. Most total stations have this capability (whether called elevation transfer, remote benchmark, etc). This method helps in reducing the error that could have been introduced in measuring the height of the station with a tape. Once the station is set-up is in orientation and elevation, a check shot on ND2 should be carried before commencing the monitoring surveys.

Surveying - general

As a minimum, each surveyed point should have face 1 and 2 observations. Taking measurements with both faces eliminate the following systematic errors of the total station:

- HZ collimation error
- Tilting axis error
- Compensator index error
- vertical index error

Once all points have been surveyed, if time allows, additional data should be obtained to confirm the observations. Should multiple prisms be used, it is recommended to use prisms that have the same prism constant. By doing so, the chances of introducing a prism constant error are reduced.

Conclusion

This document was simply prepared to help out the surveyor who will do the work. By following the same method in the station set-up as well as using the right coordinate system will help in providing reliable data to the engineering team.

Those guidelines were prepared for the scenario of having only one (1) surveyor allocated to the work. Should there be additional manpower, some of the work should also include traditional leveling method.

In the following pages are pictures and supplementary information for this work.

Prepared by:

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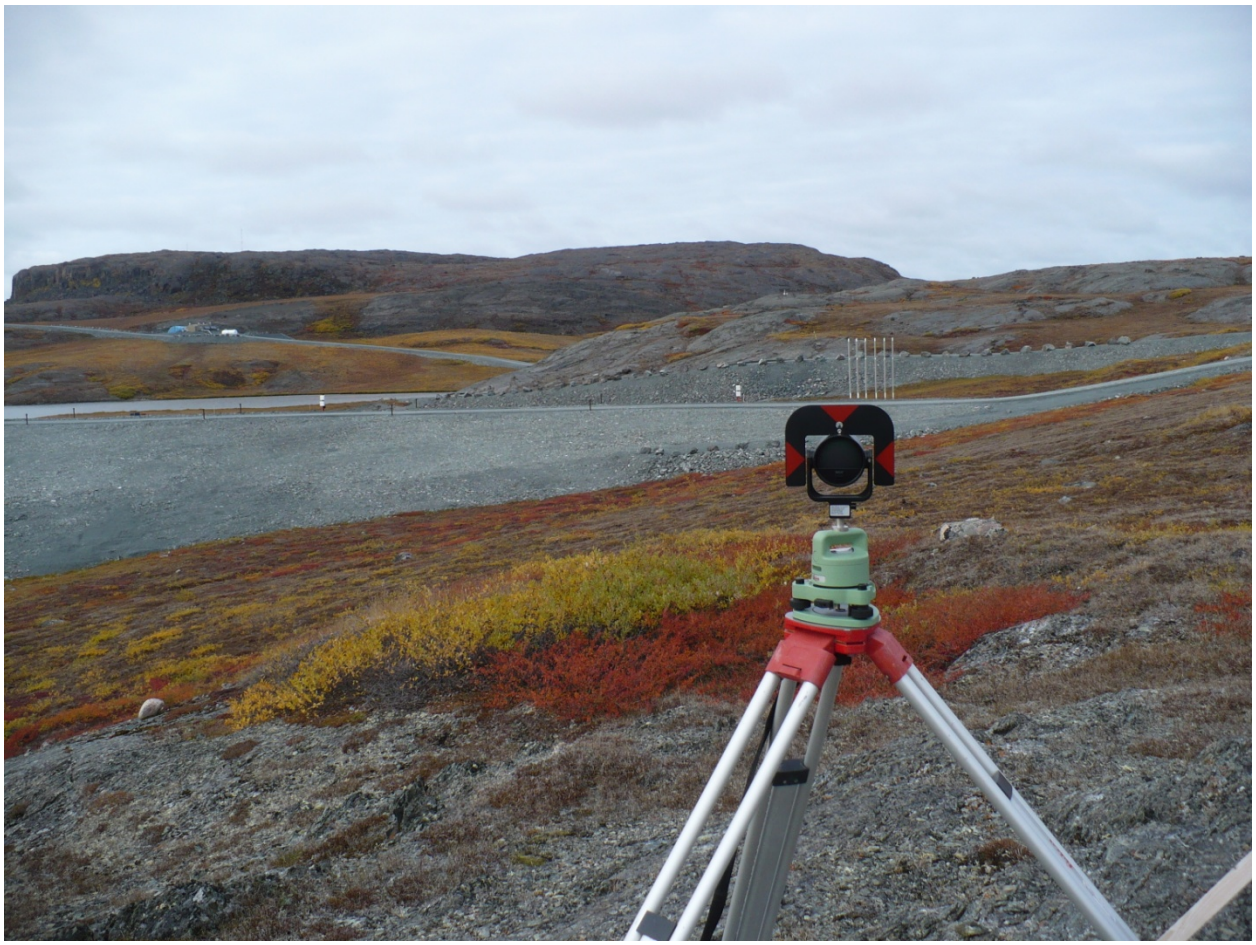
Hopebay, Nunavut
September 10, 2013

A robotic total station kit

Station at ND1



Back sight at ND4

Control Point ND5

Note: Could be weak, not recommended to use for set-up.

Mini-prisms

Note: some points require greater than 40 cm height.

Consistent prism constants

Deep settlement point

Note: Placing a transparent template with circles at 5mm Increment (example) would help to pin point exactly the center of the deep settlement points.

View inside the casing of a crest monitoring point

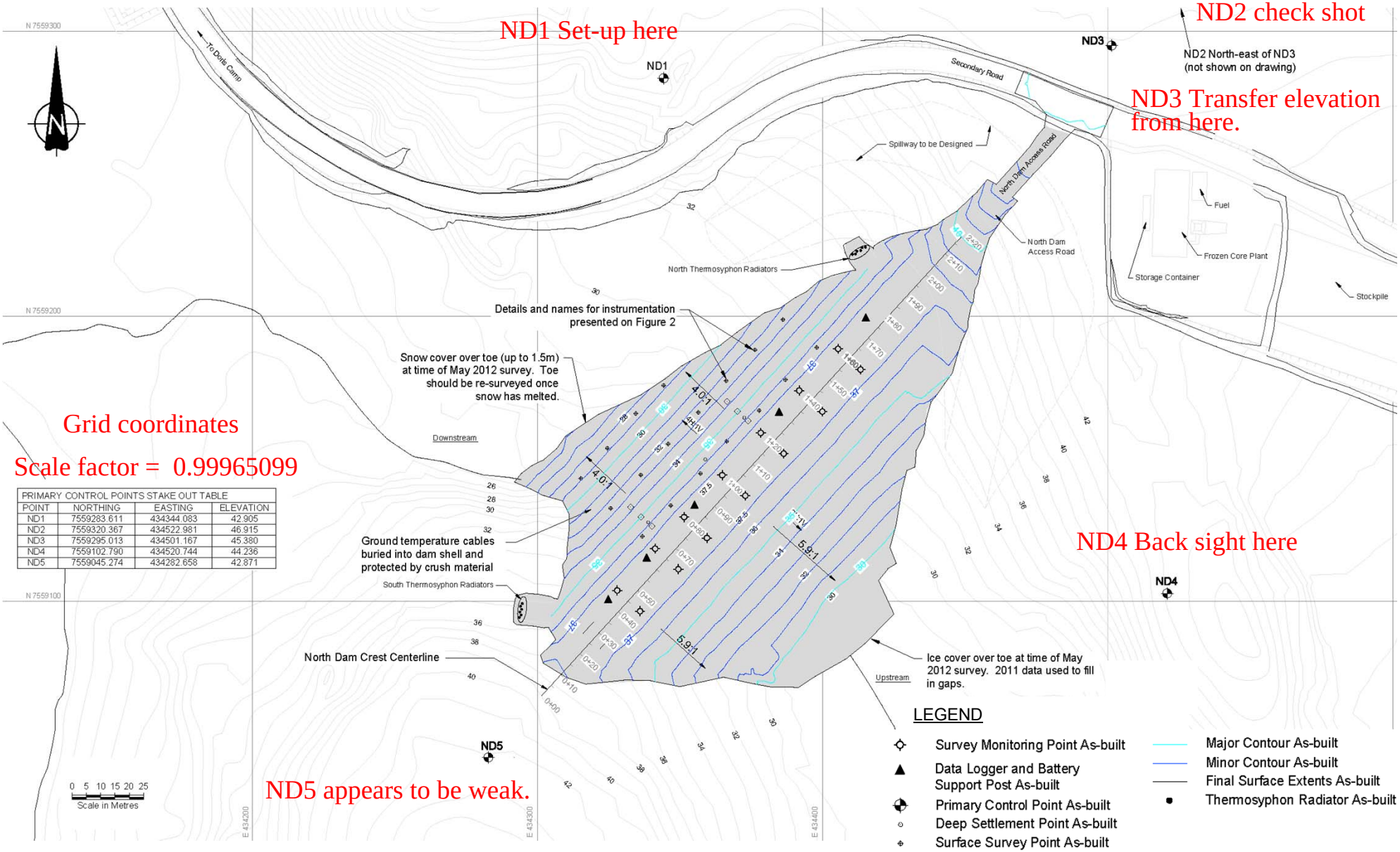
The surface survey points are constructed with same material as control points.

Please remember

The data is grid.

Scale factor at ND1 is 0.99965099.

J:\01_SITES\Hope.Bay\!ACAD\2013 Drawings\North Dam



PRIMARY CONTROL POINTS STAKE OUT TABLE

POINT	NORTHING	EASTING	ELEVATION
ND1	7559283.611	434344.083	42.905
ND2	7559320.367	434522.981	46.915
ND3	7559295.013	434501.167	45.380
ND4	7559102.790	434520.744	44.236
ND5	7559045.274	434282.658	42.871

srk consulting

TMAC RESOURCES

Job No: 1CT022.000

Filename: HopeBay_NorthDamMonitoringSOP_NodeFIGS_1CT022.000_im_jbk_20130709.pptx

Hope Bay

North Dam Monitoring SOP

North Dam General Arrangement and Primary Control Points

Date:	Approved:	Figure:
July 2013	IM / JBK	1

Appendix E - North Dam Visual Inspection / Checklist Form

North Dam Weekly Walkover Survey Report

Date:	
Inspected By:	
Conditions:	(ie. snow on ground, clear)

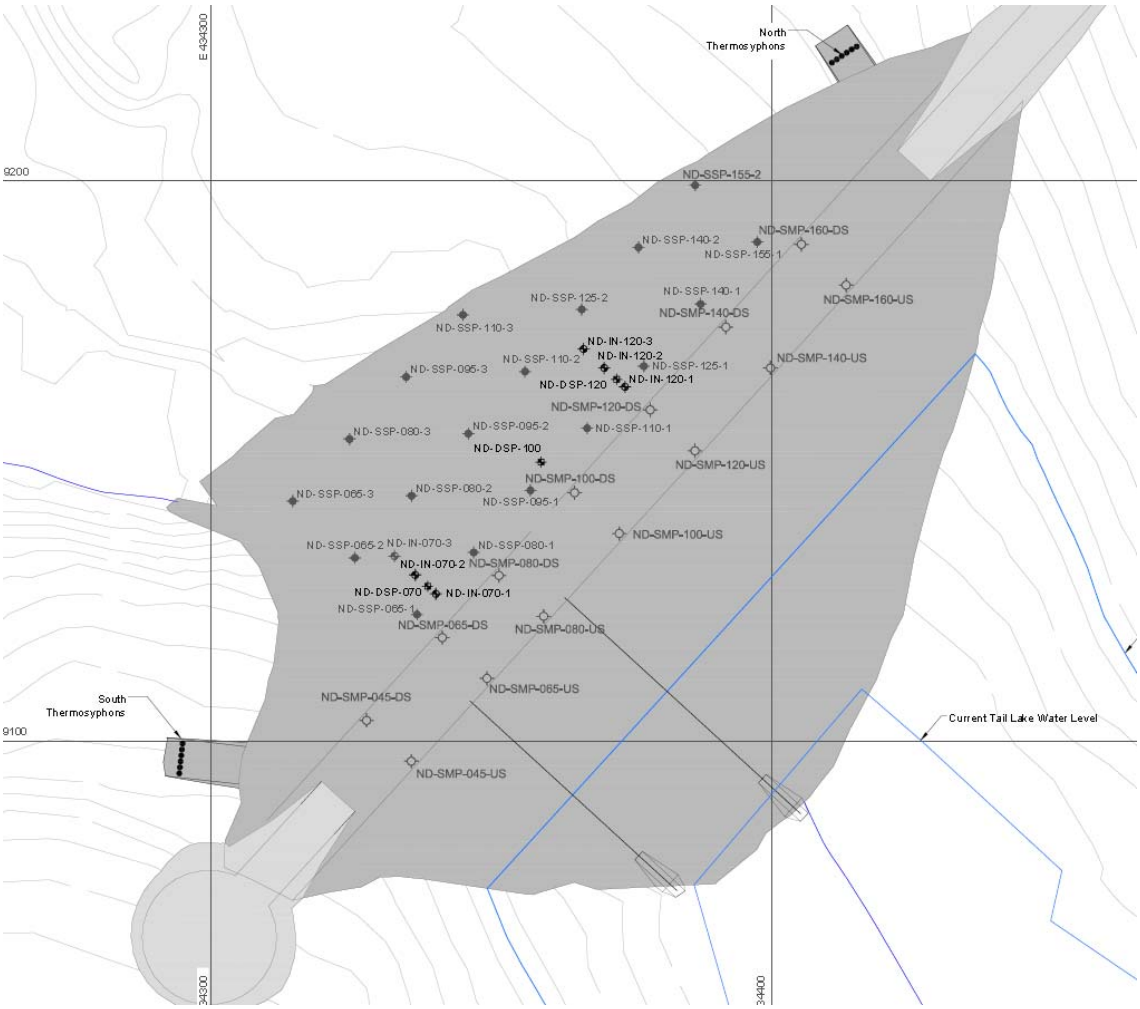
Visual Inspection:

This weekly walkover survey report is a means to track the condition on the North Dam, please provide details on changes that have developed since the previous inspection and/or any observations of particular concern. All photos are appreciated. Please send the completed form (scans are fine) and any photos to hopebaymonitoring@srk.com and pluedke@srk.com

Upstream Side of Dam		
Any visible concerns? (cracks, depressions, erosion, etc.)	Yes	No
Downstream Side of Dam		
Any visible concerns? (cracks, depressions, erosion, seepage, etc.)	Yes	No
Crest of Dam		
Any visible concerns? (cracks, depressions, erosion, etc.)	Yes	No
Thermosyphons North Side		
Any visible concerns? (cracks, punctures, peeling paint, birds nests, etc.)	Yes	No
Thermosyphons South Side		
Any visible concerns? (cracks, punctures, peeling paint, birds nests, etc.)	Yes	No
Instrumentation (on crest and downstream side)		
Any visible concerns? (bent, rusted, cracked, etc.)	Yes	No
Thermistors and Dataloggers		
Any visible concerns? (frayed or cut cables, damaged boxes, etc.)	Yes	No
Suspended Sediment in the TIA (When not frozen)		
Any suspended sediment visible in the reclaim pond?	Yes	No
Water at the Toe of the Downstream Side of the Dam		
Is water visible on the downstream side of the dam?	Yes	No

If you answered yes to any of the questions above please provide details and photos. Observations can be sketched on the figure provided on the next page. If seepage has been noted please estimate the flow.

Please provide any other observations you have made



Photos:

Please collect the following photos: Photo from north end looking south along the dam Photo from south end looking north along the dam	 ☐ ☐
Other photos, please describe.	

Appendix F - TIA-2 Station Description

Memorandum

Refer to File: ERM Memo template.dotx

Date: October 30, 2017

To: John Roberts, Vice President, Environmental Affairs, TMAC Resources Inc. (TMAC); Oliver Curran, Director, Environmental Affairs (TMAC); Shelley Potter, Manager, Environment (TMAC)

From: Cameron Evans, E.I.T; Ali Naghibi, Ph.D, P.Eng., Erin Forster, B.Sc., R.P.Bio.

Cc: Peter Luedke (SRK)

Subject: **Hope Bay Project: TIA-2 Station Description**

1. INTRODUCTION

A permanent, year round, water level monitoring station was installed in the Hope Bay Project Tailings Impoundment Area (TIA) at location TIA-2 on September 28, 2017. The new monitoring station has become the primary level monitoring station for the TIA, with the existing levelogger station at the same location becoming the backup station. The existing station was also reinforced during September 2017 to further protect it during the under-ice season. Redundant stations are in place due to the importance of data collected in the TIA and the potential for damage, particularly during the winter season. The purpose of this memorandum is to describe the station location, equipment, and setup as well as management of data collected at the station.

2. STATION DESCRIPTIONS

2.1 Location

The water level monitoring station, TIA-2, is located at UTM 13W 434905 E, 7558709 N. The pressure transducers extend south from the end of the bedrock outcrop. The telemetry tripod and levelogger station box are located on the top of the ridge approximately 25 m from the water edge, at an approximate elevation of 37 meters above sea level (masl).

The station can be accessed by parking at the pullout on the TIA road at the bedrock outcrop just south of the pump house jetty, then walking south approximately 250 m.

2.2 Equipment

Two separate pressure transducers are set up at the TIA-2 location. A telemetry station was newly installed next to the existing levelogger station (Plates 1 to 3). The telemetry station is considered the primary station, with the levelogger acting as a backup in the event the telemetry station stops functioning.

2.2.1 TIA-2 Telemetry (Primary)

The telemetry station uses a 0-15 pounds per square inch (psi) vented PS9800 pressure transducer (Instrumentation Northwest Inc.) with a 125 m long cable, paired with a HOBO Energy Pro Datalogger (Onset Computer Corp). Data is transmitted using a Solarstream solar-powered Iridium satellite transceiver (Upward Innovations Inc.) and accessible on the Data Garrison website (see Section 3). The station is powered by a 12 volt battery connected to a solar panel. Water levels are logged every 15 minutes in the summer, and every 60 minutes in the winter (to save power). Data are uploaded to the Data Garrison website via satellite once every 24 hours.

2.2.2 TIA-2 Levelogger (Backup)

The levelogger station uses a 0-5 m unvented Levelogger Edge, coupled with a barologger located at Doris Camp. The levelogger is connected to a 250 ft direct read cable. The cable connector is protected in a metal electrical junction box located approximately 10 m east of the telemetry station. The levelogger logs every 15 minutes and is set to continuous logging, meaning it will overwrite the oldest data when it becomes full. The logger can store 40,000 readings and is downloaded at minimum once per year to prevent data loss.

2.3 Station Setup

2.3.1 TIA-2 Telemetry (Primary)

The pressure transducer and cable for the telemetry station is protected inside a 2 (inch) diameter high density polyethylene (HDPE) pipe. The 2″ pipe is made up of three 40 ft (foot) sections clamped together to create a 120 ft long pipe. The lowest 40 ft section has holes drilled along the length of the pipe to allow water to pass unimpeded into the pipe so that water level measurement will not be impeded if the end of the pipe becomes buried by sediment in the future. This 120 ft long pipe is protected inside sections of 3″ aluminum pipe to protect the 2″ HDPE pipe from ice damage during the winter. The lowest section of 3″ aluminum pipe consists of two 20 ft lengths clamped together, and extended approximately 30 feet from shore at the time of installation. The lowest 20 feet of aluminum pipe has holes drilled along its length to allow water to pass unimpeded into the pipe in the event that the end becomes buried by sediment in the future. An additional 30 feet of aluminum pipe protects the 2″ HDPE pipe up to the top of the ridge to protect the pipe as water levels in the TIA continue to rise. There are short sections where the 2″ HDPE pipe is exposed to allow the 3″ aluminum pipes to be fit to the bedrock topography. A 1″ aluminum conduit protects the pressure transducer cable from the top of the 2″ HDPE pipe to the telemetry station.

The pressure transducer cable is secured in the pipe with a hose clamp at the top of the 2″ HDPE pipe. This allows for the adjustment, removal and/or replacement of the pressure transducer in the future when water levels are higher.

At the time of installation, the pressure transducer was approximately 30 feet from shore and at a depth of approximately 2.15 m.

2.3.2 TIA-2 Levelogger (Backup)

The existing levelogger station was improved in September 2017 to accommodate rising water levels in the TIA. The pressure transducer and cable for the levelogger station is protected by a combination of 2″ steel drill casing and 2″ HDPE pipe. The 2″ HDPE pipe is further protected from future ice damage by 3″ aluminum pipe.

The previous station consisted of 40 feet of 2″ drill casing that extended into the TIA approximately 35 feet. The pressure transducer and cable are housed in 1″ aluminum conduit that runs down the length of the drill casing, however the connection point to the pressure transducer cable was only 1 m above the current TIA water level and would have been submerged in the spring. The drill casing is now connected to 2″ HDPE pipe that runs 80 feet (two 40 ft sections that are clamped together) up the bank. The 3″ aluminum pipe protects the connection between the steel drill casing and HDPE pipe, as well as a further 30 feet of aluminum pipe up to the top of the ridge to protect the pipe as water levels in the TIA continue to rise to the maximum design elevation. There are short sections where the 2″ HDPE pipe is exposed to allow the 3″ aluminum pipes to be fit to the bedrock topography. A 1″ aluminum conduit protects the pressure transducer cable from the top of the 2″ HDPE pipe to the telemetry station (Plates 1 to 3).

The 1″ aluminum conduit housing the levelogger pressure transducer is clamped to the inside of the steel drill casing to prevent movement of the pressure transducer. This prevents the levelogger from being adjusted, recovered or replaced once the water level exceeds the top of the drill casing. The levelogger will remain in place and continue to gather data for the life of the pressure transducer, approximately 7 to 10 years.

At the time of installation, the pressure transducer was approximately 35 feet from shore and at a depth of approximately 2.3 m.

2.4 Station Bench Marks

Three rock bolts serve as bench marks for water level surveys of the TIA. They are located on the north side of the bedrock outcrop, just south of the reclaim jetty, at UTM coordinates 13W 434790 E, 75558934 N. Geodetic elevations for the bench marks, determined by TMAC surveyors, are presented in Table 1 below.

Table 1: TIA-2 Bench Mark Elevations

Bench Mark Tag Number	Geodetic Elevation
41	32.365
42	32.392
43	32.559

3. STATION DATA

3.1 TIA-2 Telemetry (Primary)

Data collected by the TIA-2 telemetry station are uploaded to the Data Garrison website once every 24 hours. The website displays the most recent water level and battery readings, as well as a graph of historical data. Data can be downloaded from the website in either Hoboware format or tab delimited format. The satellite data subscription must be renewed annually – this is currently performed by ERM.

Website: www.datagarrison.com
Username: 300234010417660
Password: hobo

The value reported by the telemetry station is m (meters) of water above the pressure transducer. To convert to masl, a constant of 27.761 m should be added to the telemetry pressure transducer reading. This constant may change over time due to sensor drift or movement. ERM currently performs bench mark and water level surveys at least twice annually to confirm or modify this constant. Any changes are communicated to TMAC. This procedure should be continued in future years.

3.2 TIA-2 Levelogger (Backup)

Data collected by the TIA-2 Levelogger must be manually downloaded from the connection at the end of the direct read cable, and compensated using the barologger located in Doris Camp. The levelogger data are currently collected and stored by ERM but will only be used in the event the telemetry station is not functioning properly.

The value reported by the levelogger is in m of water above the pressure transducer. To convert to masl, a constant of 27.586 m should be added to the compensated levelogger reading. This constant may change over time due to sensor drift or movement. ERM currently performs bench mark and water level surveys at least twice annually to confirm or modify this constant. Any changes are communicated to TMAC. This procedure should be continued in future years.

Prepared by:

Cam Evans, EIT
Water Resources Engineer
ERM

PHOTOGRAPHIC PLATES

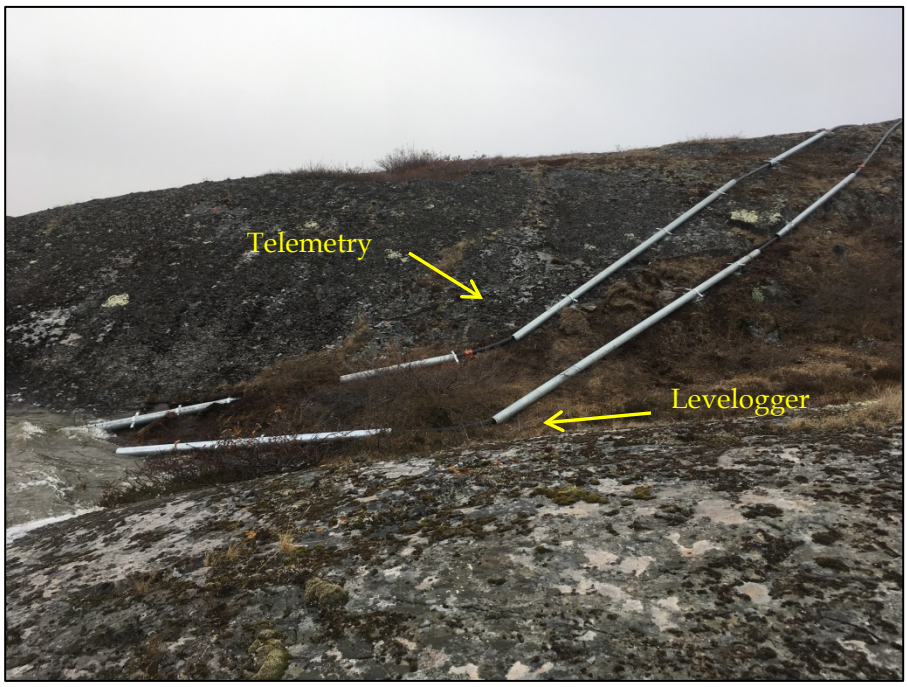


Plate 1: View of 3″ aluminum pipes, protecting the 2″ HDPE pipes that house the pressure transducer cable, extending from the TIA up to the top of the ridge. September 28, 2017.

Plate 2: View from the top of the ridge looking down at the TIA. September 28, 2017.

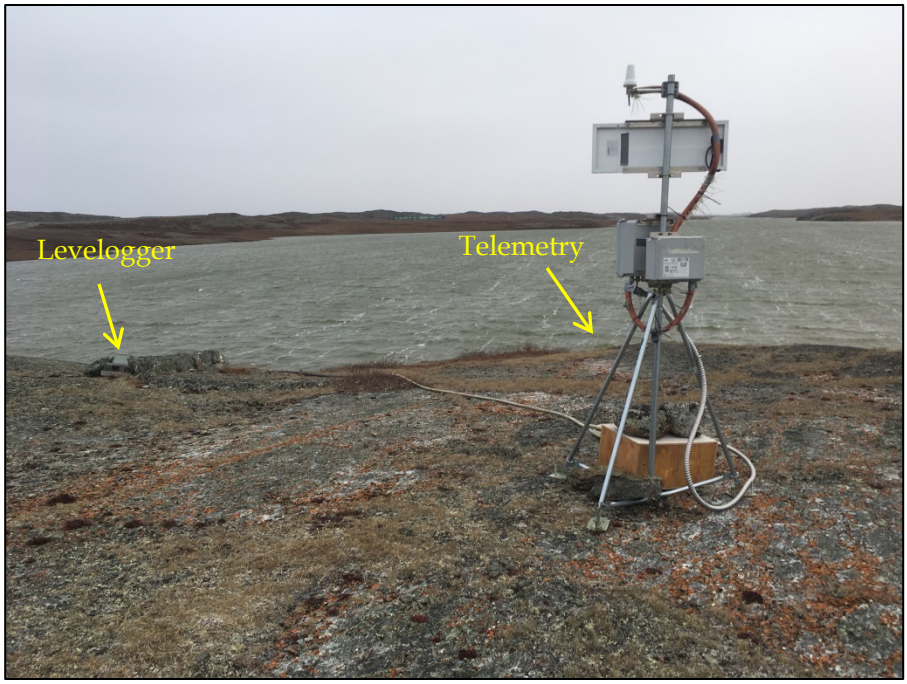


Plate 3: Southerly view of the telemetry station with the junction box housing the levelogger direct read cable in the background. September 28, 2017.