Tailings Storage Facility Operations and Maintenance Manual

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Rock Creek Project
Tailings Storage Facility
Draft Operations and Maintenance Manual

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Project 1011A

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1.0 Facility Description

1.1 General Project Description

The Rock Creek Mine Project is located on the Seward Peninsula along the west coast of Alaska, north of Norton Sound. The project area lies approximately 10 kilometers (km) north of Nome on the east flank of the Snake River Valley, as shown in Figure 1.1. Infrastructure at the Rock Creek Mine Project will include the Rock Creek pit and associated haul roads, ore and development rock stockpiles along with the plant and administration facilities, a groundwater reinjection system, and a tailings storage facility (TSF). Ore will be processed using a gravity circuit augmented with a flotation circuit. Gravity and flotation concentrates will be cyanide-leached in a conventional carbon in-pulp circuit and doré bars will be produced at site. The tailings from the mill process will be thickened prior to being pumped to the TSF for disposal. The TSF will also provide a limited seasonal water inventory for process needs, which is primarily a result of storm-water runoff control during "breakup." A process flow diagram is presented as Figure 1.2.

The processing plant and associated facilities for the project will be located on the north side of Rock Creek. The pit will be situated directly in the Rock Creek drainage upstream of other project elements. The TSF will be located south of the Rock Creek drainage below the pit and south of the plant site. Two development rock stockpiles will be required at the site, one on either side of the Rock Creek drainage (North Stockpile and South Stockpile). In addition to these facilities, site roads, surface-water diversion channels, and a groundwater reinjection gallery will be constructed at the project. See Figure 1.3 for the general arrangement for the site.

1.2 Site Selection

The TSF preferred location is based on the following criteria:

- Minimal base slope at this site provided geotechnical stability.
- Higher dam sections were avoided that would have been required on the steeper topography found throughout the alternative locations within the project site.

- The preferred location also accommodates avoidance of higher value wetlands.
- The location avoids encroachment on non-Alaska Gold Company private lands where land agreements are not in effect.
- The preferred location maintains the design principle of confining facilities within the Rock Creek drainage.

1.3 Site Conditions

1.3.1 Climate

The project site is characterized by cool summers and cold winters. Summer temperatures range between plus 8 degrees Centigrade (+8°C) and +15°C; winter temperatures average around -15°C.

The project site is also characterized by relatively low annual precipitation averaging less than 70 centimeters (cm) with the majority of the precipitation falling as rain in the late summer/early fall months. Monthly winter snowfall totals range between 12 and 28 cm on average.

1.3.2 Topography

The city of Nome is located on the shores of Norton Sound and is typically only a few meters above mean sea level (AMSL) while the Rock Creek site is located at a mean elevation of approximately 100 meters AMSL. The terrain in the vicinity of the project is mountainous with broad valleys associated with the more significant drainages and tributary drainages that are typically narrow and, in some cases, deeply incised.

1.3.3 Site Geology

A mixed sequence of metamorphic rock occurs in the Rock Creek drainage. The dominant rock type is a well foliated, “wavy” banded, quartz-muscovite schist (QMS) containing varying proportions of carbonate, graphite/carbon, and chlorite. Other distinctive rock types include graphitic schist (GS) and quartzitic graphitic schist (QGS) along with minor planar-banded marble (MBL) and planar-banded calcareous schist (CS).

Subsurface conditions around the TSF generally consist of a thin tundra mat underlain by a saturated silt layer to depths ranging up to 1 meter. Below this saturated silt layer, ice-rich silt and sandy silt layers exist. The ice-rich residual soils, with moisture contents up to and exceeding 100 percent (i.e., the weight of water exceeds the weight of the soil) overlie highly to

moderately weathered schist bedrock. Depth to bedrock varies across the project site, ranging from 6 to 25 feet. The condition of the schist ranges from largely decomposed or rubblized to competent.

Low-lying areas and drainages within the limits of the TSF are characterized by shrub and willow thickets and/or wetlands surrounded by open sedge/tundra. The shrub and willow thickets are an indicator of thawed subsurface conditions. Within these areas, subsurface water flows through coarse sand/silt to gravels. The open sedge/tundra generally lay over ice-rich residual soils. Test pits performed during the geotechnical investigations confirm the correlation of the thawed zones with topography and vegetation conditions at the site. The TSF embankment overlies about 30 percent shrub/willow thicket and 70 percent open/sedge tundra.

The Rock Creek site is located near a regional boundary between continuous and discontinuous permafrost, with permafrost depths approaching approximately 100 meters in the Nome Area. The "active layer," defined as the surficial zone that freezes and thaws seasonally, averages between 2 and 3 meters at the site.

For more details on the geology in the area, reference the design report for the TSF.

1.3.4 Hydrogeology and Hydrology

Groundwater recharge initiates as surface infiltration from snowmelt, rainfall and streams or other surface water features perched above the water table. Infiltrated water may be transmitted down slope as interflow (or very shallow groundwater), or percolate to the groundwater table. There is a significant quantity of water transmitted downslope as interflow, with visible discharge from the banks of Rock Creek.

Water entering the groundwater system travels to local discharge points within the creeks or farther downstream to discharge into the Snake River alluvium. The local discharge of deeper ground water into Rock Creek is apparent from the presence of winter base flow, artesian flow from open drill holes, and the chemistry of Rock Creek water. The estimated annual infiltration in the Rock Creek basin is approximately 20 cm, based on rainfall, estimated evapotranspiration, and limited runoff measurements. The presence of permafrost over portions of the catchment reduces the groundwater recharge. There is a significant quantity of groundwater moving downstream in the alluvium within Rock Creek Valley. Groundwater within this alluvium includes direct precipitation, interflow from the upper slopes, and groundwater recharge from depth.

The hydrogeology and hydrology at the project site are described in detail in the Water Management Plan included in Appendix B.

The present catchment area upstream of the TSF embankment location is approximately 95 hectares. The Lower South Diversion Channel will be constructed adjacent to the upstream TSF boundary to capture surface drainage from the upstream watershed that would otherwise flow into the TSF. The Lower South Diversion Channel, which has been designed to convey the 100-year/24-hour storm event around the facility, has a contributing watershed area of approximately 45 hectares.

1.3.5 Natural Hazards

Potential naturally occurring hazards in the general area include earthquake, flood, and frost action. A site specific seismic hazard analysis (Valera, September 2005), estimated peak ground accelerations of 0.10 g (firm rock) and 0.20 g (surface of TSF), which correspond to a 10-percent probability of exceedance over a 50-year design life. This probability of exceedance is based on a return period of 475 years. This level of ground motion, considered appropriate for the site, corresponds to a moment magnitude (M_W) 6.0 occurring at a distance of 24.7 km from the site. These seismic parameters have been included in the project design.

At times, in response to significant precipitation events, minor flooding can occur in the area. To reduce the potential impact on TSF operations, the Lower South Diversion Channel will intercept precipitation-generated overland flow and drainage from the thawing of surface soils and bedrock from the upper watershed and route it around the facility. The diversion channel is designed to collect and convey runoff from a 100-year/24-hour storm event. Along the east and south sides of the TSF, the diversion channel depth varies between 5 and 20 feet, with the flow-carrying portion of the channel positioned a minimum of 3 feet below the surface of the bedrock. It is estimated that bedrock permeability will vary between 1E-04 and 1E-05 cm/s, sufficient for conveying intermittent flow around the TSF without substantial loss to infiltration. The majority of the water within the diversion channel will be routed around the eastern, southern, and western limits of the TSF where it will discharge into the Rock Creek drainage, as illustrated on Figure 1.3. Any storm water that does infiltrate into the bedrock from the channel will enter the groundwater system and flow below the TSF to the Snake River or to the TSF seepage collection system.

Precipitation falling directly into the TSF as well as the portion of the TSF watershed downstream of the Lower South Diversion Channel will be contained by the TSF embankment. The water will be pumped out of the facility and used as makeup water for the processing of the

ores. The TSF embankment has been designed to contain the 100-year/24-hour storm event at all times.

1.4 Components

Design drawings have been included in Appendix A for reference. The appendix will be updated after construction when the as-built drawings become available for inclusion.

1.4.1 Tailings Storage Facility (TSF)

The TSF has been designed to store approximately 9 million tonnes (9.9 million tons) of tailings. The TSF will consist of a rock fill embankment with a naturally shaped upstream basin. The upstream slope of the embankment will be lined with a 1.5 mm (60-mil) high-density polyethylene (HDPE) geomembrane underlain by a liner-bedding layer. Seepage collection drains will be installed above the bedrock surface, along the downstream toe of each embankment stage, to collect and transfer potential seepage to the seepage collection sump.

The materials to be stored in the TSF consist primarily of tailings from the gravity and flotation circuit. These tailings from the gravity and flotation circuit, which have not been included in the cyanide in leach and carbon pulp recovery process, comprise 86.3 percent of the total tailings within the facility. The remaining 13.7 percent of the total tailings are from the cyanide in leach and carbon pulp recovery process. These tailings will be routed through a cyanide destruct process prior to disposal resulting in a small waste stream with a cyanide content of approximately 0.13 mg/kg. Figure 1.2 presents the Process Flow Diagram for the project. A deep-cone paste thickener provides commingling for these tailings with the gravity/flotation circuit tailings prior to disposal in the TSF. Geochemical testing has indicated that the tailings have low acid generating potential but may be metal leaching.

A geomembrane liner will be placed on the upstream slope, extended through the weathered rock to the underlying competent bedrock of the embankment to minimize seepage through the embankment The tailings will be delivered to the TSF as paste (pulp density of 74 percent), which results in very little supernatant water from the tailings. In fact, ponding within the TSF will be a function of “breakup” volume and direct precipitation in the form of rain. The fact that the TSF will only have limited solution storage during the year further supports the concept of a synthetically lined embankment face with no basin liner (the propensity for seepage is relatively low estimated at an average annual seepage rate of 61 gpm). The thermal and seepage evaluation of the TSF design is presented in Appendix C. Process and storm-water runoff within

the TSF will be reclaimed and pumped to the reclaim water tank located at the southeast corner of the TSF basin.

These engineered controls will ensure that groundwater quality monitored in downgradient wells, in accordance with the Rock Creek Project Operation and Closure Monitoring Plan, will meet all applicable water quality standards including metals and cyanide. If monitoring indicates seepage may be escaping from the TSF, the contingency plan is to install a seepage recovery system and/or well system downstream of the embankment that will recover errant seepage and route it to the seepage recovery sump for recycle.

1.4.2 Seepage Collection Sump

A vertical sump will be constructed as the outlet works for the seepage collection system. The proposed sump location is shown on Figure 1.3. The sump will be constructed below ground level and will be located adjacent to the downstream toe of the TSF embankment. Water collected in the seepage collection drains will be conveyed to the sump where it will be pumped to the head tank located near the southeast corner of the TSF basin.

Design drawings are included in Appendix A and will be updated with the as-built drawings prior to operational startup.

1.4.3 Reclaim Water System

The reclaim water system within the TSF consists of a sloping decant pipe with a submersible pump. The reclaim water from the supernatant pond will be pumped to the head tank located near the southeast corner of the TSF basin. The reclaim pipeline is positioned adjacent to the upstream crest of the TSF.

As-built design drawings will be included in Appendix A prior to operational startup.

1.4.4 Reclaim Water Head Tank

The reclaim water head tank is located near the southeast corner of the TSF. Water from the seepage collection and supernatant pond reclaim systems will be pumped to this tank for storage prior to being pumped to the mill recycle water pond for use in the processing of the ore.

As-built design drawings will be included in Appendix A prior to operational startup.

1.4.5 Tailings Delivery System

Following the processing of the ore, paste tailings from the deep cone thickener will be pumped to the TSF for disposal. One header pipeline will be positioned along the upper limit of the basin. This pipeline will deliver tailings from the plant site to the southeast corner of the TSF basin. Five drop bars will be positioned along the main header pipeline within the basin limits. These drop bars will convey the tailings into the basin area for deposition. The proposed drop bar locations can be referenced on Figure 1.4.

Deposition towers are positioned along the drop bars at specific locations to form a downward sloping deposit to the TSF embankment. These towers deposit the tailings at a height of five meters above the ground surface, creating a depositional cone around the base of the tower. When the cone reaches the top of the tower, the deposition will be moved to the next tower uphill of the previous point of deposition. Depositional times vary for each tower and are dependent upon the location of the tower and the geometry of the resulting tailings deposit. If additional depositional drop bars and towers are required, they will be installed during the winter months to allow access onto the tailings surface.

As-built design drawings will be included in Appendix A prior to operational startup.

1.4.6 Miscellaneous Infrastructure

1.4.6.1 Utility Corridor

A utility corridor from the plant site to the TSF site will be constructed. The corridor will consist of an HDPE geomembrane lined channel, graded to drain into the Recycle Water Pond. The lined channel will contain tailings delivery pipelines and return water pipelines. Within or adjacent to this channel there may also be electrical power lines. Electrical service is required at the head tank; reclaim water system and seepage collection sump.

A new access road will be constructed around the perimeter of the TSF site. The road alignment is positioned at the upper limits of the TSF basin and near the toe of the TSF embankment. The required electrical power lines and water pipelines will be positioned adjacent to this access road for easy access and maintenance.

As-built design drawings will be included in Appendix A prior to operational startup.

1.4.6.2 Surface Water Diversion Channels

The typical cross section of a surface-water diversion channel will position the water-carrying portion of the channel below the surface of the bedrock. The channel will be excavated through the overburden soils to a depth of approximately 3 to 5 feet below the bedrock surface. The total depth of the channel can be up to 20 feet, depending on the thickness of the overburden soils, the channel alignment, and the required channel geometry. Channel widths and depths vary across the project site, as required by the hydraulic analysis and design performed on the channels. The detailed design drawings present the geometry requirements of each channel.

Surface-water diversion channels will be constructed in the following areas:

- Upper Diversion Channel is planned above the TSF and North Development Rock Dump and will convey flow from the upper reaches of the project to Lindblom Creek located north of the project area.

- Lower South Diversion Channel is planned below the South Development Rock Dump from the northernmost limit of the dump, around the east, south, and west sides of the TSF where it will discharge into the Rock Creek Drainage below the TSF. This will limit flow entering the TSF to direct precipitation on the facility.

- Lower North Diversion Channel is planned between the North Development Rock Dump and the Plant site and will take surface flow from the North Dump and transmit it to Lindblom Creek. This is designed to keep runoff from entering the plant site area and the organic stockpile located to the north of the plant site.

- Plant Site Diversion Channels; are planned to collect surface run-off from the plant site direct the flow into the Recycle Water Pond. These channels are positioned along the north, south and west sides of the plant site. Feasibility design drawings of the Recycle Water Pond are included in Appendix A, detailed design drawings will be included in the manual prior to operational startup.

1.4.6.3 Site Roads

Site Roads will include access and haul roads designed for light vehicle and haul truck traffic, respectively. The road locations and general design criteria are presented below:

- Haul Roads: Haul roads will exist from the pit to the Development Rock Dumps, plant site, and the TSF. These roads will have a traveled width of 18 meters

(58.5 feet) with a maximum grade of 10 percent. The roads will be fitted with safety berms to the axle height of the haulage equipment outside of the traveled path, and the roadbed will use development rock as a road surface material.

- Access Roads: Access roads will be sited to provide access to project elements, including the diversion channels, TSF, seepage reclaim sump, plant site, organic stockpiles, explosive storage area, injection wells, etc. These roads will be constructed with a traveled path width of 8 meters (26 feet) with light-vehicle axle-height safety berms outside of the traveled path width. These roads will be constructed using development rock.

1.4.7 Monitoring Instrumentation

1.4.7.1 Piezometers

Vibrating wire piezometers will be installed at the downstream toe of the TSF embankment. The locations of the piezometers are shown on Figure 1.4. Piezometer cables will be routed to the downstream toe of the TSF embankment, near the seepage collection sump, where a single readout box will be located. The readings from the piezometers shall be collected weekly at the beginning of the operations. This frequency can be adjusted as necessary, based on the readings and interpretation of the collected data.

1.4.7.2 Groundwater Monitoring Wells

Three groundwater monitoring wells will be installed around the perimeter of the TSF. The locations of the groundwater monitoring wells are shown on Figure 1.4. Wells will be installed in accordance with the design provided in the Rock Creek Project Operational and Closure Monitoring Plan. As conditions at each location may vary, the final installed details for each well will be included with manual prior to operational startup.

Groundwater samples from the monitoring wells will be collected and tested to verify contaminates from the TSF have not entered the groundwater. Samples shall be collected in accordance with the Rock Creek Project Operational and Closure Monitoring Plan and are anticipated to meet all applicable standards.

If contaminates are detected, it is noted that options are available to resolve seepage issues should they occur. An interception and treatment/disposal plan could be put into place based on the location and level of detection. Based on subsurface data, the sublateral drainage near monitoring well M-4 and the Bear Gulch drainage in the area of monitoring wells M-2 and M-3

are the most likely exit points for potential seepage from the TSF. If seepage were to be detected downstream of the facility, contingency options could include converting monitoring wells into seepage recovery wells. This could be augmented with the installation of vertical French drains excavated into competent bedrock and graded to direct collected seepage to a low point for recovery.

1.4.7.3 Settlement/Movement Monuments

Vertical and lateral movements of the ground surface will be measured in three locations along the TSF embankment. The settlement monuments will be surveyed monthly until the closure/reclamation activities at the TSF has begun. The proposed locations of the settlement monuments are shown on Figure 1.4. The settlement monuments will consist of a 2-meter-long, 20-mm-diameter rebar driven into the ground and enclosed at the collar within a 150-mm-diameter plastic casing. These monuments will be protected from vehicular traffic through placement of pipe bollards or earth berming around the monuments. Settlement will be evaluated by the Engineer of Record or the site geotechnical engineer and if required, and action plan developed in response to the evaluation.

1.5 Regulatory Requirements

Upon regulatory approval of this project, the following information will be inserted into this section:

- Regulatory agency
- Permit number
- Permit issue date
- Permit expiration date
- Monitoring and reporting requirements.

1.6 Design Criteria

The following design features and criteria have been incorporated in the TSF design:

General	
Facility capacity	▪ 9 million dry tonnes (9.9 million tons)
Production	▪ 7,000 dry tonnes per day (7,700 dry tons per day) average production rate ▪ 24 hours per day, 365 days per year
Slurry characteristics	▪ 1.52 tonnes/m³ (94.8 lbs/ft³) average tailings density ▪ Paste tailings – 74% solids content
Tailings Disposal	▪ Tower depositional system ▪ Rotated/on-line as needed to maintain desired beach/deposition geometry ▪ 5% average tailings beach/deposit slope

General	
Fluid management	▪ Precipitation and supernatant water collected in a sloping decant/pump system at the upstream slope of the facility ▪ Seepage collection system within embankment to collect and convey seepage to process system. ▪ 1m (3.3 ft) freeboard maintained at all times
Embankment construction	▪ Rock fill embankment – constructed using mine personnel and equipment ▪ Synthetic geomembrane lined upstream slope ▪ Liner bedding material between synthetic geomembrane and rock fill embankment ▪ Embankment raise by downstream construction methods ▪ 10m (33 ft) minimum embankment width ▪ 2.5:1 (horizontal to vertical) upstream and downstream slopes
Seepage Collection System	▪ Perforated collection pipes encapsulated in drainage gravel material, positioned along downstream toe of each interim embankment stage ▪ Geosynthetic Clay Liner (GCL) positioned along downstream edge of the Stage 3 collection system as an added measure of containment for the ultimate facility. ▪ Collection system routed to a sump, installed to insure positive drainage (may require excavation of a trench into the bedrock), located outside the Stage 3 embankment limits for pumping back to the process.
Liner	▪ 1.5-mm (60-mil) HDPE geomembrane ▪ Anchor trench at crest of each embankment stage ▪ Bottom anchor trench to be extended into weathered bedrock

Detailed design drawings will be included in Appendix A prior to operational startup.

Design modifications that result in deviation from the established design criteria will be properly documented.

1.7 Filling Curve

The filling curve developed utilizing the design criteria presented in Section 1.6 of this document is shown on Figure 1.5. The stage 1 embankment has been designed to store approximately 1.1 million tonnes (1.21 million tons) of tailings, approximately 5 months of production. The Stage 2 embankment has been designed to store an additional 2.4 million tonnes (2.64 million tons), approximately 11 months of production. The final stage, stage 3, has a capacity of approximately 5.5 million tonnes (6.05 million tons), bringing the total storage capacity to 9 million tonnes (9.9 million tons). The filling curve is to be reviewed and updated on an annual basis, taking into account changes to the operations and production schedule.

2.0 Facility Operation

The objective of this section is to define operating standards and procedures based on the following parameters:

- Design criteria
- Regulatory requirements
- Company policies
- Sound operating practices.

2.1 Organizational Chart

The organizational structure for the project is illustrated on Figure 1.6. The organization is divided into four groups: administration, plant, exploration, and mine.

2.2 Tailings Transport and Deposition

Tailings from the plant will be pumped into a deep cone thickener where, through sheer thinning "paste tailings" will be produced. The paste tailings will be transported to the TSF for deposition in a main header pipeline. The pipeline will be routed adjacent to access and haul roads between the plant site and the TSF within an HDPE geomembrane lined channel. The pipeline will be insulated and heat traced to protect the pipeline from freezing conditions. In the event of a line break between the plant and TSF, the pipeline corridor has been graded to drain back to the plant site and into the mill recycle pond for containment.

Within the TSF basin, five drop bars are connected to the main header pipeline for conveying the tailings into the basin for deposition. Valves on the main header drop bar pipelines will regulate flow through the drop bars and deposition towers. The main header valve immediately downstream of the drop bar(s) to be actuated will be closed, and drop bar valves will be opened on those drop bars that are to be utilized for deposition. Drop bars in the previous zone(s) of deposition and mainline components with static tailings in them will be cleaned using a water plug, pumped into the line through a cleanout valve, followed by high-pressure air. These lines will require cleaning immediately after deposition is terminated in a given area. In the event of a main header line break within the TSF basin, the tailings will flow into the TSF basin.

2.2.1 Deposition Plan

The initial deposition will be positioned near the embankment toe to form the supernatant pond area. This will also create a layer of tailings at the point most susceptible to seepage loss, the

upstream embankment toe. This initial layer of tailings will aid in sealing the toe of the embankment and reducing the already low seepage potential.

The deposition will proceed in a designated pattern, directing storm water and supernatant solution to the embankment for reclaim. In general, the pattern will alternate from a north depositional tower to a south depositional tower and from upstream to downstream in a given depositional cycle throughout the life of the facility. The duration of each depositional point is a function of the topography at the tower location and the tower location within the TSF basin. The duration may also vary based upon fluctuations in the production rates at the plant.

2.3 Facility Staging

The rock fill embankment will be constructed in three stages, while the basin and depositional system will be completed during the initial stage of construction. The stage 1 embankment construction will consist of excavating the embankment foundation, installing the seepage collection and thermosyphon systems at the downstream and upstream toes of the embankment respectfully, and constructing the rock fill embankment. Upon completion of the embankment construction, the upstream slope of the embankment will be lined with an HDPE geomembrane and the seepage and reclaim water systems will be constructed. Additional components to be constructed during the stage 1 construction include the installation of the tailings distribution system, supernatant water reclaim system, perimeter road and the lower south diversion channel.

The construction of the stage 2 and 3 expansions will be almost identical. Both will require the embankment foundation to be excavated and seepage collection pipe work to be installed prior to rock fill materials being placed, raising the embankment. Upon completion of the rock fill placement, the HDPE geomembrane will be extended to the expansion crest elevation. The supernatant reclaim pipe work will then be relocated/extended as an interconnected system to the new crest elevation. No work will be required within the basin area with the exception of intermittent topsoil removal in the expanded basin areas.

Feasibility design drawings are included in Appendix A. As-built drawings will be included in Appendix A prior to operational startup.

2.4 Water Management

The TSF has been designed to contain the seasonal storm water, operational solution and the 100-year/24-hour storm event while at all times maintaining a minimum freeboard of 1 meter (3.3 feet). See the Water Balance in Appendix B.

The sizing of the seepage collection sump will be determined based on the seepage analysis being performed in conjunction with the design of the TSF. The sump will be designed with a freeboard of 0.5 meters (20 inches). See the Thermal and Seepage Evaluation in Appendix C.

Surface water above the TSF will be captured and conveyed around the facilities via the lower south diversion channel. This will minimize the amount of storm water required to be stored within the facility. The surface-water conveyance system has been sized to handle the 100-year/24-hour storm event.

2.5 Documentation

2.5.1 Construction and Repair Activities

For any construction or repair work completed to the facility, the following information will be collected and recorded:

- Daily reports
- Project related memos or communications
- Photographs
- Quality control records
- As-built drawings.

Upon completion of construction or repair work, a Record Report of the work will be issued detailing the construction and inspection activities, including discussion of any modifications made to the original design. A record of Construction Report will be submitted to the agencies, upon completion of each stage of construction.

2.5.2 Daily Operation

The following information will be collected and recorded as part of the daily operation of the facility:

- Daily general observations of the process
- Production rates including tailings solids quantity, solids content and water quantity consumed
- Instrument and monitoring records

This information will be recorded on the daily operator log.

3.0 Facility Maintenance

3.1 Objective

The objective of the Facility Maintenance Program is to ensure that the individual components of the facility are operating in accordance with the established design criteria, company standards, regulatory requirements, and sound operating practices.

3.1.1 Responsibility for maintenance

The following table outlines the individuals responsible for overall maintenance of the facility:

Individual	Responsibility	Title	Telephone (Work)	Telephone (cell)
TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD

TBD = To be determined. This table will be updated upon prior to operation of the facilities.

Maintenance issues will be addressed by the Manager responsible for each operating component. In the event that the Manager is unavailable, it will be the responsibility of the Assistant Manager, or other designated personnel, to ensure maintenance issues are addressed.

3.1.2 Components Subject to Maintenance

All components of the TSF will be subject to a routine maintenance program. It is the objective of this program to ensure that the individual components are maintained in accordance with performance criteria, company standards, legislative requirements, and sound operating practices.

In addition to a routine maintenance program, the individual components will be subject to event-driven maintenance on an as needed basis. Event-driven maintenance will be performed as a direct result of a specific incident or observation where the process has been, or could be adversely affected. Maintenance requirements, as outlined below, will be updated as manufacturer's guidelines and recommendations are received.

3.1.2.1 Tailings Pipelines

The tailings pipelines will be used to transport tailings from the plant to the TSF for disposal. The tailings pipelines may be exposed above ground or buried above ground to provide additional thermal protection. The anticipated pipeline locations are shown on Figure 1.1.

The required maintenance program is as follows:

- Routine Maintenance: When pipe wall thickness does not meet the manufacturer's recommended minimum pipe thickness and/or excessive pipe wear has occurred, the affected section of pipe shall be replaced.

- Event-Driven Maintenance: When pipeline breaks or other non-breaking damage occurs, the affected section of pipe shall be replaced.

All maintenance work performed on the tailings pipelines will be performed in accordance with the manufacturer's recommendations for materials and installation, and all completed work will meet the requirements of the design.

3.1.2.2 Depositional Towers

Depositional towers will be positioned throughout the TSF basin, at designated locations. The locations may be modified during the operational life of the TSF based on the geometry of the tailings deposition.

The required maintenance program is as follows:

- Routine Maintenance: Install new depositional towers as required.

- Event-Driven Maintenance: When a leak or a pipeline break is observed, the affected section shall be replaced or repaired if accessible. Due to tailings deposition and resulting access problems, affected section may not be repairable, in which case a new depositional line will be placed.

3.1.2.3 HDPE Geomembrane

The following maintenance program should be followed for the HDPE geomembrane:

- Routine Maintenance: All debris, large rocks, sharp edged items, or any item that could potentially puncture the liner will be removed from the liner surface.

- Event-Driven Maintenance: All holes, tears, and creases that reduce the geomembrane thickness to below accepted industry standards will be repaired through extrusion welding and patching.

All maintenance work performed on the HDPE geomembrane will be performed in accordance with manufacturer's recommendations.

3.1.2.4 Supernatant Solution Reclaim System

Process solution/storm water will be reclaimed from the TSF by means of a sloping decant.

The required maintenance program is as follows:

- Routine Maintenance: The pump is to be maintained in accordance with the manufacturer's recommendations.

- Event-Driven Maintenance: At the end of the summer/fall reclaim season, prior to the onset of freezing conditions, the pump should be drained. Prior to the winter shutdown for the pump, it should be flushed with clean water to avoid corrosion. After shutdown of the reclaim system, makeup water will be drawn from the TSF and/or interception wells.

All maintenance work will be performed in accordance with the manufacturer's recommendations.

3.1.2.5 Seepage Collection Sump

The seepage collection sump will collect seepage and groundwater from the TSF embankment foundation. Water collected in the sump will be directed to the reclaim water system throughout the year. The location of the sump is shown on Figure 1.3.

The following maintenance program should be followed for the seepage collection sump:

- Routine Maintenance: All sediment, scaling, debris, large rocks, or any item that could potentially damage the sump and/or pumps will be removed. Routine maintenance will be performed on the pumps and valves in accordance with the manufacturer's recommendations.

- Event-Driven Maintenance: Event-driven maintenance on the pumps and valves will be governed by the manufacturer's recommendation.

All maintenance work will be performed in accordance with the manufacturer's recommendations.

3.1.2.6 Diversion Channel

The lower south diversion channel will be constructed around the facility to divert storm water away from the TSF and reduce the amount of storm water reporting to the facilities. The diversion channel does not intercept any flowing drainages, but will collect precipitation generated overland flow, and the thawing of surface soils and bedrock from the upper watershed and route it around the facility. The diversion channel is designed to collect and convey runoff from a 100-year/24-hour storm event. Along the east and south sides of the TSF, the diversion channel depth varies between five and 20 feet, with the flow-carrying portion of the channel positioned a minimum of three feet below the surface of the bedrock. It is estimated that bedrock permeability will vary between 1E-04 and 1E-05 cm/s, sufficient for conveying intermittent flow around the TSF. The majority of the water within the diversion channel will be routed around the eastern, southern, and western limits of the TSF where it will discharge into the Rock Creek drainage, as illustrated on Figure 1.3. Any storm water that does infiltrate into the bedrock from the channel will enter the groundwater system and flow below the TSF to the Snake River or to the TSF seepage reclaim system.

The following maintenance program will be followed for the diversion channel:

- Routine Maintenance: All debris, foreign objects, and brush will be removed from the diversion channel and its associated structures.
- Event-Driven Maintenance: All erosional gullies will be repaired and riprap replaced following storm events.

Maintenance work performed on the diversion channels will result in the maintained diversion channel meeting or exceeding the original design requirement.

Feasibility design drawings of the diversion channels are included in Appendix A. As-built drawings will be included in Appendix A prior to operational startup.

3.1.2.7 Access/Perimeter Roads

Access/perimeter roads will be constructed around the facility to provide access to all operational elements of the facility. The alignment for the access/perimeter roads is shown on Figure 1.3.

The following maintenance program should be followed for the access/perimeter roads:

- Routine Maintenance: The road surface will be maintained in a smooth and passable condition and will be sloped to provide positive drainage from the road surface (where applicable to the adjacent diversion channel). The road surface will be treated to prevent dusting issues when required. Safety berms will be monitored and maintained to ensure proper height to satisfy MSHA requirements.

- Event-Driven Maintenance: All surface erosion will be repaired after storm events and when needed during the wet season.

3.2 Documentation

The following information will be collected and recorded as part of the facility's maintenance program:

- Equipment logs with information regarding: location of equipment, identification number, equipment type, problem history, repair history

- Quality control records detailing maintenance work

- Photographic records

4.0 Facility Surveillance

The objective of the Facility Surveillance Program is to monitor the operation, safety, and performance of the tailings and water management facilities; to identify and evaluate deviations from expected behavior that affect operational safety, structural integrity, and environmental performance of the facility; and to report significant observations for response.

4.1 Embankment

The basic inspections and evaluations for the facility embankment are as follows:

- Daily: Visually check for the presence of foreign objects on or damage to the embankment liner.

- Weekly: Visually confirm possible changes to the structure, including:

  - Evidence of slope deformation
  - Crest settlement
  - Cracking
  - Slope erosion or degradation of fill material
  - Embankment toe erosion
  - Seepage: First, clear vegetation and debris to facilitate observation; second, record quantity of seepage; and third, identify how we dealt with seepage.

- Monthly: Carry out detailed visual inspection of the embankment liner. Pay particular attention to all seams, connections to structures, and anchor trenches. If liner penetrations are added to the system at a later date they should be added to the inspection list.

The results of all inspections should be properly documented on applicable forms. Report any damage to liner, cracks, settlement, erosion, or seepage to the appropriate manager.

- Annually: A dam safety inspection (DSI) will be performed as required in the Rock Creek Project Operational and Closure Monitoring Plan. The purpose of a DSI is to evaluate, on a regular basis, the current and past performance of the TSF embankment and observe potential deficiencies in the dam conditions, performance, or operation. The DSI includes both a field inspection of the facility and a review of past inspections and monitoring data collected for the facility.

- Items to be included in the DSI shall include the following:
  - Evaluation of the embankment crest for signs of cracking, ponding water, or animal burrows
  - Evaluation of the embankment slopes for sloughing or other movement, vegetative growth, erosion, or animal burrows
  - Inspection of the embankment HDPE liner condition
  - Review of the semi-annual piezometer reports for the facility
  - Review of the settlement monument, piezometer and other geotechnical monitoring data
  - Inspection of the seepage collection sump and the discharge from the collection pipelines
  - Review of the current Operations and Maintenance Manual
  - Review of the current, past, and anticipated production rates.

Major improvements/repairs recommended in the DSI report, if any, are identified with name of person responsible for implementing same, and schedule for completion. The DSI will be completed using the DSI forms currently approved for use with the Alaska Department of Water Resources Dam Safety Division.

4.2 Piezometers

The basic inspections and evaluations for the piezometers are as follows:

- Weekly: Record piezometer readings and compare with previous readings. Record the elevation of tailings and supernatant water surface.
- Semi-Annually: Evaluate results of the piezometer readings and prepare a report of findings.

The results of all inspections will be documented on applicable forms.

4.3 Settlement Monuments

The basic inspections and evaluations for the settlement monuments are as follows:

- Monthly: Record readings and compare with previous readings (weather dependent). Generated field data will be entered into logbooks. Data to be forwarded to the Engineer of Record for the TSF or the site geotechnical engineer for review and analysis.

- Annual: Evaluate results of the settlement readings and prepare a formal report of findings.

4.4 Groundwater Monitoring Wells

All monitoring will be in accordance with the Rock Creek Project Operational and Closure Monitoring Plan.

4.5 Tailings Delivery Components

The basic inspections for the tailings delivery components are as follows:

- Daily: Document on the daily operator log the production rate, tailings delivery pipeline pressures, tailings solids quantity, solids content, and depositional tower operation. Report any readings that are significantly different than the previous reading. Visually check tailings pipeline route and alignment for damage or any other irregularities. Verify that quiescent lines have been cleaned immediately after cessation of deposition in a given zone.

- Quarterly: Tailings samples will be collected, tested, and reported as required by the Rock Creek Project Operational and Closure Monitoring plan.

The results of all inspections will be documented on applicable forms.

4.6 HDPE Geomembrane

The basic inspections for the HDPE geomembrane are as follows:

- Weekly: Visually confirm the integrity of geomembrane in all areas.

The results of all inspections will be documented on applicable forms.

4.7 Sloping Decant Reclaim System

The basic inspections for the sloping decant reclaim system are as follows:

- Daily: Document the reclaim pumping rate and supernatant pond depth. Visually confirm the absence/presence of floating debris, satisfactory pump operation, and the reclaim pipe integrity. Where applicable, take action to correct the problem. All information will be recorded on the daily operator log.

- Weekly: Visually confirm that all anchors and supports are in place, that the reclaim pipe is properly aligned, and that there is no damage to the pipeline. Document the supernatant pond elevation and clarity of the solution. Note tailings elevation inside the decant and pump elevation.

- Quarterly: Collect, test, and report water quality of the reclaim solution as required by the approved monitoring plan.

The results of all inspections will be documented on applicable forms.

4.8 Seepage Collection Sump

The basic inspection requirements are as follows:

- Daily: Document water levels, flow rates, pump operations, and solution clarity. Visually confirm satisfactory operation of the sump pump. Document total flow between inspection times. Verify that emergency overflow is clear of obstruction.

- Weekly: Visually confirm satisfactory operation of all pipes, pumps, and fittings. This information will be recorded on the weekly operator summary log. Check for sediment buildup and presence of foreign objects.

- Quarterly: Collect, test, and report water quality of the reclaim solution as required by the approved monitoring plan.

- Semi-Annually: Conduct detailed inspection of the sump.

The results of all inspections will be documented on applicable forms.

4.9 Diversion Channel

The basic surveillance inspections and evaluations are as follows:

- Weekly: Visually inspect the channels for presence of foreign objects, brush and debris accumulation, groundwater seeps, erosion, and possible damage to channel foundation.

- Monthly (or as required by regulatory agencies): Collect, test, and report water quality of the water flowing in the diversion channels as required by the approved monitoring plan.

- As Needed: Visually inspect the channels for presence of foreign objects, brush and debris accumulation, groundwater seeps, erosion, and possible damage to foundation. Generally performed following significant precipitation events.

The results of all inspections will be documented on applicable forms.

4.10 Access/Perimeter Roads

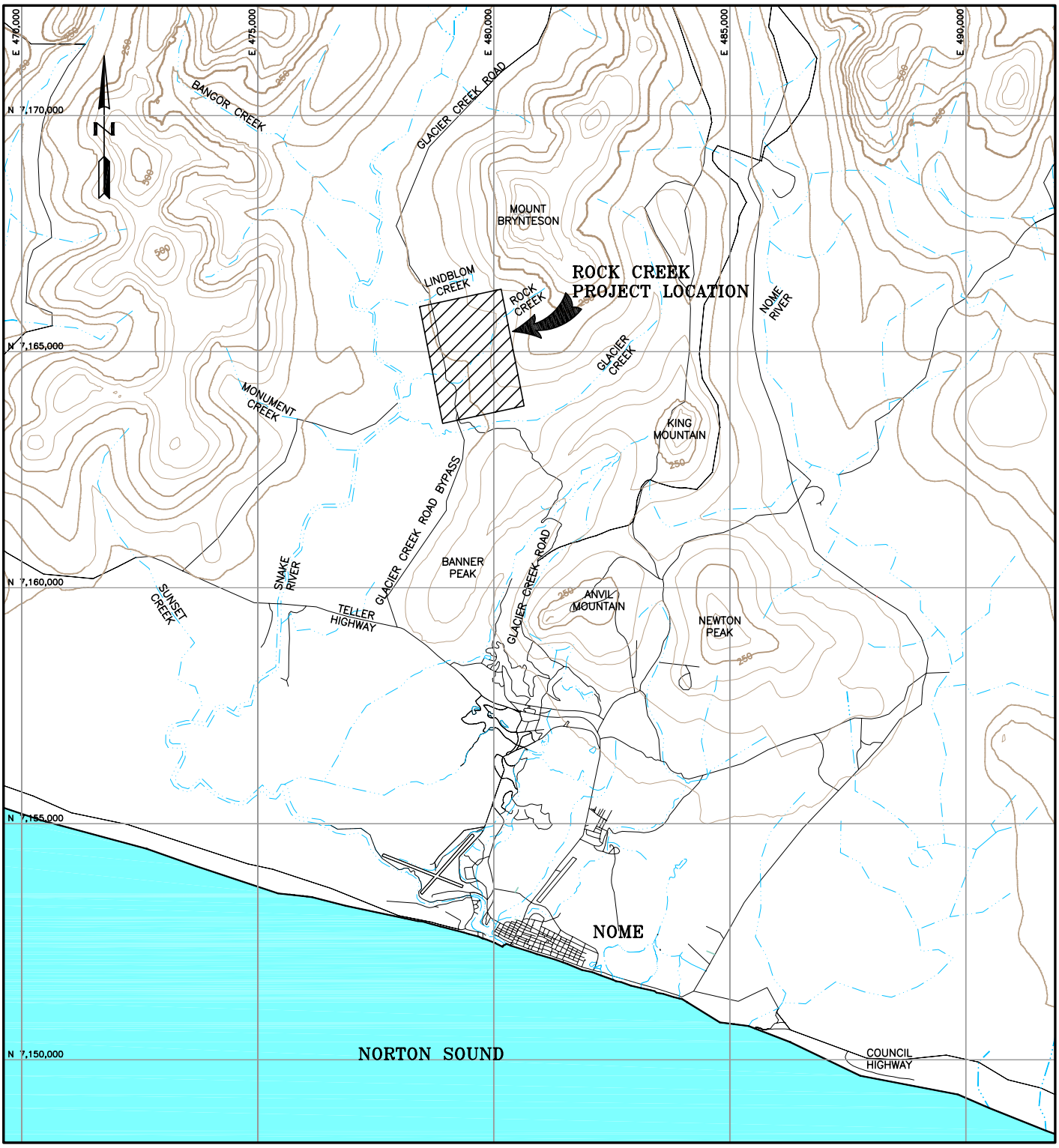
The basic surveillance inspections and evaluations are as follows:

- Weekly: Visually confirm that all roads are in passable condition and properly graded to provide positive drainage from the road surface.

- Semi-Annually: Perform inspection on all drainage culverts and ditches for presence of foreign objects, brush, and debris accumulation

The results of all inspections will be documented on applicable forms.

Figures



1200 0 1200 2400 METERS

SCALE = 1:60,000

LEGEND:

- 5000 — EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING DRAINAGES
- EXISTING ROAD

CLIENT	ALASKA GOLD COMPANY
PROJECT	ROCK CREEK PROJECT
TITLE	PROJECT LOCATION MAP

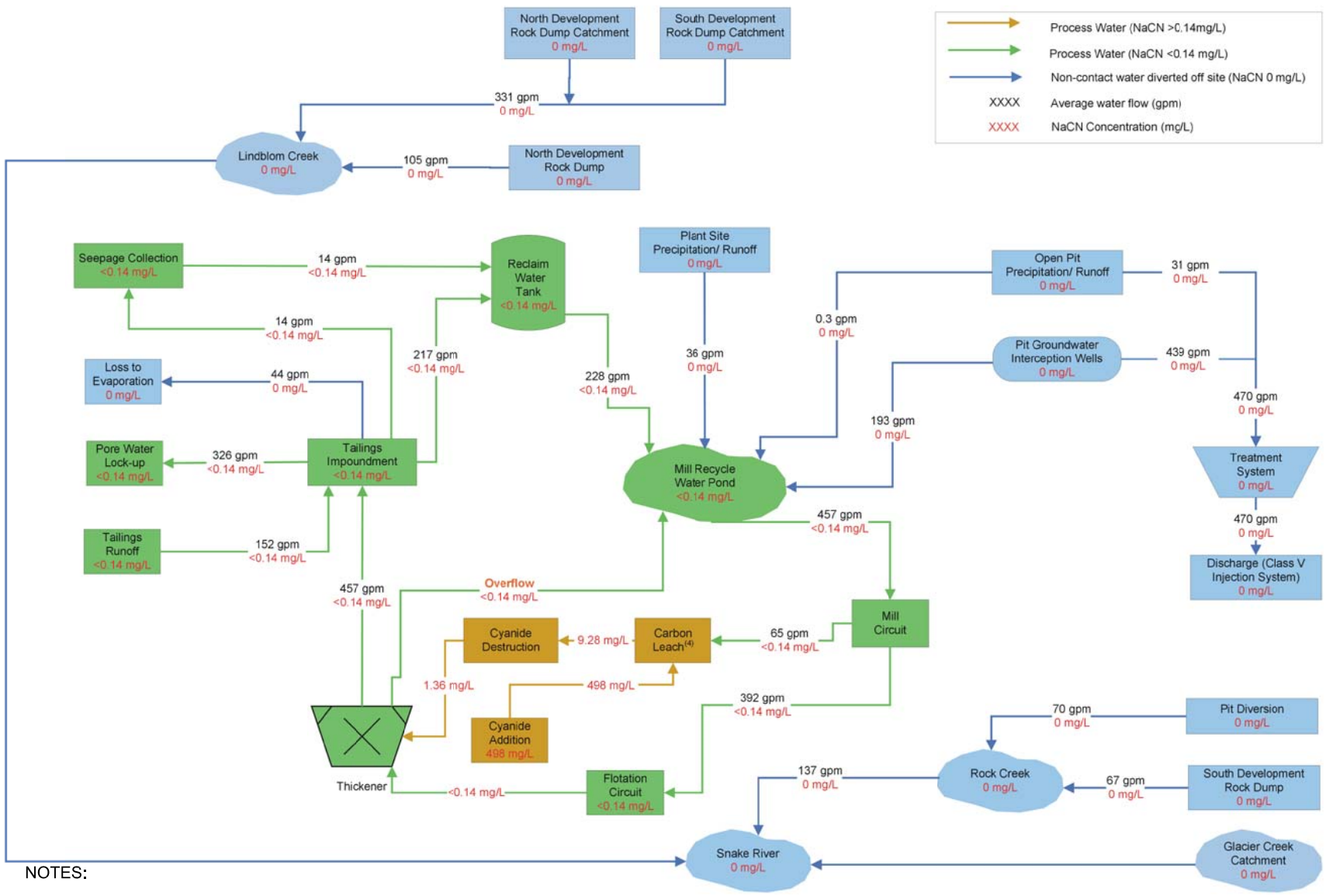
Alaska Gold Company

SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	RTB	CHECKED BY	RMS	DATE
DRAWN BY	DS	APPROVED BY	RMS	1/20/06

FILENAME	FIGURE No.	REV
1011F166	1.1	A

F:\2509 - ROCK CREEK\WATER BALANCE\FIGURE-1.DWG



NOTES:

1) Precipitation and snowmelt contribute to all areas.

2) Water volumes represent average rates for the time period 1-31-07 through 12-31-10.

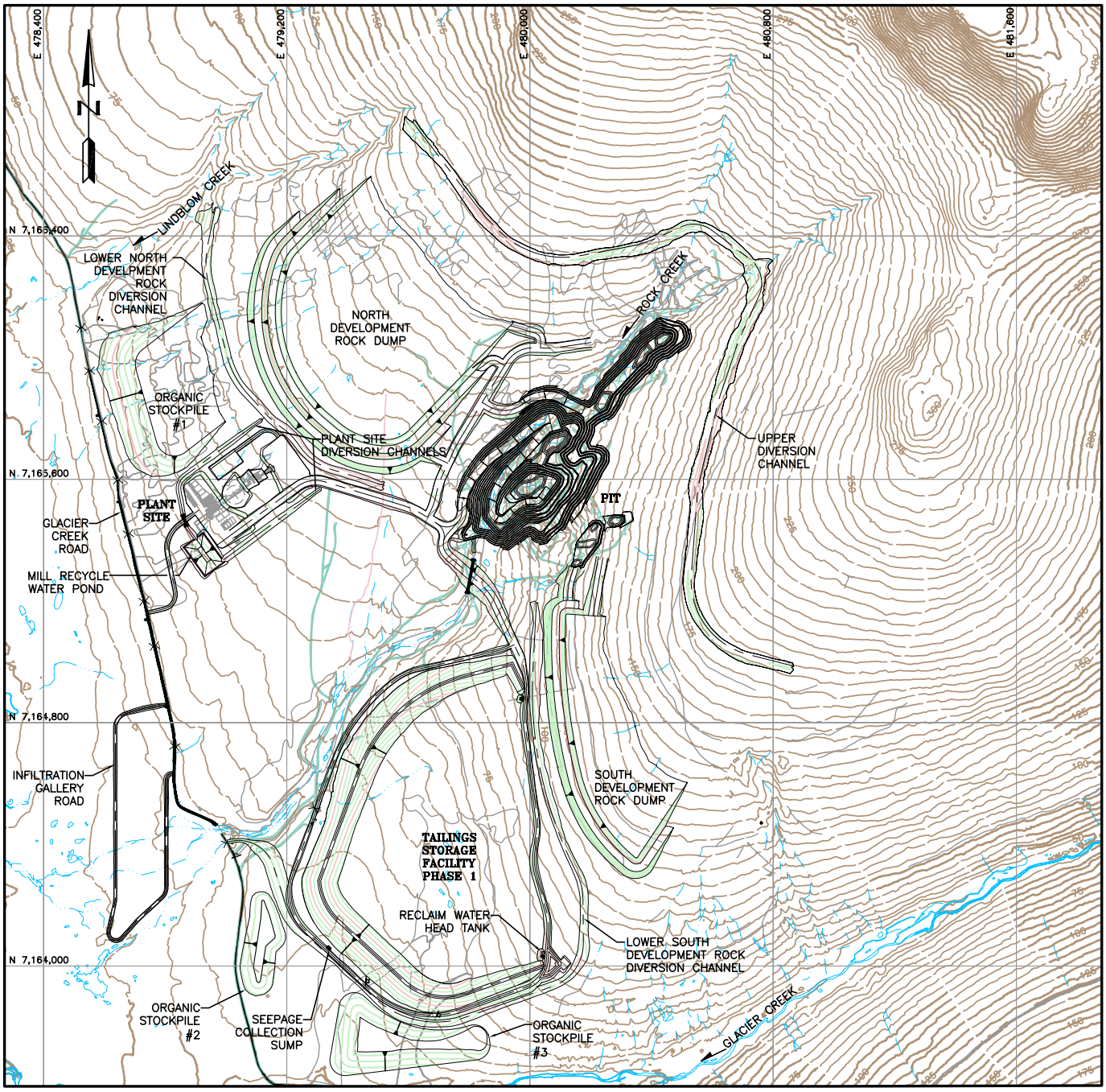
3) Volumes may not balance precisely due to rounding errors.

4) Carbon leach includes electroplating circuit.

WATER MANAGEMENT CONSULTANTS
Denver, CO

PROCESS FLOW DIAGRAM WITH AVERAGE FLOW VALUES AND NaCN CONCENTRATIONS

CLIENT: NOVA GOLD
PROJECT: ROCK CREEK
JOB: 2509
FILE: FIGURE-1.DWG
DRAWN: PG
CHECKED: BJ
DATE: APRIL 2006
FIGURE: 1.2



200 0 200 400 m

SCALE = 1:20,000

LEGEND:

- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING CULVERT
- EXISTING TRAIL
- PROPOSED CULVERT

CLIENT	ALASKA GOLD COMPANY			
PROJECT	ROCK CREEK PROJECT			
TITLE	GENERAL SITE PLAN			

SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	RTB	CHECKED BY	RTB	DATE
DRAWN BY	JNM	APPROVED BY	RMS	3/31/06

FILENAME	FIGURE No.	REV.
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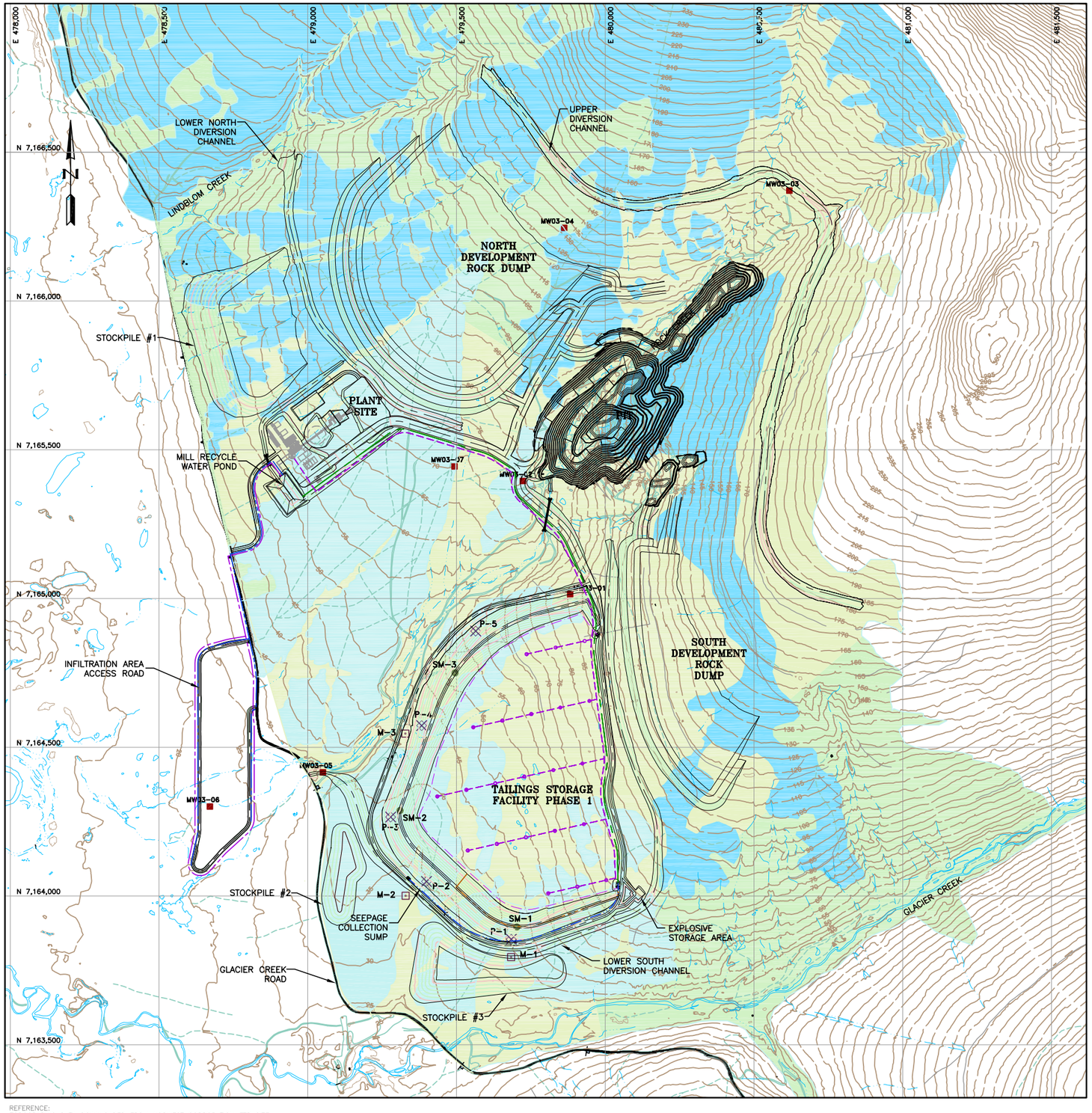

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150 0 150 300 METERS
SCALE = 1:15,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- PROPOSED PIT LIMITS
- SM-1 PROPOSED EMBANKMENT SETTLEMENT MONUMENTS
- P-1 PROPOSED PIEZOMETERS
- M-1 PROPOSED MONITORING WELLS
- MW03-01 EXISTING MONITORING WELL LOCATION
- FROZEN GROUND
- FROZEN GROUND – INFERRED
- THAWED GROUND
- THAWED GROUND INFERRED

NOTES:

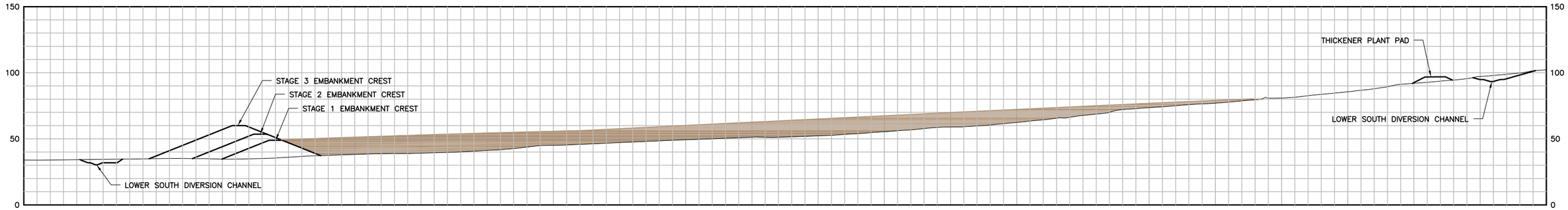
1. THERMISTER STRINGS WILL BE INSTALLED WITH THE TSF PIEZOMETERS.

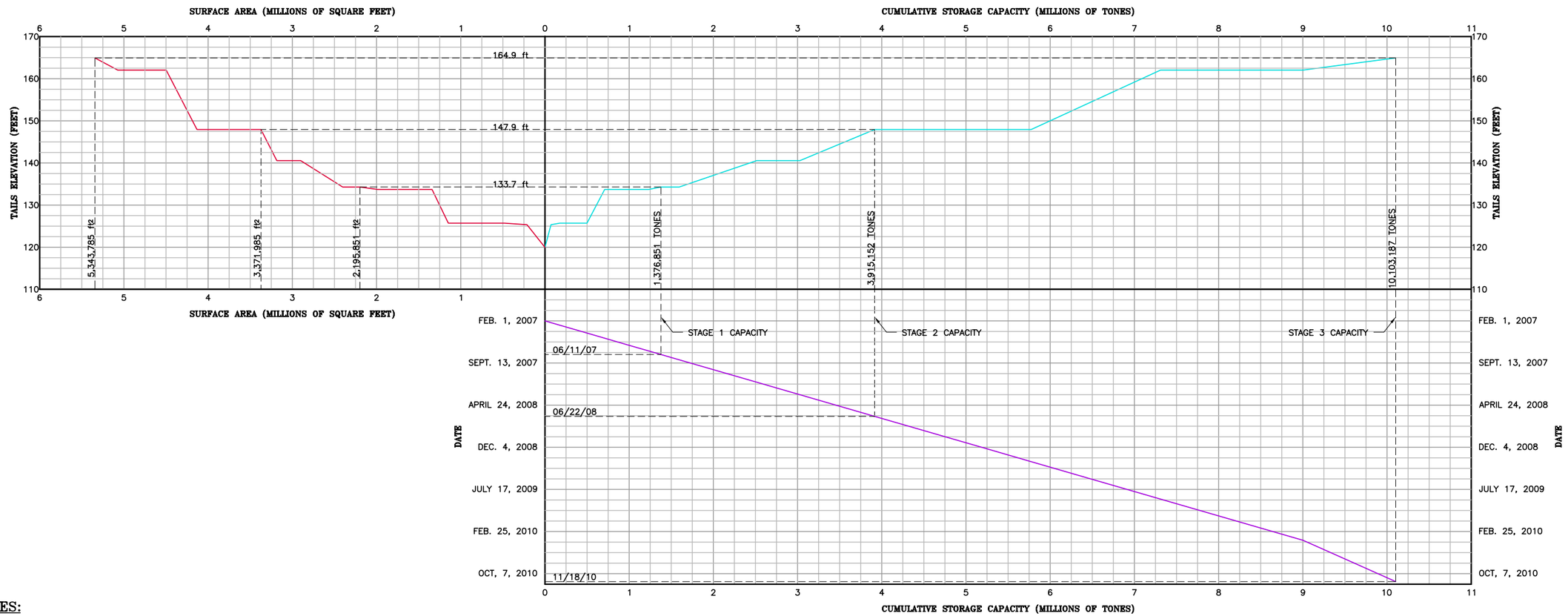
CLIENT	ALASKA GOLD COMPANY
PROJECT	ROCK CREEK PROJECT
TITLE	MONITORING PLAN

SMITH WILLIAMS CONSULTANTS, INC.
2420 West 26th Avenue, Building D, Suite 110, Denver, CO 80211
Phone: 303-0262 Fax: 303-433-0262

DESIGNED BY	RTB	CHECKED BY	RMS	DATE
DRAWN BY	DS	APPROVED BY	RTB	3/31/06
FILENAME 1011F168			FIGURE No. 1.4	REV. B

PLOT SCALE | XREF: NO





NOTES:

1. SURFACE OF TAILINGS IS ASSUMED TO HAVE A SLOPE OF 5%.
2. TAILINGS DENSITY IS ASSUMED TO BE 94.8 lbs/ft^3 (1.52 tonnes/m^3).
3. STAGES BASED ON A 2.65 MILLION TONS/YEAR PRODUCTION RATE.
4. THREE FEET OF FREEBOARD MAINTAINED AT ALL TIMES.

TAILINGS FACILITY FILLING CURVE

CLIENT	ALASKA GOLD COMPANY
PROJECT	ROCK CREEK PROJECT
TITLE	TAILINGS STORAGE FACILITY FILLING CURVE

Alaska Gold Company

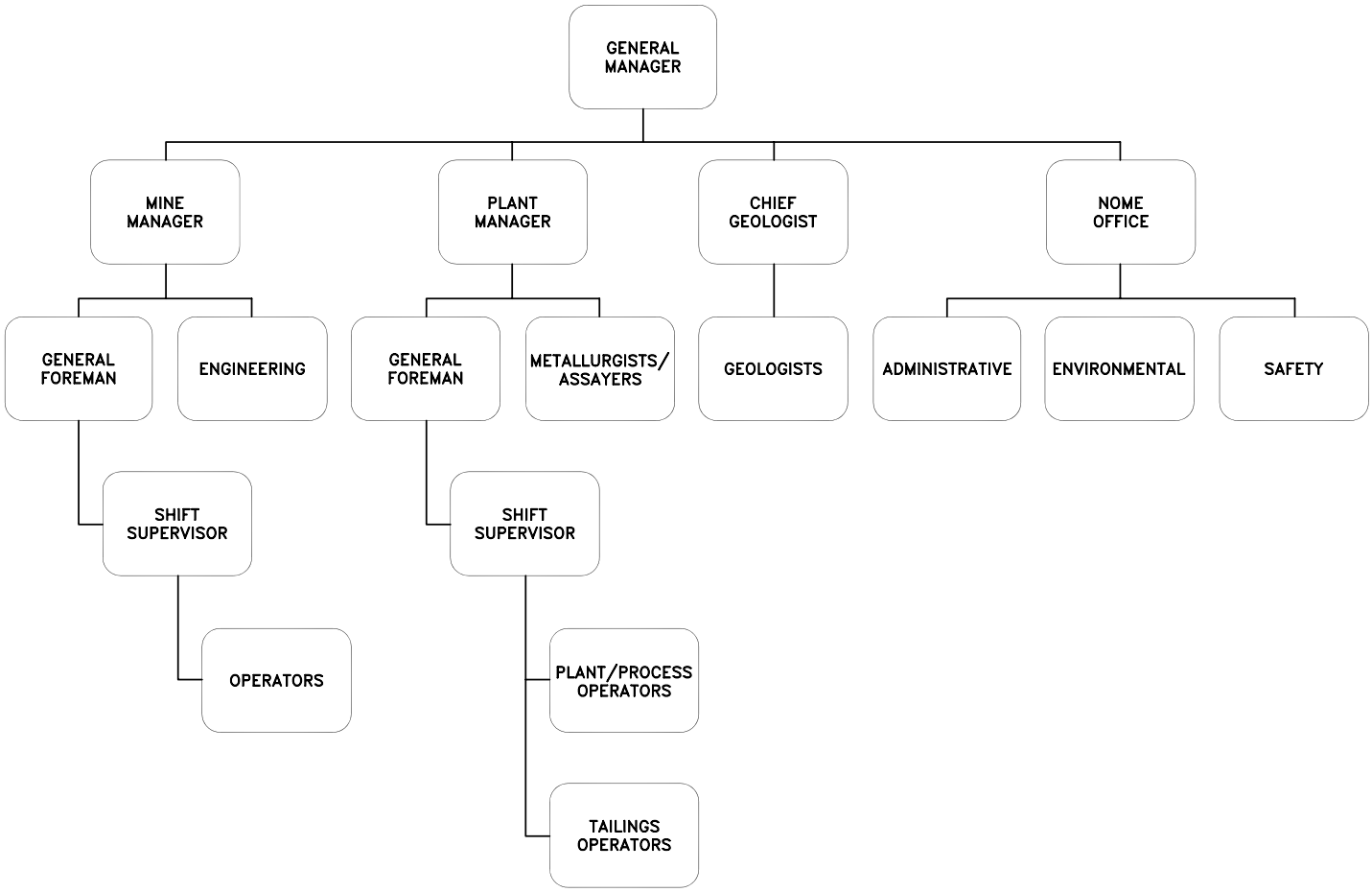
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0282 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB	DATE
DRAWN BY	DS	APPROVED BY	RMS	3/31/06

FILENAME	FIGURE No.	REV
1011F169B	1.5	B

XREF: NO

PLOT SCALE



CLIENT	ALASKA GOLD COMPANY			
PROJECT	ROCK CREEK PROJECT			
TITLE	ORGANIZATIONAL CHART			
DESIGNED BY	RTB	CHECKED BY	RMS	DATE
DRAWN BY	DS	APPROVED BY	RTB	3/31/06
FILENAME	1011F170	FIGURE No.	1.6	REV B

Alaska Gold Company

SMITH WILLIAMS CONSULTANTS, INC.
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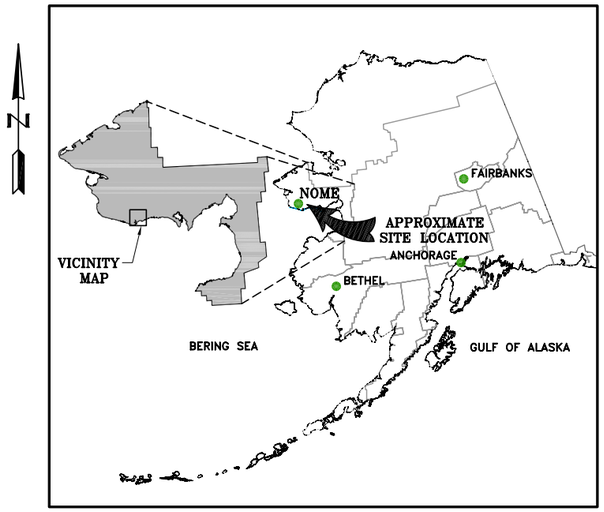
Phone: 303-433-0262 Fax: 303-433-0362

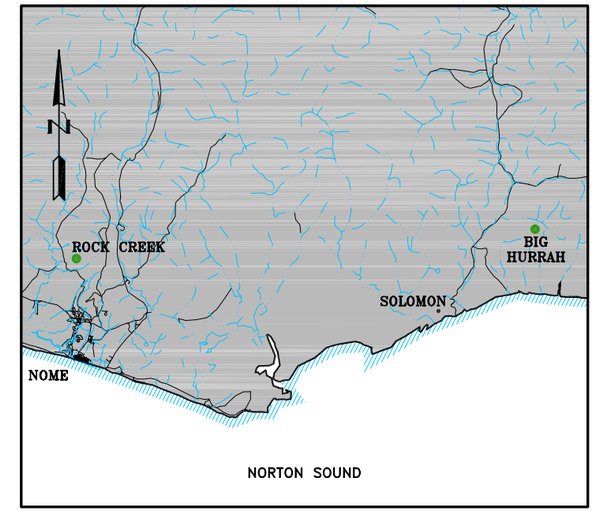
Appendix A
Feasibility Design Drawings

ALASKA GOLD COMPANY
ROCK CREEK PROJECT

ISSUED FOR FEASIBILITY DESIGN
JUNE 17, 2005



LOCATION MAP
NTS



VICINITY MAP
NTS

INDEX OF DRAWINGS

TITLE	AUTOCAD FILENAME	DRAWING NO.	REV
COVER SHEET AND INDEX	1011C55	–	B
GENERAL SITE PLAN, FEASIBILITY DESIGN	1011M63	A100	B
GENERAL SITE PLAN, PERMITTED DESIGN	1011M61	A105	B
TAILINGS FILLING CURVES	1011D76	A110	B
TAILINGS STORAGE FACILITY, PHASE 1 – STAGE 1	1011M60	A120	B
TAILINGS STORAGE FACILITY, PHASE 1 – STAGE 2	1011M79	A130	B
TAILINGS STORAGE FACILITY, PHASE 1 – STAGE 3	1011M73	A140	B
TAILINGS STORAGE FACILITY, SECTIONS AND DETAILS SHEET 1 OF 3	1011D77	A200	B
TAILINGS STORAGE FACILITY, SECTIONS AND DETAILS SHEET 2 OF 3	1011D78	A210	B
TAILINGS STORAGE FACILITY, SECTIONS AND DETAILS SHEET 3 OF 3	1011D118	A220	A
DIVERSION CHANNEL PLAN	1011M72	A400	B
UPPER DIVERSION CHANNEL PLAN AND PROFILE SHEET 1 OF 2	1011P64	A410	B
UPPER DIVERSION CHANNEL PLAN AND PROFILE SHEET 2 OF 2	1011P65	A420	B
LOWER NORTH DIVERSION CHANNEL PLAN AND PROFILE	1011P66	A430	B
LOWER SOUTH DIVERSION CHANNEL PLAN AND PROFILE SHEET 1 OF 2	1011P67	A440	B
LOWER SOUTH DIVERSION CHANNEL PLAN AND PROFILE SHEET 2 OF 2	1011P68	A450	B
PLANT SITE DIVERSION CHANNEL PLAN AND PROFILE	1011P69	A460	B
TEMPORARY DIVERSION CHANNEL PLAN AND PROFILE	1011P90	A470	A
DIVERSION CHANNEL SECTION AND DETAILS	1011D82	A480	B
RECYCLE WATER POND PLAN	1011M75	A490	B
RECYCLE WATER POND, SECTION AND DETAILS SHEET 1 OF 2	1011D116	A495	A
RECYCLE WATER POND, SECTION AND DETAILS SHEET 2 OF 2	1011D117	A496	A

PREPARED FOR:

ALASKA GOLD COMPANY
P.O. BOX 640
NOME, ALASKA 99762

Alaska Gold Company

PREPARED BY:

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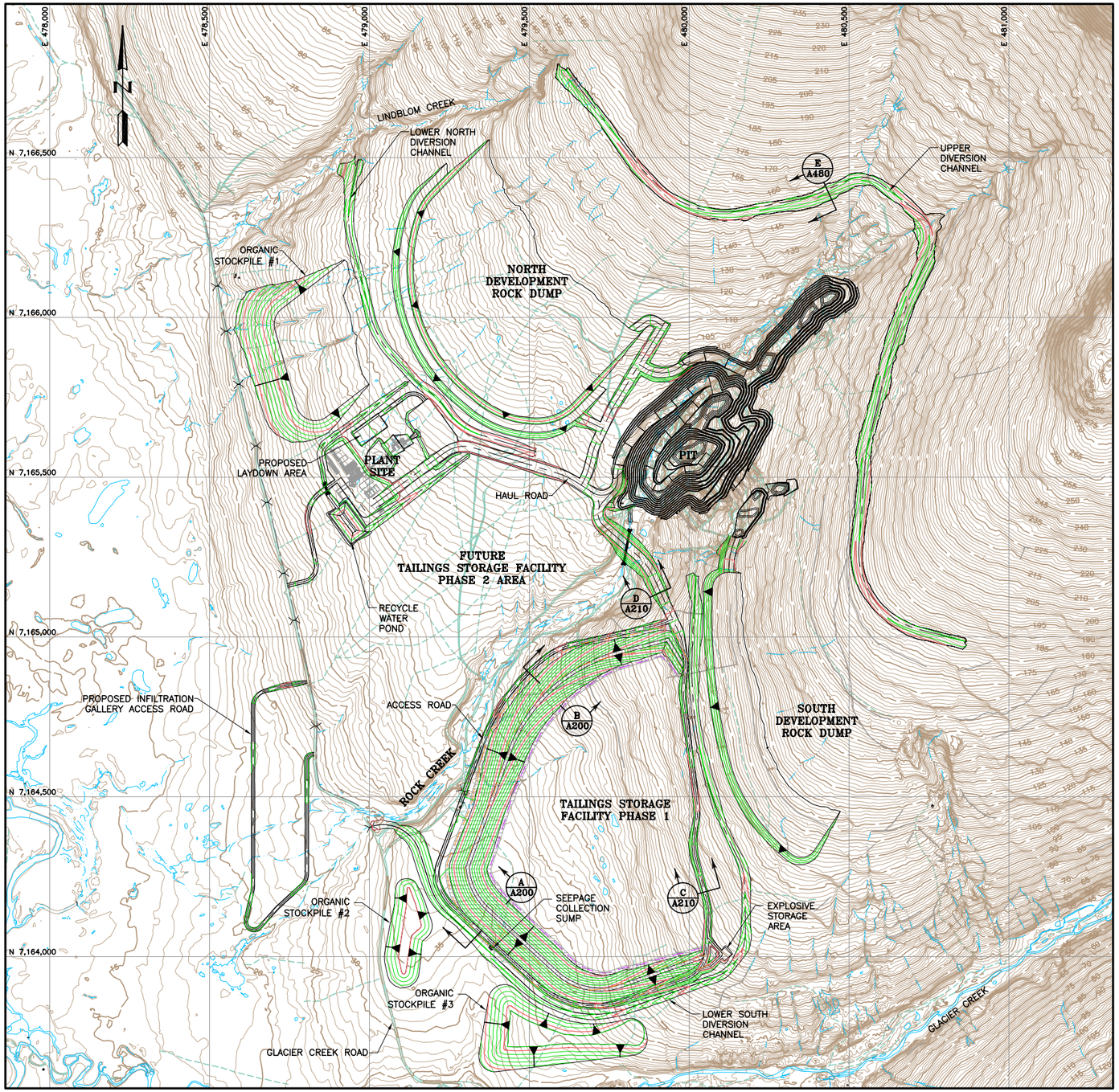
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

AUTOCAD FILENAME: 1011C55.DWG



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DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

150 0 150 300 METERS

SCALE = 1:15,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- PROPOSED PIT LIMITS
- SEEPAGE COLLECTION PIPE
- THERMOSYPHON SYSTEM
- LIMITS OF FOUNDATION EXCAVATION/BACKFILL
- PROPOSED CULVERT

NOTES:

1. ALL HAUL ROADS HAVE A TRAVEL WIDTH OF 18 METERS AND A MAXIMUM GRADE OF 10%. ALL ACCESS ROADS HAVE A TRAVEL WIDTH OF 8 METERS AND A MAXIMUM GRADE OF 10%.
2. DIVERSION CHANNELS HAVE A BOTTOM WIDTH OF 1 METER AND 3:1 SIDE SLOPES. DIVERSION CHANNELS HAVE A MAXIMUM SLOPE OF 10%.
3. TAILING STORAGE FACILITY EMBANKMENT HAS A CREST WIDTH OF 10 METERS AND 2.5:1 SIDE SLOPES.
4. ORGANIC STOCKPILES HAVE 4:1 SIDE SLOPES AND A MAXIMUM HEIGHT OF 10 METERS.
5. DEVELOPMENT ROCK DUMPS HAVE A MAXIMUM LIFT HEIGHT OF 15 METERS AND AN OVERALL SLOPE OF 3:1.
6. RECYCLED WATER POND WILL CAPTURE ALL RUNOFF FROM THE PLANT SITE.
7. PLANT LAYOUT WAS RECEIVED BY SMITH WILLIAMS CONSULTANTS ON MAY 13, 2005 FROM ROBERTS AND SCHAEFER COMPANY.
8. EXPLOSIVE STORAGE AREA SHOWN IS 30 METERS BY 30 METERS.

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER
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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: GENERAL SITE PLAN FEASIBILITY DESIGN

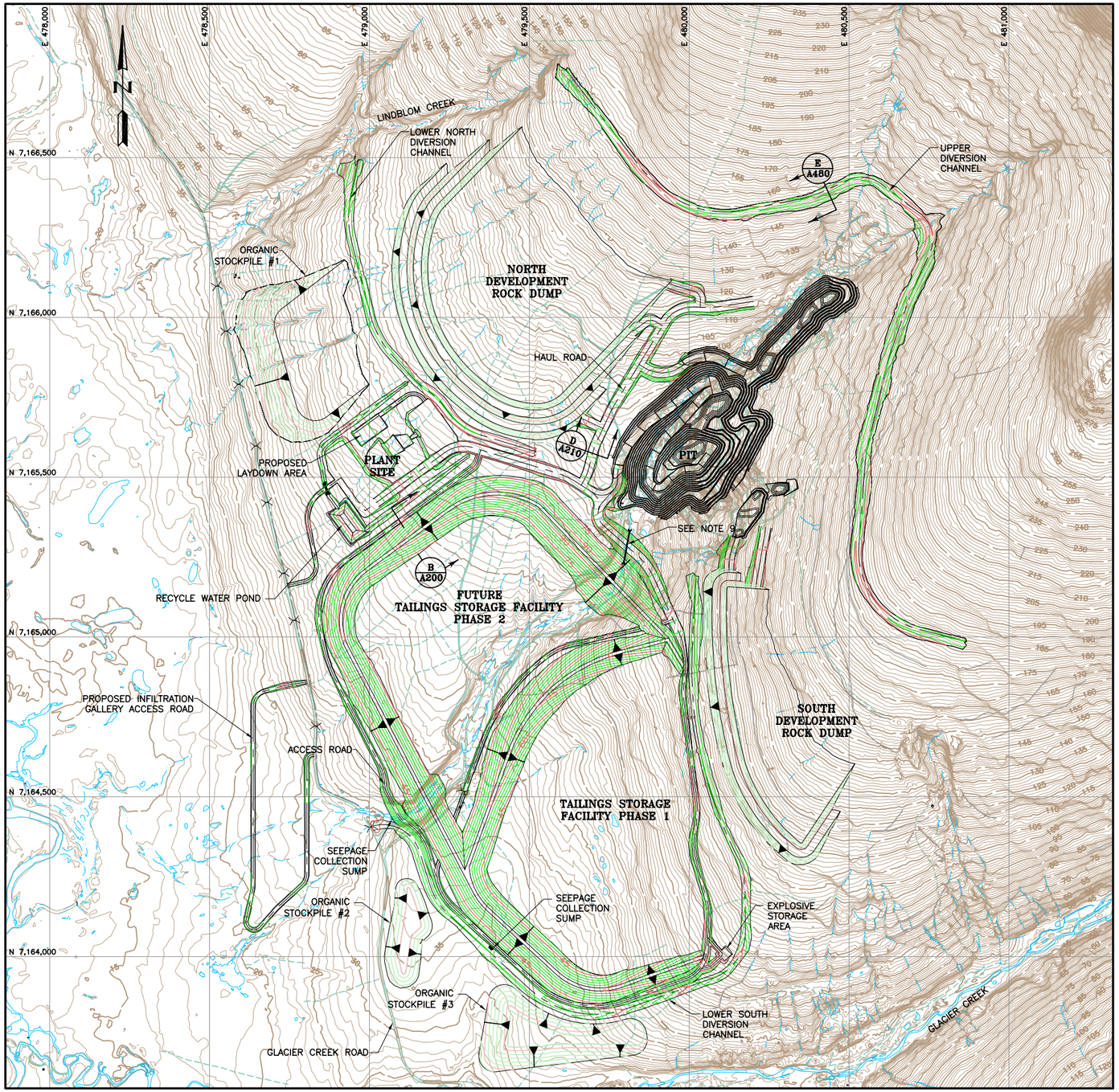
SWC SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS

FILENAME	DRAWING No.	REV
1011M63	A100	B

XREF: NO

PLOT SCALE



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DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

150 0 150 300 METERS

SCALE = 1:15,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- PROPOSED PIT LIMITS
- PROPOSED CULVERT

NOTES:

1. ALL HAUL ROADS HAVE A TRAVEL WIDTH OF 18 METERS AND A MAXIMUM GRADE OF 10%. ALL ACCESS ROADS HAVE A TRAVEL WIDTH OF 8 METERS AND A MAXIMUM GRADE OF 10%.
2. DIVERSION CHANNELS HAVE A BOTTOM WIDTH OF 1 METER AND 3:1 SIDE SLOPES. DIVERSION CHANNELS HAVE A MAXIMUM SLOPE OF 10%.
3. TAILING STORAGE FACILITY EMBANKMENT HAS A CREST WIDTH OF 10 METERS AND 2.5:1 SIDE SLOPES.
4. ORGANIC STOCKPILES HAVE 4:1 SIDE SLOPES AND A MAXIMUM HEIGHT OF 10 METERS.
5. DEVELOPMENT ROCK DUMPS HAVE A MAXIMUM LIFT HEIGHT OF 15 METERS AND AN OVERALL SLOPE OF 3:1.
6. RECYCLE WATER POND WILL CAPTURE ALL RUNOFF FROM THE PLANT SITE.
7. PLANT LAYOUT WAS RECEIVED BY SMITH WILLIAMS CONSULTANTS ON MAY 13, 2005 FROM ROBERTS AND SCHAEFER COMPANY.
8. EXPLOSIVE STORAGE AREA SHOWN IS 30 METERS BY 30 METERS.
9. PROPOSED CULVERT TO BE INSTALLED DURING PHASE 1, STAGE 1 CONSTRUCTION ACTIVITIES. CULVERT WILL BE PLUGGED IF PHASE 2 IS CONSTRUCTED.

FOR INFORMATION PURPOSES ONLY

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

SMITH WILLIAMS CONSULTANTS, INC. PRODUCED THE INFORMATION PRESENTED ON THIS DRAWING THROUGH THE USE OF TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE SPECIFIC TO ITS EFFORTS. RECEIVING THIS DRAWING DOES NOT GUARANTEE ANY RIGHTS TO SUCH TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE. ANY ALTERATION OR ADAPTATION OF THE DATA OR CONTENTS OF THIS DRAWING SHALL BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY TO SMITH WILLIAMS CONSULTANTS, INC

CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

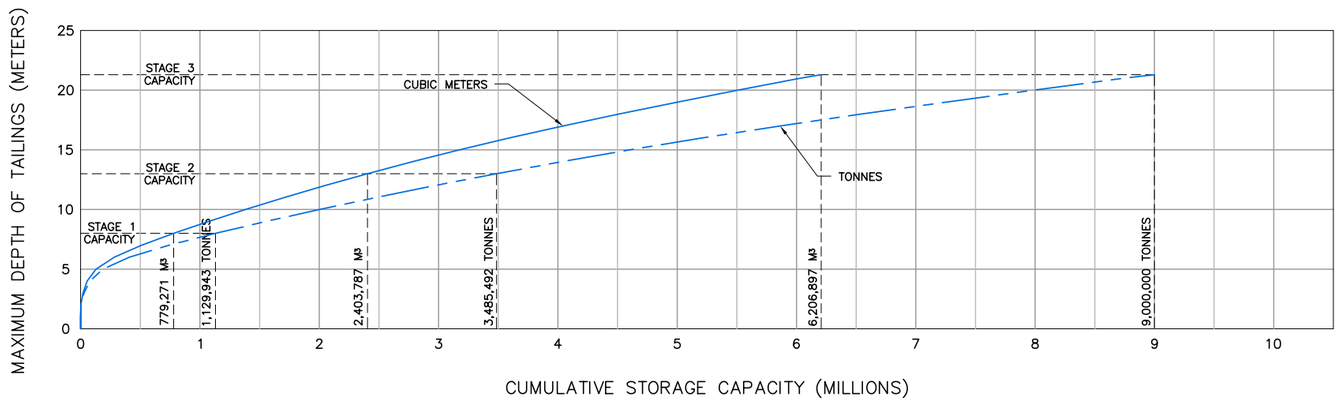
TITLE: GENERAL SITE PLAN PERMITTED DESIGN

SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS
FILENAME 1011M61		DRAWING No. A105	REV B

XREF: NO

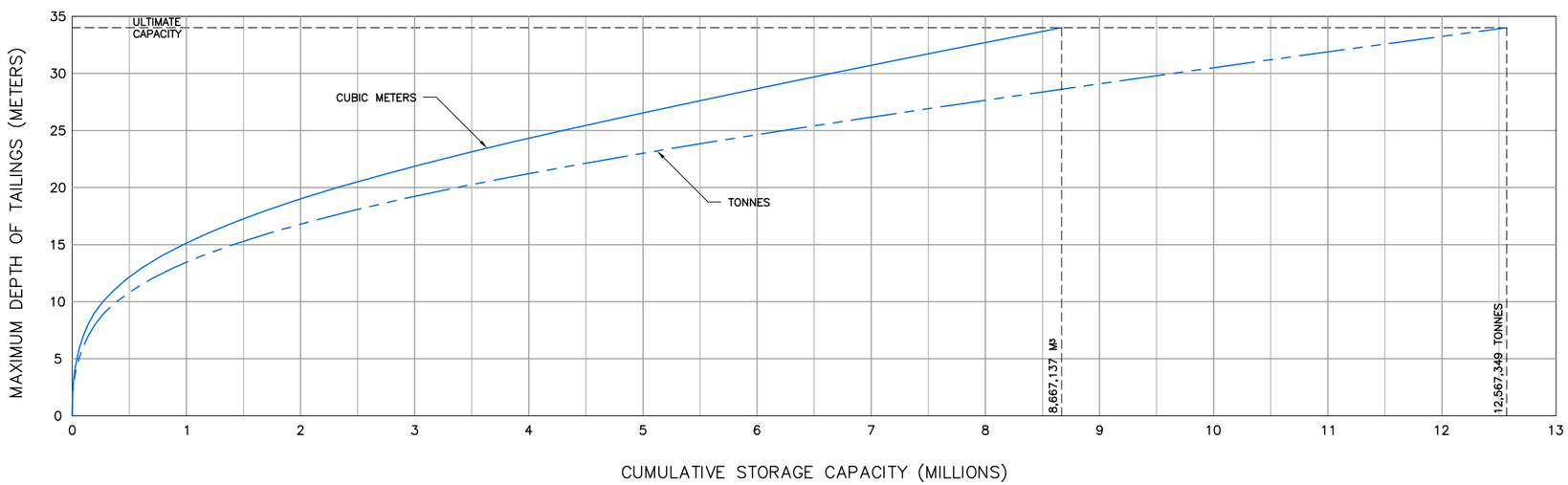
PLOT SCALE



PHASE 1 TAILINGS FACILITY FILLING CURVE

NOTES:

1. SURFACE OF TAILINGS IS ASSUMED TO HAVE A SLOPE OF 5%.
2. TAILINGS DENSITY IS ASSUMED TO BE 1.45 tonnes/m^3.
3. PHASE I STAGES BASED ON A 2.4 MILLION TONNES/YEAR PRODUCTION RATE.
4. ONE METER OF FREEBOARD AND 380,000 M^3 OF WATER STORAGE MAINTAINED AT ALL TIMES.



PHASE 2 TAILINGS FACILITY FILLING CURVE

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JMN
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: TAILINGS FILLING CURVES

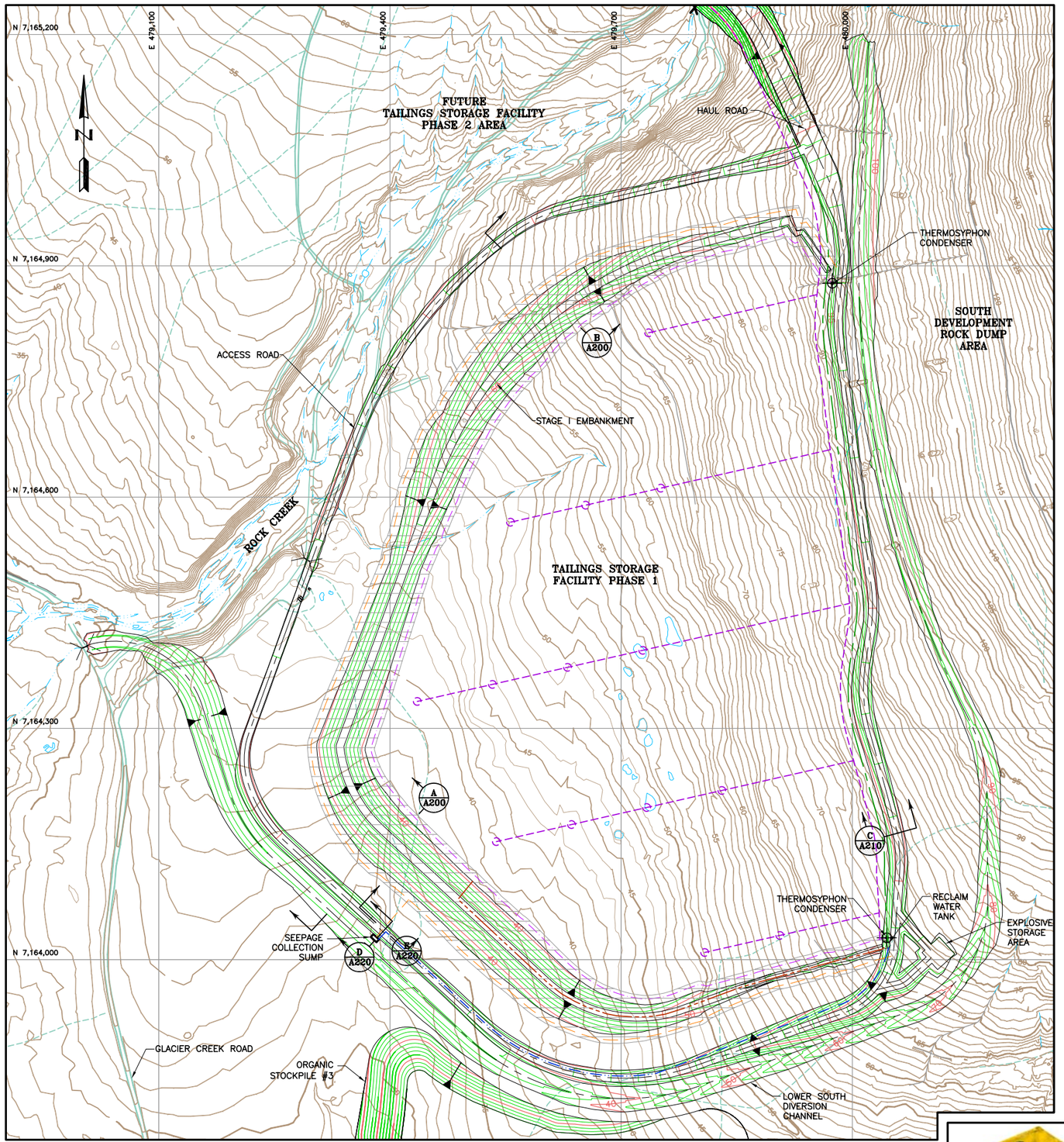
SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS

FILENAME	DRAWING No.	REV
1011D76	A110	A

XREF: NO

PLOT SCALE



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TOPOGRAPHIC DATA RECEIVED FROM KODIAK MAPPING SURVEY, VIA CD.
DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

60 0 60 120 METERS
SCALE = 1:6,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- SEEPAGE COLLECTION PIPE
- THERMOSYPHON SYSTEM
- SEEPAGE RECLAIM PIPE
- TAILINGS DISTRIBUTION PIPE
- POND RECLAIM PIPE
- RECLAIM WATER PIPE
- THERMOSYPHON SYSTEM CONDENSER
- PROPOSED CULVERT
- LIMITS OF FOUNDATION EXCAVATION/BACKFILL

NOTE:

1. THE INITIAL CONSTRUCTION REQUIRES THE UPSTREAM TOE OF THE ULTIMATE EMBANKMENT TO BE EXCAVATED TO NON-ICE RICH BEDROCK FOR THE INSTALLATION OF THE THERMOSYPHON SYSTEM.
2. SEEPAGE COLLECTION PIPE TO BE INSTALLED AT THE DOWNSTREAM TOE OF THE STAGE I EMBANKMENT.

B	6/17/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	JNM / DS

Alaska Gold Company

DISCLAIMER
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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

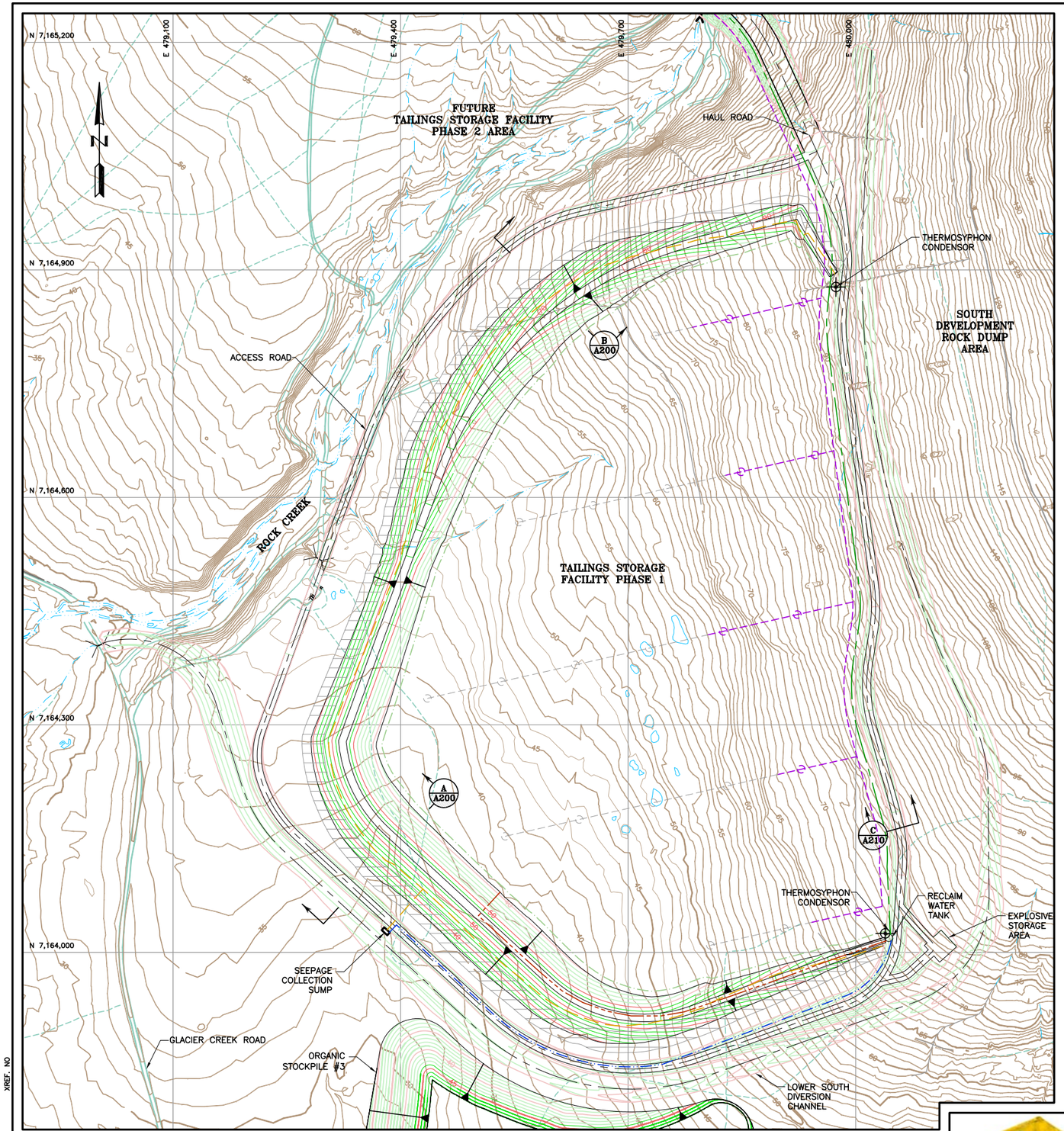
TITLE: TAILINGS STORAGE FACILITY PHASE 1 – STAGE 1

SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JNM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS
FILENAME 1011M60		DRAWING No. A120	REV B

XREF. NO

PLOT SCALE



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DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

60 0 60 120 METERS

SCALE = 1:6,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- SEEPAGE COLLECTION PIPE
- THERMOSYPHON SYSTEM
- SEEPAGE RECLAIM PIPE
- TAILINGS DISTRIBUTION PIPE
- POND RECLAIM PIPE
- THERMOSYPHON SYSTEM CONDENSER
- LIMITS OF FOUNDATION EXCAVATION/BACKFILL

NOTES:

1. PROPOSED GROUND SURFACE CONTOURS FOR ITEMS CONSTRUCTED DURING STAGE I HAVE BEEN FADED.
2. EXTEND DECANT PIPE AND RELOCATE SUPERNATENT RECLAIM PIPE TO STAGE 2 CREST.
3. EXCAVATE ALLUVIAL OVERBURDEN SOILS TO NON ICE RICH BEDROCK WITHIN THE LIMITS OF THE STAGE 2 EMBANKMENT.

B	6/17/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	JNM / DS

Alaska Gold Company

DISCLAIMER

SMITH WILLIAMS CONSULTANTS, INC. PRODUCED THE INFORMATION PRESENTED ON THIS DRAWING THROUGH THE USE OF TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE SPECIFIC TO ITS EFFORTS. RECEIVING THIS DRAWING DOES NOT GUARANTEE ANY RIGHTS TO SUCH TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE. ANY ALTERATION OR ADAPTATION OF THE DATA OR CONTENTS OF THIS DRAWING SHALL BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY TO SMITH WILLIAMS CONSULTANTS, INC

CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

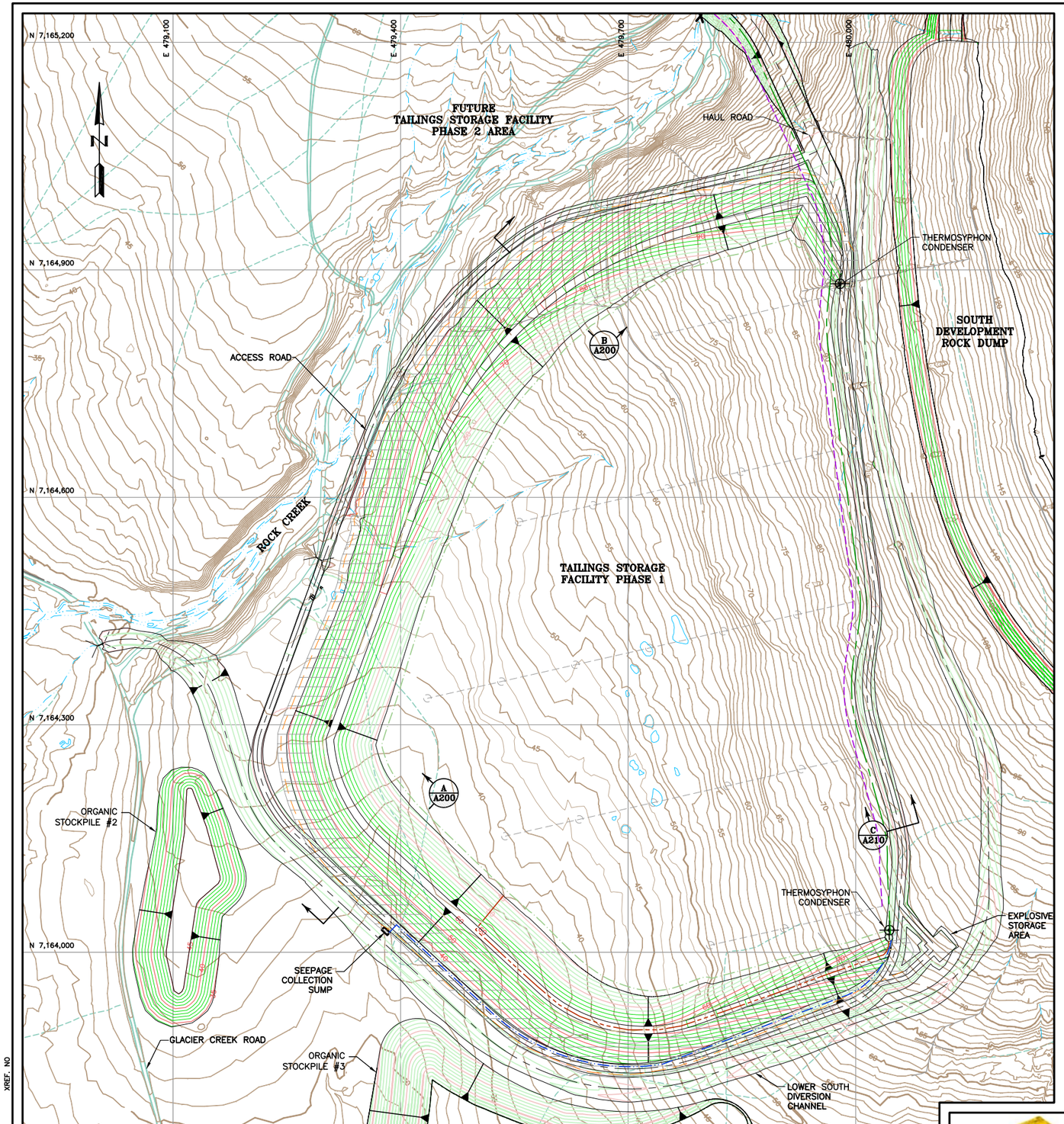
TITLE: TAILINGS STORAGE FACILITY PHASE 1 – STAGE 2

SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JNM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS
FILENAME 1011M79		DRAWING No. A130	REV B

XREF: NO

PLOT SCALE



REFERENCE:
TOPOGRAPHIC DATA RECEIVED FROM KODIAK MAPPING SURVEY, VIA CD.
DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

60 0 60 120 METERS
SCALE = 1:6,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- SEEPAGE COLLECTION PIPE
- THERMOSYPHON SYSTEM
- SEEPAGE RECLAIM PIPE
- TAILINGS DISTRIBUTION PIPE
- POND RECLAIM PIPE
- RECLAIM WATER PIPE
- THERMOSYPHON SYSTEM CONDENSER
- LIMITS OF FOUNDATION EXCAVATION/BACKFILL

NOTES:

1. PROPOSED GROUND SURFACE CONTOURS FOR ITEMS CONSTRUCTED DURING STAGES 1 AND 2 HAVE BEEN FADED.
2. EXTEND DECANT PIPE AND RELOCATE SUPERNATANT RECLAIM PIPE TO STAGE 3 CREST.
3. EXCAVATE ALLUVIAL OVERBURDEN SOILS TO NON ICE RICH BEDROCK WITHIN LIMITS OF THE STAGE 3 EMBANKMENT. INSTALL A NEW SEEPAGE COLLECTION PIPE AT THE DOWNSTREAM TOE OF THE EMBANKMENT FILL.

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

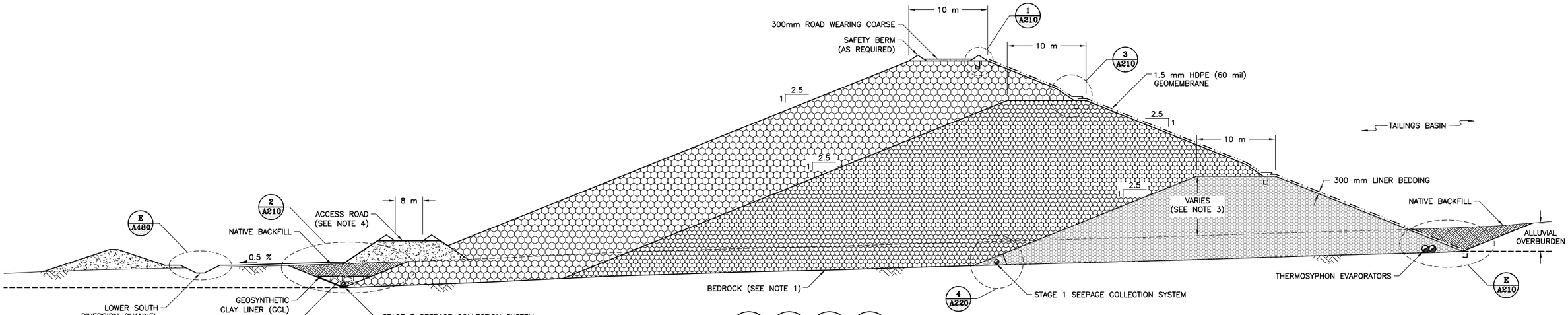
TITLE: TAILINGS STORAGE FACILITY PHASE 1 – STAGE 3

SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

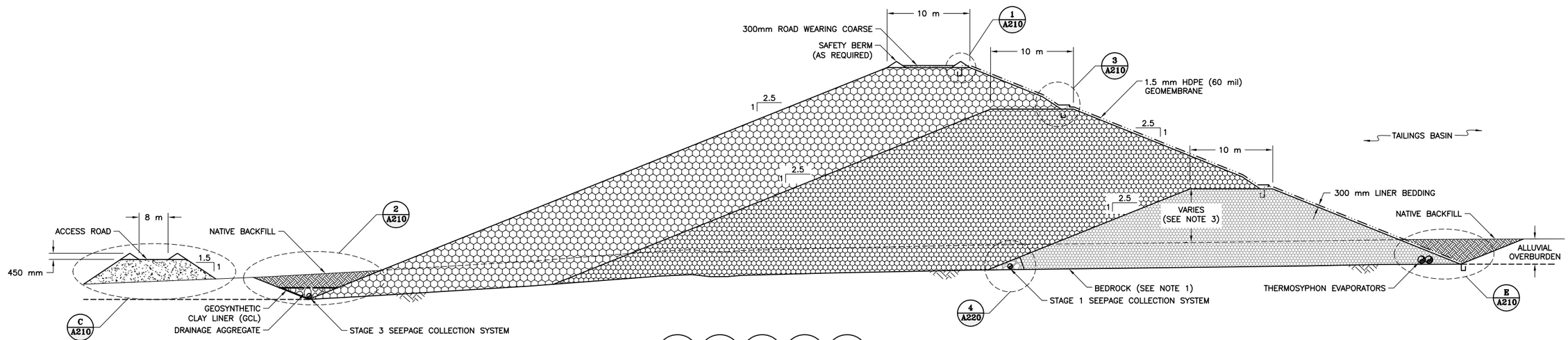
DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS
FILENAME 1011M73		DRAWING No. A140	REV B

XREF: NO

PLOT SCALE



A A A A
A100 A120 A130 A140
SOUTH EMBANKMENT
NTS



B B B B B
A100 A105 A120 A130 A140
NORTH EMBANKMENT
NTS

NOTES:

1. FOUNDATION AREA MUST BE EXCAVATED TO NON–ICE RICH BEDROCK. FOUNDATION TO BE INSPECTED AND APPROVED BY THE ENGINEER.
2. EMBANKMENT RANDOM FILL SHALL CONSIST OF DEVELOPMENT ROCK FROM THE MINE PIT DEVELOPMENT.
3. EMBANKMENT HEIGHTS VARY ALONG ALIGNMENT. MAXIMUM HEIGHTS ARE: 9 m FOR STAGE 1, 20 m STAGE 2 AND 24 m FOR STAGE 3.
4. ACCESS ROAD WITHIN EMBANKMENT FOOTPRINT TO BE REMOVED DURING STAGE 3 EMBANKMENT FOUNDATION EXCAVATION. ROAD TO BE RECONSTRUCTED DURING STAGE 3 FILL PLACEMENT ACTIVITIES.

LEGEND:

- EMBANKMENT RANDOM FILL – STAGE 1
- EMBANKMENT RANDOM FILL – STAGE 2
- EMBANKMENT RANDOM FILL – STAGE 3
- RANDOM FILL
- NATIVE BACKFILL
- DRAINAGE AGGREGATE

B	6/17/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER
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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: TAILING STORAGE FACILITY SECTIONS AND DETAILS SHEET 1 OF 3

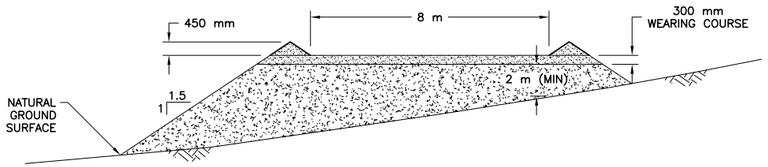
SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JNM	CHECKED BY	RTB
DRAWN BY	JNM	APPROVED BY	RMS

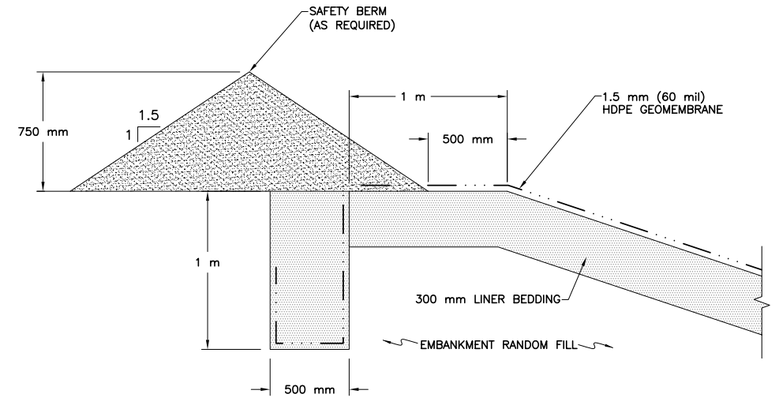
FILENAME	DRAWING No.	REV
1011D77	A200	B

XREF: NO

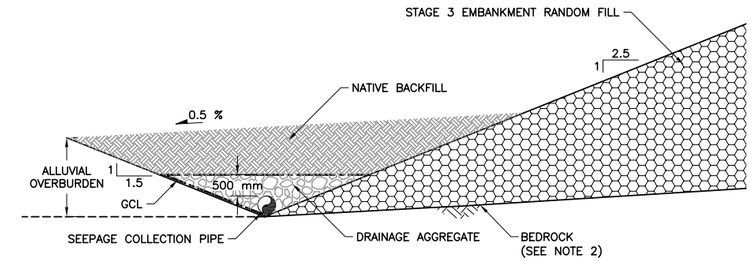
PLOT SCALE



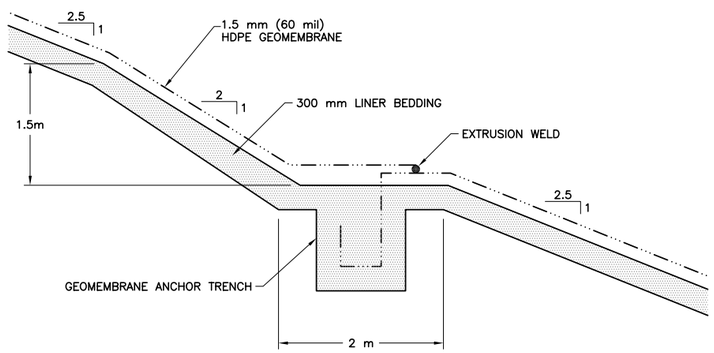
C/A100 C/A120 C/A130 C/A140 C/A200 C/A500 TYPICAL PERIMETER/ACCESS ROAD
NTS



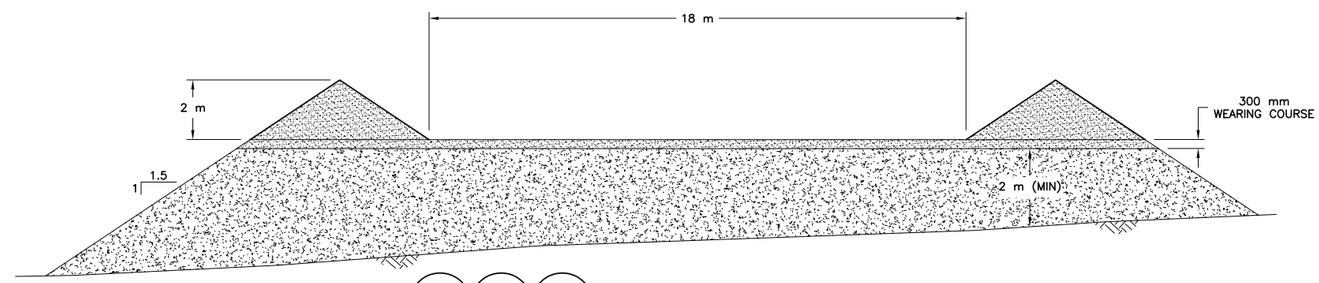
1/A200 ANCHOR TRENCH AND SAFETY BERM DETAIL
NTS



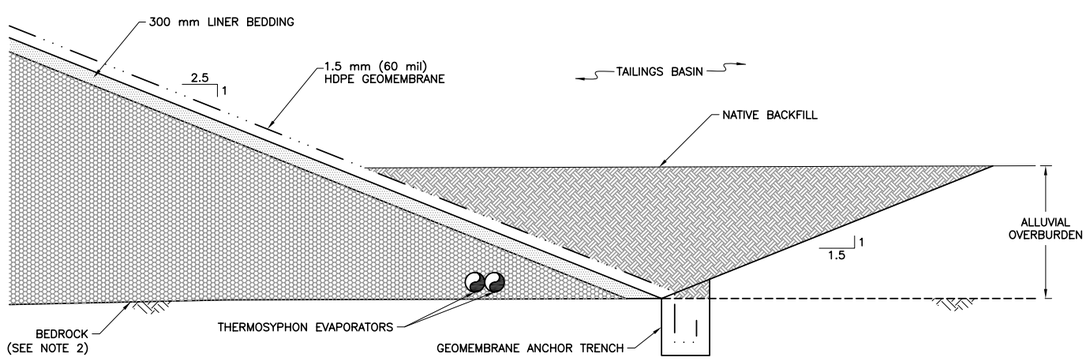
2/A200 STAGE 3 SEEPAGE COLLECTION SYSTEM
NTS



3/A210 TYPICAL EXPANSION BENCH
NTS



D/A100 D/A105 D/A500 HAUL ROAD TYPICAL SECTION
NTS



E/A200 TYPICAL UPSTREAM TRENCH DETAIL
NTS

NOTES:

1. LINER BEDDING MATERIAL SHALL BE ACCEPTABLE FINE GRAINED ALLUVIAL OVERBURDEN OR SPENT PLACER TAILINGS.
2. FOUNDATION AREA MUST BE EXCAVATED TO NON-ICE RICH BEDROCK. FOUNDATION TO BE INSPECTED AND APPROVED BY THE ENGINEER.

B	6/17/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER
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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: TAILING STORAGE FACILITY SECTIONS AND DETAILS SHEET 2 OF 3

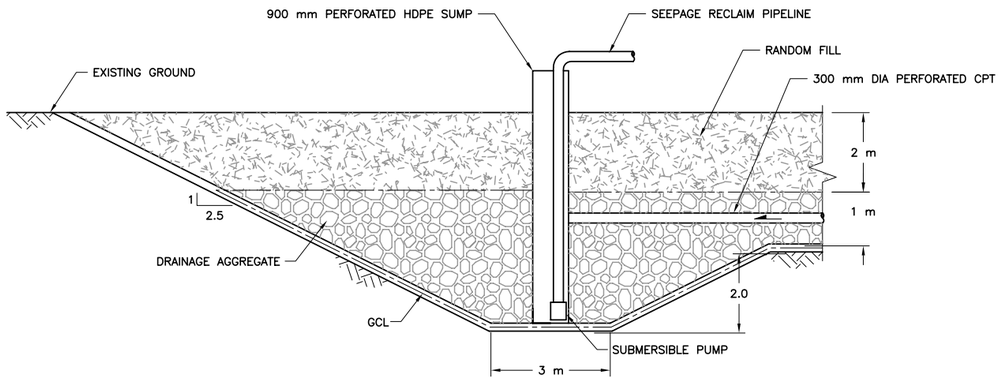
SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JNM	CHECKED BY	RTB
DRAWN BY	JNM	APPROVED BY	RMS

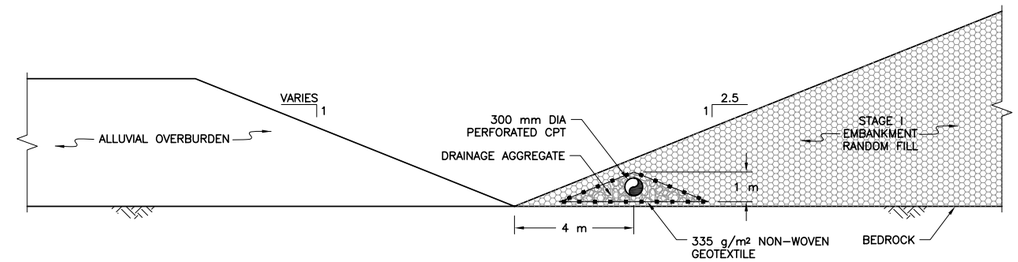
FILENAME	DRAWING No.	REV
1011D78	A210	B

XREF. NO

PLOT SCALE

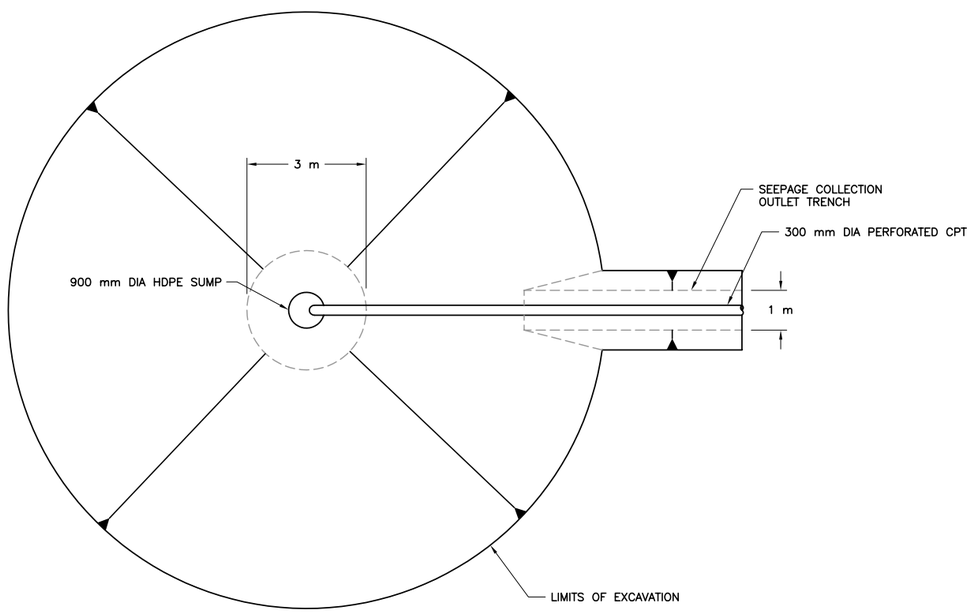


PROFILE



4 / A200 STAGE 1 SEEPAGE COLLECTION SYSTEM

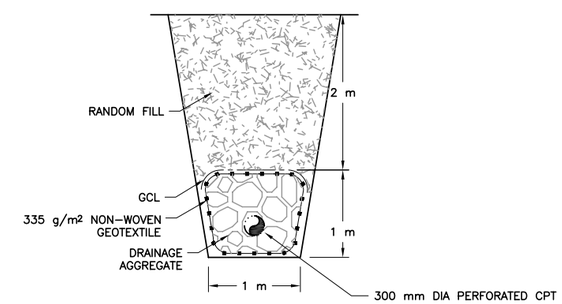
NTS



PLAN

D / A120 STAGE 1 SEEPAGE COLLECTION SYSTEM

NTS



E / A120 SEEPAGE COLLECTION OUTLET TRENCH

NTS

A	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JMN

Alaska Gold Company

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SMITH WILLIAMS CONSULTANTS, INC. PRODUCED THE INFORMATION PRESENTED ON THIS DRAWING THROUGH THE USE OF TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE SPECIFIC TO ITS EFFORTS. RECEIVING THIS DRAWING DOES NOT GUARANTEE ANY RIGHTS TO SUCH TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE. ANY ALTERATION OR ADAPTATION OF THE DATA OR CONTENTS OF THIS DRAWING SHALL BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY TO SMITH WILLIAMS CONSULTANTS, INC

CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: TAILINGS STORAGE FACILITY SECTIONS AND DETAILS SHEET 3 OF 3

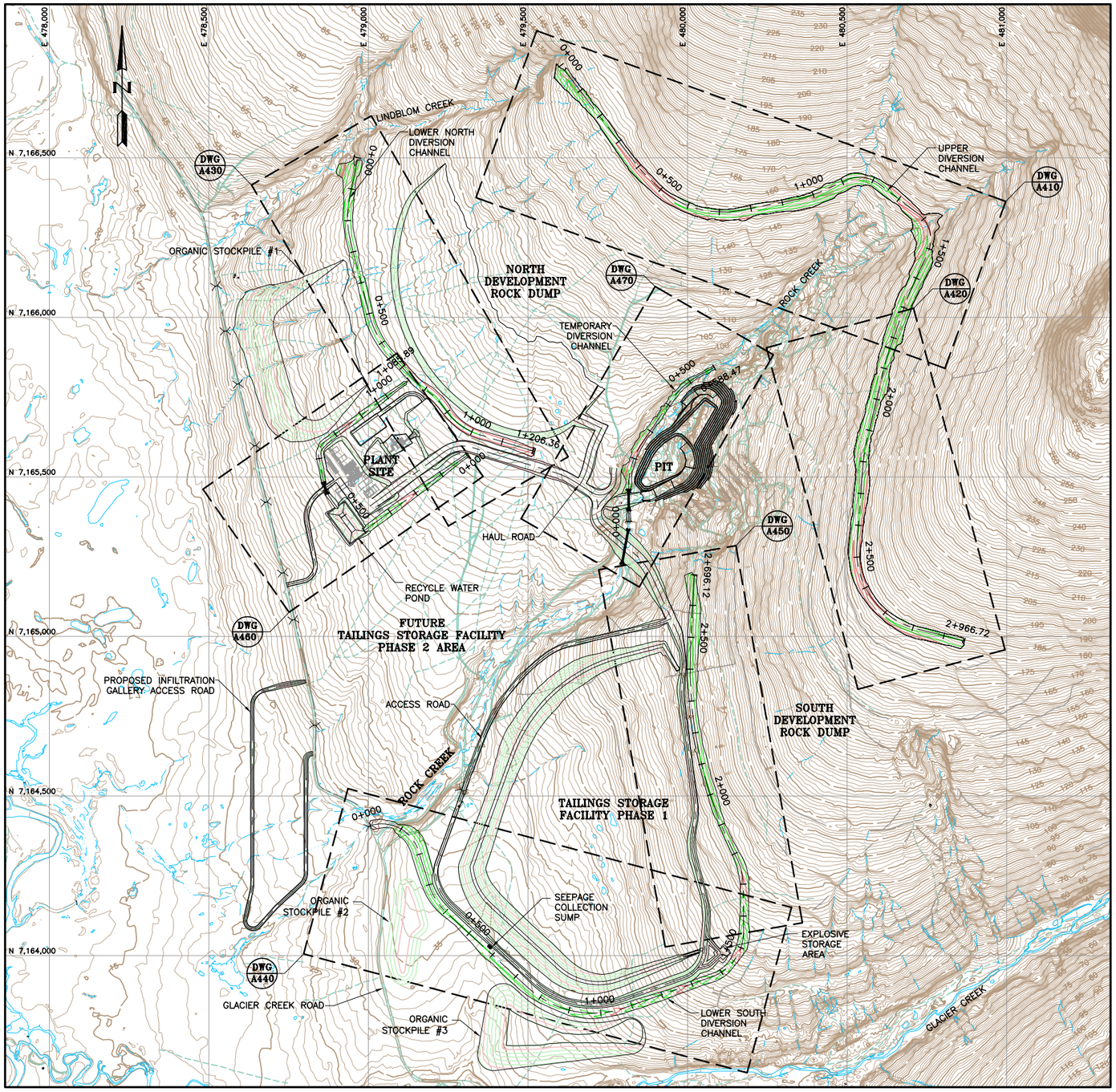
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JNM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RTB

FILENAME	DRAWING No.	REV
1011D118	A220	A

XREF: NO

PLOT SCALE



REFERENCE:
TOPOGRAPHIC DATA RECEIVED FROM KODIAK MAPPING SURVEY, VIA CD.
DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

150 0 150 300 METERS

SCALE = 1:15,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- EXISTING TRAIL
- PROPOSED PIT LIMITS
- PROPOSED CULVERT

NOTES:

1. DIVERSION CHANNELS HAVE A BOTTOM WIDTH OF 1 METER AND 3:1 SIDE SLOPES. DIVERSION CHANNELS WILL HAVE A MAXIMUM SLOPE OF 10%.
2. RECYCLE WATER POND WILL CAPTURE RUNOFF FROM THE PLANT SITE.
3. PLANT LAYOUT WAS RECEIVED BY SMITH WILLIAMS CONSULTANTS ON MAY 13, 2005 FROM ROBERTS AND SCHAEFER COMPANY.
4. PROPOSED GROUND SURFACE CONTOURS FOR ALL COMPONENTS EXCEPT DIVERSION CHANNELS HAVE BEEN FADED FOR CLARITY.
5. STAGE 2 OF THE PHASE 1 TAILINGS STORAGE FACILITY IS ILLUSTRATED.
6. THE UPPER DIVERSION CHANNEL WILL NOT BE REQUIRED PRIOR TO COMMENCEMENT OF PRODUCTION.

B	6/15/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

SMITH WILLIAMS CONSULTANTS, INC. PRODUCED THE INFORMATION PRESENTED ON THIS DRAWING THROUGH THE USE OF TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE SPECIFIC TO ITS EFFORTS. RECEIVING THIS DRAWING DOES NOT GUARANTEE ANY RIGHTS TO SUCH TECHNICAL INFORMATION AND PRACTICAL EXPERIENCE. ANY ALTERATION OR ADAPTATION OF THE DATA OR CONTENTS OF THIS DRAWING SHALL BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY TO SMITH WILLIAMS CONSULTANTS, INC

CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

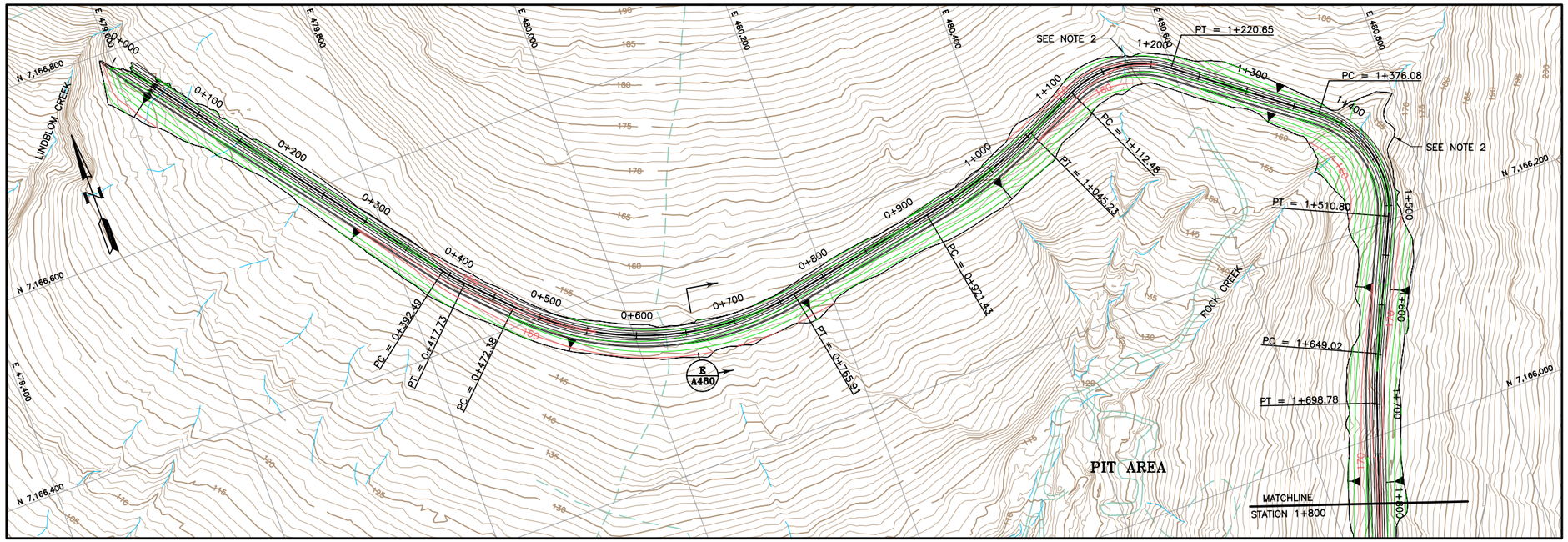
TITLE: DIVERSION CHANNEL PLAN

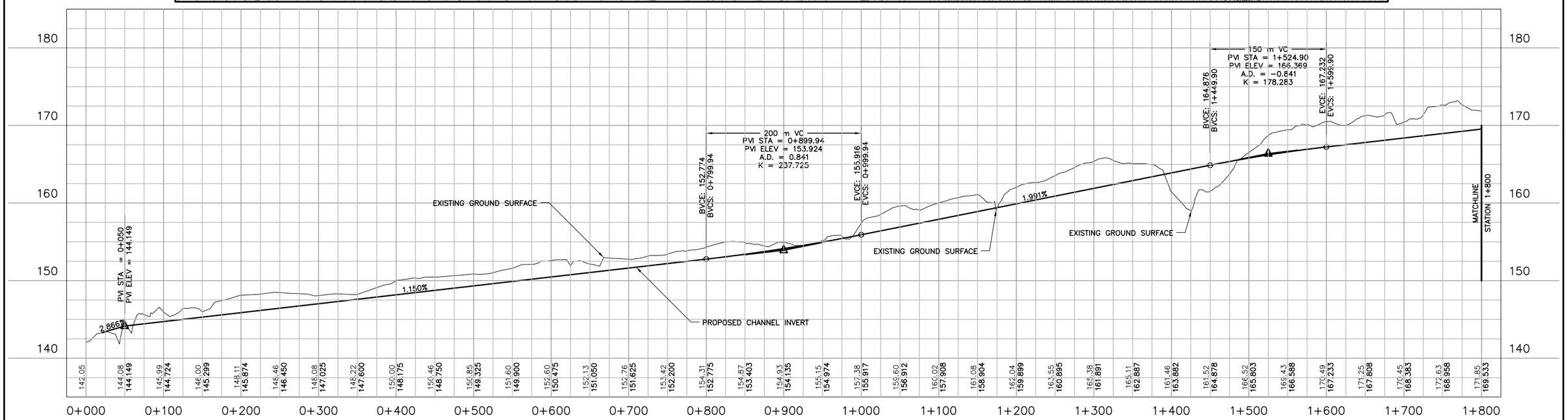
SWC
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS
FILENAME 1011M72		DRAWING No. A400	REV B

XREF. NO

PLOT SCALE





LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- EXISTING POND/WATER

NOTES:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.
2. EXISTING DRAINAGES TO BE BACKFILLED TO DIRECT FLOW INTO DIVERSION.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: UPPER DIVERSION CHANNEL PLAN AND PROFILE SHEET 1 OF 2

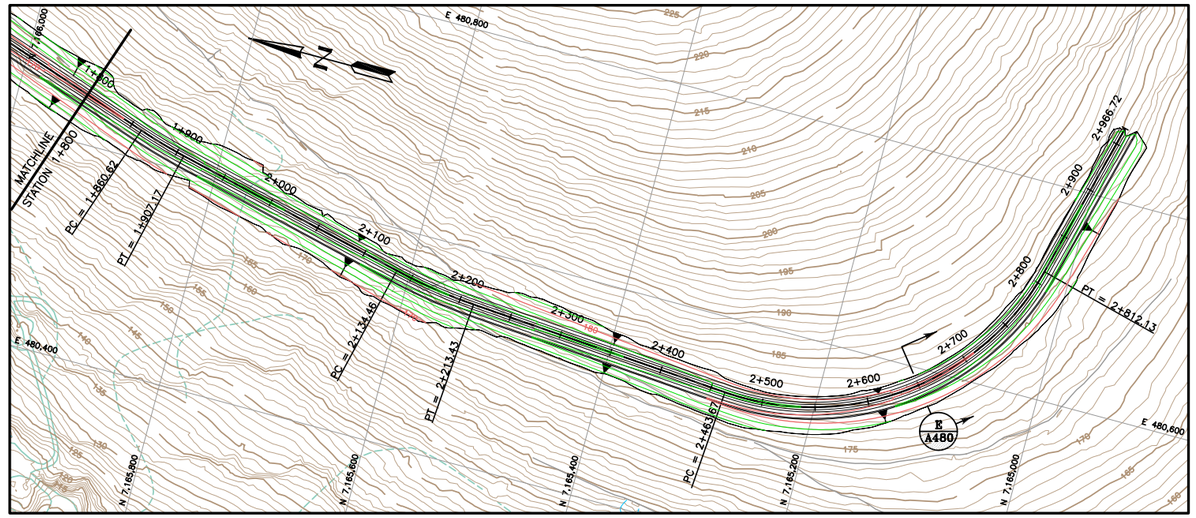
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS

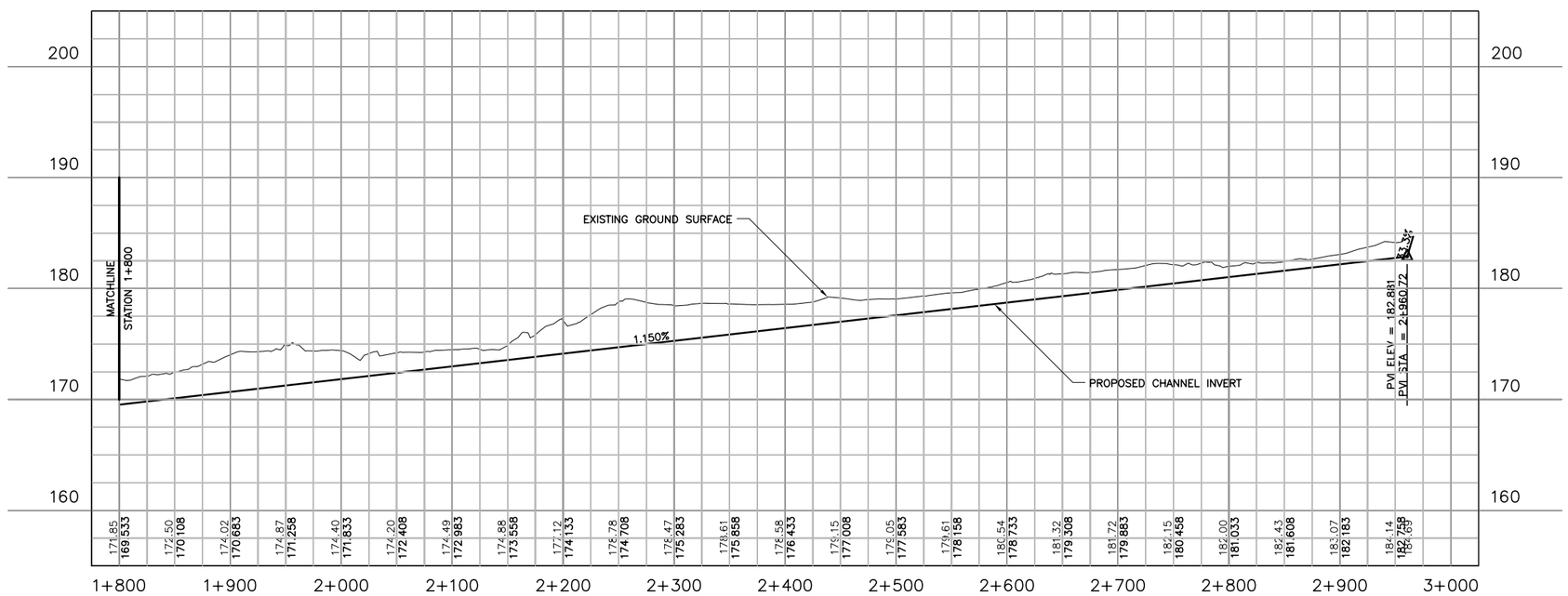
FILENAME	DRAWING No.	REV
1011P64	A410	B

XREF: NO

PLOT SCALE



UPPER DIVERSION CHANNEL ALIGNMENT DATA						
	STATION	NORTHING	EASTING	DELTA (D–M–S)	RADIUS (m)	LENGTH (M)
PI	0+000	7,166,789.625	479,603.157			
PC	0+392.49	7,166,477.562	479,841.194			
				07–13–58	199.993	25.246
PT	0+417.73	7,166,458.507	479,857.730			
PC	0+472.38	7,166,419.579	479,896.078			
				56–03–52	299.978	293.531
PT	0+765.91	7,166,335.272	480,165.139			
PC	0+921.43	7,166,363.978	480,317.986			
				14–11–17	499.965	123.806
PT	1+045.23	7,166,401.586	480,435.609			
PC	1+112.48	7,166,429.822	480,496.645			
				61–58–43	99.992	108.164
PT	1+220.65	7,166,418.762	480,599.016			
PC	1+376.08	7,166,324.878	480,722.898			
				77–11–17	99.999	134.717
PT	1+510.80	7,166,203.959	480,753.607			
PC	1+649.02	7,166,078.025	480,696.636			
				05–42–08	499.994	49.760
PT	1+698.78	7,166,031.744	480,678.414			
PC	1+860.62	7,165,878.398	480,626.690			
				05–20–06	499.996	46.555
PT	1+907.17	7,165,833.656	480,613.883			
PC	2+134.46	7,165,612.468	480,561.577			
				09–02–59	499.997	78.973
PT	2+213.43	7,165,534.502	480,549.534			
PC	2+463.67	7,165,284.950	480,530.963			
				79–51–51	249.989	348.458
PT	2+812.13	7,165,024.245	480,718.115			
PI	2+966.72	7,164,985.819	480,867.852			



LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- EXISTING POND/WATER

NOTE:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: UPPER DIVERSION CHANNEL PLAN AND PROFILE SHEET 2 OF 2

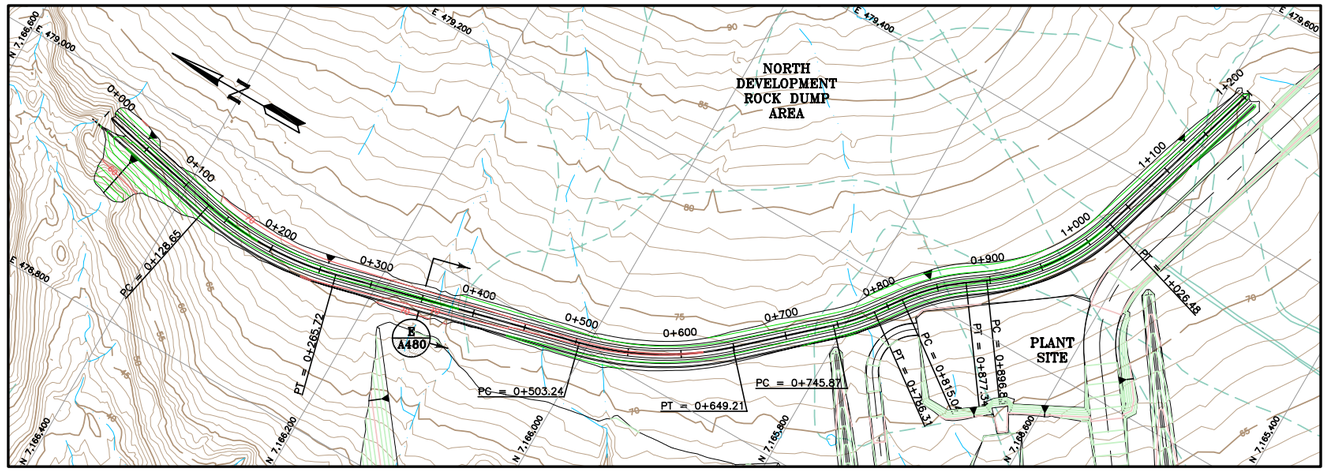
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	JJM	APPROVED BY	RMS

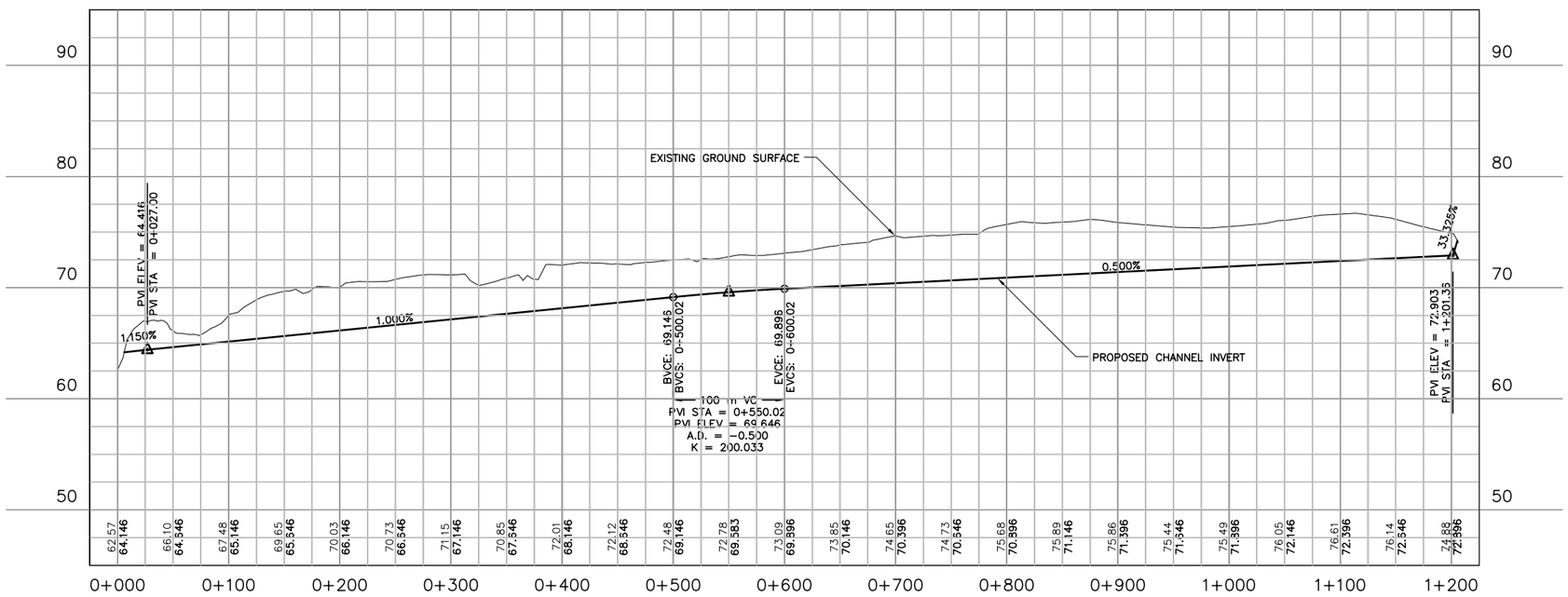
FILENAME: 1011P65 — DRAWING No.: A420 — REV: B

XREF: NO

PLOT SCALE



LOWER NORTH DIVERSION CHANNEL ALIGNMENT DATA						
	STATION	NORTHING	EASTING	DELTA (D–M–S)	RADIUS (m)	LENGTH (m)
PI	0+000	7,166,500.129	478,967.184			
PC	0+128.65	7,166,374.192	478,940.904			
				26–10–40	299.999	137.066
PT	0+265.72	7,166,238.351	478,943.988			
PC	0+503.24	7,166,008.281	479,003.010			
				27–52–46	299.995	145.974
PT	0+649.21	7,165,881.051	479,071.595			
PC	0+745.87	7,165,809.521	479,136.605			
				11–35–09	199.991	40.441
PT	0+786.31	7,165,782.538	479,166.635			
PC	0+815.04	7,165,765.590	479,189.835			
				17–50–58	199.992	62.304
PT	0+877.34	7,165,721.657	479,233.657			
PC	0+896.83	7,165,705.889	479,245.115			
				37–08–32	199.989	129.643
PT	1+026.48	7,165,632.050	479,348.916			
PI	1+206.48	7,165,579.894	479,521.076			



LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- EXISTING POND/WATER

NOTES:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: LOWER NORTH DIVERSION CHANNEL PLAN AND PROFILE

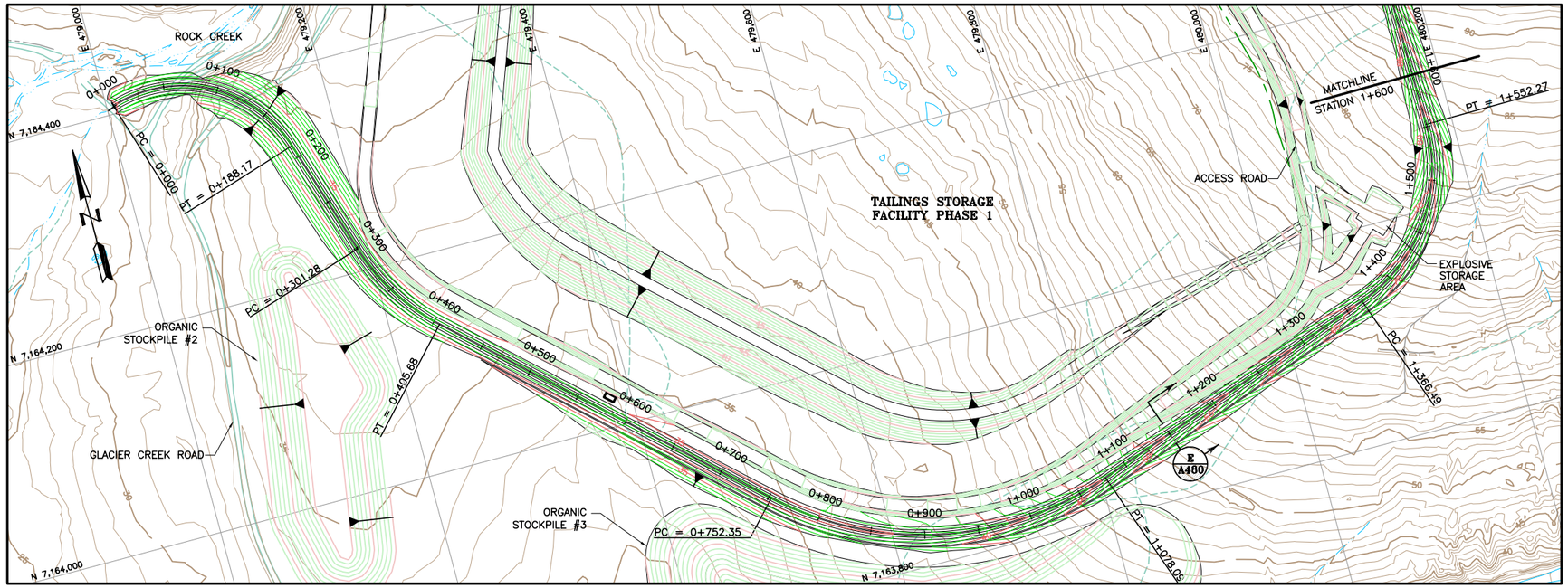
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

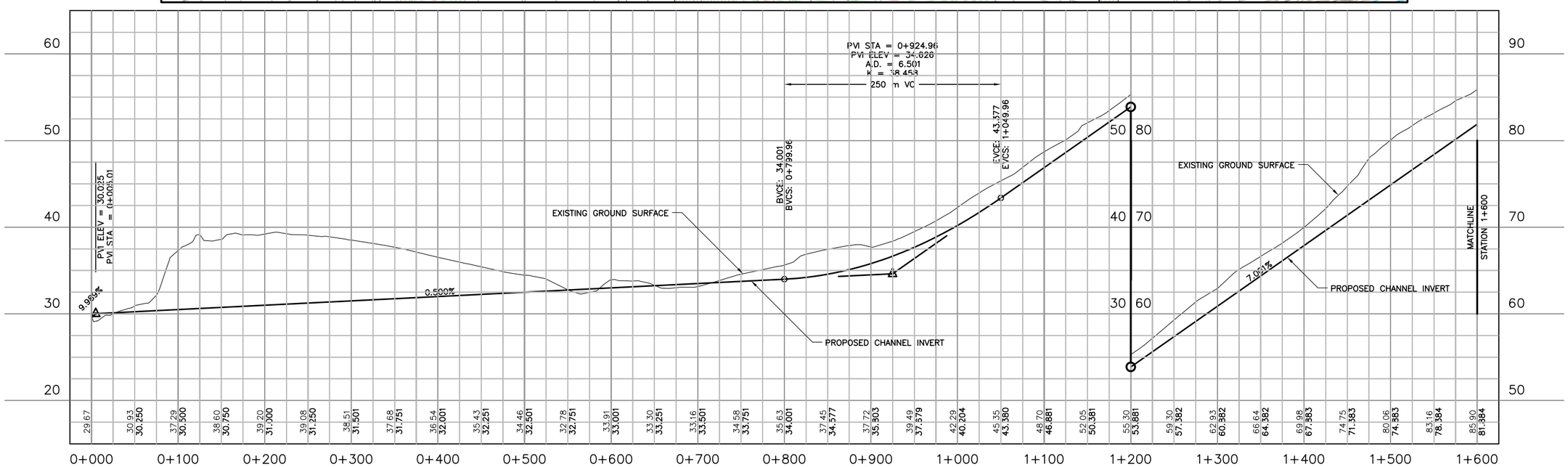
DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	DS	APPROVED BY	RMS

FILENAME	DRAWING No.	REV
1011P66	A430	B

XREF: NO

PLOT SCALE





LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- EXISTING POND/WATER

NOTE:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBLITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: LOWER SOUTH DIVERSION CHANNEL PLAN AND PROFILE SHEET 1 OF 2

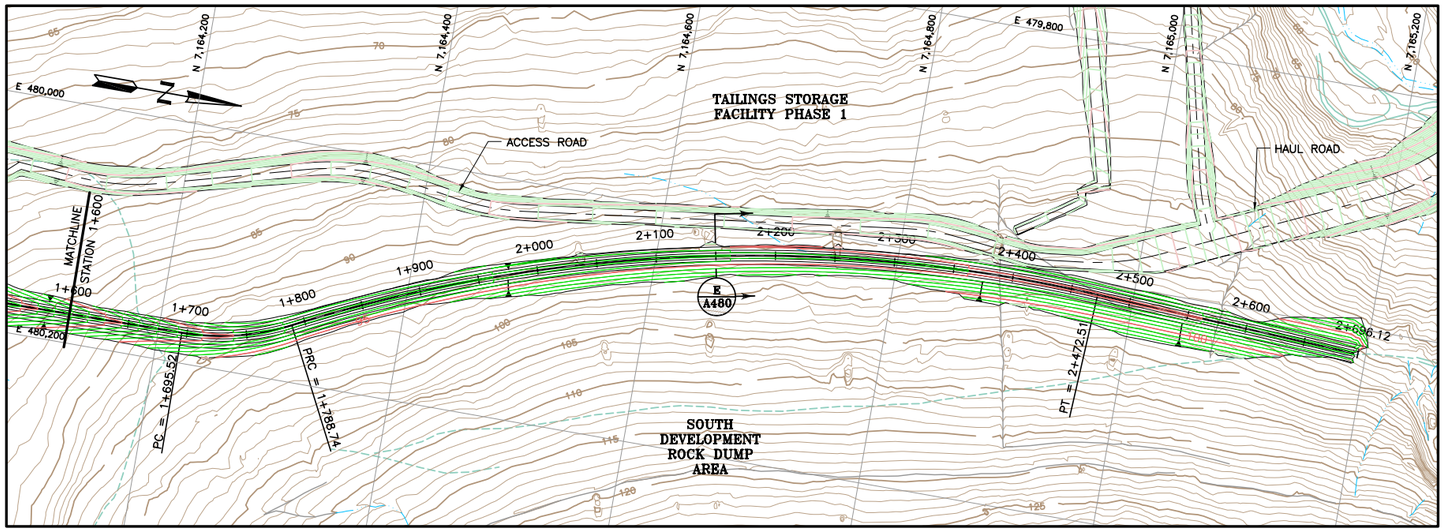
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	JJM	APPROVED BY	RMS

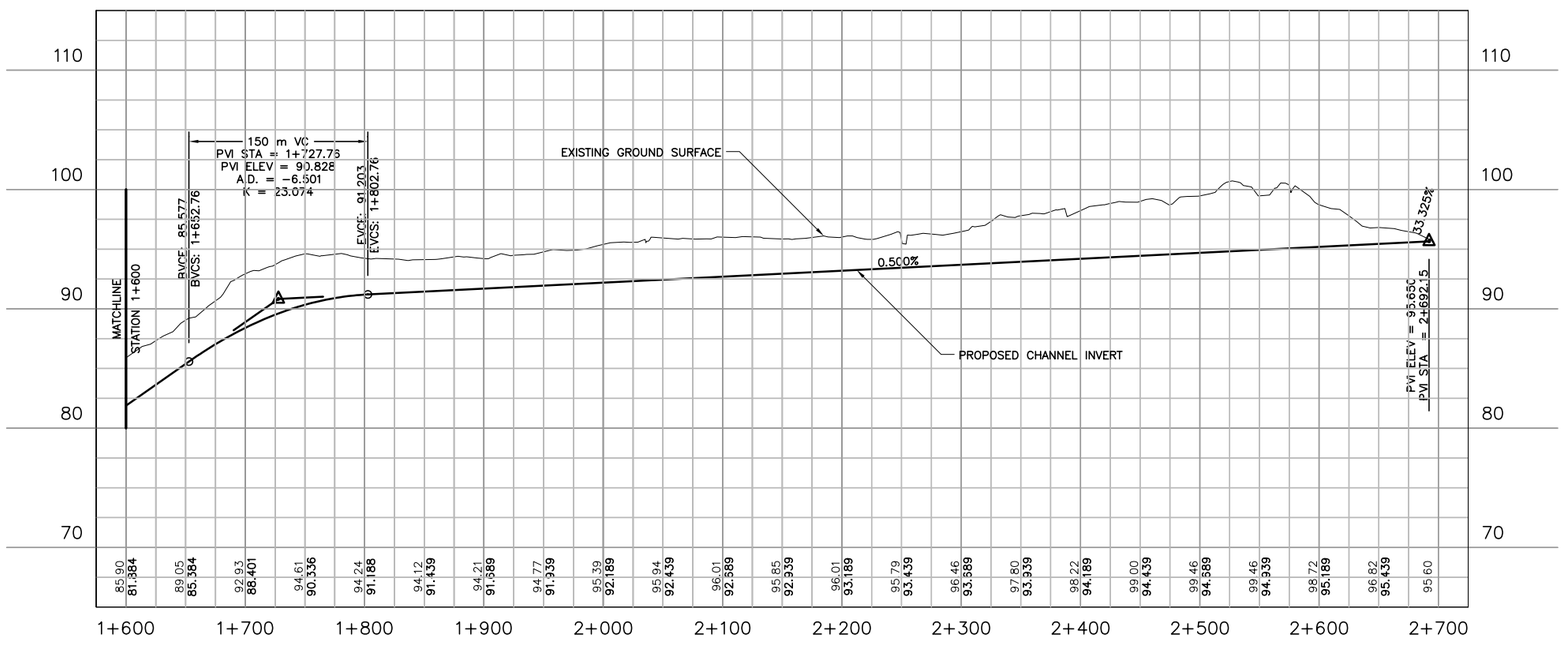
FILENAME	DRAWING No.	REV
1011P67	A440	B

XREF: NO

PLOT SCALE



LOWER SOUTH DIVERSION CHANNEL ALIGNMENT DATA						
	STATION	NORTHING	EASTING	DELTA (D–M–S)	RADIUS (m)	LENGTH (m)
PI/PC	0+000	7,164,407.620	479,006.389			
				89–51–14	119.990	188.174
PT	0+188.17	7,164,329.009	479,156.530			
PC	0+301.28	7,164,221.105	479,190.424			
				29–54–39	199.994	104.405
PT	0+405.68	7,164,133.944	479,245.723			
PC	0+752.35	7,163,899.056	479,500.694			
				62–13–03	299.967	325.734
PT	1+078.09	7,163,837.037	479,804.390			
PC	1+366.49	7,163,933.642	480,076.135			
				70–57–41	150.000	185.77
PT	1+552.27	7,164,076.369	480,175.885			
PC	1+695.52	7,164,219.608	480,174.555			
				26–42–19	200.000	93.219
PRC	1+788.74	7,2+5,309.287	480,152.388			
				30–08–13	1299.986	683.776
PT	2+472.51	7,164,970.022	480,009.912			
PI	2+696.12	7,165,193.342	480,021.219			



LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- PROPOSED CULVERT
- EXISTING POND/WATER

NOTE:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:2500

5 0 5 10 METERS — VERTICAL SCALE = 1:250

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: LOWER SOUTH DIVERSION CHANNEL PLAN AND PROFILE SHEET 2 OF 2

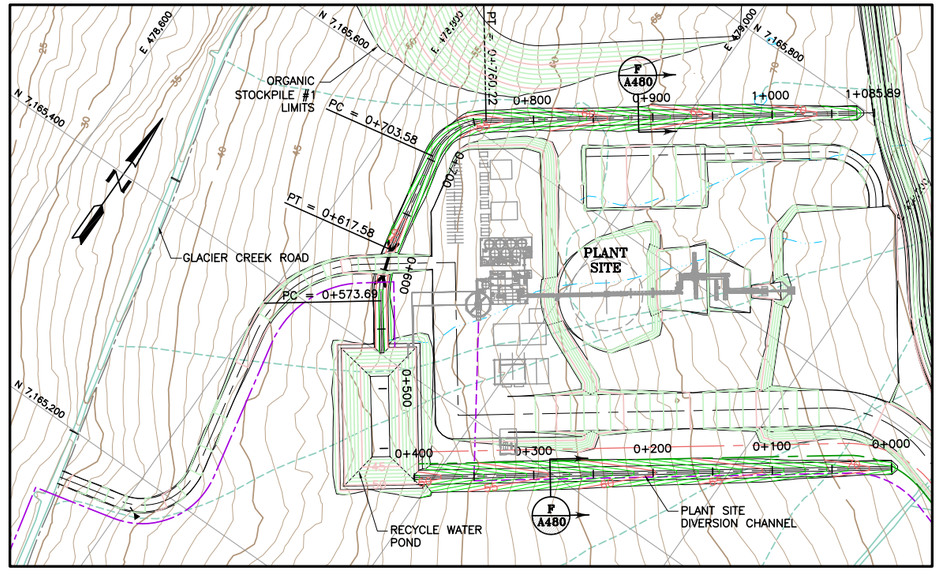
SMITH WILLIAMS CONSULTANTS, INC.
304 Inverness Way South, Suite 490, Englewood, Colorado 80112
Phone: 303-433-0262 Fax: 303-433-0362

DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	JJM	APPROVED BY	RMS

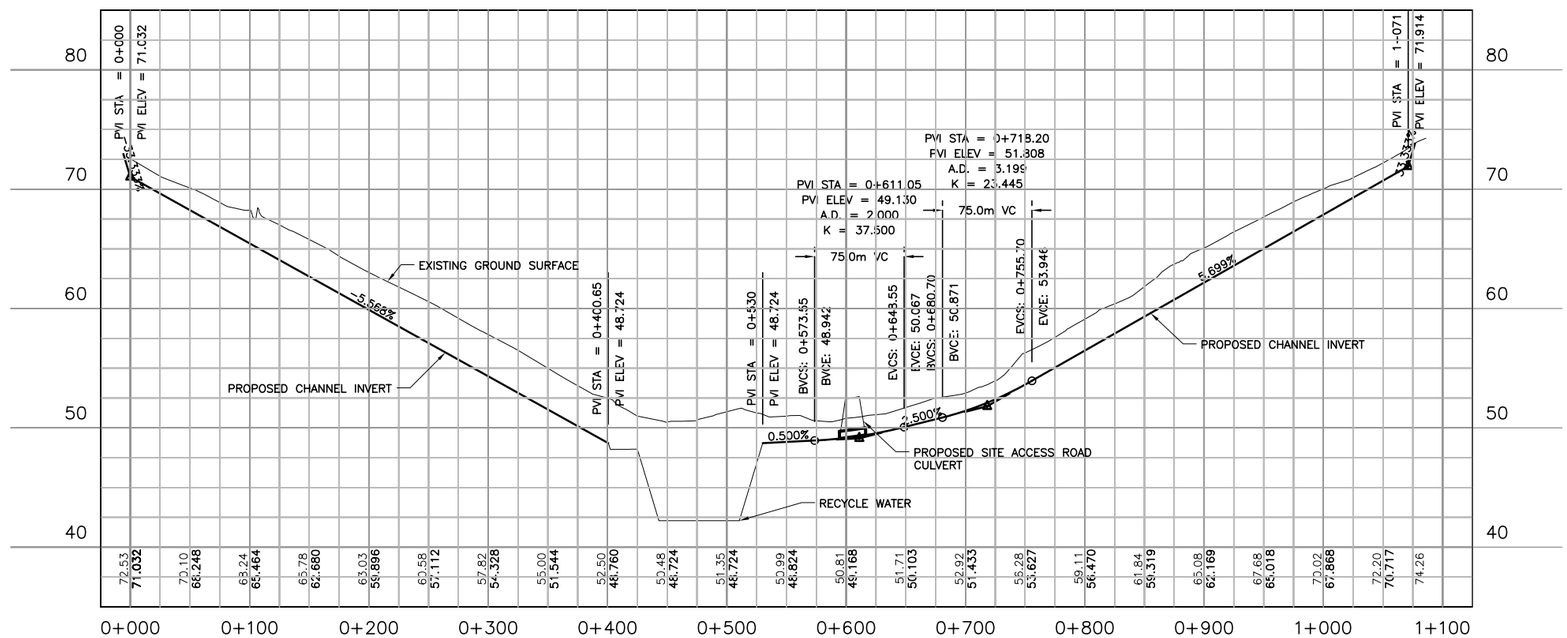
FILENAME: 1011P68 | DRAWING No.: A450 | REV: B

XREF: NO

PLOT SCALE



PLANT SITE DIVERSION CHANNEL ALIGNMENT DATA						
	STATION	NORTHING	EASTING	DELTA (D–M–S)	RADIUS (m)	LENGTH (M)
PI	0+000	7,165,567.419	479,309.476			
PI	0+425.03	7,165,316.702	478,966.263			
PC	0+573.69	7,165,436.658	478,878.470			
				25–08–55	100.000	43.893
PT	0+617.58	7,165,476.550	478,861.021			
PC	0+703.58	7,165,560.961	478,844.536			
				64–54–10	50.000	56.638
PT	0+760.22	7,165,610.920	478,864.115			
PI	1+085.89	7,165,803.023	479,127.092			



LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- PROPOSED CULVERT
- EXISTING POND/WATER
- EXISTING CULVERT

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

B	6/17/05	ISSUED FOR FEASIBILTY DESIGN	RTB / JJM
A	3/24/05	ISSUED FOR CLIENT REVIEW	RTB / DS

Alaska Gold Company

DISCLAIMER

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

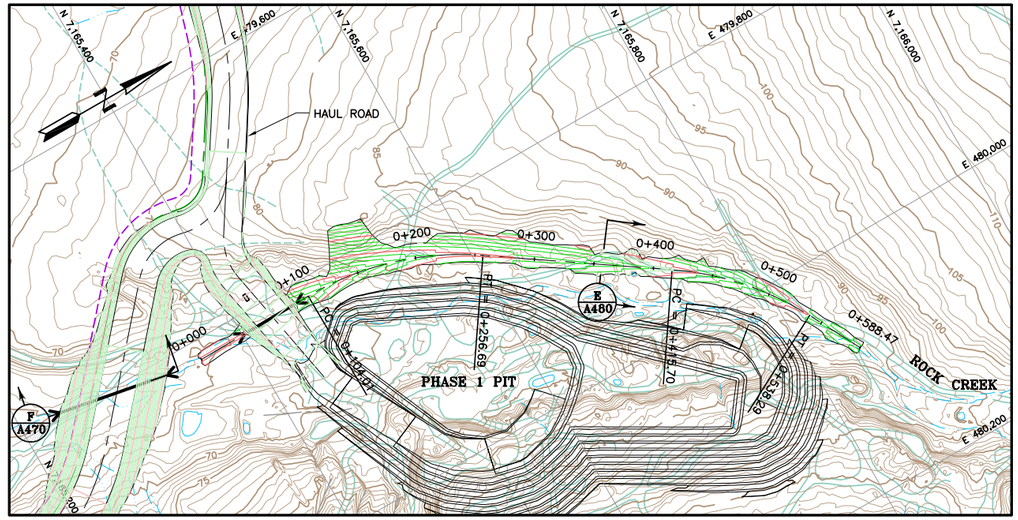
TITLE: PLANT SITE DIVERSION CHANNEL PLAN AND PROFILE

SWC
SMITH WILLIAMS CONSULTANTS, INC.
2420 West 26th Avenue, Building D, Suite 110, Denver, CO 80211
Phone: 303-433-0262 Fax: 303-433-0362

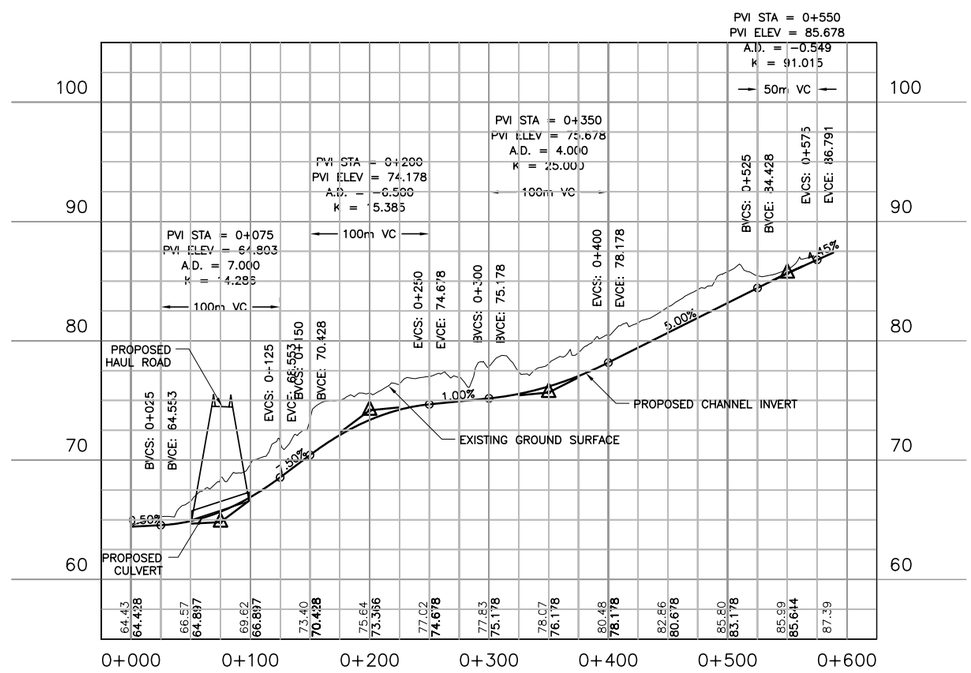
DESIGNED BY	JJM	CHECKED BY	RTB
DRAWN BY	JJM	APPROVED BY	RMS
FILENAME 1011P69		DRAWING No. A460	REV B

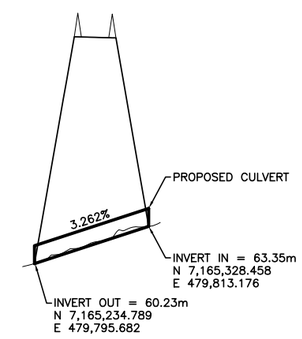
XREF: NO

PLOT SCALE



TEMPORARY DIVERSION CHANNEL ALIGNMENT DATA						
	STATION	NORTHING	EASTING	DELTA (D–M–S)	RADIUS (m)	LENGTH (m)
PI	0+000	7,165,360.057	479,816.275			
PC	0+104.01	7,165,542.864	479,815.113			
				34–59–32	250.00	152.682
PT	0+256.69	7,165,607.925	479,858.700			
PC	0+415.70	7,165,739.195	479,948.421			
				28–05–49	250.00	122.596
PT	0+538.29	7,165,819.777	480,039.182			
PI	0+588.47	7,165,842.988	480,083.673			





F A470 TYPICAL HAUL ROAD CULVERT CROSSING

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING TRAIL
- PROPOSED CULVERT
- EXISTING POND/WATER

NOTE:

1. SEE CHANNEL SECTION FOR CHANNEL INVERT REFERENCE POINT.

50 0 50 100 METERS — HORIZONTAL SCALE = 1:5000

5 0 5 10 METERS — VERTICAL SCALE = 1:500

VERTICAL EXAGGERATION = 10X

A	6/17/05	ISSUED FOR FEASIBILITY DESIGN	RTB	JJM

Alaska Gold Company

DISCLAIMER
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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: TEMPORARY DIVERSION CHANNEL PLAN AND PROFILE

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1011P90	A470	A

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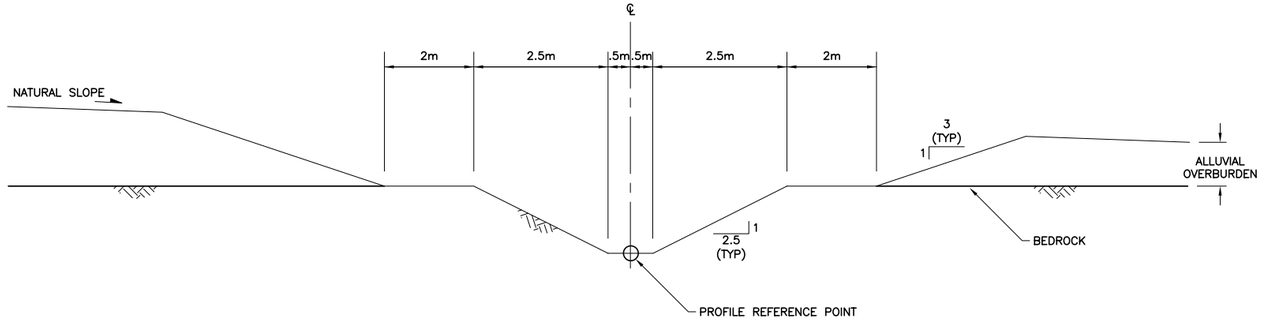

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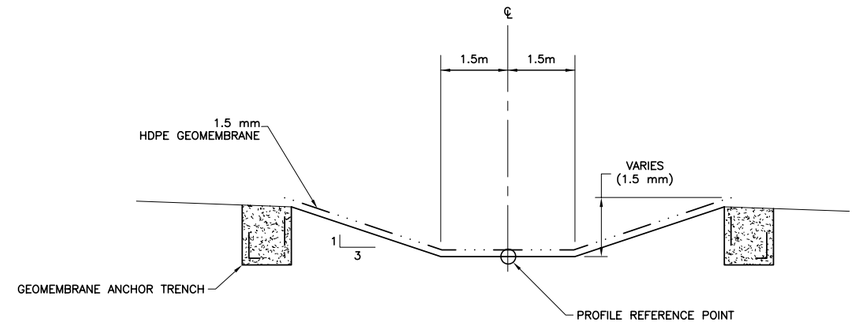

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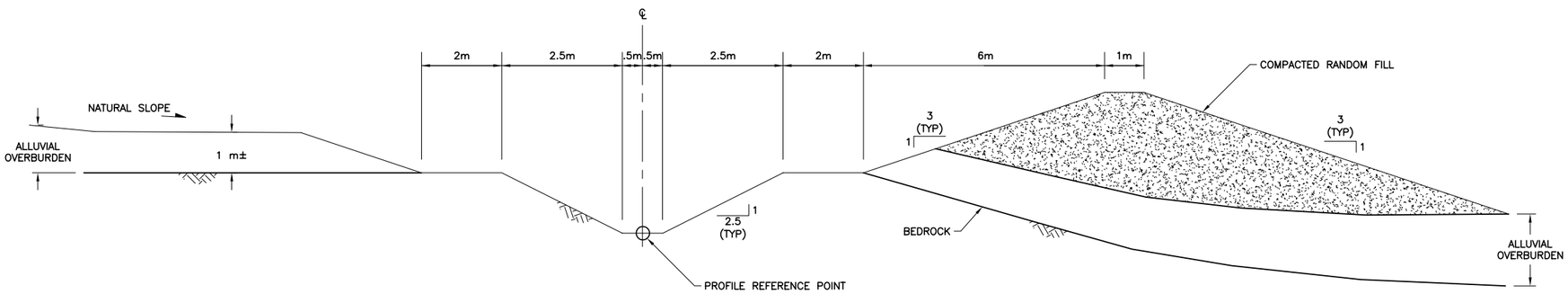

TYPICAL FILL SECTION

NTS

E A200 E A100 E A105 E A410 E A420 E A430 E A440 E A450 E A470 TYPICAL DIVERSION CHANNEL SECTIONS

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: DIVERSION CHANNEL SECTIONS AND DETAILS

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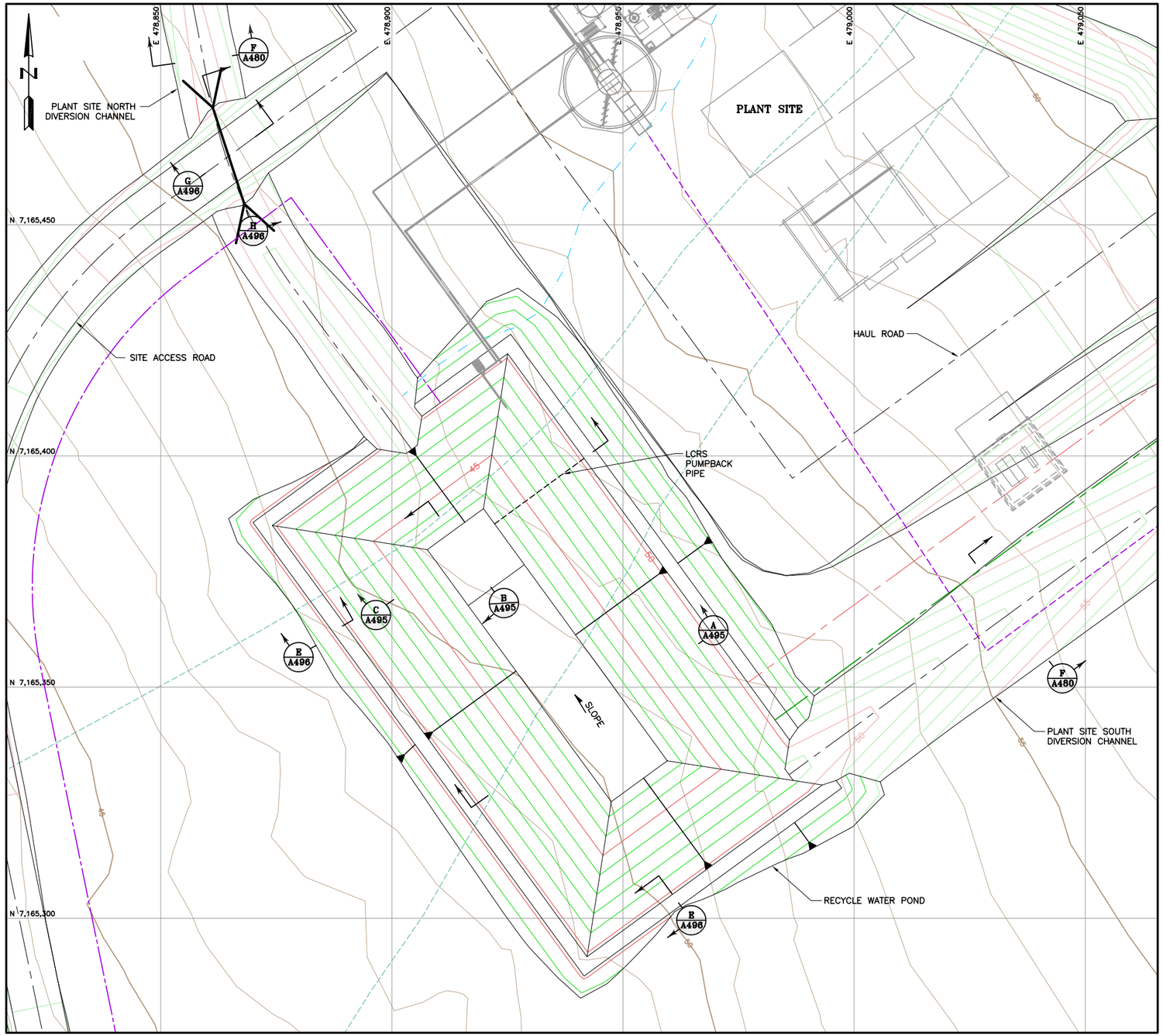

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DATE: NOVEMBER 30, 2004. FILENAME: S:\CAD\1011-rock creek\recv\20041130-Kodiak Mapping Survey\CD02\dwgROCK_CREEK_2004.dwg

PLAN

10 0 10 20 METERS
SCALE = 1:1,000

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, METERS
- PROPOSED GROUND SURFACE CONTOUR AND EL, METERS
- EXISTING ROAD
- EXISTING STREAM
- EXISTING DITCH
- EXISTING POND/WATER
- EXISTING STRUCTURE
- EXISTING CULVERT
- PROPOSED CULVERT
- EXISTING TRAIL
- TAILINGS DISTRIBUTION PIPE
- BACKUP DEWATERING PIPE
- LCRS PUMPBACK TUBE
- RECLAIM WATER PIPE
- DEWATERING PIPE

NOTES:

1. PLANT LAYOUT WAS RECEIVED BY SMITH WILLIAMS CONSULTANTS ON MARCH 13, 2005 FROM ROBERTS AND SCHAEFER COMPANY.
2. RECYCLE WATER POND WILL CAPTURE ALL RUNOFF FROM THE PLANT SITE.
3. CONTAINMENT POND CREST DIMENSIONS ARE 115.5m BY 63m.
4. RECYCLE WATER POND IS SIZED TO CONTAIN THE 100-YR/24 HR STORM EVENT AND 9,300 M³ OF SOLUTION FROM THE TAILINGS THICKENER OVERFLOW.

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: RECYCLE WATER POND PLAN

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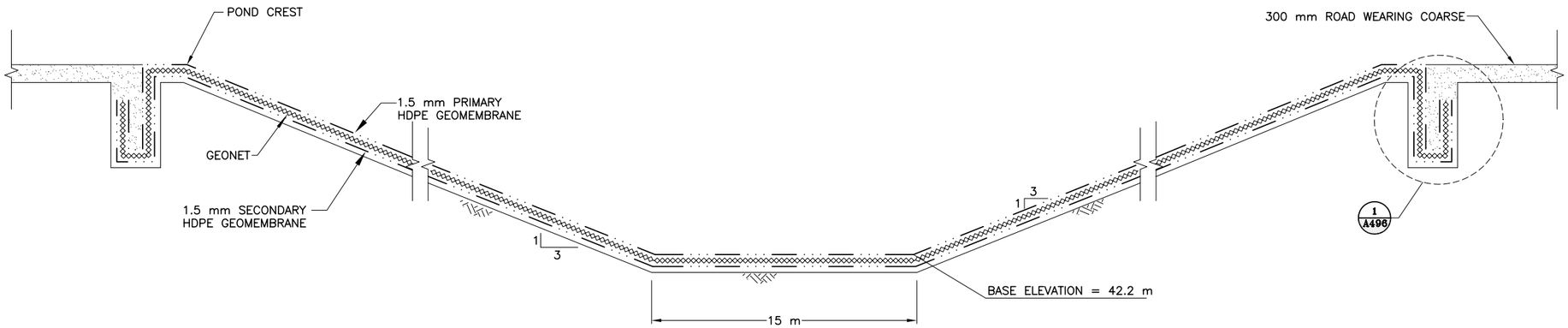

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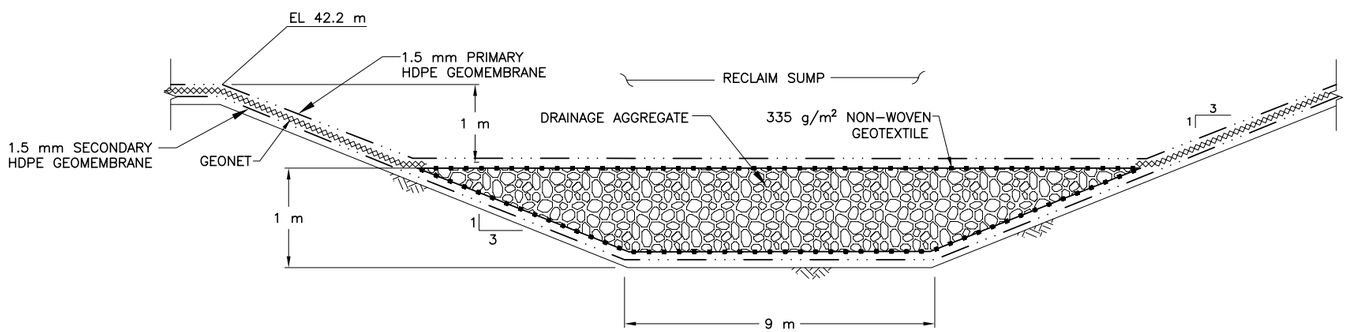

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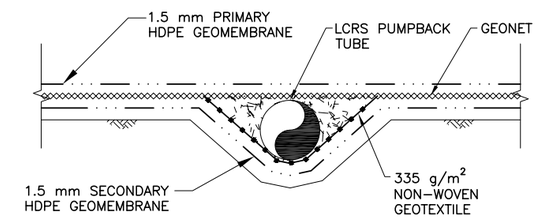

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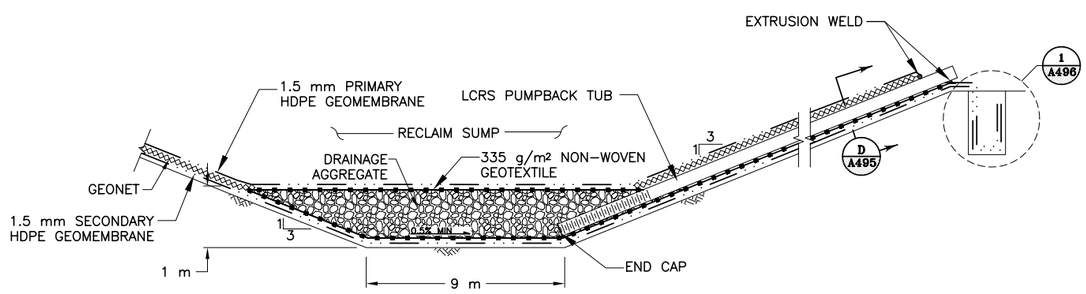

C A490 LCRS SUMP WITH LCRS PUMP BACK TUBE
NTS

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CLIENT: ALASKA GOLD COMPANY

PROJECT: ROCK CREEK PROJECT

TITLE: RECYCLE WATER POND SECTIONS AND DETAILS SHEET 1 OF 2

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1011D116	A495	A

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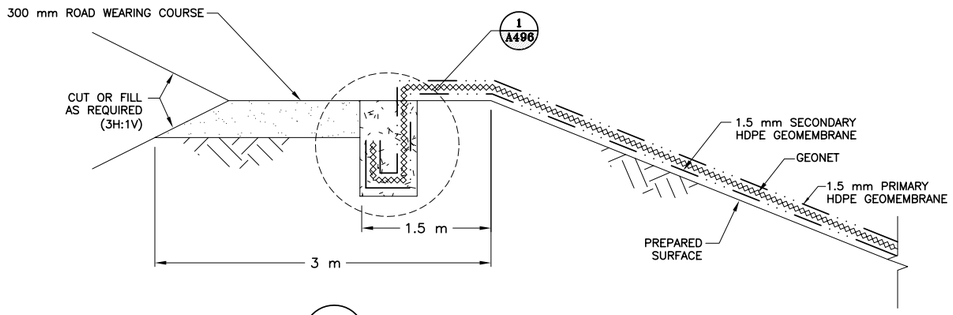
PLOT SCALE



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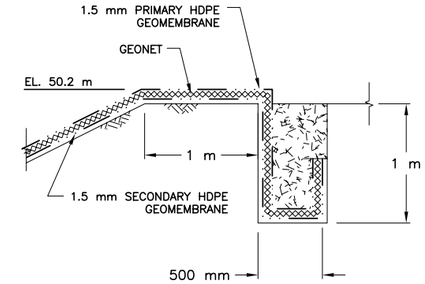

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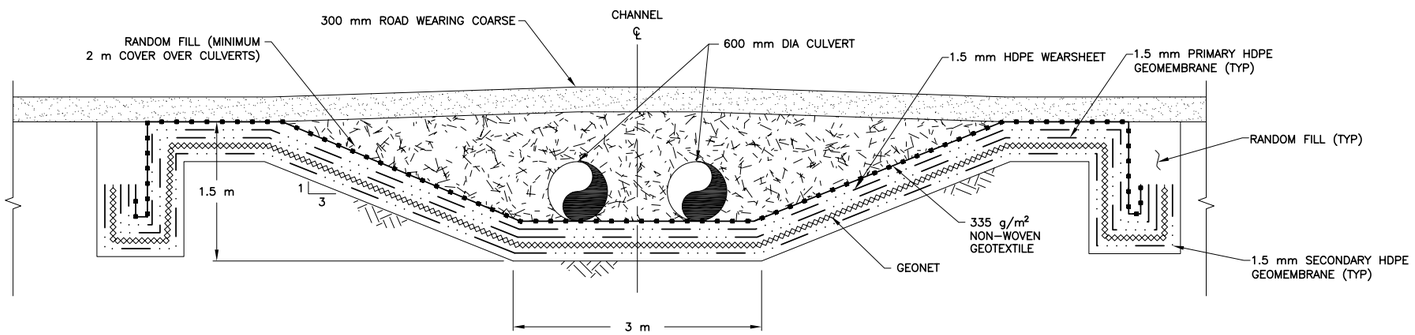

G A490 DIVERSION CHANNEL CULVERT
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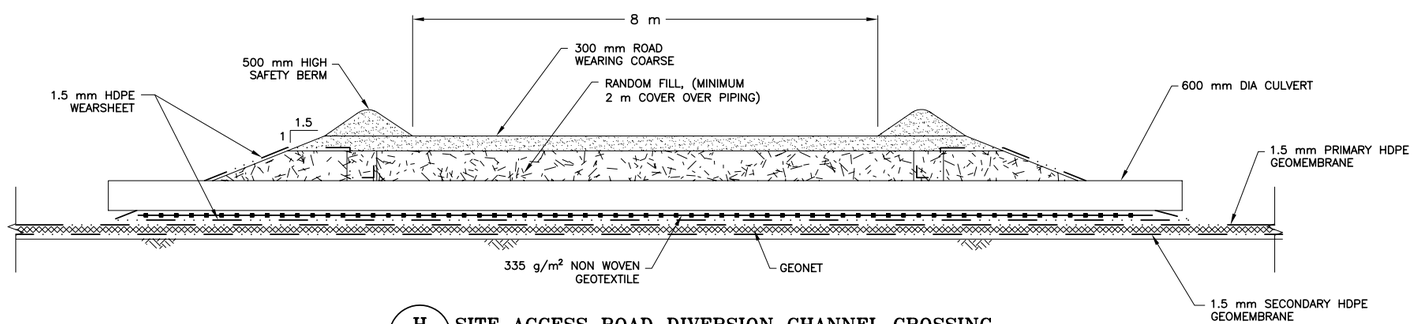

H A490 SITE ACCESS ROAD DIVERSION CHANNEL CROSSING
NTS

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PROJECT: ROCK CREEK PROJECT

TITLE: RECYCLE WATER POND SECTIONS AND DETAILS SHEET 2 OF 2

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1011D117	A496	A

XREF: NO

PLOT SCALE

Appendix B
Water Management Plan

ROCK CREEK MINE PROJECT
WATER MANAGEMENT REPORT

April 2006

2509

Prepared for:

Alaska Gold
Rock Creek Project
P.O. Box 82430
Fairbanks, Alaska 99708-2430

Prepared by:

Water Management Consultants
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Richmond, BC V6X 2W8

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Appendix I Tailings Storage Facility Process Solution System Analysis

1 INTRODUCTION

The proposed Rock Creek project encompasses two mine sites, the Rock Creek Mine site and the Big Hurrah Mine site. This report will reference the Rock Creek Mine site only which lies within the Snake River catchment approximately 10 km north of Nome Alaska. The Big Hurrah Mine site is addressed in a separate report. The facilities for the operation of a mine in the Rock Creek basin involve the construction of a tailings area, development rock dump areas, a plant site and a pit. These mine elements are almost entirely located within the surface water catchment boundaries of Rock Creek.

The mine facilities require a water management plan to describe the water aspects of the project and to develop an operating and closed mine with acceptable environmental impacts. Water Management Consultants has provided consulting services to Alaska Gold and assisted with development of the water management plan. The activities have included:

- Review of available climate data for the region and the site.
- Review of local stream flow data and determination of likely variation of climatic information that the stream flow data indicates.
- Development of watershed models for Snake River, Glacier Creek, Lindblom Creek and Rock Creek to provide an indication of the range of local stream flows.
- Development of a groundwater model based on available subsurface information and development of a design for interception well field for the pit area.
- Conceptual design of a Class V underground injection system for discharge of water.
- Development of a site wide water balance that considered losses and gains of water from the mill and tailings circuit and quantified probable quantities of water that would be shed from the site as a result of the water management plan.

The water balance for the proposed Rock Creek mine site that was developed incorporates topography, geology, physical hydrogeologic conditions as well as climate and flow data. The water balance was completed using a spreadsheet that addressed the possible recharge sources by catchment area and potential recharge rates. Calculations were completed on a month by month basis, and were reported on an annual basis, with an aim to determine all water interactions between mine elements.

2 PROJECT SETTING

2.1 General

The proposed Rock Creek project site lies within the Snake River catchment (see Figure 1.1). The Snake River, which flows about 11 miles south from the Rock Creek confluence to Norton Sound near Nome Alaska, has a 85 mi^2 (220 km^2) catchment area. The Rock Creek project site is situated on the eastern side of the Snake River valley. Three creeks, all tributary to Snake River, are in the immediate vicinity of the proposed project, Lindblom Creek to the north, Rock Creek in the middle, and Glacier Creek to the south.

The Rock Creek catchment has an elevation gain of 1300 ft from the valley floor which lies at 100 ft. The N-S trending foothills in which the catchment lies have elevations that range up to 2000 ft. The catchment area for Rock Creek is approximately 2 square miles. Glacial, alluvial and tectonic processes shaped the eastern wall of the Snake River Valley, upon which this catchment lies. The hydrogeology of the Rock Creek basin is controlled by the surficial and bedrock geology, the topographic setting as well as the climate and hydrology. Steep slopes of local bedrock dominate the higher elevations on site. The surface topography quickly shallows over the 2.5 mile (4 km) creek path which ends on the alluvial plain of the Snake River.

Within the Rock Creek drainage the dominant bedrock is a well foliated, “wavy” banded, quartz-muscovite schist containing varying proportions of carbonate graphite/carbon and chlorite. Outcrops and near surface bedrock are highly weathered and fractured. Drilling with an RC air rotary rig results in significant water return in many of the drillholes to the full depth, indicating at least moderate bedrock permeability over a significant portion of the site. Overburden materials include silts formed as a weathering profile overlying the schist, as well as glacial, alluvial and colluvial materials. Sands and gravels have been observed at some locations on the lower slopes. The bottom of Rock Creek valley is infilled with sand and gravel. This material has been reworked with a dredge for some distance upstream. West of the Rock Creek site, the Snake River valley has been infilled, primarily with alluvium. The remnants of abandoned and infilled channels are apparent on the valley floor. Silt infill, as well as channel and bar sands are expected. Sand and gravel deposits are codepositional and overlie the Snake River alluvium as fans from Lindblom Creek, Rock Creek and Glacier Creek.

The climate and physiography create typical high latitude vegetation. Tundra, consisting of low lying shrubs and grasses, cover a majority of the region. Higher regions have areas of bedrock outcrop. Discontinuous permafrost has been documented in the planned development area.

2.2 Hydrometeorology

2.2.1 General

Regional climate data has been evaluated to estimate an extended monthly precipitation and temperature dataset for the Rock Creek site. Precipitation frequency analysis has been completed on the precipitation dataset to estimate average, and wet and dry values for various return periods.

The regional data utilized for this task were as follows:

- Daily precipitation and temperature data from the Nome Airport weather station in Nome, AK from 1907 through 2003 (National Climatic Data Center);
- Daily precipitation data for 2005 from an on site meteorological station;
- Stream gage data from the Snake River for the years 1965 through 1991 (Hydraulic Unit Code: 19010504, USGS); and
- Stream gage data for a few recent dates for Rock Creek, Lindblom Creek, Snake River and Glacier Creek.

Precipitation reaches a maximum in late summer and drops to a minimum in April and May. The moderating influence of open water of Norton Sound is effective from early June to about the middle of November. Overcast conditions are common during July and August. Temperatures generally remain well below freezing from the middle of November to the latter part of April. Snow begins to fall in September, but usually does not accumulate on the ground until the first part of November. The snow cover decreases rapidly in April and May, and normally disappears by the middle of June. Severe wind storms are common.

2.2.2 Temperature

The average monthly temperatures for the Nome Airport are presented on Table 2.1. The site temperatures at lower elevations are expected to be similar to Nome, as the site is fairly close to Norton Sound. To develop an understanding of historical climate trends, a graph displaying the five year running average for the Nome airport temperature was developed and is shown on Figure 2.1. Based on Figure 2.1, a cooler period (about -4°C) was present from about 1950 to 1975. The most striking feature of the Nome record and other records in Alaska is the sudden warming in the late 1970's (see Papineau).

2.2.3 Precipitation

Precipitation has been measured at Nome since 1906, an excellent historical record for mine design. The average monthly precipitations are presented in Table 2.1.

As illustrated on Figure 2.1, the precipitation record indicates wet periods from 1920 to 1925 (average of about 550 mm/year) and 1942 to 1952 (average of about 500 mm/year) and a dry period from 1960 to 1980 (average of about 320 mm/year). Average Nome Airport precipitation from 1985 through 2005 was 441 mm.

Table 2.1 Average Monthly Temperature and Precipitation at Nome Airport

Month	Temperature (^oC)	Precipitation (mm)
	Nome	Nome
Jan	-13.1	24.4
Feb	-13.0	20.7
Mar	-11.9	18.5
Apr	-6.5	17.9
May	1.8	17.6
June	7.9	27.0
July	10.3	59.2
Aug	9.8	84.0
Sept	5.6	64.3
Oct	-1.8	38.2
Nov	-8.3	27.2
Dec	-12.7	24.3
Annual		423.3

Benning and Yang (2005) describe an evaluation of the Nome airport precipitation data based on studies comparing the catch of precipitation using various gage types. They describe the results of applying an algorithm developed for comparing the gage used at Nome with a gage with extensive wind shielding. The findings of the study indicate that the Nome gage has significant undercatch as there is no wind shield at all on the Nome gage, and the gage is on top of a building where it is exposed to high wind. They report that the actual precipitation at Nome was 1.3 to 4.8 times the measured precipitation, with the larger factors for winter months. The calculated average adjustment is about 4.1 in winter and 1.5 in summer. In summary, the published paper implies a potential for measured snowfall at Nome to be much less than the actual snowfall. Flow data from the Snake River catchment, which may be subject to orographic effects, generally supports the papers results. However, such a high winter multiplier is not supported by measured Snake River Flows (see Section 2.4.10). The paper provides a reminder that snow control may be important. The pit could provide an excellent snow trap if snow fences are not installed. Snow load, particularly in the plant site area might be evaluated at the end of winter and snow removed if required to help with the overall water balance.

There is more than one year of precipitation data collected at the Rock Creek site climate station. That information, reported as monthly precipitation on Table 2.2, indicates that monthly site precipitation is 0.6 to 2.5 times Nome, with an average of 1.7 times Nome. A plot illustrating the monthly rainfall at the two sites, presented as Figure 2.2, illustrates that the multiplication factor increases with precipitation depth. The wet months were September, August, October, and July.

Table 2.2: Comparison of 2005 Nome and Rock Creek Recorded Precipitation (mm)

Month	Nome Airport	Rock Creek	Ratio
Sept/04	16	20	1.3
Oct/04	70	109	1.6
Jan/05	5	11	2.2
Feb/05	21	22	1.0
Mar/05	12	8	0.7
Apr/05	8	4	0.5
May/05	27	47	1.7
June/05	22	21	1.0
July/05	41	68	1.7
Aug/05	74	133	1.8
Sept/05	123	302	2.5
Oct/05	41	69	1.7
Nov/05	10	9	0.9
Dec/05	11	13	1.2
Annual	394	708	1.7

A precipitation frequency analysis was completed for the wet and dry distribution of the Nome airport annual precipitation over the 96-year period of record from 1907 through 2003. Listed in Table 2.3 are the average, 5, 10, 50, 100, and 200-year return period annual wet and drought precipitation levels for the Nome Airport. For comparison, the Nome Airport minimum annual precipitation recorded was 188 mm and the maximum annual precipitation recorded was 749 mm. The site return precipitation predictions were derived by multiplying the wet airport data by 1.7.

Table 2.3: Nome Airport and Estimated Rock Creek Annual Precipitation Distribution

Return Period (yr)	**Wet Annual Precipitation (mm)**		**Dry Annual Precipitation (mm)**	
	Airport	**Site***	**Airport**	**Site***
Average	425	722	425	722
5	520	884	322	547
10	574	976	280	476
20	620	1054	250	425
100	709	1205	202	343
200	743	1263	187	318

* Site precipitation at 1.7 times Nome Airport

2.2.4 Evapotranspiration and Evaporation

There is no evaporation data available for the site or the airport. Evapotranspiration in the area has not been studied in detail. Munter et al. (1991) quoting Patric and Black (1968) calculated the actual evapotranspiration in the Nome area to be 14 inches/yr based on Thornthwaite's

classification. A study by Fraver (2003) of thermokarst ponds in the Council area, about 75 miles northeast of Nome, included evaluation of evapotranspiration. Extrapolation of the results from that study indicated an annual evapotranspiration of about 14 inches (356 mm) for ponds, 10 inches (254 mm) for wetlands and 7 inches (178 mm) for uplands. This precipitation and evaporation information indicates there is a significant quantity of water available for runoff and groundwater recharge in the area. The average monthly potential evapotranspiration (PET) and estimated actual evapotranspiration (AET) for this study is illustrated on Table 2.4.

Table 2.4: Calculated Average Evapotranspiration (mm)

	PET		Natural AET	
Month	<1,000'	>1,000'	<1,000'	>1,000'
Jan				
Feb				
Mar				
Apr				
May	32	26	13	13
June	109	108	41	43
July	127	127	52	53
Aug	101	101	46	46
Sept	52	56	25	24
Oct				
Nov				
Dec				
Annual	423	412	181	179

Note: Ponded water evaporated at PET

2.3 Hydrogeologic Setting

2.3.1 General

In the proposed project area there are three creeks that potentially have hydrologic influence. Rock Creek runs down the center of the site, Lindblom Creek borders the site on the north and Glacier Creek borders the site to the south. Lindblom Creek has a smaller catchment than Rock Creek while Glacier Creek is larger, encompassing the entire east and south side of Mount Brynteson (see Figure 1.1). All of these creeks are tributary to the Snake River.

Potential sources of groundwater recharge include snowmelt, rainfall, and sites where streams or other surface water features are perched above the water table.

Groundwater recharge initiates as surface infiltration. The infiltrated water may be transmitted downslope as interflow (or very shallow groundwater) or percolate to the groundwater table. There is a significant quantity of water that transmits down the slope as interflow, with visible discharge from the banks of Rock Creek. This flow path results in a significant retention of storm water, probably reducing the peaks from rainfall events. Some of this retention is within the tundra grasses and some is within the overburden and near surface fractured rock. This interflow may be within the active area, where permafrost is present.

Water entering the groundwater system travels to local discharge within the creeks or further to discharge into the Snake River alluvium. The local discharge of deeper groundwater into Rock

Creek is apparent from the presence of winter base flow, artesian flow from open drill holes and from the chemistry of Rock Creek water. The estimated annual infiltration in the Rock Creek basin is approximately 8 inches (200 mm), based on rainfall, estimated evapotranspiration, and limited runoff measurements. The presence of permafrost over the catchment could significantly reduce groundwater recharge.

There is a significant quantity of groundwater moving downstream in the alluvium within Rock Creek Valley. The permeability of this alluvium was probably enhanced by dredging operations. Groundwater within this alluvium includes direct precipitation, interflow from upper slopes and groundwater discharged from depth. The water character is expected to be similar to the character of the creek water although there may be a higher percentage of deep groundwater.

Recharge of groundwater in the Snake River alluvium occurs as direct precipitation, as discharge of deep groundwater into the alluvium and as stream recharge of alluvial fans. The sand and gravel fans (Rock Creek, Lindblom Creek, and Glacier Creek) transmit considerable water as a result of higher hydraulic conductivity and gradients than the underlying Snake River alluvium. As a result, groundwater discharge is expected into the alluvium, as well as into channels and ponds surrounding the fans.

2.3.2 Hydrogeologic Investigations

A groundwater monitoring program was planned and initiated in October 2003. The objective of the monitoring program was to document the existing, natural groundwater chemistry and flow regime within the areas in which mine development is proposed. The open pit, development rock storage and tailings storage are the three mine facilities that will have the greatest effect on groundwater. Hydraulic testing was also conducted to determine aquifer properties.

Seven monitoring wells, summarized on Table 2.5, and seven additional test holes were completed between 2003 and 2004. Their locations, shown on Figure 2.3, are up gradient and down gradient of the proposed mine facilities. All monitoring wells were installed with 12 m of 0.020 inch factory slotted 4 inch diameter PVC screen. T&J Drilling constructed the wells in 8 inch holes using an exploration air rotary rig.

Bedrock was intercepted in all of the test holes and was screened in all of the monitoring wells except MW03-06. The bedrock consists primarily of fractured carbonate rich schist which is highly weathered at the surface.

Two wells were installed to document groundwater quantity and quality within the shallow bedrock and alluvium of Rock Creek and the Snake River. The down gradient tailing facility well (MW03-05) documents the groundwater quality in the bedrock just before it reaches alluvium and MW03-06 documents the groundwater in the alluvium closer to the Snake River. MW03-06, drilled through the Rock Creek Fan, penetrated 35 ft of sand and gravel overlying silt and clay, finally encountering bedrock at a depth of 61 ft.

To refine expected groundwater inflow estimates, Alaska Gold drilled a number of additional test holes and pump wells and carried out three pump tests in 2004 and 2005. Three sites were initially selected for pump testing. Two pilot holes (A and B) were drilled at each of these three sites in 2004. Following an iteration of the mine layout, the test sites were moved to reflect the expected layout of the open pit and pump wells. Two additional test wells (C and D) and a pump well (E) were drilled were drilled at each of the three sites in 2005. Inflow rates during airlifting from some of these holes are provided on Table 2.6.

Following is a summary of the 2005 drilling for the pump testing program.

- One pumping well (E) and two monitoring wells (C, D) were installed at each test site with a depth from 86 to 116 m, and a diameter of 200 mm.
- Monitoring wells C and D are 15 to 25 m distant from the pumping wells (E). Wells C and D were installed about 100-300 m from monitoring wells drilled the previous year (1A, 1B, 2A, 2B, 3A and 3B). Locations of all wells are shown in Figure 2.3.
- During drilling, groundwater inflow into boreholes was frequently measured. Table 2.6 summarizes depth and major inflow zones as documented by an Alaska Gold employee.
- Inflow rates were similar to rates from the A and B wells and in the MW series wells.

Trends in the groundwater flow regime were identified in the data from observations made during drilling of the monitoring wells and test wells. Air lift flows up to 200 gpm were measured during air rotary drilling of wells around the pit area. Inflows generally reached significant rates in the lower portion of each hole. This did not occur in 2D, although it was within 15 to 20 m of holes (2C and 2E) that did have that response. Lower inflows were also observed in MW03-07. Lower values in MW03-02 and MW03-01 may have been related to the limited depth of these holes. Figure 2.4 shows an E-W profile through the pit with air lift returns labelled for drill holes. The flow rate distribution indicates that most of the groundwater flow is from discrete fractures and faults.

Water return was generally low in the shallow portions of the drillholes. That is expected as air lift return will be less with less submergence of the drill pipe. However, the low return from shallow portions of some of the holes may be due to permafrost. Permafrost distribution has been described in more detail by Smith Williams Consulting Inc.

Water quality samples were collected and analyzed from each of the monitoring wells on a quarter annual basis to document natural groundwater quality conditions in sufficient detail to identify seasonal fluctuations. Field measurements of pH, electrical conductivity, temperature, oxidation reduction potential, ferrous iron, and depth to water were made at the time of, or before, sample collection. Samples are continuing to be collected from the wells for water quality analysis.

Investigations were also carried out in surficial materials to identify areas where Class V injection systems could be constructed. As part of this program, 20 borings were drilled into the alluvial fans of Rock Creek and Lindblom Creek and the Snake River alluvium. Soil samples were collected from these borings and grain size distributions and moisture contents measured. Slotted PVC pipe was installed so that water levels could be measured. Silty sands, silty sand and gravel, and sand and gravel were logged in the holes. Lindblom Creek fan is overlain by a significant thickness of silty soils so that near surface Class V systems are not applicable. There is an adequate area of the Rock Creek fan covered with relatively permeable materials that a near surface Class V system might be feasible.

To further define the surficial soils of the Rock Creek Fan, percolation testing was completed at four sites on the fan. Slug tests were then carried out in four of the observation wells installed into Rock Creek fan material. The location of the 20 borings and 4 test pits are presented on Figure 2.3.

Table 2.5: Monitoring Well Summary

Well ID	Location (UTM)		Total Drilled Depth	Elevation	Depth to Water	Date Sampled	Potentiometric Elevation	Conductivity Estimates (K)
	Easting	Northing	(m)	Measuring Porch (m amsl)	(m)	(d-m-y)	(m amsl)	(m/s)
MW03-01	480011	7164903	24.4	86.5	10.2	22-1-04	76.3	1.3E-06
MW03-02	479855	7165284	45.7	75.2	9.9	29-1-04	65.3	2.5E-07
MW03-03	480751	7166260	36.6	162.3	3.6	30-1-04	158.7	5.0E-07
MW03-04	479994	7166135	21.3	133.1	3.9	21-1-04	129.2	2.0E-05
MW03-05	479178	7164306	27.0	30.9	2.9	15-1-04	28.0	2.5E-06
MW03-06	478802	7164190	9.1	22.4	2.7	22-1-04	19.7	1.0E-05*[1]
					2.7	26-1-04	19.7	
MW03-07	479620	7165330	33.5	70.0	3.1	21-1-04	66.9	4.0E-07
					2.1	28-1-04	67.9	

Table 2.6: Groundwater Inflow from Air Lifting Monitoring Results

Well	Interval (feet)		Air-lift data
	From:	To:	Q = gpm
1C	70	75	10
	80	85	50
	90	95	70
	95	100	100
	115	120	125
	140	145	200
	375	378	200
1D	75	80	1
	80	85	30
	100	105	43
	120	125	60
	140	145	100
	160	165	150
	200	205	150
	205	210	180
	275	277	180
1E	85	90	< 5
	90	95	20
	115	120	60
	160	165	75
	190	195	85
	200	205	100
	220	225	100
	225	230	150
	320	325	150
	340	345	180
	350	353	180

Well	Interval (feet)		Air-lift data
	From:	To:	Q = gpm
2C	80	85	6
	85	90	10
	100	105	20
	105	110	30
	125	130	50
	165	170	60
	185	190	75
	225	230	85
	265	270	95
	305	310	100
	310	315	110
	360	362	110
2D	115	120	< 3
	120	125	6
	180	185	6
	185	190	8
	205	210	8
	210	215	12
	355	360	12
2E	95	100	5
	100	105	50
	115	120	50
	120	125	70
	135	140	150
	215	220	150
	230	235	175
	375	382	175

Well	Interval (feet)		Air-lift data
	From:	To:	Q = gpm
3E	90	95	5
	95	100	10
	100	105	10
	105	110	50
	110	115	60
	140	145	80
	150	155	100
	160	165	110
	180	185	120
	210	215	130
	215	220	150
	250	255	170
	265	270	180
3C	40	45	1
	45	50	20
	65	70	40
	110	115	50
	130	135	80
	155	160	100
	200	205	120
	215	220	135
	255	260	135
3D	85	90	5
	110	115	35
	115	120	60
	135	140	80
	145	150	120
	170	175	135
	235	240	180
	260	265	180

2.3.3 Hydraulic Conductivity:

To estimate hydraulic conductivity recovery data obtained during response testing of the monitoring wells were placed on Hvorslev plots. The hydraulic conductivity results range over two orders of magnitude from 10^{-7} m/s to 10^{-5} m/s. Table 2.7 includes the results of the Hvorslev analysis. Typically, the monitoring wells were installed to sample the more permeable horizons intersected by the drillhole. Monitoring well MW03-06, within the alluvium of the Snake River valley, recovered too quickly to run a recovery test. The hydraulic conductivity is expected to be on the order of 10^{-4} m/s due to the nature of the alluvial material.

Pumping tests were carried out in test wells drilled in 2005. All pumping and monitoring wells tested in 2005 were installed in fractured bedrock with a thin overburden cover. The pumping and monitoring was carried out in open holes. Total hole depths are presented on Table 2.6 as are water return rates. A summary of the interpreted hydrogeologic parameters derived from the pump test data is presented on Table 2.7.

Table 2.7: Summary of Pump Test Results

Test Site	Average well depths (m)	Assumed aquifer width (m)	Assumed Storativity	Transmissivity (m2/s)	Hydraulic Conductivity (m/s)
1	100	30	0.02	$2.5x10^{-4}$	$2.5x10^{-6}$
	100	60	0.03	$1.5x10^{-4}$	$1.5x10^{-6}$
2	110	>200	0.0008	$5.9x10^{-5}$	$5.4x10^{-7}$
	110	>200	0.0008	$6.5x10^{-5}$	$5.9x10^{-7}$
3	80	>65	0.0009	$5.5x10^{-4}$	$6.9x10^{-6}$

Of significance is the presence of no flow boundaries at Test Site 1, and the potential for similar boundaries at Test Site 2. A constant head boundary was present at a distance of about 65 m at Test Site 3. Test site 3 is adjacent to Rock Creek.

Percolation testing was carried out on the Rock Creek fan in four machine excavated test pits. The percolation testing results were consistent with the mix of clean and silty material mapped within the pits. Slug tests were carried out in four observation wells on Rock Creek fan, RKIG-TB1, RKIG-TB12, RKIG-TB13 and RKIG-TB15. Results of the tests ranged from $1x10^{-5}$ to $5x10^{-5}$ m/s, with the lower hydraulic conductivity from the zones with 12% passing the 200 sieve, and the higher hydraulic conductivity with less than 10% passing the 200 sieve. The results of percolation and slug tests are presented on Table 2.8

Table 2.8: Summary of Percolation and Slug Tests

Test Site	Percolation results (m/s)	Materials
TP-1	$5x10^{-5}$	Silty sand, gravel and silt
TP-12	$8x10^{-5}$	Silty sand, gravel and clay
TP-13	$2x10^{-4}$	Gravel in wall during fast response
TP-15	$<5x10^{-6}$	Silty peat, silty clay

Obs well	Slug Test result (m/s)	
RKIG-TB1	$3x10^{-5}$	<10 % passing 200 sieve
RKIG-TB12	$3x10^{-5}$	<10 % passing 200 sieve
RKIG-TB13	$1x10^{-5}$	Approx 12 % passing 200 sieve
RKIG-TB15	$1x10^{-5}$	Approx 12 % passing 200 sieve

2.3.4 Recharge:

Recharge rates for the site were estimated by first comparing recorded base flows from the Snake River with the watershed model described in Section 2.4. Base flows are the sustained flows of a river or creek between storm or seasonal runoff events, due to groundwater discharge where lakes are not present. Base flow can easily be converted to apparent recharge rate for a watershed by multiplying the flow by the catchment surface area. In this manner a single base flow measurement taken in January, 2004 on Rock Creek resulted in a rate of 110 mm/yr. However this is only one measurement, when ice would make precise measurement difficult and does not consider the expected decay in base flows over the winter. In order for the watershed model (Section 2.4) to output this base flow an annual recharge rate of 250 mm/yr was input. Based on the above findings, an average annual recharge of 200 mm was selected for the Rock Creek catchment.

2.3.5 Groundwater Levels

The groundwater table is expected to be a muted image of the ground topography. This is the case throughout most of the Rock Creek basin. Piezometric surface contours derived from a groundwater modelling calibration are presented on Figure 2.3. Some groundwater level data is presented in Table 2.5. Given the locally moderate permeability of the bedrock, the groundwater levels exhibit more variation than expected. This is probably the result of compartmentalization of the groundwater by low permeability faults in the proposed mine area. The Boulder Creek Fault strikes northwest directly above the pit area, the Rock Creek Fault underlies the creek bed which runs through the pit and Sophies Gulch Fault, a low angle normal fault, can be seen in the surface topography at the southeast corner of the pit. Three other high angle strike slip faults, all of which strike north, are the Anvil Fault, Brynteson Fault and the Upper Albion Creek fault. These faults and probably additional unmapped discontinuities all have the ability to compartmentalize groundwater through low permeability gouge zones and high permeability fractures.

2.4 Site Wide Water Balance

2.4.1 Introduction:

The water balance modelling strategy used for this study was to first develop a model that balanced the recorded flows on Snake River for the 26 years of discharge data with the Nome Airport Precipitation Data. Once the model was calibrated for this time period, it was adjusted to the area of mine operations, more specifically the Rock Creek, Lindblom Creek and Glacier Creek Catchments. The methodology is widely used for consideration of surface water and groundwater conditions in basins (see Alley, 1984 and Steenhuis and Van der Molen, 1986).

2.4.2 Input Areas

The catchment areas input for each of the creeks is presented on Table 2.9

Table 2.9: Areas used for Watershed Models (km^2)

		Elevation Bands		Total
		Under	Above	
Item	Name	1,000 ft	1,000 ft	
1	Snake River	176.82	43.51	220.33
2	Lindblom Creek	1.28	0.03	1.31
3	Rock Creek	3.61	0.77	4.38
4	Glacier Creek	16.60	2.24	18.84

2.4.3 Temperature and Precipitation

The temperature was adjusted for elevation using:

$$T = T_s - \frac{(E-E_s)}{360}$$

where
- T = required temperature (deg C);
- T_s = temperature at Nome Airport (deg C);
- E = elevation of site (m); and
- E_s = elevation at Nome Airport (m)

The precipitation record was constructed by multiplying Nome Airport precipitation by 1.7.

$$P = P_s * K$$

where
- P = required precipitation;
- P_s = precipitation at Nome Airport; and
- K = factor selected through calibration and precipitation data (1.7).

The distribution of precipitation to snow and rainfall assumed that all precipitation fell as rain if the average monthly temperature was greater than 2°C and all as snow if the average

monthly temperature was below -2°C. In between the ratio of precipitation as snow was varied linearly with the temperature between -2°C and 2°C.

The elevation gain of the site was too small to require any further linear extrapolation of precipitation data with elevation gain.

2.4.4 Sublimation

Sublimation is complex and requires tabulation of a number of variables for a rigorous determination. In this analysis, we have assumed that maximum sublimation is 0.3 mm/day. Sublimation was allowed in the months November through April. Although sublimation rates may be high during snowmelt, the sublimation is often countered by night time condensation into the snow pack. Sublimation therefore was not considered for May and June. The snow was assumed to sublimate at the set rate until none remained on the ground.

2.4.5 Snowmelt

Although snowmelt can be estimated, the required meteorological parameters are not available for this site. The snowmelt was estimated using a temperature index method. A first order estimate of the apparent losses were:

Snow melt (mm) = 150(T+2).

Where T is the average monthly temperature in °C.

The values (150 and 2) were defined in matching the precipitation record with Snake River Flows. This equation was used to estimate the potential snowmelt for each month. The actual snowmelt was up to the potential after considering the available snow after sublimation. The water available each month was calculated as the sum of snowmelt and rainfall.

2.4.6 Evapotranspiration

Evapotranspiration was calculated with a methodology after Thornthwaite (1948). First, the potential evapotranspiration (PET) was estimated based on the average monthly temperature and modified by the site latitude and the number of days in the month. The monthly water balance was calculated assuming the soil profile could retain some moisture from month to month. A maximum soil moisture retention was defined. The balance considered losses and gains to soil moisture, rainfall and snowmelt, evapotranspiration and surplus water (available for infiltration and runoff). Evapotranspiration was limited by the soil moisture condition. Below the soil moisture capacity of the soil, the PET was reduced linearly with soil moisture.

During snowmelt, the ground may be frozen, preventing contribution of snowmelt to soil moisture, and thereby contributing more water to runoff. This was addressed by preventing any contribution to soil moisture below a set temperature and ramping the water available to soil moisture up linearly to a second temperature. Finally, based on calibration to Snake River flows, a portion of the PET (0.7) was selected to provide an analogue for runoff and recharge speeds that limited the evapotranspiration over the month.

Open water was assumed to evaporate at the full PET.

2.4.7 Infiltration

Infiltration was modelled at an adjustable rate that is dependent on surface conditions, soil permeability and available storage capacity. The infiltration was set equal to available water up to a volume equal to the product of an infiltration rate and the subcatchment area. For wetter months, a fraction of the remaining available water was infiltrated.

2.4.8 Groundwater Discharge

Water was infiltrated into storage in each subcatchment. The infiltration accumulated within the groundwater compartment was released at a rate determined by the product of the volume of water in storage and a discharge factor. In this way, month to month storage was allowed within each subcatchment, with increasing discharge rate with increasing groundwater in storage. Lower discharge factors resulted in larger accumulated storage with the same recharge. The effect of decreasing the factor was to cause a more uniform discharge rate.

2.4.9 Model Structure

For each subcatchment, the water available for runoff and infiltration was calculated based on the Thornthwaite calculation and the subcatchment area. The water that was not infiltrated was passed on to the next subcatchment downstream as immediate runoff. Groundwater was stored and released at a rate proportional to the volume in storage. The groundwater released was passed on to the next subcatchment downstream up to an amount defined by estimated transmissivity, width and gradient in the groundwater system. The remainder of the released water was discharged within the subcatchment and was passed on to the next subcatchment downstream with the surface water.

2.4.10 Snake River Watershed Results

There are no long-term flow records of precipitation or flow for Rock Creek. Flow records from the neighboring Snake River and precipitation data from Nome Airport were used for the water balance modelling (rainfall-runoff analysis). The goal of this analysis was to determine the factor by which Nome Airport precipitation data would need to be changed to estimate average precipitation over the Snake River Basin. The gage station on the Snake River includes a catchment area of 85 km^2 (220 km^2) and is located at a bridge 3.7 miles (6 km) inland from Norton Sound at an elevation of 8.6 feet above sea level. Rock Creek, whose catchment covers 1.8 mi^2 (4.7 km^2), is a tributary to the Snake River located 3 miles (5 km) North Northeast of the Snake River gauging station.

The watershed model inputs long-term precipitation and temperature data and outputs flow volumes. The calibrated output and the measured flows are illustrated for the years 1982 to 1992 on Figure 2.5 and the cumulative flow over the period 1983 to 1992 on Figure 2.6. The illustrated match was obtained by multiplying the Nome Airport winter precipitation by 3.0 and the Nome Airport summer precipitation 2.5. The general fit is good over the last years of record. The annual average multiplier of Nome Airport precipitation to generate the Snake River flow volumes was 2.7. As the measured Nome airport precipitation over the 1983 to 1992 period was16.5 in (418 mm), the average Snake River Basin precipitation over that same period was expected to be 44.5 inches (1130 mm). As Rock Creek is not near the headwaters, Rock Creek is most probably less than 40 inches (1000 mm) per year.

2.4.11 Local Watersheds

A few flow measurements were completed on Rock Creek, Glacier Creek and Lindblom Creek for this study. Models similar to the Snake River Watershed model were set up for these three creeks. Calculated flow rates for all four watersheds are presented on Figure 2.7 along with recent flow measurements. The precipitation input to these models used a factor of 2 times the Nome Airport precipitation.

3 OPERATING MINE WATER MANAGEMENT

3.1 Introduction

To minimize fresh surface water runoff from passing through the mine site, surface water from upslope will be diverted through a ditch to Lindblom Creek. Interception ditches will be constructed downstream of the development rock dumps to route this water to Lindblom Creek or Rock Creek. Water will not be diverted to Glacier Creek. A layout of mine facilities including ditches is presented on Figure 3.1

Groundwater moving towards the pit will be intercepted with perimeter pumping wells as shown on Figure 3.2. Well water required to meet process needs (low flow periods) will be pumped to the mill and the remainder will be treated and reintroduced to the groundwater through a Class V injection system.

Water used in process will be recycled except for process losses. Much of the water will be recovered from the slurry at the mill in a thickener. The tailings will be transported to the tailings area as a paste in a pipeline. Supernatant will be recovered from the tailings pond with a reclaim pump. Temporary excess water from snowmelt and rainfall will be stored in the tailings area. This stored water will be used as process water during dry periods.
Process losses will be made up from sources of water on site. Site wide and tailings water management is conceptualized on Figure 3.4.

The losses within the mill and tailings circuit will include:

- water in the tailings pores;
- evaporation from the tailings pond and from moisture on exposed tailings sand;
- seepage from the tailings area;
- minor losses within the mill; and
- minor losses to the foundation pore spaces.

The losses will be made up from:

- direct precipitation and snowmelt within the tailings area during the ice free period;
- moisture content of ore;
- runoff collected from the plant site area;
- mine water pumped from sumps in the open pit;
- seepage recovery from the toe of the tailings dam;
- when required, water from the open pit groundwater interceptor wells will be used in processing. The remainder of the open pit well water will be treated and reinjected to the groundwater.

- When additional make up water is required, water supply wells will be used.

3.2 Open Pit Groundwater Interception wells

3.2.1 Pit Hydrogeology

Recharge areas on the slopes of the upper watershed provide water for creeks, alluvium and deeper groundwater. Shallow groundwater travels down the valley across an alluvial fan and discharges to surface water and alluvium of the Snake River. Excavation of the pit will intersect these groundwaters.

As the pit depth increases, groundwater will be pumped to keep the groundwater level below the bottom of the pit. Storage properties of the aquifer will determine how much water is released from an area by gravity drainage due to a decline in the water table. The pumping will also cause a cone of depression so that the groundwater catchment area of the pit will increase. As a result some areas that were initially not in hydraulic communication with the pit will become sources of pit inflows.

The surface geology and vegetation effect groundwater recharge rates. The site is similar to that of most high latitude regions with low lying shrubs and grass (tundra) cover over most of the area except for some bedrock outcrop on the high steeper slopes. Vegetation can store precipitation allowing a longer time period for evaporation and recharge.

The primary bedrock geologic units in the pit area are calcareous schists and marbles from the Nome Group. Fractures in the bedrock are the primary matrix for the transportation of groundwater towards the pit. Hydraulic heterogeneities, low permeable gouge zones and high permeability fractures through bedrock, will cause compartmentalization of groundwater.

Another control on groundwater movement and recharge is permafrost. Groundwater flow is impeded by permafrost. Test pits and boreholes to the west of the pit have intersected permafrost that reaches depths of up to 100 ft. Groundwater was observed in some permafrost areas to concentrate flow above the frozen surface or just below the tundra. This concentration of near surface flow above frozen ground (observed near the top of Rock Creek) was also observed in non permafrost areas. Pit inflows may be influenced if the excavation passes through frozen ground.

Permafrost was not considered when estimating pit inflows but is recognized as a potential factor in controlling groundwater movement.

3.2.2 Groundwater Model

A 2D (single layer) finite difference groundwater model was produced using MODFLOW and Vistas 4 which is a user interface for MODFLOW. The groundwater model includes watershed catchments of Rock Creek, Lindblom Creek, Prospect Creek and some of Glacier Creek. The top elevation is 1480 ft (450) m at Brynteson Mountain and a bottom elevation of -300 ft (–100 m), significantly below the depth of the proposed pit. This single layer model does not consider vertical movement of groundwater. As a result all mine elements are assumed to completely penetrate the aquifer.

Hydraulic heads and regional discharges were the two calibration targets for modelling. Hydraulic head elevations were available at spring locations and at monitoring wells. Regional flow rates have been recorded historically for the Snake River and have been recently measured for Rock Creek, Lindblom Creek and Glacier Creek. Low flow (base flow) measurements are the result of groundwater discharges in the absence of major lakes in the system.

The recharge rates required to produce the target hydraulic heads were estimated with a range of hydraulic conductivities. As hydraulic conductivity is lowered less recharge is required to produce the target potentiometric surface. The results of this investigation are shown in Table 3.1. The values that were tested are within the appropriate boundaries for both conductivity and recharge. The highlighted values were used in the calculations, as they are considered to be a reasonable value given the information available. The piezometric surface illustrated on Figure 2.3 is output from the calibrated groundwater model.

Table 3.1: Relationship Between Hydraulic Conductivity and Recharge

K (m/s)	Recharge (mm/yr)
1.9×10^{-7}	95
3.0×10^{-7}	158
3.8×10^{-7}	200
6.3×10^{-7}	300

3.2.3 Dewatering Calculations

Mining will continue for a period of up to four years, with the ultimate pit floor at an elevation of about 10 m below sea level. The pit outline and depths were input to the groundwater model described above and the groundwater flows to dewatering wells calculated to keep the pit floor dry. The dewatering rate calculated using the groundwater model is presented on Table 3.2.

Table 3.2: Estimate of Groundwater Dewatering Rate from Pit Wells

End of Year	Elevation of pit bottom (m)	Pit Well Field Pumping Rate (gpm)	Number of Perimeter wells
2006	Phase I = 85 Phase II = 95		5
2007	Phase I = 60 Phase II = 80	600	11
2008	Phase I = 50 Phase II = 45	600	11
2009	Phase I = 50 Phase II = 0 Phase III = 115	635	11
2010	Phase I = 50 Phase II = -10 Phase III = 70	635	11

The expected maximum required pumping rate from the open pit perimeter interception wells will be 635 gpm (Table 3.2). Pumping will need to begin at 600 gpm early in mine life to meet planned mine depth. Installation of three wells (together with operation of two existing wells) is recommended in 2006 so that excavation below the water table will be possible early in 2007.

The dewatering rate estimate is based on an assumption of average groundwater recharge (200 mm/year) and that the single layer model will provide a reasonable estimate of inflows. If permafrost cover is extensive, then recharge over the remaining ground would need to be higher (for example, if permafrost covers 50% of the ground, the average recharge rate over the remaining ground would need to be 400 mm, which is about 50 % of precipitation). From this standpoint, an average annual recharge of 200 mm is conservative.

The calculations also allow complete penetration of the aquifer by the pumping wells, which will not be true. Incomplete penetration of the wells will result in more drawdown near the wells with a vertical component of groundwater flow to the well screens. This provides an additional component of conservatism to the perimeter well design.

Based on air lift production testing, pumping rates from producing wells will vary from 50 to 150 gpm. About 11 such production wells are anticipated to be required around the perimeter of the pit. Possible locations for the wells are illustrated on Figure 3.2 A static head of 300 to 500 ft is expected. This should be possible with submersible pumps of 5 to 15 horsepower if head loss in installed piping is low.

The submersible pumps will be connected to a header that will transfer the pumped water to process or to the Class V injection area via the treatment system (section 3.5.5). Also included in the perimeter well system will be hour meters, flow measurement devices, well water level meters and piezometers for measuring system effectiveness.

3.3 Class V Underground Injection System

3.3.1 Background

The objective is to reinject water from the pit pumping wells that is not required in the process. The reinjection would be using Class V wells, relatively shallow and simply constructed devices which inject under the force of gravity. In wet weather, all of the water from the perimeter wells may need to be treated and injected. In dry weather and particularly in the winter, much of the water from the perimeter wells will be used in process. Injection methods considered were:

- Injection wells or dry wells
- Seepage pits
- Drainfields
- Surface discharge
- Infiltration gallery

Based on site investigation work, limited injection using a drainfield is possible on the Rock Creek fan. The remainder of the water will be injected into bedrock wells.

3.3.2 Rock Creek Fan Injection Site

This Class V reinjection system will be located on the Rock Creek fan. The fan toe is adjacent to side channels of the Snake River. Water injected into this fan would migrate through the fan deposits towards the toe of the fan where it would discharge into alluvium and into the side channels at the toe of the fan.

During operations, water from the upper reaches of the Rock Creek basin will be diverted to Lindblom Creek, reducing the quantity of water reaching this fan. Following treatment, the water from the pit pumping wells will be reinjected to the fan to make up for this reduction.

Drilling and testing indicated that the upper half of the fan is underlain by suitably permeable material. The injection system will consist of a network of perforated pipes buried within the Rock Creek alluvial fan. The installation of the system will require trench excavation, pipe installation within the trenches and encapsulation of the pipes with imported gravel materials. The trenches will then be backfilled with the native alluvial materials to the natural ground elevation. The injection system will cross the upper part of the fan in a north south direction, about 200 m downslope of the fan apex.

The capacity of this system was estimated to be about 100 gpm. The velocity from the injection system to discharge points downstream was calculated as follows:

v = Ki/n, where	
K (hydraulic conductivity) =	$5x10^{-5}$ m/s and
i (gradient) =	0.02 and
n (porosity) =	0.25; so
v (velocity) =	4x10-6 m/s or 0.35 m/day

The distance to the toe of the fan is approximately 700 m, so the travel time to the fan toe is approximately 2,000 days or 5.5 years.

3.3.3 Bedrock Injection Well Field

All of the perimeter well water not used in process, except the 100 gpm injected into the fan, will be injected into the bedrock injection wells. The preliminary locations for these wells are illustrated on Figure 3.2. Pumping test results and water returns during drilling indicate fracture sets are permeable enough to receive the remaining water. Injection pumping may be required.

Each well will inject into a relatively permeable environment that is bounded by lower permeability materials. This will result in considerable dispersion of the injected water along a variety of discontinuous fractures and fault. The dispersed water will enter alluvium at depth under the local surface water, and travel downstream in the alluvium prior to discharging along a considerable length of Snake River.

Each well will be about 120 m deep. The top 50 m will be sealed to prevent annular flow to the ground surface. The lower 70 m will be screened for injection. Actual dimensions will be adjusted during construction. The injection capacity of the wells should exceed 50 gpm.

A total of 15 injection wells are anticipated to be adequate for injecting the required volume of water. The injection program will include resting of wells to allow dissipation of groundwater mounding.

Travel time of groundwater flowing into the injection wells to the Snake River alluvium was calculated with the same numerical model used to estimate perimeter well pumping rates. Travel path lines with travel times (in years) are shown of Figure 3.2. Calculated travel times are in excess of two years. Typically, about 10 wells will be in operation during the summer months, and about four wells injecting through the winter. Figure 3.3 presents a schematic cross section through the injection wells with estimated pre-mine flows as well as flow direction of injected water.

3.4 Mill and Tailings Circuit Water Losses

3.4.1 Tailings Voids

The majority of the losses in the mill and tailings circuit are to tailings voids. In this project, these losses have been reduced by adopting a paste tailings placement system rather than a conventional tailings pond system. This results in a higher density tailings and lower void volume. The tailings assumptions are:

- Solids specific gravity of 2.75 tonnes/m^3;
- A dry unit weight of the paste tailings of 1.52 tonnes/m^3;
- A milling rate of 7,000 tonnes/day of ore; and
- A tailings saturation of 85%.

The resulting void ratio is 0.447 and water lost to voids is 2,750 m^3/day (320 gpm).

3.4.2 Evaporation

Evaporation losses occur from tailings area open water and from moisture on exposed tailings deposits. Evaporation was estimated using the Thornthwaite (1948) procedure. The full PET was used for open water. Some of the tailings area will be a natural ground surface. The water balance on this natural ground was calculated with the same parameters as used for the pre-mine condition (see Section 2.4). Evaporation from the pond requires an assumption of the pond area. The relationship between pond area and water volume used was:

Volume (m3)	Area (m^2)
1,000	13,600
10,000	15,700
50,000	24,800
100,000	35,900
200,000	57,000
500,000	112,800

The evaporation losses from the surface of the pond were based on the PET values listed on Table 2.4.

Evaporation from the tailings deposit was a product of the tailings area and the expected evaporation rate. The tailings area was estimated by subtracting the pond area from the total expected area. The total expected area used was:

End of year	Total Area (m^2)
1	271,140
2	360,171
3	441,108
4	497,764

The evaporation rate used was the PET on Table 2.5, but only 50% of the result was taken to account for the likely dry areas on the tailings surface.

Sublimation was accounted for on natural surfaces, but was not included in the tailings pond balance.

3.4.3 Seepage

Seepage from the tailings area will be minimized by keeping the stored volume of water low, and by appropriate design of the tailings dam. Seepage from the pond was estimated as a function of the stored water volume. The seepage rate used was:

Volume (m3)	Seepage (m^3/day)
20,000	1.1
50,000	1.6
100,000	2.6
200,000	4.9
500,000	13.5

3.4.4 Minor Losses

Other minor losses considered were net losses in the mill area such as loss to evaporation and product and gain from moisture in the ore and losses to the foundation pore spaces as the tailings elevation increased. The assumptions were:

- Approximately 3.3 m^3/day (0.6 gpm) lost in the mill area; and
- Approximately 50 m^3/day (9 gpm) lost to pore spaces in the tailings foundation.

3.5 Mill and Tailings Circuit Water Makeup

3.5.1 Rainfall and Snowmelt in Tailings Area

Diversion ditches upslope of the tailings facility will reduce the quantity of water entering the mine area from precipitation and snowmelt. The surface area used to estimate the quantity flowing into the tailings area was 651,667 m^2. The quantity of water from this source was modified to account for sublimation and evapotranspiration, both on natural ground and tailings surface. Water will also accompany the underflow from the tailings thickener (2460 m^3/day). The pond area accepted the total water volume and the full evaporation rate (in losses) was applied to the pond area. The pond area did not include sublimation. Other pond losses were seepage (Section 3.4.3), water lost to voids (Section 3.4.1) and water pumped to the reclaim tank.

3.5.2 Plant Site Runoff

Rainfall and snowmelt within the plant site collection ditches will be routed directly to the mill recycle water pond where it will be used as make up water to the mill circuit. The plant site area used was 194,249 m^2.

3.5.3 Open Pit Surface Water Inflows

The surface water runoff component of inflow to the pit will be minimized by the construction of ditches upslope of the pit (see Section 3.1) to divert water to Lindblom Creek. The inflow will be further reduced by construction of temporary diversion ditches to direct most of the area below the diversion ditch into Rock Creek. Inflow from surface water will be derived primarily from direct snowmelt and precipitation. Although some snow will be removed from the pit during operations this component has not been included in the estimate due to the small proportion.

The catchment area reporting to the pit sumps was estimated to be:

year	Area (m^2)
1	225,000
2	225,000
3	285,000
4	285,000

The proposed open pit dewatering system will require sumps which will manage surface water inflows and residual groundwater inflows not captured by the groundwater interception wells. Water collected will be routed to the mill recycle pond if required. Excess pit water will be treated and injected. As much of the runoff will be snowmelt, there may be a period in the spring when there may be some ponding on the pit floor, until it can be removed with installed treatment and injection capacity.

3.5.4 Seepage Recovery

Seepage will be recovered from the toe of the tailings dam to isolate the tailings from the downstream environment. Water collected from this facility will be pumped directly to the reclaim water tank where it will feed the mill recycle water pond. The quantity of water to be collected from this facility includes runoff from the small area that this facility will capture, and a groundwater component that is a function of the calculated volume of groundwater that is in storage. Seepage from the tailings area and local recharge contribute to volume of groundwater in storage. Typical recovery rates are expected to range up to 500 m^3/day (90 gpm) with an average annual rate of up to 150 m^3/day (25 gpm).

3.5.5 Open Pit Perimeter Wells

Water from the open pit perimeter wells will be treated and discharged to a Class V underground injection system. Water in excess of the treatment plant capacity will be routed to the mill circuit or the tailings pond. In dry periods (when the tailings pond is dry or frozen), water from the perimeter wells will be used for make up water.

3.6 Operating Site Wide Water Balance

3.6.1 General

The site wide water balance for operating conditions was developed with the same calculation procedure as described in Section 2.4. The conceptual surface and mill water flow diagram is presented as Figure 3.4. Subcatchment areas were established to reflect natural and operations barrier to flows. The watersheds were divided into subcatchments to facilitate suitable inflows for mine operation planning. The subcatchments are illustrated on Figure 3.5 and are listed along with their respective surface area in Table 3.3. The model was run over the life of the mine with average climate conditions (1978 precipitation distribution).

Table 3.3: Site Wide Water Balance Subcatchment Areas

		Elevation Bands		
		Lower	Upper	Total
Area	Name	<1000'	>1000'	(m^2)
1	Lindblom Creek	1,335,484	29,060	1,364,544
2	North Development Rock Dump Catchment	246,783		246,783
3	North Development Rock Dump	793,251		793,251
4	Plant Site	194,249		194,249
5	Snake River and Rock Ck Wetlands	3,757,560		3,757,560
6	Snake River u/s of Glacier Creek	125,199,654	40,575,369	165,775,023
7	Open Pit Catchment	1,564,202	807,389	2,353,681
8	Open Pit	824,013		824,,013
9	South Development Rock Dump Catchment	124,247		124,247
10	Tailings Impoundment	651,667		651,667
11	Seepage Collection	27,082		27,082
12	Glacier Creek Catchment	19,602,219	2,096,697	21,698,916
13	South Development Rock Dump	503,591		503,591

Table 3.4 presents the climatic (precipitation and temperature) conditions that were used in the calculations.

Most of the water demand is from tailings operations. This includes water retained in tailings and foundation materials as well as seepage and evaporation. Evaporation will occur both from the tailings solid surface and from the retained pond. A total of 47 months of operations was assumed.

The tailings area is designed to retain excess water from snowmelt or rainfall events. This will result in some ponding. The storage available for water should retain the wet year pond volume and the design storm.

Table 3.4: Life of Mine Assumed Climatic Inputs

	Temperature (°C)			Precipitation (mm)	
Month	Nome	<1,000'	>1,000'	Nome	Site
Jan	-5.8	-6.2	-7.0	10.9	18.6
Feb	-11.2	-11.6	-12.5	10.2	17.3
Mar	-11.9	-12.3	-13.1	5.6	9.5
Apr	-3.9	4.4	-5.2	27.7	47.1
May	5.6	5.2	4.4	9.9	16.8
June	7.1	6.6	5.8	105.4	179.2
July	12.5	12.1	11.2	42.4	72.1
Aug	12.4	12.0	11.1	63.2	107.5
Sept	8.1	7.7	6.9	89.9	152.9
Oct	-2.8	-3.2	-4.0	19.1	32.4
Nov	-4.5	-4.9	-5.8	43.9	74.7
Dec	-9.8	-10.2	-11.1	30.5	51.8
Annual				458.7	779.8

Site precipitation 1.7 times Nome Airport precipitation

3.6.2 Life of Mine Water Balance

A site wide water balance was prepared that combined all the site water including estimates of seepage loss from the tailings area, pit inflows, development rock dump storage, and site discharge requirements. The methodology followed the general procedures defined in Section 2.4. The life of mine water balance was calculated using the average climatic conditions presented on Table 3.4. Water losses were primarily tailings pore water lock-up, tailings seepage, evaporation from the tailings area and net losses within the mill. Mill circuit water is derived from the mill recycle water pond. Mill recycle water pond sources are in order of need:

- Thickener water.
- Plant site precipitation/runoff. All of this water would be used.
- Water from the reclaim tank, which is derived from water from the seepage collection system and the tailings pond. As there is little storage associated with the seepage collection sump, it is assumed that this source is used in preference to the tailings water which could pond.
- Open pit precipitation/runoff if required. When not required, this water would be treated and injected in a Class V injection system.
- Pit interception wells, if required. When not required, this water would be treated and injected in a Class V injection system.

Table 3.5 lists the expected water balance items for the 4 year mine life while pumping the pit interception wells at the rate listed in Table 3.2. Treatment plant and injection well capacity was assumed to be adequate to meet the needs of operations. Following are comments regarding the information on Table 3.5.

- All of the water from the plant site will report directly to the mill recycle pond with water from the thickener. In addition all of the water from the seepage collection sump will report to the mill recycle pond, through the reclaim water tank.
- Table 3.5 indicates that the mill recycle storage will contain 20,000 m^3 through most of the year. In practise, this volume will be drawn down to provide some storage for wet periods.

- Table 3.5 indicates that essentially none of the open pit runoff will be used in the process, and this water will be treated and injected to ground in a Class V system. Nonetheless, whenever possible during operations, open pit runoff should be pumped to the mill recycle water pond for use as process water.
- During dry periods, and particularly during the winter, some of the pit interception well water will be pumped to the mill recycle water pond. The remainder of the interception well water will be treated and injected in a Class V Injection System.
- Table 3.5 indicated that the most significant contributors of water to the TSF are thickener underflow and runoff within the TSF area.
- The water from the tailings pond will report to the mill recycle pond through the reclaim water tank in ice free months (May through November). Through the winter, water will accumulate in the pond, predominantly as snow and ice. During snowmelt, and perhaps in wet summer/fall months, there will be excess water that will pond in the tailings storage facility. The calculated volume of water stored in the pond over the mine life is illustrated on Figure 3.6.
- Significant volumes of water will be diverted to Lindblom and Rock creeks, thereby reducing the volume of water that must be managed on site.

3.6.3 Wet and Dry Water Balance

To illustrate the impact of operating in wet or dry years, the water balance was run in a repeating mode rather than a life of mine mode. The water balance was computed for year 1 using the climate data from 1907 to 2004. Ten year return period wet and dry conditions were selected by computing statistics on the annual runoff rather than the precipitation, as runoff is more important to mine operations. The selected climate years to represent expected operating conditions were:

- 1978 for the average year;
- 1933 for the 10 year return period dry year; and
- 1932 for the ten year return period wet year.

Table 3.6 provides a summary of the average, wet and dry year site responses for the first year of operations with twice Nome precipitation and a pit interception well pumping rate of 600 to 635 gpm.

With the dry year (1933), water from the interception wells is required for process make up (to the Mill Recycle Water Pond) over most of the year. The tailings pond is expected to dry for five months. Although pit runoff would be treated, very little runoff is predicted from the pit in these dry conditions.

With the wet year (1932), water from the interception wells is mostly treated and released through the year as is the pit runoff. The tailings pond fluid volume exceeds 280,000 m^3 in June of the wet year.

Under the range of conditions examined, the annual treatment volume in year one would range from 562,000 to 866,000 m^3.

Table 3.5: Water Balance Calculation Summary (m^3) for 1978 Climate Year

Year	Month	Water Sources					Mill Recycle Water Pond								Tailings Pond								Treated and Injected			Diverted Water			
							from					to			from		To												
		pit runoff	interception wells	seepage recovery	plant site runoff	tailings runoff	plant site	seepage recovery	tailings pond	pit runoff	interception wells	net mill losses	thickener underflow	Pond Volume	tailings runoff	thickener underflow	Seepage	Bank Storage	Evaporation	Pore water lock up	Recycle Pond	Pond Volume	from interception wells	from pit runoff	total	Upper Channel to Lindblom	North Rk Dump to Lindblom	Pit Catchment to Rock Ck	South Rk Dump to Rock Ck
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385	7,400	6,437
	2	979	94,962	0	213	1,119	213	0	0	979	67,788	100	68,880	0	1,119	68,880	0	1,500	0	49,023	0	19,476	27,175	0	27,175	0	22	2,607	2,771
	3	0	101,511	0	0	0	0	0	0	0	96,285	100	76,260	19,925	0	76,260	34	1,500	0	54,276	0	39,925	5,226	0	5,226	0	11	0	4
	4	0	98,237	0	0	0	0	0	0	0	73,975	100	73,800	20,000	0	73,800	44	1,500	0	52,525	0	59,656	24,262	0	24,262	0	5	0	2
	5	25,264	101,511	3,288	26,275	82,139	26,275	3,288	46,796	0	0	100	76,260	20,000	82,139	76,260	2,163	1,500	5,343	54,276	46,796	107,977	101,511	25,264	126,776	308,052	84,570	67,261	57,984
	6	16,451	98,237	2,898	17,907	63,867	17,907	2,898	53,095	0	0	100	73,800	20,000	63,867	73,800	2,383	1,500	9,264	52,525	53,095	126,877	98,237	16,451	114,688	186,874	53,533	43,798	35,917
	7	1,180	101,511	1,337	0	21,875	0	1,337	75,023	0	0	100	76,260	20,000	21,875	76,260	1,257	1,500	16,287	54,276	75,023	76,668	101,511	1,180	102,691	0	3,830	3,141	1,356
	8	417	101,511	1,426	2,011	28,920	2,011	1,426	72,923	0	0	100	76,260	20,000	28,920	76,260	2,129	1,500	13,880	54,276	72,923	37,140	101,511	417	101,929	0	4,777	1,111	1,691
	9	15,421	98,237	3,639	16,972	60,835	16,972	3,639	53,288	0	0	100	73,800	20,000	60,835	73,800	3,296	1,500	7,861	52,525	53,288	53,304	98,237	15,421	113,657	172,506	47,833	41,054	32,662
	10	1,225	101,511	1,944	0	7,178	0	1,944	74,416	0	0	100	76,260	20,000	7,178	76,260	53	1,500	0	54,276	74,416	6,498	101,511	1,225	102,737	0	3,527	3,263	1,249
	11	0	98,237	1,373	0	3,888	0	1,373	30,161	0	32,527	100	73,800	10,161	3,888	73,800	0	1,500	0	52,525	30,161	0	65,709	0	65,709	0	1,698	0	601
	12	0	101,511	926	0	1,109	0	926	0	0	66,866	100	76,260	1,593	1,109	76,260	0	1,500	0	54,276	0	21,593	34,646	0	34,646	0	818	0	290
2	1	0	101,993	608	0	0	0	608	0	0	94,159	100	76,260	20,000	0	76,260	36	1,500	0	54,276	0	42,041	7,835	0	7,835	0	394	0	139
	2	0	92,559	409	0	0	0	409	0	0	71,031	100	71,340	20,000	0	71,340	42	1,500	0	50,774	0	61,065	21,528	0	21,528	0	190	0	67
	3	0	102,958	212	0	0	0	212	0	0	76,148	100	76,260	20,000	0	76,260	57	1,500	0	54,276	0	81,492	26,810	0	26,810	0	91	0	32
	4	0	100,103	102	0	0	0	102	0	0	73,798	100	73,800	20,000	0	73,800	67	1,500	0	52,525	0	101,200	26,305	0	26,305	0	44	0	16
	5	25,264	103,922	3,990	26,275	93,337	26,275	3,990	46,095	0	0	100	76,260	20,000	93,337	76,260	5,886	1,500	12,050	54,276	46,095	150,991	103,922	25,264	129,186	308,052	79,185	67,261	56,078
	6	15,283	101,036	4,225	17,907	73,092	17,907	4,225	51,768	0	0	100	73,800	20,000	73,092	73,800	4,856	1,500	16,314	52,525	51,768	170,918	101,036	15,283	116,319	186,874	53,457	40,688	35,890
	7	0	104,886	2,746	0	28,831	0	2,746	73,614	0	0	100	76,260	20,000	28,831	76,260	2,067	1,500	24,743	54,276	73,614	119,810	104,886	0	104,886	0	8,129	0	2,878
	8	0	105,368	2,711	2,011	38,820	2,011	2,711	71,638	0	0	100	76,260	20,000	38,820	76,260	3,186	1,500	20,161	54,276	71,638	84,127	105,368	0	105,368	0	9,551	0	3,382
	9	14,169	102,436	4,903	16,972	64,585	16,972	4,903	52,025	0	0	100	73,800	20,000	64,585	73,800	4,646	1,500	11,158	52,525	52,025	100,658	102,436	14,169	116,604	172,506	46,320	37,721	32,126
	10	0	106,332	3,058	0	5,942	0	3,058	73,302	0	0	100	76,260	20,000	5,942	76,260	81	1,500	0	54,276	73,302	53,701	106,332	0	106,332	0	6,696	0	2,371
	11	0	103,369	2,207	0	2,975	0	2,207	71,693	0	0	100	73,800	20,000	2,975	73,800	51	1,500	0	52,525	71,693	4,706	103,369	0	103,369	0	3,224	0	1,142
	12	0	107,297	1,549	0	433	0	1,549	0	0	60,434	100	76,260	5,623	433	76,260	0	1,500	0	54,276	0	25,623	46,863	0	46,863	0	1,552	0	550
3	1	0	107,297	1,069	0	0	0	1,069	0	0	89,667	100	76,260	20,000	0	76,260	38	1,500	0	54,276	0	46,070	17,629	0	17,629	0	747	0	265
	2	0	96,913	750	0	0	0	750	0	0	68,230	100	68,880	20,000	0	68,880	44	1,500	0	49,023	0	64,383	28,683	0	28,683	0	360	0	127
	3	0	107,297	465	0	0	0	465	0	0	75,895	100	76,260	20,000	0	76,260	59	1,500	0	54,276	0	84,807	31,401	0	31,401	0	173	0	61
	4	0	103,836	289	0	0	0	289	0	0	73,611	100	73,800	20,000	0	73,800	69	1,500	0	52,525	0	104,513	30,225	0	30,225	0	83	0	30
	5	32,002	107,297	4,375	26,275	99,174	26,275	4,375	45,709	0	0	100	76,260	20,000	99,174	76,260	7,777	1,500	15,197	54,276	45,709	155,489	107,297	32,002	139,298	308,052	73,799	60,524	54,171
	6	19,359	103,836	4,972	17,907	79,515	17,907	4,972	51,021	0	0	100	73,800	20,000	79,515	73,800	6,510	1,500	20,594	52,525	51,021	176,653	103,836	19,359	123,194	186,874	53,381	36,613	35,863
	7	0	107,297	3,597	0	34,680	0	3,597	72,763	0	0	100	76,260	20,000	34,680	76,260	2,704	1,500	30,765	54,276	72,763	125,585	107,297	0	107,297	0	12,428	0	4,400
	8	0	107,297	3,541	2,011	47,293	2,011	3,541	70,808	0	0	100	76,260	20,000	47,293	76,260	4,090	1,500	24,886	54,276	70,808	93,577	107,297	0	107,297	0	14,326	0	5,072
	9	17,947	103,836	5,801	16,972	68,499	16,972	5,801	51,127	0	0	100	73,800	20,000	68,499	73,800	5,919	1,500	13,825	52,525	51,127	110,979	103,836	17,947	121,782	172,506	44,806	33,942	31,590
	10	0	107,297	3,888	0	5,139	0	3,888	72,472	0	0	100	76,260	20,000	5,139	76,260	88	1,500	0	54,276	72,472	64,042	107,297	0	107,297	0	9,865	0	3,493
	11	0	103,836	2,822	0	2,381	0	2,822	71,078	0	0	100	73,800	20,000	2,381	73,800	57	1,500	0	52,525	71,078	15,063	103,836	0	103,836	0	4,750	0	1,682
	12	0	107,297	2,009	0	0	0	2,009	0	0	69,866	100	76,260	15,515	0	76,260	32	1,500	0	54,276	0	35,515	37,431	0	37,431	0	2,287	0	810
4	1	0	107,297	1,414	0	0	0	1,414	0	0	79,431	100	76,260	20,000	0	76,260	43	1,500	0	54,276	0	55,956	27,865	0	27,865	0	1,101	0	390
	2	0	96,913	1,006	0	0	0	1,006	0	0	67,974	100	68,880	20,000	0	68,880	49	1,500	0	49,023	0	74,263	28,939	0	28,939	0	530	0	188
	3	0	107,297	655	0	0	0	655	0	0	75,705	100	76,260	20,000	0	76,260	65	1,500	0	54,276	0	94,683	31,592	0	31,592	0	255	0	90
	4	0	103,836	432	0	0	0	432	0	0	73,468	100	73,800	20,000	0	73,800	75	1,500	0	52,525	0	114,383	30,367	0	30,367	0	123	0	44
	5	32,002	107,297	4,691	26,275	104,215	26,275	4,691	45,394	0	0	100	76,260	20,000	104,215	76,260	9,382	1,500	17,968	54,276	45,394	166,339	107,297	32,002	139,298	308,052	68,414	60,524	52,264
	6	19,359	103,836	5,580	17,907	89,192	17,907	5,580	50,413	0	0	100	73,800	20,000	89,192	73,800	7,782	1,500	24,014	52,525	50,413	193,098	103,836	19,359	123,194	186,874	53,306	36,613	35,837
	7	0	107,297	4,279	0	38,260	0	4,279	72,081	0	0	100	76,260	20,000	38,260	76,260	3,217	1,500	35,855	54,276	72,081	140,689	107,297	0	107,297	0	16,727	0	5,922
	8	0	107,297	4,211	2,011	53,681	2,011	4,211	70,138	0	0	100	76,260	20,000	53,681	76,260	4,849	1,500	29,054	54,276	70,138	110,813	107,297	0	107,297	0	19,100	0	6,763
	9	17,947	103,836	6,534	16,972	77,314	16,972	6,534	50,393	0	0	100	73,800	20,000	77,314	73,800	6,986	1,500	16,172	52,525	50,393	134,350	103,836	17,947	121,782	172,506	43,292	33,942	31,054
	10	0	107,297	4,571	0	2,380	0	4,571	71,789	0	0	100	76,260	20,000	2,380	76,260	103	1,500	0	54,276	71,789	85,322	107,297	0	107,297	0	13,034	0	4,615
	11	0	103,836	3,331	0	341	0	3,331	70,569	0	0	100	73,800	20,000	341	73,800	69	1,500	0	52,525	70,569	34,800	103,836	0	103,836	0	6,276	0	2,222
	12	0	107,297	2,388	0	0	0	2,388	0	0	73,972	100	76,260	20,000	0	76,260	42	1,500	0	54,276	0	55,241	33,325	0	33,325	0	3,022	0	1,070

Table 3.6: Year One Water Balance (m3) Calculation Summary for Dry, Average and Wet Years

Year	Month	Water Sources					Mill Recycle Water Pond								Tailings Pond									Treated and Injected			Diverted Water			
							from					to			from			To						from	from	total	Upper	North Rk	Pit	South Rk
		pit runoff	interception wells	seepage recovery	plant site runoff	tailings runoff	plant site	seepage recovery	tailings pond	pit runoff	interception wells	net mill losses	thickener underflow	Pond Volume	tailings runoff	tailings moisture	thickener underflow	Seepage	Bank Storage	Evaporation	Pore water lock up	Recycle Pond	Pond Volume	interception wells	pit runoff		Channel to Lindblom	Dump to Lindblom	Catchment to Rock Ck	Dump to Rock Ck
Dry 1933	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,400	6,412
	2	997	91,688	0	243	3,361	243	0	0	997	69,458	100	68,880	1,718	3,361	0	68,880	0	1,500	0	49,023	0	21,718	22,230	0	22,230	0	0	2,653	2,847
	3	0	101,511	0	0	794	0	0	0	0	94,642	100	76,260	20,000	794	0	76,260	36	1,500	0	54,276	0	42,960	6,869	0	6,869	0	0	0	5
	4	0	98,237	0	0	0	0	0	0	0	73,900	100	73,800	20,000	0	0	73,800	45	1,500	0	52,525	0	62,689	24,337	0	24,337	0	0	0	2
	5	11,721	101,511	1,534	18,824	55,084	18,824	1,534	56,003	0	0	100	76,260	20,000	55,084	0	76,260	1,113	1,500	0	54,276	56,003	81,141	101,511	11,721	113,233	105,916	14	31,206	49,949
	6	0	98,237	450	0	7,809	0	450	73,450	0	0	100	73,800	20,000	7,809	0	73,800	676	1,500	9,652	52,525	73,450	24,946	98,237	0	98,237	81,374	1	0	582
	7	0	101,511	387	0	4,194	0	387	35,000	0	35,973	100	76,260	15,000	4,194	0	76,260	417	1,500	14,208	54,276	35,000	0	65,539	0	65,539	0	0	0	280
	8	0	101,511	551	0	22,297	0	551	28,286	0	40,810	100	76,260	8,286	22,297	0	76,260	2,230	1,500	12,265	54,276	28,286	0	60,702	0	60,702	0	2	0	1,384
	9	0	98,237	744	0	8,513	0	744	22,279	0	44,870	100	73,800	2,279	8,513	0	73,800	851	1,500	5,158	52,525	22,279	0	53,367	0	53,367	0	1	0	811
	10	0	101,511	579	0	0	0	579	20,484	0	53,502	100	76,260	484	0	0	76,260	0	1,500	0	54,276	20,484	0	48,009	0	48,009	0	0	0	351
	11	0	98,237	357	0	0	0	357	19,775	0	53,284	100	73,800	0	0	0	73,800	0	1,500	0	52,525	19,775	0	44,952	0	44,952	0	0	0	169
	12	0	101,511	175	0	0	0	175	0	0	76,669	100	76,260	484	0	0	76,260	0	1,500	0	54,276	0	20,484	24,843	0	24,843	0	0	0	68
Average 1978	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7,400	6,412
	2	997	91,688	0	246	3,567	246	0	0	997	69,660	100	68,880	1,923	3,567	0	68,880	0	1,500	0	49,023	0	21,923	22,028	0	22,028	0	0	2,653	2,847
	3	0	101,511	0	0	945	0	0	0	0	94,437	100	76,260	20,000	945	0	76,260	36	1,500	0	54,276	0	43,317	7,074	0	7,074	0	0	0	5
	4	0	98,237	0	0	0	0	0	0	0	73,900	100	73,800	20,000	0	0	73,800	46	1,500	0	52,525	0	63,046	24,337	0	24,337	0	0	0	2
	5	12,922	101,511	1,750	19,963	64,948	19,963	1,750	54,646	0	0	100	76,260	20,000	64,948	0	76,260	1,651	1,500	5,370	54,276	54,646	86,811	101,511	12,922	114,433	200,948	16	34,401	53,196
	6	14,912	98,237	2,603	20,283	72,991	20,283	2,603	51,014	0	0	100	73,800	20,000	72,991	0	73,800	2,453	1,500	9,053	52,525	51,014	117,057	98,237	14,912	113,149	204,718	18	39,701	54,671
	7	1,803	101,511	1,341	0	16,547	0	1,341	75,019	0	0	100	76,260	20,000	16,547	0	76,260	1,266	1,500	16,146	54,276	75,019	61,657	101,511	1,803	103,314	0	2	4,800	1,224
	8	878	101,511	1,434	2,278	24,982	2,278	1,434	72,649	0	0	100	76,260	20,000	24,982	0	76,260	2,156	1,500	13,697	54,276	72,649	18,622	101,511	878	102,389	0	2	2,338	7,027
	9	14,000	98,237	3,444	19,224	69,551	19,224	3,444	51,232	0	0	100	73,800	20,000	69,551	0	73,800	3,351	1,500	7,732	52,525	51,232	45,633	98,237	14,000	112,237	190,350	16	37,272	51,326
	10	1,937	101,511	2,018	0	1,993	0	2,018	68,062	1,937	4,344	100	76,260	20,000	1,993	0	76,260	48	1,500	0	54,276	68,062	0	97,168	0	97,168	0	2	5,156	1,234
	11	0	98,237	1,427	0	56	0	1,427	19,831	0	32,642	100	73,800	0	56	0	73,800	0	1,500	0	52,525	19,831	0	65,595	0	65,595	0	1	0	594
	12	0	101,511	966	0	0	0	966	0	0	75,878	100	76,260	484	0	0	76,260	0	1,500	0	54,276	0	20,484	25,634	0	25,634	0	1	0	207
Wet 1932	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,400	6,412
	2	995	91,688	0	96	3,254	96	0	0	995	74,419	100	71,340	4,070	3,254	0	71,340	0	1,500	0	49,023	0	24,070	17,268	0	17,268	0	0	2,650	2,847
	3	0	101,511	0	0	862	0	0	0	0	92,290	100	76,260	20,000	862	0	76,260	37	1,500	0	54,276	0	45,379	9,222	0	9,222	0	0	0	5
	4	0	98,237	0	0	0	0	0	0	0	73,900	100	73,800	20,000	0	0	73,800	47	1,500	0	52,525	0	65,108	24,337	0	24,337	0	0	0	2
	5	48,105	101,511	6,204	53,375	167,702	53,375	6,204	16,780	0	0	100	76,260	20,000	167,702	0	76,260	2,857	1,500	0	54,276	16,780	233,656	101,511	48,105	149,616	527,838	60	128,068	141,881
	6	21,346	98,237	3,646	25,475	93,266	25,475	3,646	44,778	0	0	100	73,800	20,000	93,266	0	73,800	2,414	1,500	12,683	52,525	44,778	286,822	98,237	21,346	119,583	364,628	26	56,828	69,375
	7	2,596	101,511	1,611	0	17,087	0	1,611	74,749	0	0	100	76,260	20,000	17,087	0	76,260	1,121	1,500	17,909	54,276	74,749	230,615	101,511	2,596	104,108	0	2	6,912	1,827
	8	823	101,511	1,427	0	16,344	0	1,427	74,933	0	0	100	76,260	20,000	16,344	0	76,260	1,310	1,500	14,807	54,276	74,933	176,394	101,511	823	102,335	0	1	2,192	1,254
	9	12,292	98,237	3,045	18,263	63,283	18,263	3,045	52,592	0	0	100	73,800	20,000	63,283	0	73,800	2,715	1,500	6,217	52,525	52,592	197,928	98,237	12,292	110,529	179,217	14	32,725	48,761
	10	1,967	101,511	1,856	1,743	6,470	1,743	1,856	72,761	0	0	100	76,260	20,000	6,470	0	76,260	512	1,500	0	54,276	72,761	151,609	101,511	1,967	103,478	0	2	5,236	5,543
	11	936	98,237	1,450	0	893	0	1,450	72,450	0	0	100	73,800	20,000	893	0	73,800	112	1,500	0	52,525	72,450	99,715	98,237	936	99,173	0	1	2,493	718
	12	0	101,511	1,008	0	0	0	1,008	0	0	75,352	100	76,260	20,000	0	0	76,260	81	1,500	0	54,276	0	120,119	26,160	0	26,160	0	0	0	247

3.6.4 Design Capacity for Water in Tailings Area

A memorandum prepared by Ecological Resource Consultants, Inc (ERC) and dated April 12, 2006 regarding the tailings storage facility process solution requirements is attached as Appendix I. As the objective of defining fluid retention for input to the tailings facility design is different from the needs of a water balance, the calculation procedures used are different in the calculations reported in the memorandum than described in this study. For example:

1. Climate data used by ERC to define average conditions was average monthly values whereas this study used 1978 precipitation to illustrate a year with average precipitation.
2. To define wet conditions, ERC used the wettest four year period and inserted a 100 return period wet year to model mine operations during a significant wet period. This study used the 1932 rainfall to illustrate the impact of a wet year with a return period of about 10 years on year one of operations. ERC also used a 100 year return period fro Drought conditions while this study used the 1933 climate record to approximate a 10 year return period dry condition.
3. ERC used runoff coefficients to define expected runoff from natural ground. This study calculated evapotranspiration based on precipitation and temperature data and included groundwater recharge and discharge to define runoff.
4. Seepage from the tailings was calculated for the ERC report based on the design of the tailings facility. Seepage was assumed in this study as a function of solution volume.
5. ERC assumed water would arrive in the process stream as moisture in the ore. This study does not consider this source of moisture except as a small contribution to net process loss.

Given the above, the fluid balance derive by ERC is very similar to the site wide water balance developed in this study.

4 CLOSURE MINE WATER MANAGEMENT

4.1 Introduction

Following mine operations, the mine will be closed. This will include the following to the water management systems at the site.

- The diversion ditch upslope of the North Development Rock Dump from Rock Creek to Lindblom Creek will be removed and the area graded to discourage flow concentration.
- A new diversion ditch will be installed upslope of the North Development Rock Dump to direct water from this catchment towards the pit lake.
- The diversion ditch from upslope of the South Development Rock Dump to upper Rock Creek will be left intact, diverting flow to Rock Creek and the pit lake.
- Development rock dump surfaces will be graded to discourage flow concentration and potential erosion.
- The interception ditch downslope of the North Development Rock Dump and the South Development Rock Dump will be removed and the area graded to discourage flow concentration.
- The tailings area will be capped and graded to shed water without erosion.
- The seepage collection system will be removed, assuming that groundwater concentrations meet regulatory requirements.
- The plant site structures and related surface features will be removed. The site will be graded to discourage flow concentration.
- The pit perimeter wells will be turned off and pumps and piping removed. Surface expressions will be removed and the well bores capped.
- The Class V underground injection system will be left in place, but with all surface features removed.
- The Rock Creek Fan wells will be turned off and pumps and piping removed. Surface expressions will be removed and the well bores capped.
- The open pit will be allowed to flood from groundwater and surface water inflow. The low crest on the pit is at about 68 m. The high point on the pit wall will be about 150 m. The pit floor will be at an elevation of about –10 m. The pit lake water level after flooding is expected to reach an elevation of about 68 m. Following flooding, water will discharge from the pit lake, possibly throughout the year. This water will discharge into Rock Creek.

Most of the mine elements will therefore be removed on closure as shown on Figure 4.1. Topographic changes will remain at the tailings area and the Development Rock Dumps. A

pit lake will form at the pit site. Only one ditch will be retained, and it will be along a hillside that already has ditches training water towards Rock Creek. The following sections address the timing of pit lake filling and the expected water balance for the pit lake.

4.2 Pit Lake Filling

Pit lake filling time was estimated assuming an elevation volume relationship within the pit, and with water flow criteria established in the water balance. The water surface was considered to determine the pit lake evaporation. The elevation volume assumed is presented on Table 4.1. The filling curve for average conditions at 2 times Nome Airport precipitation is illustrated on Figure 4.2. The filling time is expected to take from 1.5 to 3 years.

Table 4.1: Pit Lake Elevation, Area and Volume Relationships

Elevation (m)	Area (m2)	Volume (m3)
-10	2,655	0
-5	2,656	13,278
0	4,892	34,673
5	9,050	76,308
10	13,099	136,575
15	18,490	223,343
20	22,388	328,911
25	28,344	462,161
30	33,076	620,229
35	43,000	832,232
40	52,923	1,094,044
45	62,847	1,397,595
50	70,053	1,736,892
55	80,000	2,133,970
60	91,421	2,579,769
65	105,147	3,092,953
68	110,000	3,421,313

4.3 Pit Lake Water Balance

The pit will be filled and the spill elevation of the pit lake will be 68 masl. Contributions to the pit lake water balance will be direct precipitation on the lake surface, surface water inflow and groundwater inflow. Discharge from the lake will include spillage and evaporation. The long term average water balance for the pit lake is presented on Tables 4.2 and 4.3 for 1.5 and 2 times the Nome precipitation, to provide a range of potential inflows.

From Tables 4.2 and 4.3, the range of average annual pit inflows will be 1 to 2 million m^3 with about 69% from the catchment and from diversion ditches to the pit lake, 6% from snowmelt and rainfall on the pit lake surface and 25% as groundwater inflow. Approximately 96% of the water spills from the pit lake and 4% evaporates.

The spill from the pit lake will flow down the original Rock Creek channel to the confluence with Snake River. The most significant change to the closure Rock Creek Flows from the

pre-mine condition is attenuation of peak flows from storage in the pit lake and the increase in expected winter groundwater discharge and therefore base flows.

Table 4.2: Pit Lake Water Balance Estimate (Precipitation 1.5 times Nome)

Month	Surface water into pit (m^3)				GW to pit (m^3)	total to pit (m^3)	evaporation from pond	volume spilled (m^3)
	from pit catchment	from pit walls	snowmelt and rain on lake	total to pit lake				
Jan	0	0	0	0	21,427	21,427	0	21,427
Feb	0	0	0	0	20,045	20,045	0	20,045
Mar	0	0	0	0	21,427	21,427	0	21,427
Apr	0	0	0	0	20,736	20,736	7,713	20,736
May	271,973	12,609	16,877	301,458	21,427	322,886	10,014	315,172
Jun	223,753	11,994	17,393	253,140	20,736	273,876	14,684	263,862
Jul	0	0	6,999	6,999	21,427	28,426	12,055	13,742
Aug	8,047	4,402	10,436	22,884	21,427	44,312	6,740	32,257
Sep	211,063	11,104	14,836	237,003	20,736	257,739	0	251,000
Oct	0	0	0	0	21,427	21,427	0	21,427
Nov	0	0	0	0	20,736	20,736	0	20,736
Dec	0	0	0	0	21,427	21,427	0	21,427
Annual	714,836	40,109	66,540	821,485	252,979	1,074,464	51,206	1,023,258

Table 4.3: Pit Lake Water Balance Estimate (Precipitation 2 times Nome)

Month	Surface water into pit (m^3)				GW to pit (m^3)	total to pit (m^3)	evaporation from pond	volume spilled (m^3)
	runoff to pit	from pit walls	snowmelt and rain on lake	total to pit lake				
Jan	0	0	0	0	42,854	42,854	0	42,854
Feb	0	0	0	0	40,090	40,090	0	40,090
Mar	0	0	0	0	42,854	42,854	0	42,854
Apr	0	0	0	0	41,472	41,472	7,713	41,472
May	490,485	19,995	24,504	534,984	42,854	577,839	10,014	570,125
Jun	384,577	17,609	23,190	425,376	41,472	466,848	14,684	456,834
Jul	0	1,927	9,332	11,259	42,854	54,113	12,055	39,429
Aug	87,178	7,638	13,914	108,729	42,854	151,584	6,740	139,529
Sep	348,249	15,893	19,782	383,923	41,472	425,395	0	418,655
Oct	0	0	0	0	42,854	42,854	0	42,854
Nov	0	0	0	0	41,472	41,472	0	41,472
Dec	0	0	0	0	42,854	42,854	0	42,854
Annual	1,310,488	63,061	90,722	1,464,272	505,958	1,970,230	51,206	1,919,025

5 CONCLUSIONS

Hydrometeorology

A long term climate record is available for Nome, only 10 km south of the Rock Creek gold mine prospect. Stream flow data and limited site precipitation data indicates that the annual site precipitation at the site is approximately 1.7 times the precipitation at Nome, possibly due to orographic effects. The annual site precipitation may therefore be approximately 720 mm (28 in.). On average, the highest precipitation months are July, August and September when about 50% of precipitation occurs. Site evaporation is expected to be approximately 420 mm (16 in.) per year, almost all from May to September. Evapotranspiration on natural slopes is expected to be approximately 180 mm (7 in.) The average monthly temperatures range from -13.1^{o}C in January to 10.3^{o}C in July.

Mine Water Management

Diversion Ditches
To minimize fresh surface water runoff from passing through the mine site, surface water from upslope will be diverted through a ditch to Lindblom Creek. Interception ditches will be constructed downstream of the development rock dumps to route this water to Lindblom Creek or Rock Creek. Water will not be diverted to Glacier Creek.

Pit Dewatering Wells
Groundwater moving towards the pit will be intercepted with pumping wells. This water will either be used as process water or will be treated and reintroduced to the groundwater through a Class V injection system.

Process Water
Process water will come from the following sources:

- Plant site runoff;
- Water from the seepage collection system
- Recycled tailings transport water and precipitation from the tailings pond;
- Open pit runoff derived from precipitation; and
- Pit interception wells

If additional process make up water is required in addition to the above sources, water supply wells can be installed in the Rock Creek Alluvium or additional wells can be pumped from the pit area.

Water Balance

Process Water Supply

The water balance indicates that there will be water at the mine site in excess of that required for processing. Thus, no external sources of makeup water are expected to be required through the life of the mine. Excess water at the mine will need to be treated and reintroduced to groundwater in a Class V injection system on the Rock Creek alluvial fan and in bedrock injection wells. Excess water on the site means that the mine needs to allow for the capability to store excess water during wet periods. Storage capacity considerations are addressed in Appendix I.

Water treatment capacity for Class V injection

Excess water from the pit dewatering wells will require treatment prior to reintroduction to the groundwater. The expected pit well field pumping rate is expected to be on the order of 635 GPM. The water treatment capacity for the pit dewatering wells will need to be on the order of 110,000 m^3 per month over a five month period of the year. In addition there can be up to 44,000 m^3 of runoff water in the pit during spring break up.

The Class V injection system must be capable of accepting a maximum flow rate of on the order of 150,000 m^3 per month. The proposed Class V system can be expanded as necessary, based on the actual monitored performance.

The expected travel time at the Rock Creek Injection site for the injected treated water to reach the Snake River alluvium is on the order of 5 years. The expected travel time for water injected into the bedrock Injection Wells to reach the Snake River Alluvium is in excess of 2 years.

Pit Filling

The annual average pit inflows are expected to be 1 to 2 million m^3 with about 69% from the catchment and from diversion ditches to the pit lake, 6% from snowmelt and rainfall on the pit lake surface and 25% as groundwater inflow. The open pit filling time is expected to take from 1.5 to 3 years.

Recommendations

1. Due to the predicted excess water at site, water supply wells to provide make up water should only be installed if and when they are needed. The need for these water supply wells will be evident upon analysis and consideration of water balance information collected upon start up of the mining operation.

2. Take steps to decrease the excess water on site as follows:
    - Snow fencing can be installed around the tailings area and open pit to minimize the potential for snow accumulation within the pit.
    - Snow removal equipment and capability can be considered to enable snow removal from the catchment of the mine workings and plant site.

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FIGURES

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Figure 1.1 Site Location Plan

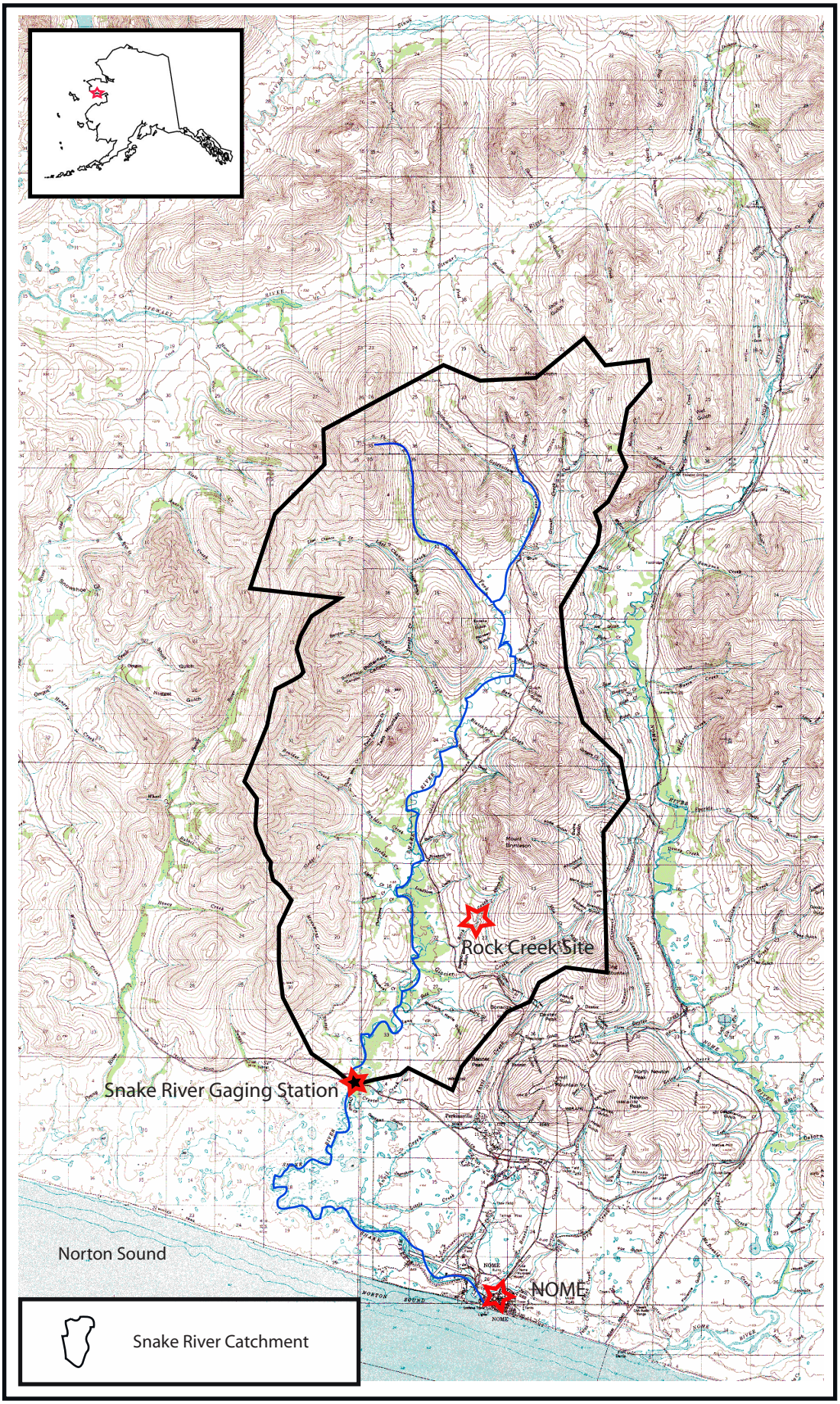

Figure 2.1: Five Year Running Average of Nome Precipitation and Temperature

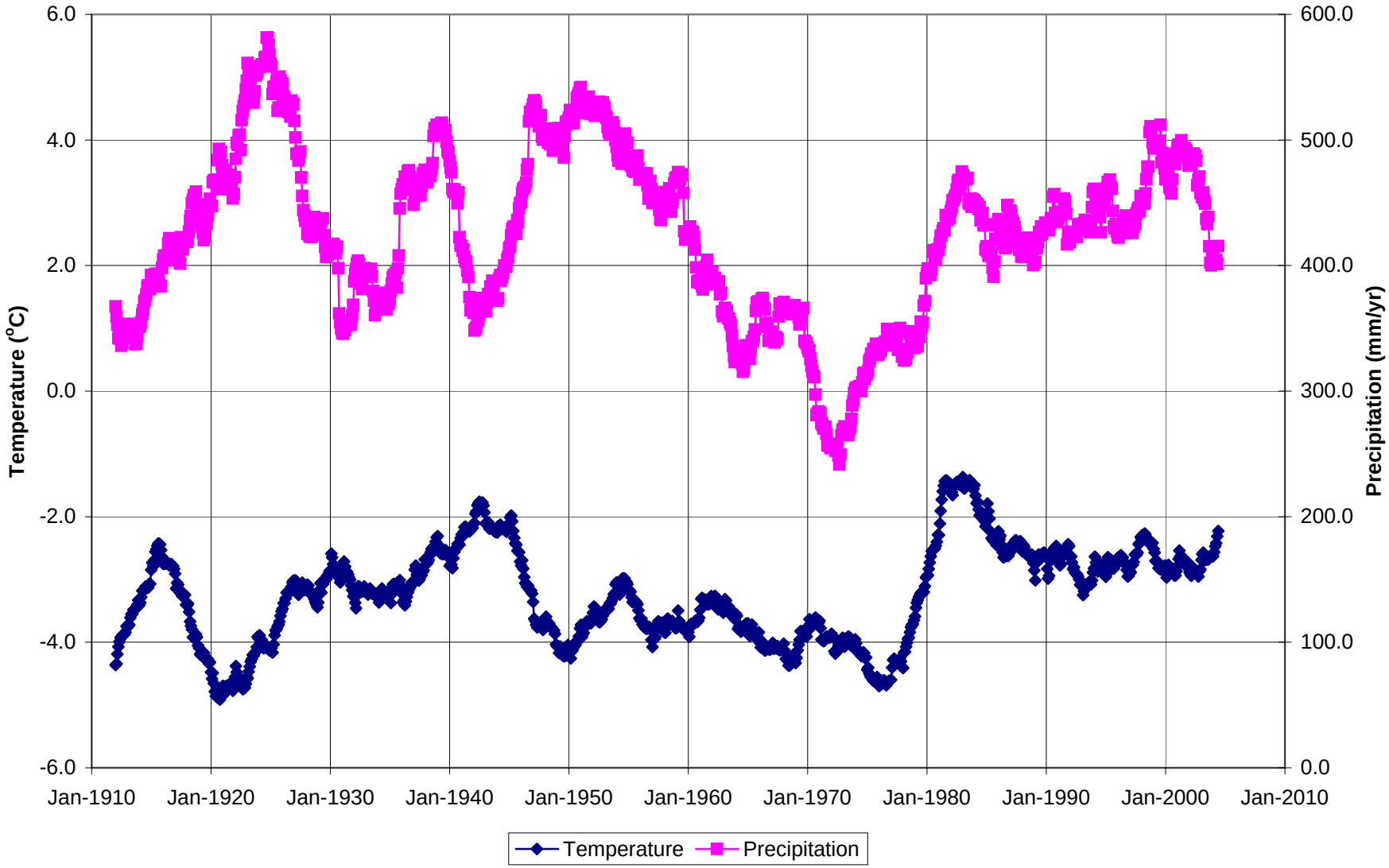

Figure 2.2: Comparison of 2005 Monthly Precipitation for Nome Airport and Rock Creek

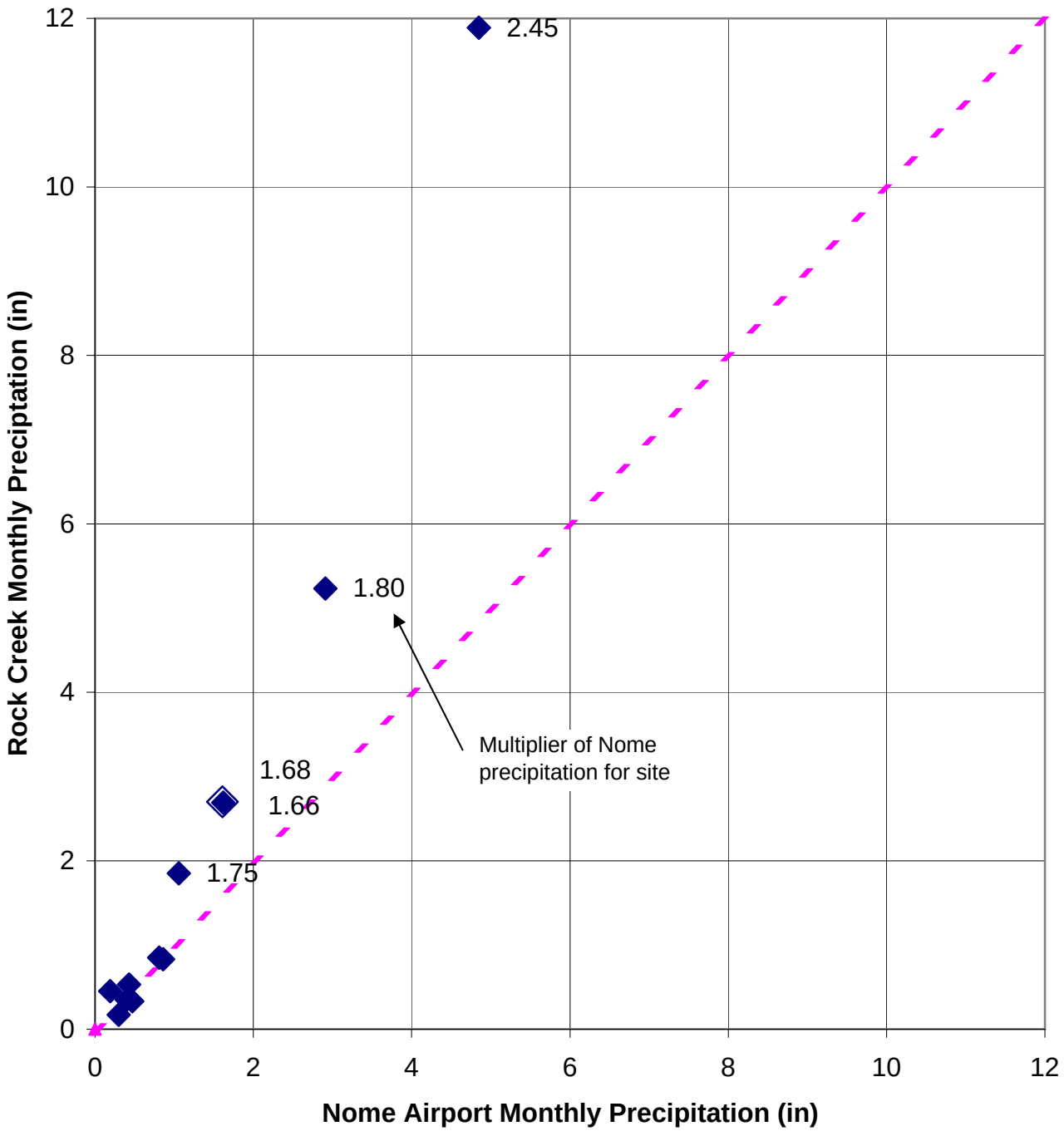

Table 3 - Continued

Water Balance Calculations

Scenario #	PHASE I (AUG:01 to AUG:02)		PHASE II (AUG:02 to AUG:03)		PHASE III (AUG:03 to AUG:04)		EXTENDED RUN (AUG:04 to AUG:05)		EXTENDED RUN (AUG:05 to AUG:06)	
5	Instantaneous Inflow Rate (m^3/hr)	0.0259	Instantaneous Inflow Rate (m^3/hr)	0.0525	Instantaneous Inflow Rate (m^3/hr)	0.0743	Instantaneous Inflow Rate (m^3/hr)	0.0695	Instantaneous Inflow Rate (m^3/hr)	0.0226
	Instantaneous Outflow Rate (m^3/hr)	0.0268	Instantaneous Outflow Rate (m^3/hr)	0.0492	Instantaneous Outflow Rate (m^3/hr)	0.0744	Instantaneous Outflow Rate (m^3/hr)	0.0502	Instantaneous Outflow Rate (m^3/hr)	0.0185
	Avg. Inflow Rate (m^3/yr)	227	Inflow (m^3/yr)	460	Inflow (m^3/yr)	651	Inflow (m^3/yr)	609	Inflow (m^3/yr)	198
	Avg. Outflow Rate (m^3/yr)	235	Outflow (m^3/yr)	431	Outflow (m^3/yr)	652	Outflow (m^3/yr)	440	Outflow (m^3/yr)	162
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.001	Avg. Vol. Water Content Change (w/in Dam)	0.0277	Avg. Vol. Water Content Change (w/in Dam)	0.0025	Avg. Vol. Water Content Change (w/in Dam)	0.0042	Avg. Vol. Water Content Change (w/in Dam)	-0.0001
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0.007	Avg. Vol. Water Content Change (Below Dam)	0.0076	Avg. Vol. Water Content Change (Below Dam)	0.0008
	Amount of Water Stored as Ice (m3)	-1	Amount of Water Stored as Ice (m3)	68	Amount of Water Stored as Ice (m3)	21	Amount of Water Stored as Ice (m3)	30	Amount of Water Stored as Ice (m3)	1
	% Difference Between Inflow & Outflow	6	% Difference Between Inflow & Outflow	1	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	28	% Difference Between Inflow & Outflow	33
5	Instantaneous Inflow Rate (m^3/hr)	0.0244	Instantaneous Inflow Rate (m^3/hr)	0.0618	Instantaneous Inflow Rate (m^3/hr)	0.077	Instantaneous Inflow Rate (m^3/hr)	0.0754	Instantaneous Inflow Rate (m^3/hr)	0.0207
	Instantaneous Outflow Rate (m^3/hr)	0.0274	Instantaneous Outflow Rate (m^3/hr)	0.0644	Instantaneous Outflow Rate (m^3/hr)	0.0784	Instantaneous Outflow Rate (m^3/hr)	0.0656	Instantaneous Outflow Rate (m^3/hr)	0.0188
	Avg. Inflow Rate (m^3/yr)	214	Inflow (m^3/yr)	541	Inflow (m^3/yr)	675	Inflow (m^3/yr)	661	Inflow (m^3/yr)	181
	Avg. Outflow Rate (m^3/yr)	240	Outflow (m^3/yr)	564	Outflow (m^3/yr)	687	Outflow (m^3/yr)	575	Outflow (m^3/yr)	165
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.0015	Avg. Vol. Water Content Change (w/in Dam)	-0.0027	Avg. Vol. Water Content Change (w/in Dam)	-0.011	Avg. Vol. Water Content Change (w/in Dam)	0.0046	Avg. Vol. Water Content Change (w/in Dam)	-0.0009
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	-0.0155	Avg. Vol. Water Content Change (Below Dam)	0.0082	Avg. Vol. Water Content Change (Below Dam)	-0.0005
	Amount of Water Stored as Ice (m3)	-2	Amount of Water Stored as Ice (m3)	-7	Amount of Water Stored as Ice (m3)	-71	Amount of Water Stored as Ice (m3)	32	Amount of Water Stored as Ice (m3)	-5
	% Difference Between Inflow & Outflow	1	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	29
7	Instantaneous Inflow Rate (m^3/hr)	0.0235	Instantaneous Inflow Rate (m^3/hr)	0.0184	Instantaneous Inflow Rate (m^3/hr)	0.0882	Instantaneous Inflow Rate (m^3/hr)	0.0816	Instantaneous Inflow Rate (m^3/hr)	0.0046
	Instantaneous Outflow Rate (m^3/hr)	0.0258	Instantaneous Outflow Rate (m^3/hr)	0.0285	Instantaneous Outflow Rate (m^3/hr)	0.0907	Instantaneous Outflow Rate (m^3/hr)	0.0922	Instantaneous Outflow Rate (m^3/hr)	0.008
	Avg. Inflow Rate (m^3/yr)	206	Inflow (m^3/yr)	161	Inflow (m^3/yr)	773	Inflow (m^3/yr)	715	Inflow (m^3/yr)	40
	Avg. Outflow Rate (m^3/yr)	226	Outflow (m^3/yr)	250	Outflow (m^3/yr)	795	Outflow (m^3/yr)	808	Outflow (m^3/yr)	70
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.0035	Avg. Vol. Water Content Change (w/in Dam)	-0.0198	Avg. Vol. Water Content Change (w/in Dam)	-0.0135	Avg. Vol. Water Content Change (w/in Dam)	-0.0138	Avg. Vol. Water Content Change (w/in Dam)	-0.0012
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0	Avg. Vol. Water Content Change (Below Dam)	-0.0217	Avg. Vol. Water Content Change (Below Dam)	-0.0011
	Amount of Water Stored as Ice (m3)	-4	Amount of Water Stored as Ice (m3)	-49	Amount of Water Stored as Ice (m3)	-95	Amount of Water Stored as Ice (m3)	-92	Amount of Water Stored as Ice (m3)	-7
	% Difference Between Inflow & Outflow	2	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	6	% Difference Between Inflow & Outflow	26

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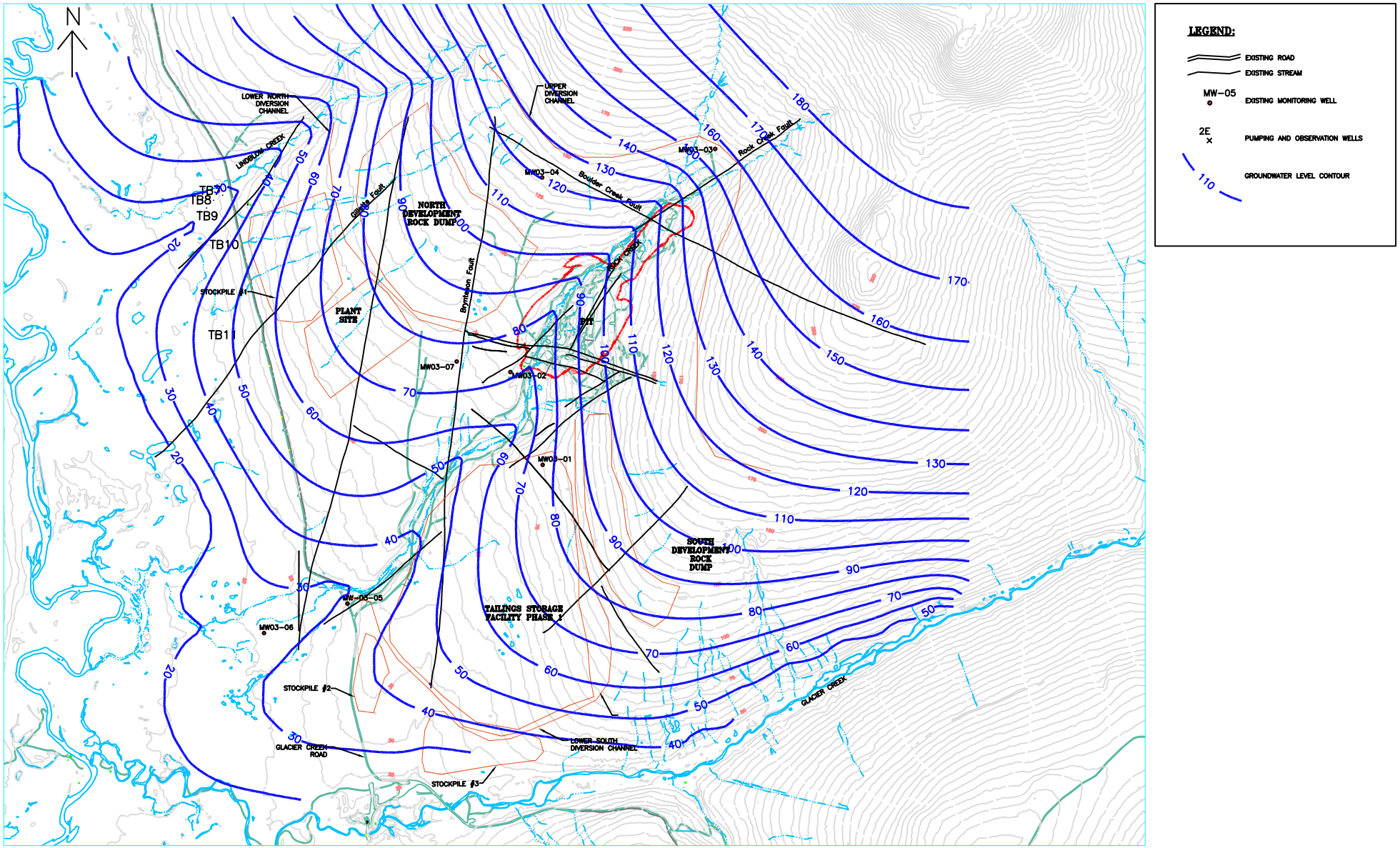
Figure 2.3 Borehole Locations and Piezometric Surface



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Original drawing (1011F35 – Preliminary Permafrost Frozen/Thawed Zone Delineation) provided by Smith Williams Consultants, Inc.

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Figure 2.4 Profile with Airlift Returns

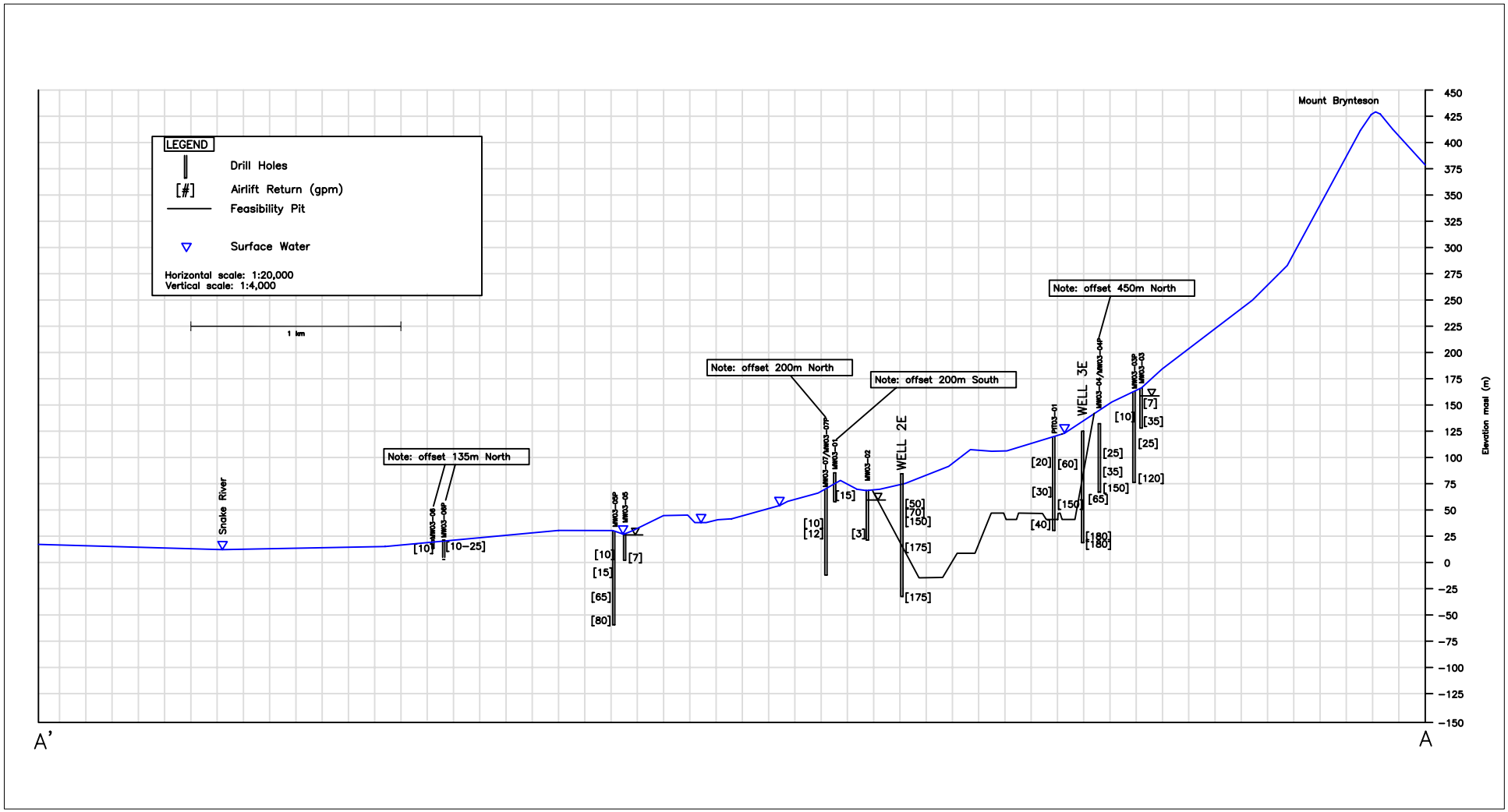

Figure 2.5: Measured and Calculated Monthly Flows for Snake River (1982 to 1992)

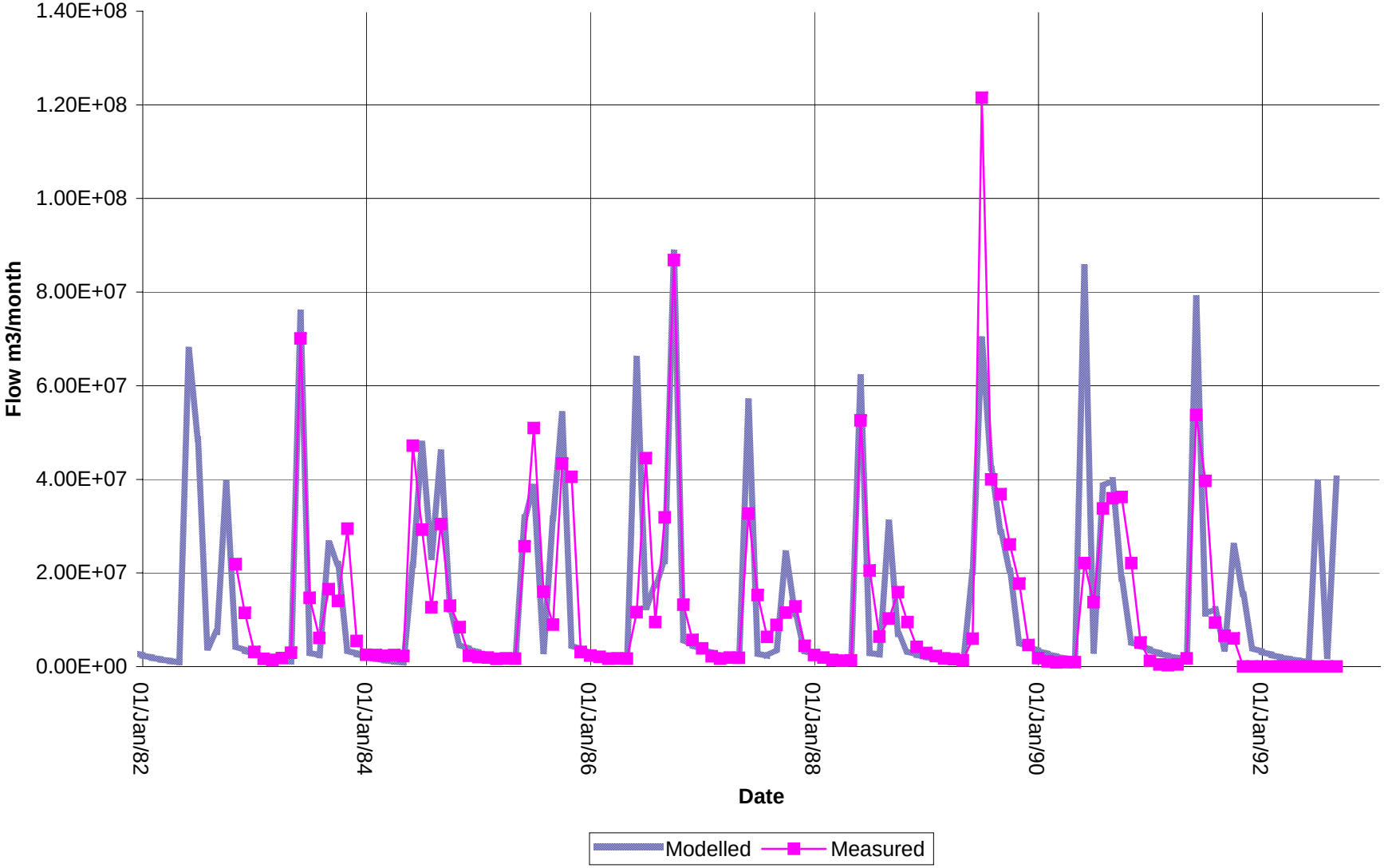

Figure 2.6 Measured and Calculated Cumulative Volume for Snake River (1983 to 1992)

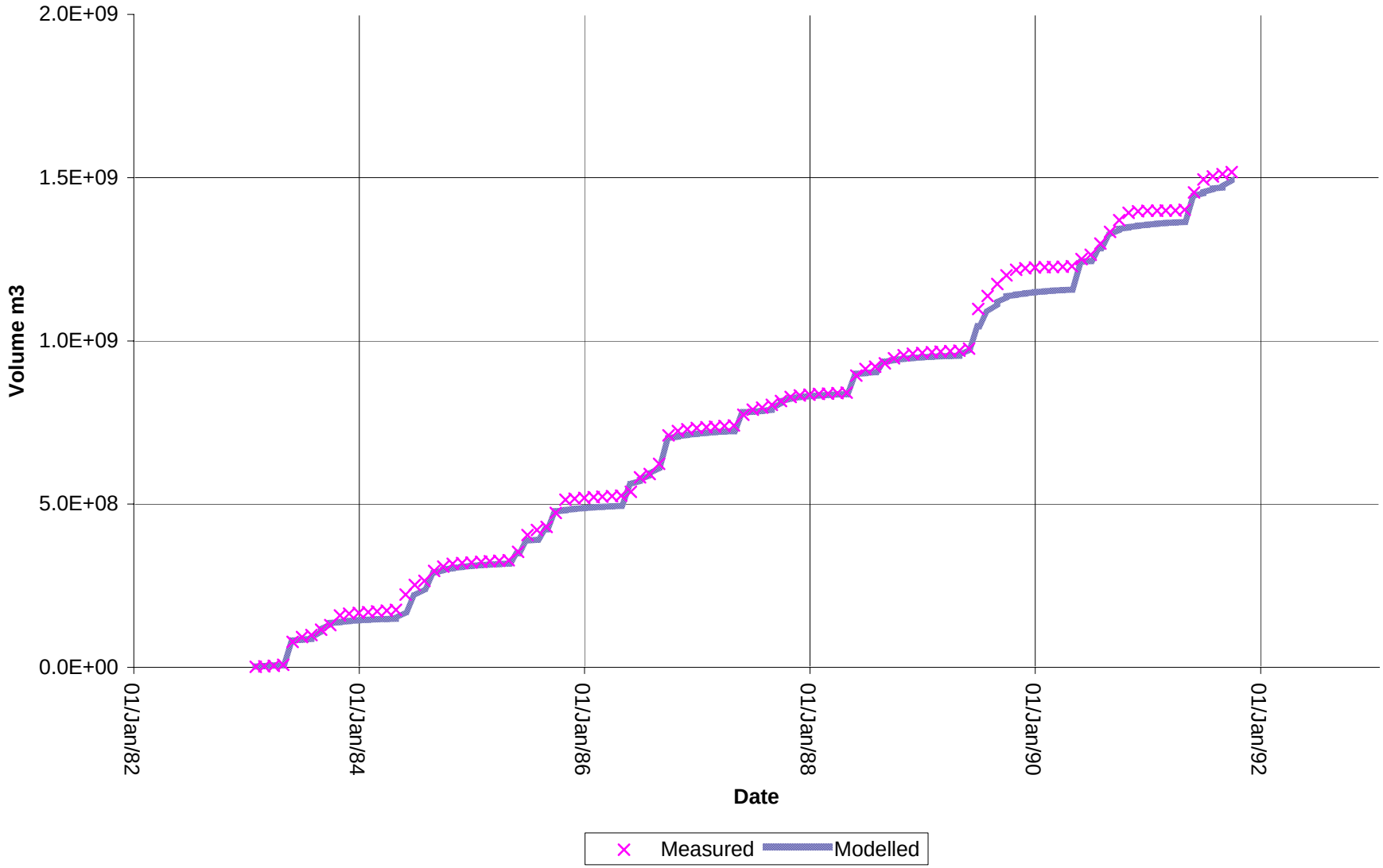

Figure 2.7: Measured and Modelled Creek Flows

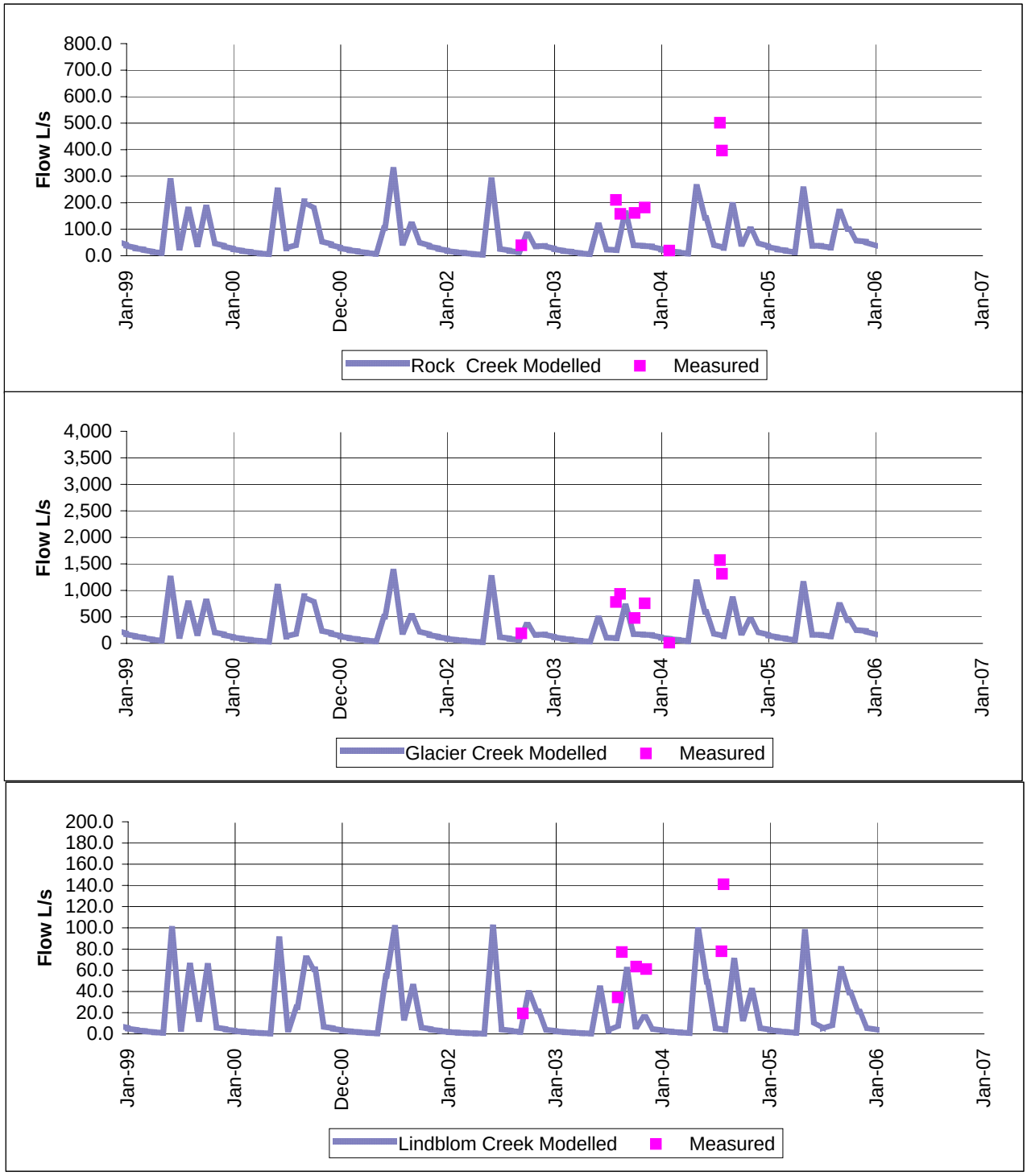

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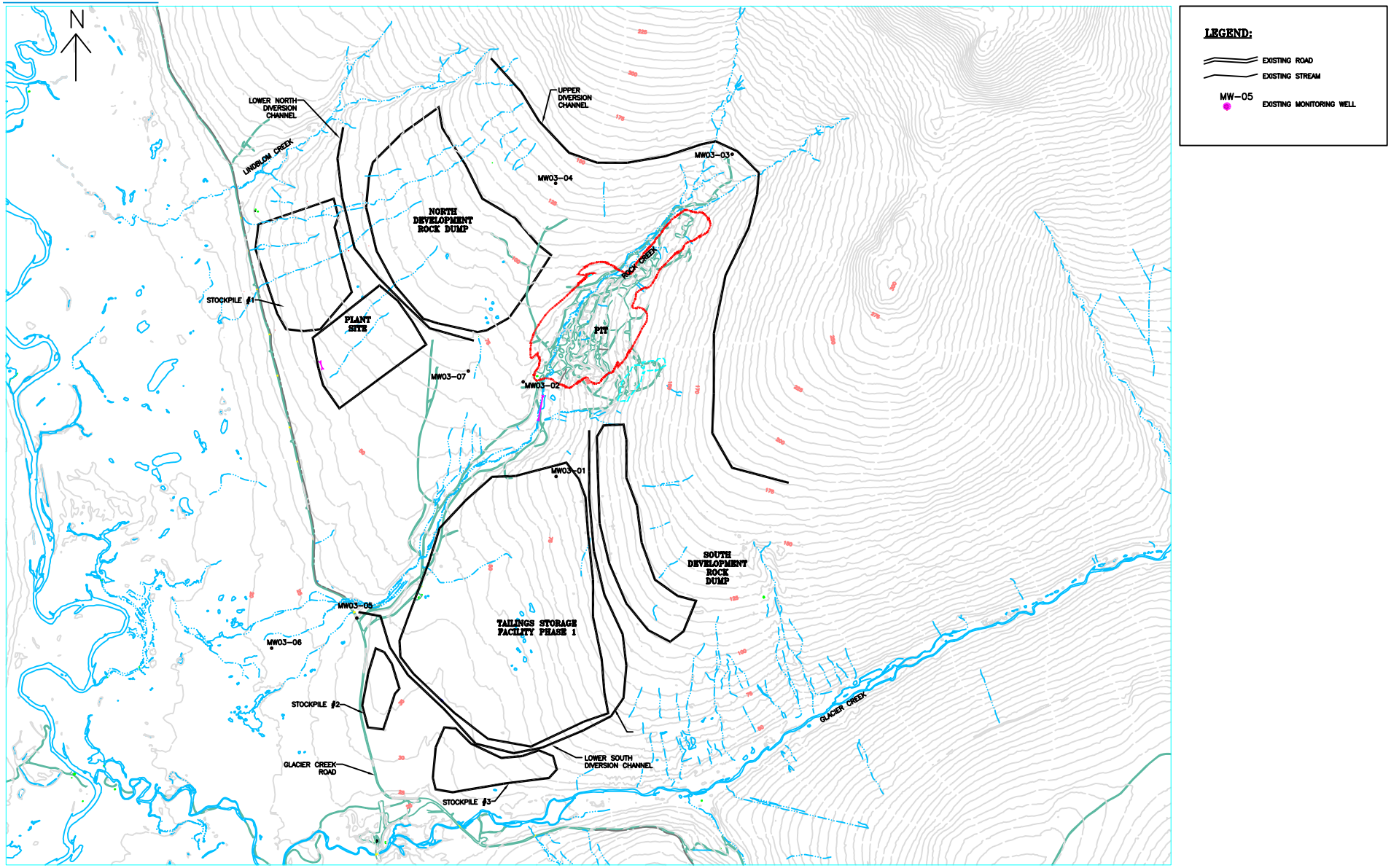
Figure 3.1Mine Layout



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100 0 100 200 METERS
SCALE = 1:15000

Original drawing (1011F35 – Preliminary Permafrost Frozen/Thawed Zone Delineation) provided by Smith Williams Consultants, Inc.

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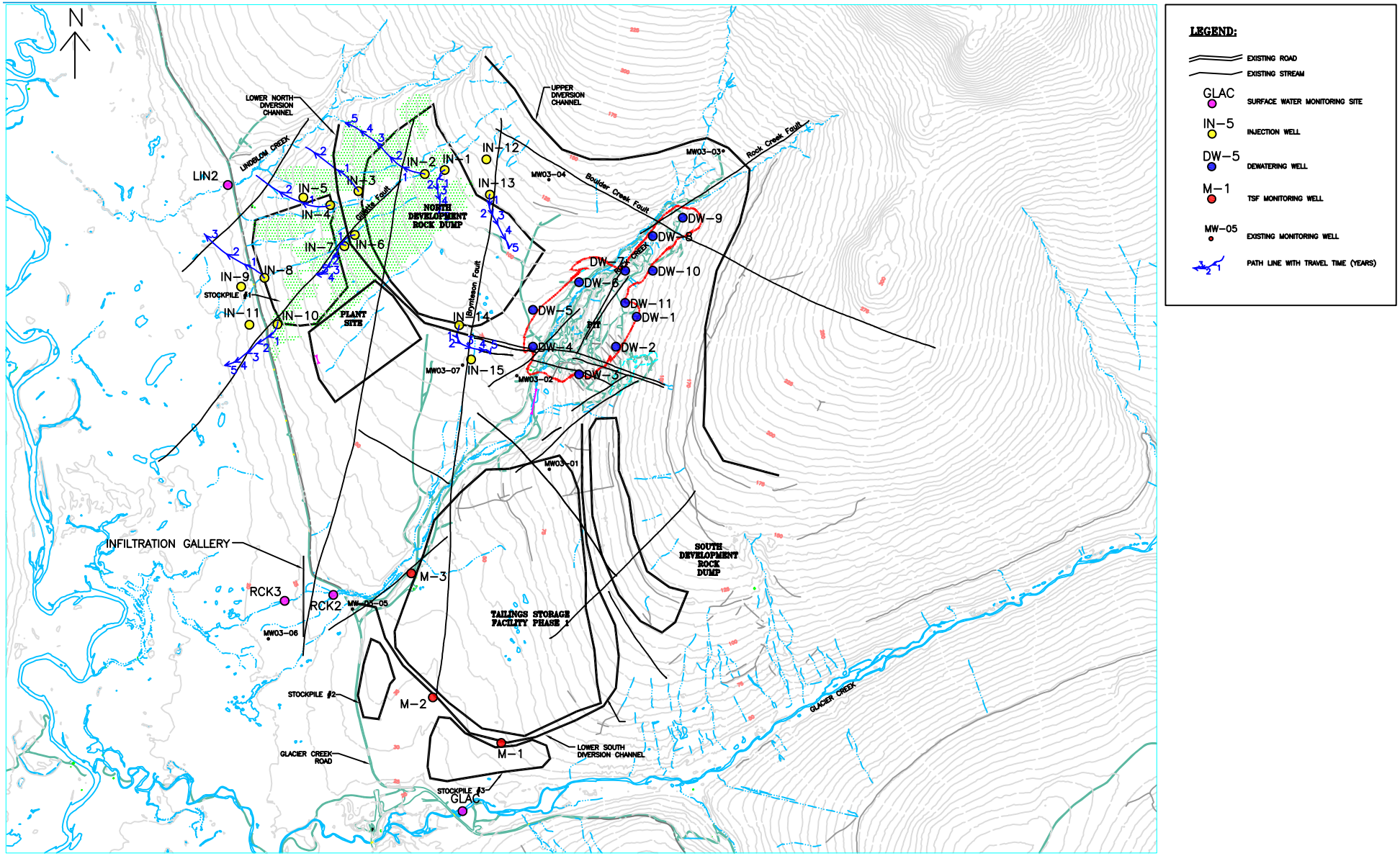
Figure 3.2 Dewatering Well and Injection Well Layout



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ON 10-2-2004 FILENAME: S:\CAD\1011-rock creek\rev\20050203-Big
Hurrah\big_hurrah_2004.dwg

Original drawing (1011F35 – Preliminary Permafrost Frozen/Thawed Zone Delineation) provided by Smith Williams Consultants, Inc.

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Figure 3.3 Schematic Section Through Injection Wells

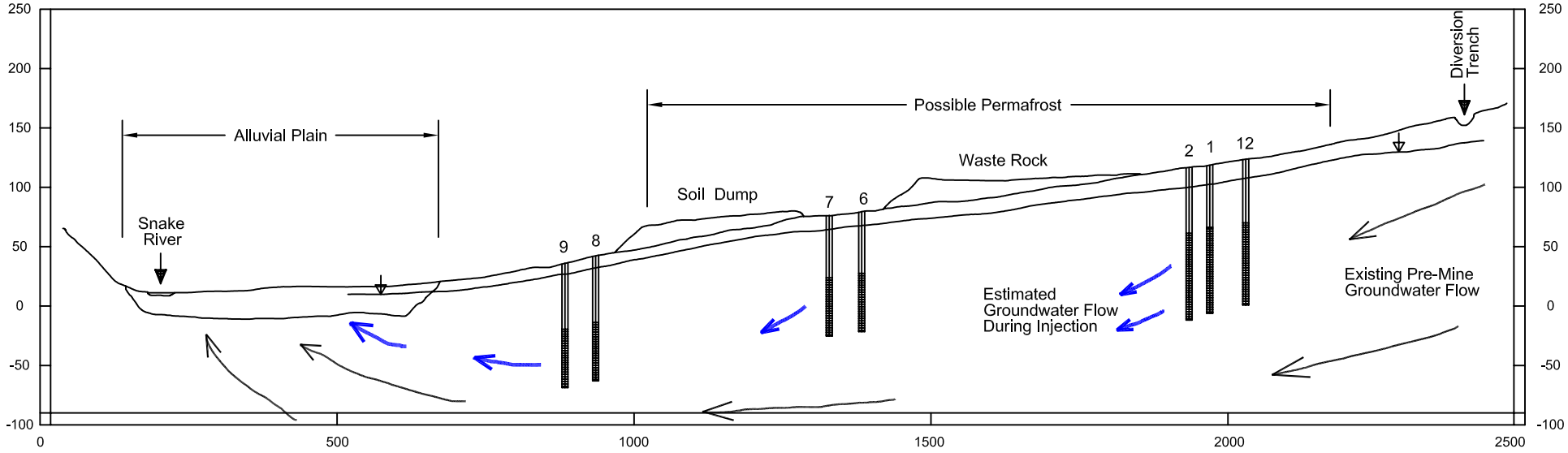
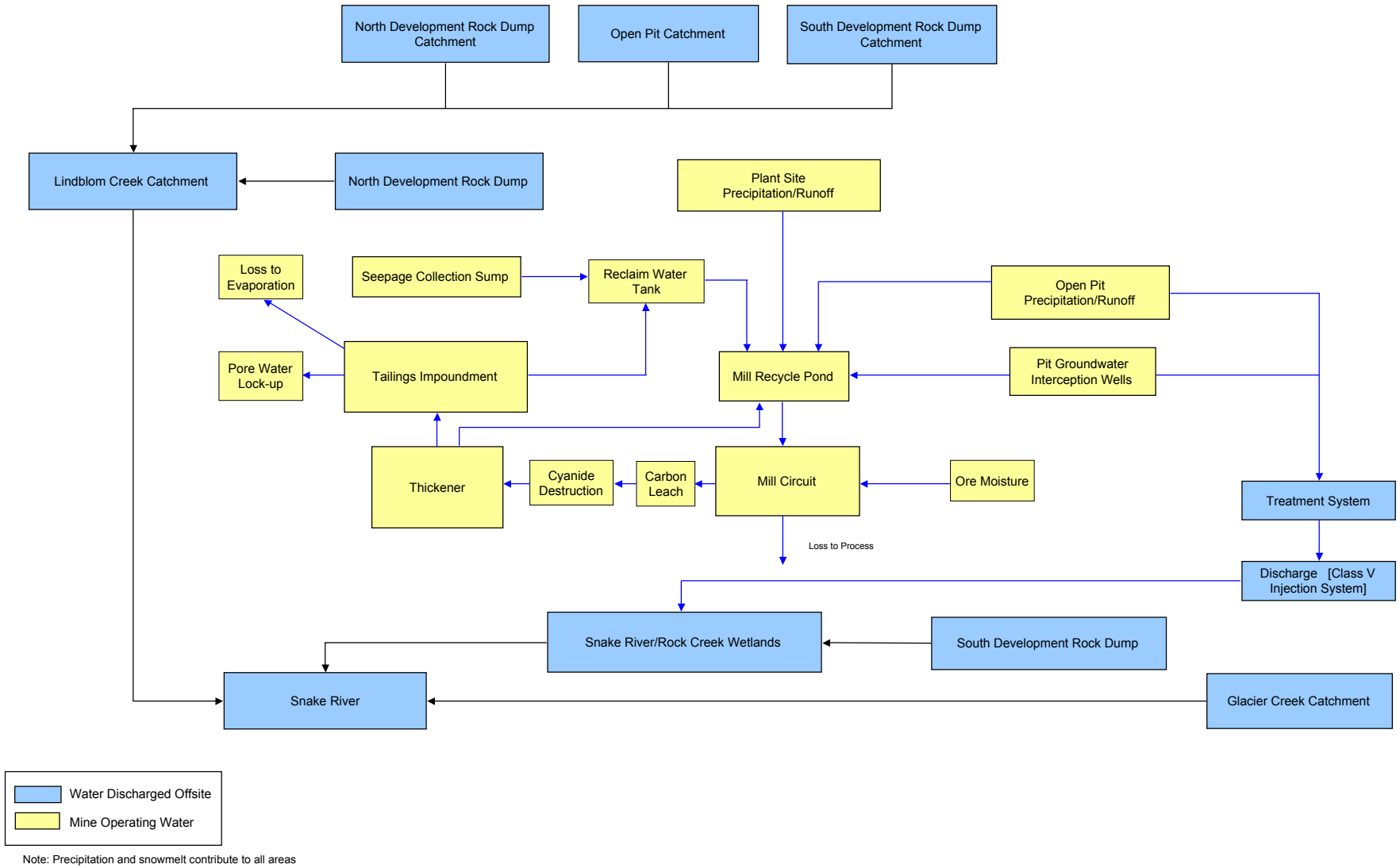


Figure 3.4: Conceptual Surface and Mill Water Flow Diagram



Note: Precipitation and snowmelt contribute to all areas

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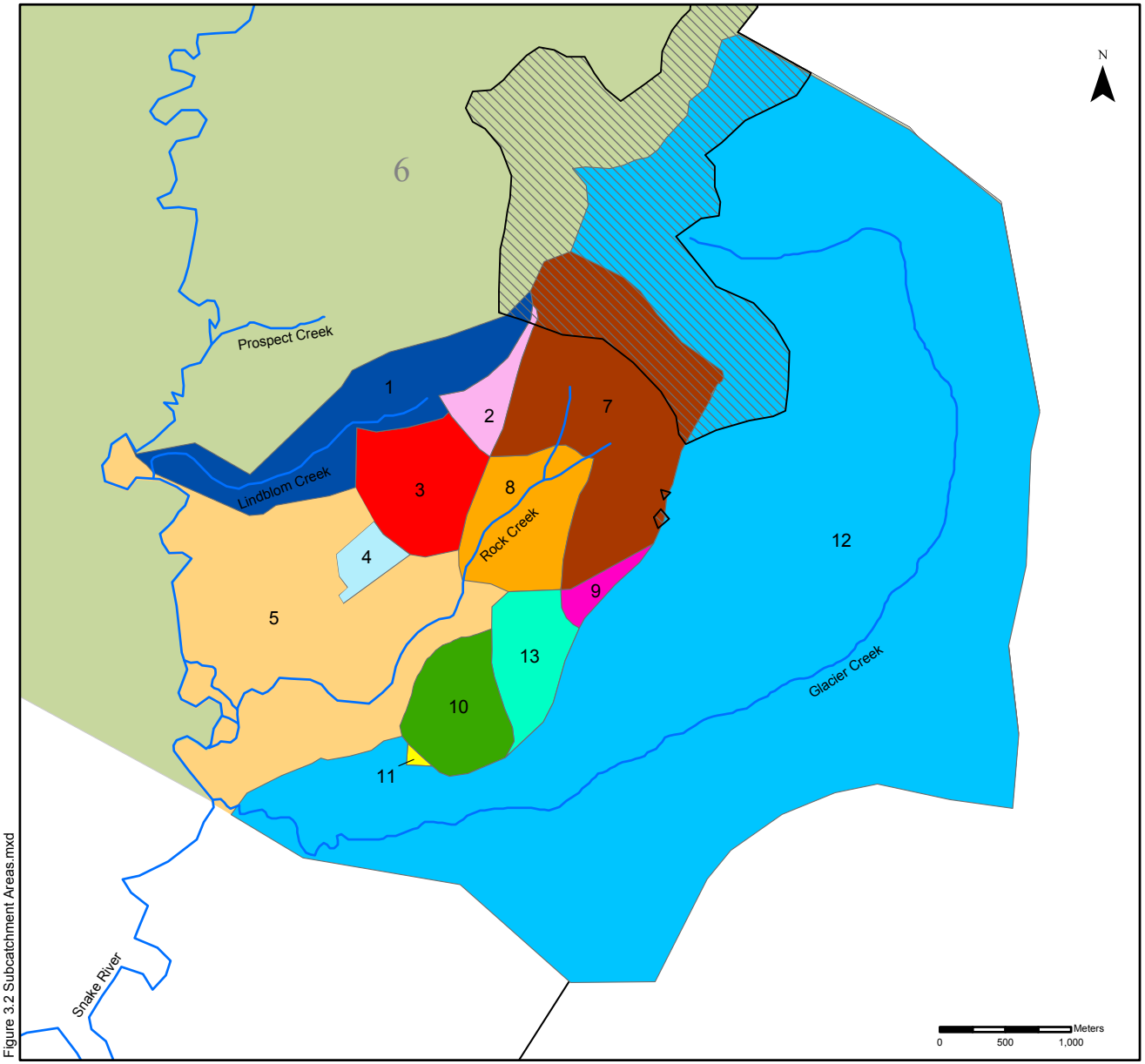
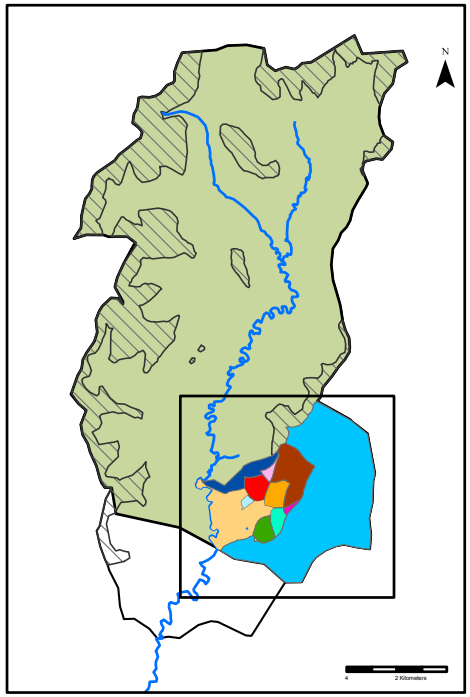
Figure 3.5: Subcatchment Areas





Watershed Model Units

- Snake River Watershed Unit (0)
- Snake River Catchment
- Area with Elevation > 1000 ft

Units

- Glacier Creek (12)
- Lindblom Creek Catchment (1)
- North Development Rock Dump (3)
- North Development Rock Dump Catchment (2)
- Open Pit (8)
- Open Pit Catchment (7)
- Plant Site (4)
- Seepage Recovery (11)
- Snake R/Rock Cr Wetlands (5)
- South Development Rock Dump (13)
- South Development Rock Dump Catchment (9)
- Tailings Impoundment (10)

Figure 3.2 Subcatchment Areas.mxd

Figure 3.6: Calculated Volume of Water Stored in Tailings Pond with Average Precipitation

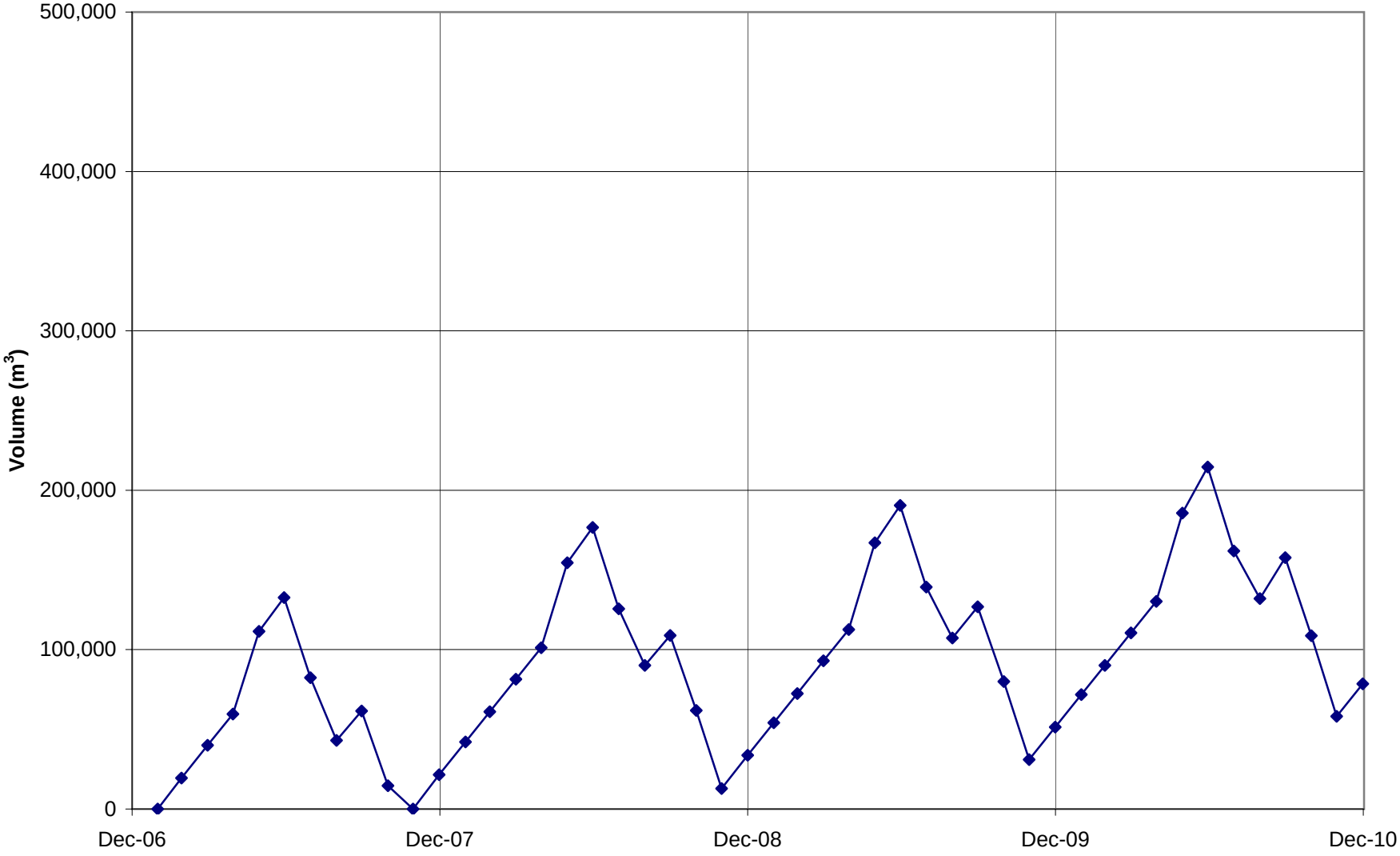


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Figure 4.1 Closure Plan Layout

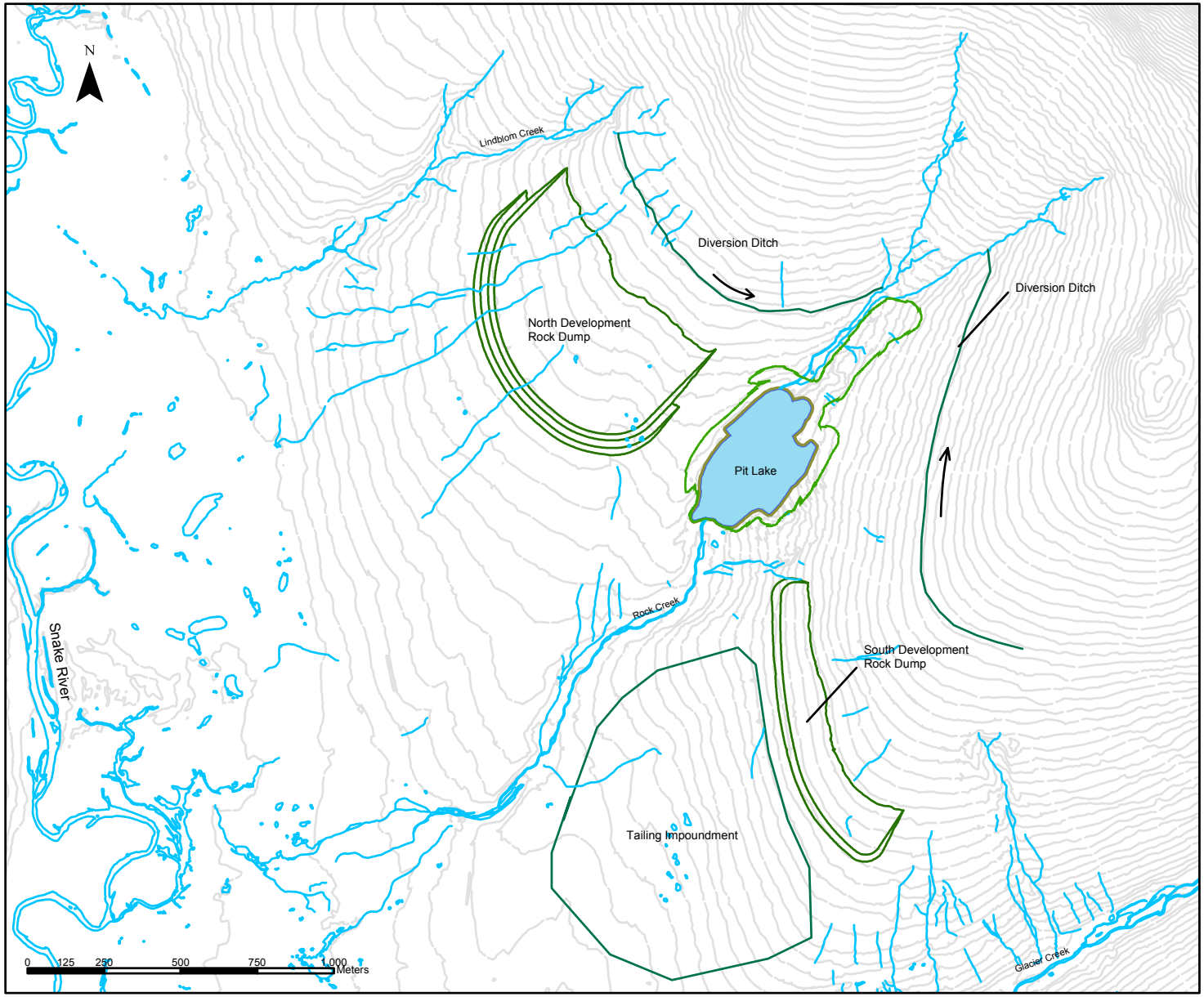
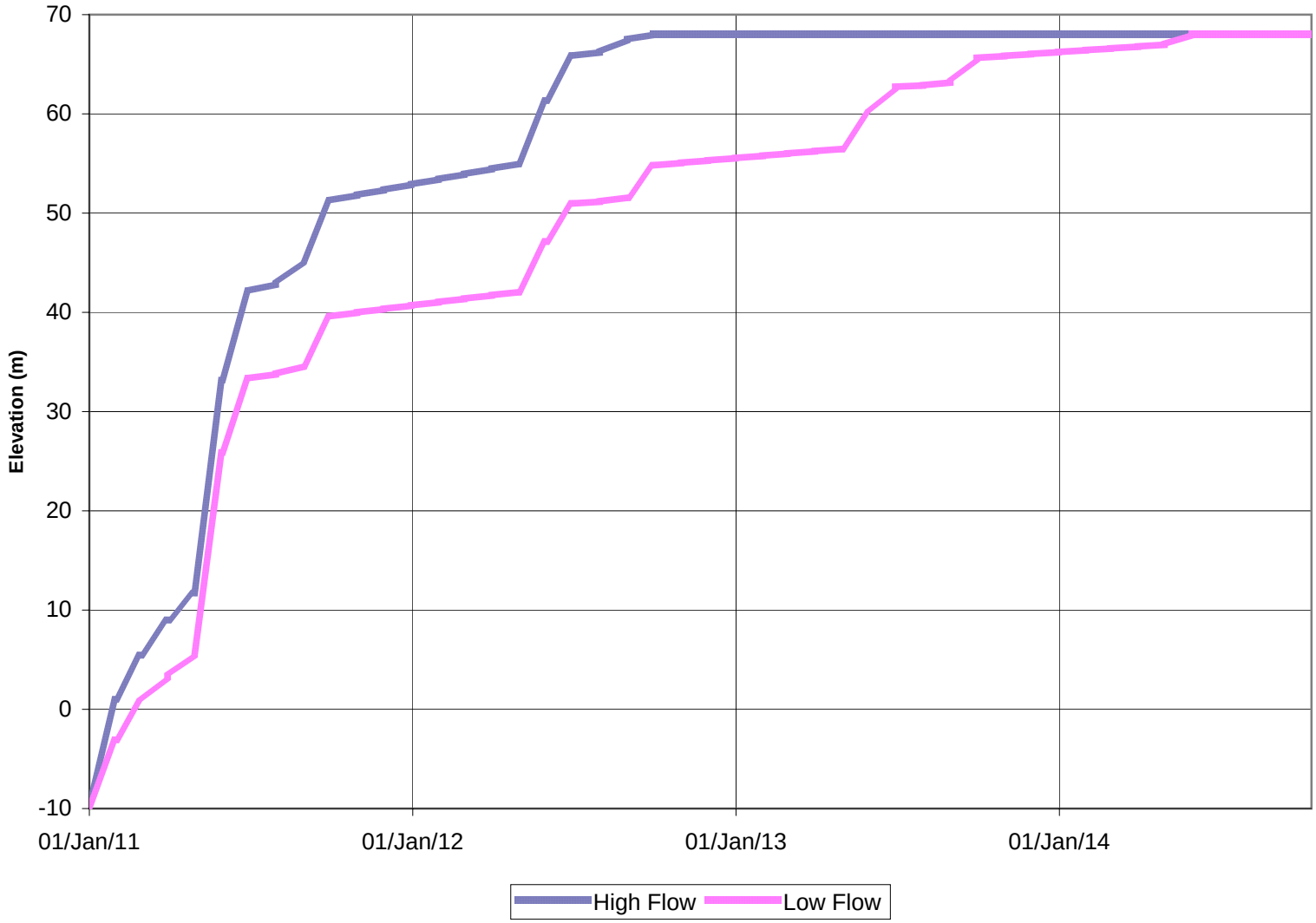


Figure 4.1 Closure Plan Layout

Figure 4.2: Pit Water Level Following Closure



APPENDICES

Ecological Resource Consultants, Inc.

35715 US Hwy. 40, Suite D204 ~ Evergreen, CO 80439 ~ 303.679.4820

Technical Memorandum

Date: April 12, 2006

To: Ryan Baker, Smith Williams Consultants, Inc.

From: Troy Thompson

Project: Rock Creek Mine

Re: Water Balance Analysis

Ecological Resource Consultants, Inc. (ERC) has completed a water balance model for the proposed Rock Creek mine site at the request of Smith Williams Consultants, Inc. (SWC). The purpose of this model is to predict monthly fluctuations in solution volumes and water flow rates within the mine system. Assumptions used in the model, modeling techniques and results obtained are presented herein.

1.0 WATER BALANCE COMPONENTS

This water balance incorporates water inputs into the system including pit dewatering wells, ore water and meteorological water. It also specifically tracks free water/solution within the tailings storage facility (TSF) and average monthly flow rates within the system. **Figure 1** shows a schematic of the overall flow diagram as modeled in the water balance.

2.0 MODEL ASSUMPTIONS/INPUTS

2.1 Production

Mine Plan

The current mine plan, which has a duration of 47 months, was used for the water balance model. Operations were modeled as commencing in February of 2007 (Year 1) and continuing through the end of December 2010 (Year 4).

Monthly Production Rates – Production rates were assumed to remain at a constant level of 7,716 short tons per day (dry) for the 47 month life of the mine.

2.2 Climatologic & Hydrologic

Climatologic Data

Background climatologic data used in the water balance models is presented in the Technical Memo "Rock Creek and Big Hurrah Mine Sites – Climate Data" by ERC dated September 23, 2005. Precipitation values presented in the September 2005 technical memo were revised in ERC's Updated Precipitation Analysis memo dated January 5, 2006. Precipitation data used in the model is based on the January update. Site precipitation was modeled as 170% of precipitation recorded at the Nome Station.

Rain verses Snow Season

As presented in the climate evaluation, average temperatures are above freezing for the months of May through September. Any precipitation during this season is assumed to occur in the form of rain. Temperatures are below freezing for the months of November through March and all precipitation during this time is anticipated to be in the form of snow. For the months of April and October approximately half of the days are above freezing and half are below freezing given normal conditions. As a result, half of the precipitation in these months is modeled in the form of snow and half in the form of rain.

Reclaim Solution Season

The model assumes that solution can be reclaimed from the TSF impoundment beginning in April and continuing through December (9 months) of each year during operations, as needed. During the remainder of the year, free water in the impoundment is assumed to be in an ice form and reclaim is not available.

Snow and Ice Melt

Based on results of the climate evaluation (ERC, 2005), the model assumes that half of the winter snow/ice accumulation melts in the month of April and the remaining half melts in the month of May. This assumption includes ice and snow within the TSF impoundment in addition to snowpack from the tributary drainage areas.

Evaporation Coefficients

The modeled evaporation coefficient for the tailings pond surface is assumed to be 50% of pond evaporation. This accounts for a portion of the surface being tailings and a portion being free water.

Runoff Coefficient

A runoff coefficient of 1 was used to model direct runoff from the tailings. This assumes that rainfall on the tailings remains in the system to contribute to the free water pond, evaporate or be lost as seepage.

Monthly Rainfall Runoff Coefficients

Modeled monthly runoff coefficients during the warmer months for undisturbed ground tributary to the impoundment are:

- April 0.5
- May 0.3
- June 0.3
- July 0.35
- August 0.35
- September 0.4
- October 0.5

Monthly Snowmelt Runoff Coefficients

Modeled runoff from snowpack is assumed to be 95% for snow on the tailings surface, 100% for snow on the lined face of the embankment and 65% for snow on the undisturbed ground tributary to the impoundment.

2.3 TSF Embankment and Impoundment

Embankment Staging

Embankment staging was provided by SWC. Three stages of construction are anticipated. Stage 1 will be completed for the February 2007 start up date. The initial embankment will be constructed to a crest elevation of 160 feet. The second phase, constructed to a crest elevation of 176 feet, will be operational starting in August of 2007 and the final embankment phase will come on line in July of 2008 with a crest elevation of 197 feet. Tributary drainage areas at the three different phases are 5,586,735 square feet (0.20 square miles) for Stage 1, 5,802,249 square feet (2.1 square miles) for Stage 2 and 6,137,739 square feet (0.22 square miles) for Stage 3.

Embankment Freeboard

The TSF design criteria require that a minimum of 3.3 feet of freeboard be maintained at all times in the impoundment. This equates to 90 acre-feet of storage within the freeboard limits.

Tailings and Available Water Storage

Tailings and water storage capacity of the impoundment was provided by SWC and used in the water balance model. ERC interpolated values for months when data was not calculated. Storage at different times during the life of the facility along with planned embankment phasing is provided on the following table. Highlighted cells indicate values interpolated by ERC.

Date	Tailings Surface Area (acres)	Exposed Liner (acres)	Max. Water Storage Vol. (ac-ft)
2/1/2007	0	8	577
2/10/2007	5	8	545
2/23/2007	11	7	493
3/20/2007	19	7	411
4/6/2007	26	6	373
5/3/2007	31	6	281
6/11/2007	41	6	270
7/10/2007	46	5	270
7/29/2007	50	5	240
8/26/2007	55	10	678
9/25/2007	58	9	638
10/25/2007	61	9	597
11/24/2007	64	9	557
12/23/2007	67	8	517
1/26/2008	70	8	450
2/28/2008	73	7	384
3/28/2008	74	7	349
4/25/2008	75	7	315
5/24/2008	76	7	281
6/22/2008	77	7	247
7/21/2008	79	9	401
8/20/2008	81	11	555
9/18/2008	82	13	709
10/18/2008	84	14	863
11/10/2008	87	14	858
12/4/2008	89	13	852
1/11/2009	92	12	805
2/18/2009	95	11	758
3/18/2009	96	11	718
4/16/2009	97	11	678
5/14/2009	98	11	638
6/12/2009	100	11	598
7/10/2009	101	11	558
8/8/2009	102	10	518
9/5/2009	103	10	478
10/6/2009	105	10	460
11/7/2009	107	9	442
12/8/2009	109	9	424
1/8/2010	111	9	406
2/9/2010	113	8	389
3/12/2010	115	8	371
4/12/2010	116	7	353
5/3/2010	117	7	341
5/23/2010	118	7	329
6/12/2010	119	7	317
7/3/2010	120	7	305

7/23/2010	121	7	292
8/12/2010	122	7	280
9/2/2010	123	7	268

Initial Impoundment Water Storage

The Stage 1 embankment is scheduled for completion prior to production commencing in February of 2007. For the water balance model it was assumed that no water/ice will be stored in the impoundment at startup.

2.4 Tailings Properties

Tailings Moisture Contents

The following tailings moisture contents have been used in the water balance model.

- Tailings Slurry Percent Solids (by weight) 74%
- Tailings Slurry Moisture Content 35.1%
- Tailings Specific Gravity 2.75
- Consolidated Tailings Density (dry) 1.52
- Consolidated Tailings Moisture Content 25%
- Consolidated Tailings Saturation (%) 85%

Consolidated tailings moisture content is assumed to be “locked” in the tailings and not available to be reclaimed.

2.5 Other Water Sources

Pit Water

Pit dewatering requirements were developed based on pit interception estimates presented in the report “Rock Creek Mine Project, Water Management Report” prepared by Water Management Consultants (WMC). Dewatering rates were estimated for the end of year conditions based on pit development. The dewatering rates at the end of each year of operation used in the model are presented below.

End of Year	Pit Dewatering Rate (gpm)
2007	600
2008	600
2009	635
2010	635

Dewatering rates were assumed to be constant at 600 gpm throughout the first year of operations and were linearly interpolated based on these year-end values during 2009.

This water is available as raw water that can be used to supplement reclaim from the impoundment to meet the demands of the ore processing. Any pit water that is not used as reclaim will be discharged into the infiltration gallery. The pit dewatering system is assumed to be operational year-round beginning at the start of production.

Seepage

SWC provided estimated seepage losses from the TSF. Seepage lost will be collected by the seepage collection system within the TSF and reclaimed as process water separate from the impoundment reclaim system. Estimates for annual seepage given the three embankment stages were generated and monthly distributions developed by others.

Average annual seepage rates for the three embankment stages are:

- Stage 1 6.0 gpm
- Stage 2 22.6 gpm
- Stage 3 60.8 gpm

Seepage over the three stages was distributed monthly according to the following percentages:

Month	Stage 1	Stage 2	Stage 3
January	0%	0%	7%
February	0%	0%	2%
March	0%	0%	0%
April	0%	0%	0%
May	4%	2%	1%
June	6%	2%	1%
July	8%	4%	2%
August	17%	32%	39%
September	37%	24%	19%
October	27%	18%	10%
November	1%	12%	10%
December	0%	6%	9%
Total	100%	100%	100%

The seepage collection systems will be designed so that seepage water is pumped back to the plant to satisfy a portion of the reclaim water required by the plant operations.

The model limits seepage to available water in the pond within the TSF impoundment. Seepage was not allowed to reduce water in the pond below 16 acre-feet.

Process Plant Stormwater

Stormwater runoff from the process plant site is collected by the diversion channels around the perimeter of the plant site and routed to the mill recycle water pond. This water is accounted for in the water balance model. The area within the process plant diversion ditches that contributes meteorological water to the system was modeled as 2,090,880 square feet.

2.6 Reclaim System, Makeup and Infiltration

Maximum Reclaim Rate

A maximum reclaim rate of 412.1 gpm is used in the model. This value includes a 96% production utilization factor. Reclaim water needs are met by seepage water, stormwater collecting in the mill recycle water pond, reclaim from the TSF impoundment and pit dewatering water. The model assumes that seepage and stormwater collected in the process pond are the first waters reclaimed and brought into the process. Whenever available, water from the impoundment will then be used to meet remaining water demands. When reclaim from the impoundment is not be available and other sources is not available (between December and March) or available in limited supply, pit dewatering will act as the makeup water source for the process.

Infiltration Gallery

Pit water that is not used in the process is to be pumped to the Class V injection system and released. This value is computed by the model on a monthly basis.

3.0 MODEL RUNS

Three different meteorological scenarios were modeled: average conditions, a wet cycle and drought (dry) conditions. Wet and drought conditions each have an approximately 1% annual chance of occurrence. Results provide information on storage volumes, reclaim, makeup and treatment requirements that can be anticipated throughout the mine life.

3.1 Precipitation Values

Dry, average and wet year monthly precipitation totals used in the model are shown below.

Monthly Precipitation Totals (inches – water equivalents)

Mon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Dry	0.70	0.54	0.48	0.55	0.57	0.83	1.71	2.62	1.89	1.15	0.87	0.69	12.61
Avg.	1.51	1.18	1.04	1.20	1.23	1.81	3.70	5.68	4.10	2.49	1.90	1.50	27.33
Wet	2.54	1.97	1.74	2.01	2.05	3.03	6.19	9.51	6.87	4.17	3.17	2.51	45.77

Wet cycle model runs were generated assuming that the extreme wet year could occur during any of the four years of operations. Based on the available precipitation records from Nome, ERC determined the wettest consecutive four (4) years of record and used this data in the model. These four years were modeled so that the highest annual precipitation years were adjacent to the single wet year. Precipitation was distributed between the 12 months following the average annual distribution above.

Modeled Annual Wet Cycle Precipitation (inches)

Model Year	Wet Year 1	Wet Year 2	Wet Year 3	Wet Year 4
1	45.8	34.8	29.5	29.5
2	34.8	45.8	34.8	31.2
3	31.2	31.2	45.8	34.8
4	25.9	29.5	31.2	45.8

4.0 MODEL RESULTS

Water/solution storage, reclaim from the impoundment and discharge/reclaim requirements for pit dewatering water were calculated by the model on a monthly basis for each of the three separate meteorological scenarios (Dry, Average and Wet). Results are summarized below.

4.1 Total Inflows and Losses

Total annual water inputs to and “losses” from the system are tabulated below based on year 4 modeling results. For the wet year, these results assume that the one percent wet year occurs in year 4. All values are given in acre-feet.

Summary of Year 4 Model Results

	Dry Year	Average Year	Wet Year
System Inputs			
TSF Impoundment Area Precipitation	120	281	464
Plant Site Precipitation	19	46	75
Tailings Water	728	728	728
Pit Dewatering Water	1,024	1,024	1,024
Total Inputs	**1,890**	**2,079**	**2,290**
System "Losses"			
Evaporation	142	142	142
Seepage	30	71	89
Tailings Lockup	519	519	519
TSF Impoundment Reclaim	157	278	335
Pit Area and Plant Site Precipitation Reclaim	19	46	75
Pit Dewatering Reclaim	459	271	166
Pit Dewatering Treatment	564	753	857
Total "Losses"	**1,890**	**2,079**	**2,183**

A number of conclusions can be drawn from these general results.

1. Pit dewatering and tailings water are the largest contributors to water in the system.
2. During dry and average years, seepage losses will be limited by available water in the impoundment.
3. Given dry and average conditions, inflows match losses indicating that the impoundment can be dewatered prior to the winter season.
4. Given extreme wet conditions (1% annual chance), it is anticipated that the TSF impoundment will not be fully dewatered.

4.2 Storage Requirements

Anticipated average water/solution storage requirements in the TSF impoundment were determined on a monthly basis. These values were then compared with

available storage to ensure sufficient capacity existed at all times during the proposed project. A summary of the maximum water/solution stored during different years of operation along with the minimum additional available storage volume is shown on the table below. Detailed monthly results are shown graphically on **Figures 2-4**. Note that available storage listed below is calculated as the capacity up to an elevation of 3.3 feet below the embankment crest to ensure freeboard requirements are met.

Calculated Maximum Water/Solution Storage Verses Minimum Remaining Storage (acre-feet)

Year	Dry		Average		Wet Years	
	Maximum Storage Required	Minimum Storage Remaining	Maximum Storage Required	Minimum Storage Remaining	Maximum Storage Required	Minimum Storage Remaining
1 (2007)	16	224	19	224	53	224
2 (2008)	52	229	120	161	227	98
3 (2009)	50	408	124	408	252	226
4 (2010)	46	252	123	206	258	10

Results indicate that for all conditions, sufficient capacity exists in the TSF impoundment to contain all water/solution predicted to enter the system.

As **Figures 2 and 3** indicate, for dry and average conditions, planned reclaim facilitates full evacuation of free water in the impoundment prior to winter in all years of operations. If an extreme wet cycle were to occur during operations (**Figure 4**), free water may be held over in the impoundment during the winter, but sufficient capacity exists for this water.

In the event an extreme wet cycle occurs during operations and solution accumulates from year to year, the volume of free water stored can be further decreased from the values presented in this report by extending the reclaim period beyond the typical April – December window.

4.3 Short Duration Storm

The tributary area to the impoundment is approximately 6,158,000 square feet and the 100-year, 24-hour rainfall value is 5.1 inches. Assuming 100% runoff from the 100-year storm, a total volume of 60 acre-feet of water would enter the impoundment. Actual runoff would be below 100%, so this is a conservatively high estimate. Results above indicate that during normal operating conditions and dry or average climate conditions, storage capacity within the TSF impoundment will always be available for the 100-year storm event. In all but a couple of months towards the end of operations, the TSF would have capacity for the 100-year, 24-hour storm in addition to the 100-year wet cycle. It is overly conservative to design for the 100-year, 24-hour storm in addition to the wet cycle as each separate event has a 1% annual chance of occurring.

4.4 TSF Impoundment Reclaim

Reclaim water is taken from the TSF impoundment between April and December, when available. **Figure 5** shows the monthly reclaim volume for each of the three meteorological scenarios.

Results indicate that in most months calculated reclaim given average and wet conditions are similar indicating that reclaim taken from the TSF will be maximized for these precipitation scenarios. Given dry conditions, calculated reclaim from the TSF is significantly less indicating that the TSF is drained of water during dry years well before the winter. Monthly TSF impoundment reclaim rates peak between 375 gpm and 400 gpm, mainly between the months of April and June. Reclaim rates from the TSF impoundment are anticipated to decrease notably during the months of August and September. This is attributable to higher seepage losses requiring reclaim at these times (see Section 2.5 – Seepage)

4.5 Pit Dewatering Treatment

Pit dewatering water will be used as a water source if needed. Any pit water not required for use in the processing of the ore will be treated and pumped to the infiltration gallery for discharge. **Figure 6** shows anticipated discharge for the pit dewatering water.

Peak treatment/discharge rates are dictated by dewatering rates and are up to 600 gpm in years 1 and 2 and 635 gpm in years 3 and 4.

4.6 Pit Makeup Water

During the months of January through March the model assumes TSF impoundment water will not be reclaimed. During these months and in conditions where TSF impoundment water is not available to meet process needs, pit dewatering water will be used to meet the demands of the process. Monthly makeup requirements for the pit and additional water are shown on **Figure 7**.

During times when pit water is the sole source of makeup water, it will be used as process water at a peak rate of 413 gpm. In dry conditions, pit water will likely be used at this rate consistently from November through March.

5.0 REFERENCES

Ecological Resource Consultants, Technical Memo on Rock Creek Climate Data, September 23, 2005.

Ecological Resource Consultants Updated Rock Creek Precipitation Analysis, January 5, 2006.

Water Management Consultants, Rock Creek Mine Project Water Management Report, March, 2006.

Attachments

Figure 1 – Rock Creek Flow Diagram
Figure 2 – Impoundment Solution Storage and Remaining Capacity – Dry Cycle
Figure 3 – Impoundment Solution Storage and Remaining Capacity – Avg. Cycle
Figure 4 – Impoundment Solution Storage and Remaining Capacity – Wet Cycle
Figure 5 – Impoundment Reclaim Rates
Figure 6 – Pit Dewatering Discharge
Figure 7 – Pit Water and Additional Makeup Requirements

Figure 1-- Rock Creek Flow Diagram

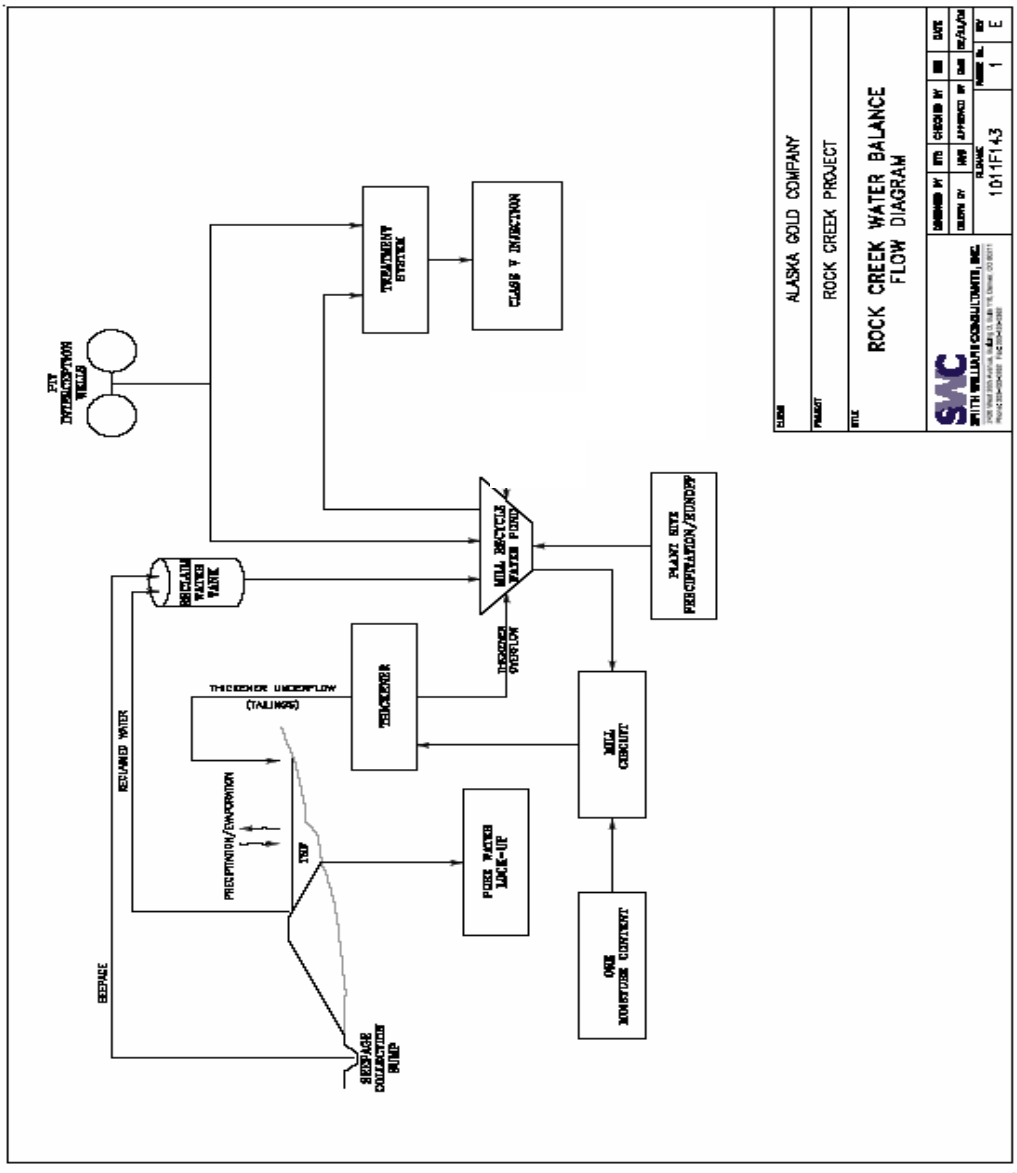


Figure 2 – Impoundment Solution Storage and Remaining Capacity – Dry Cycle

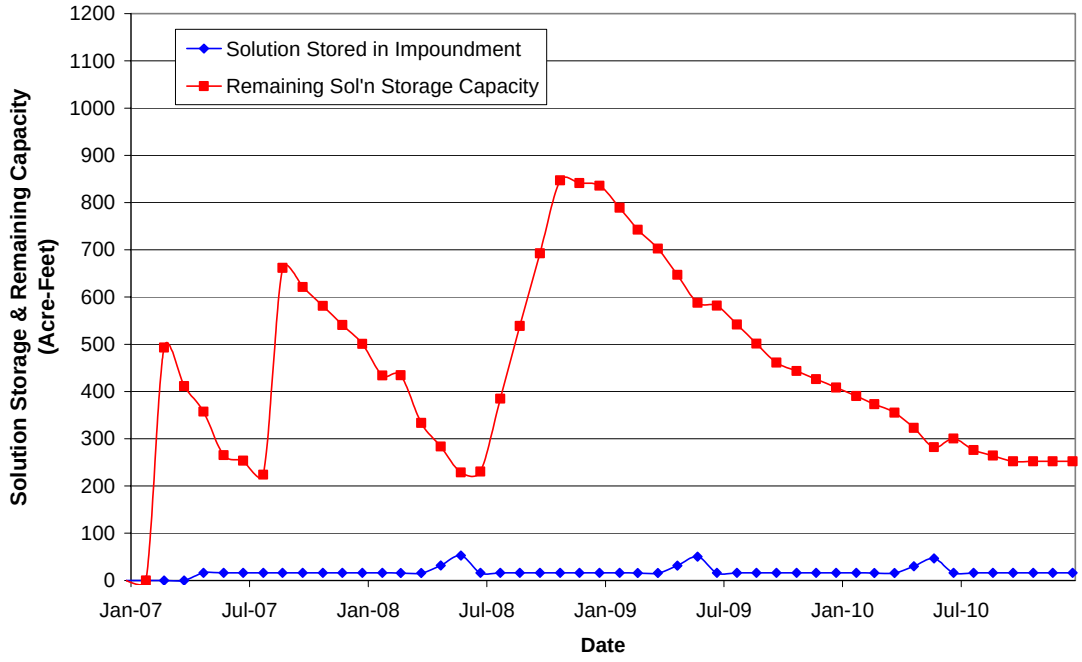


Figure 3 – Impoundment Solution Storage and Remaining Capacity – Avg. Cycle

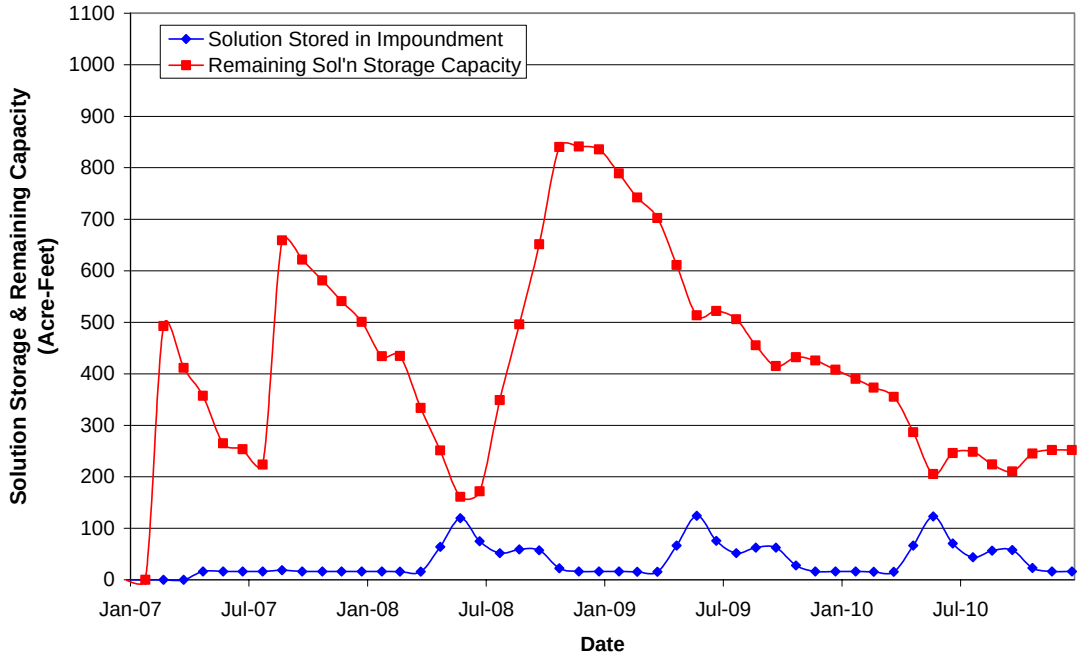


Figure 4 – Impoundment Solution Storage and Remaining Capacity – Wet Cycle

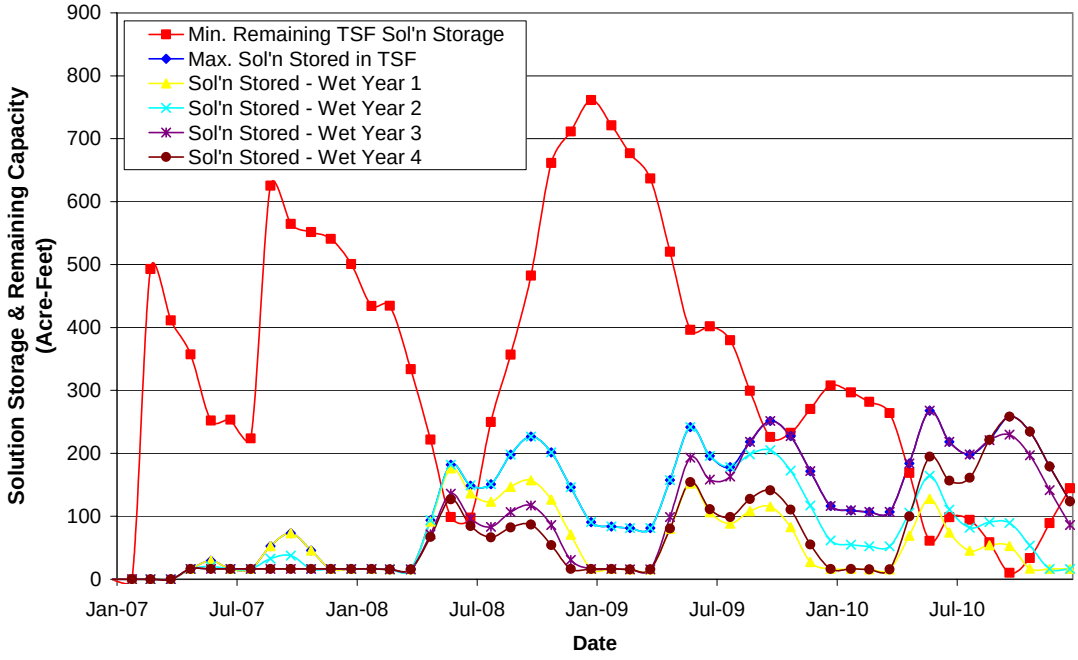


Figure 5 – Impoundment Reclaim Rates

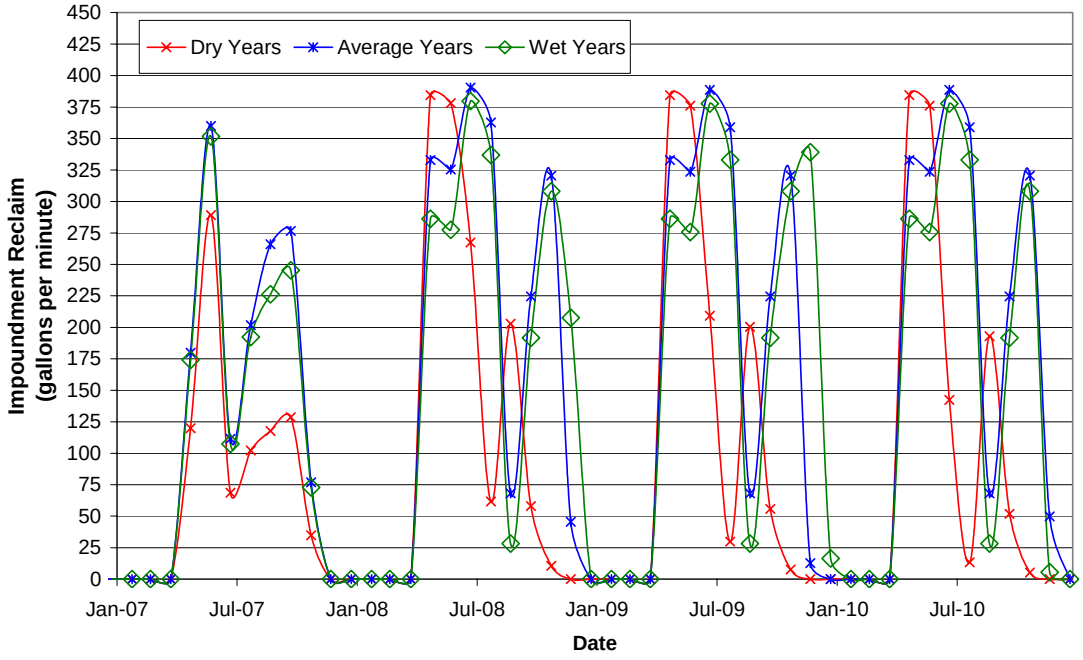


Figure 6 – Pit Dewatering Discharge

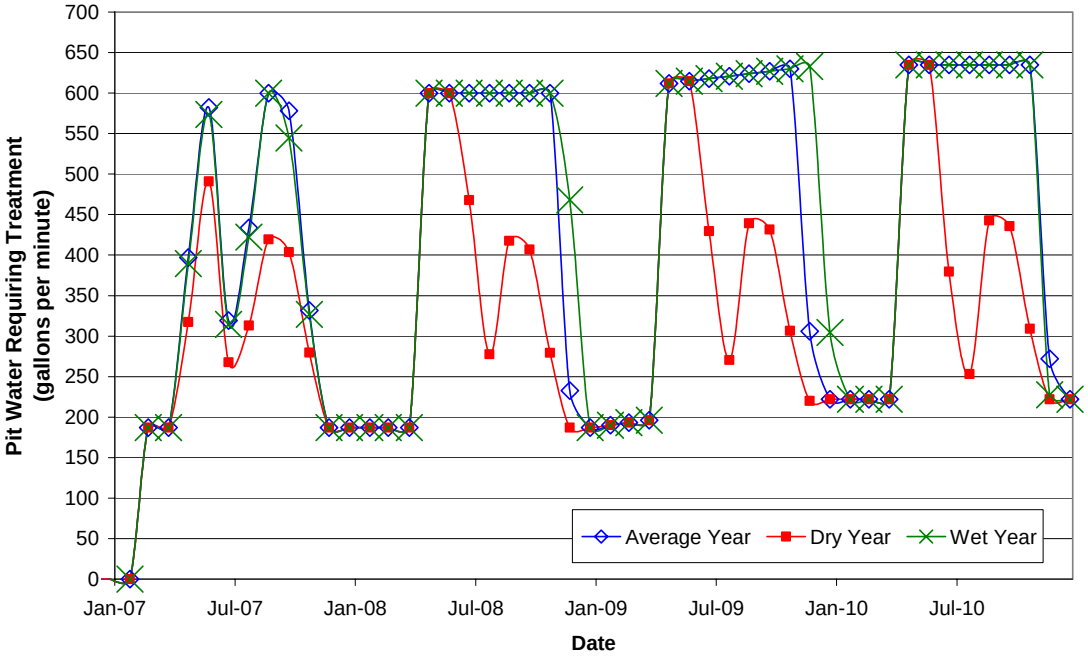
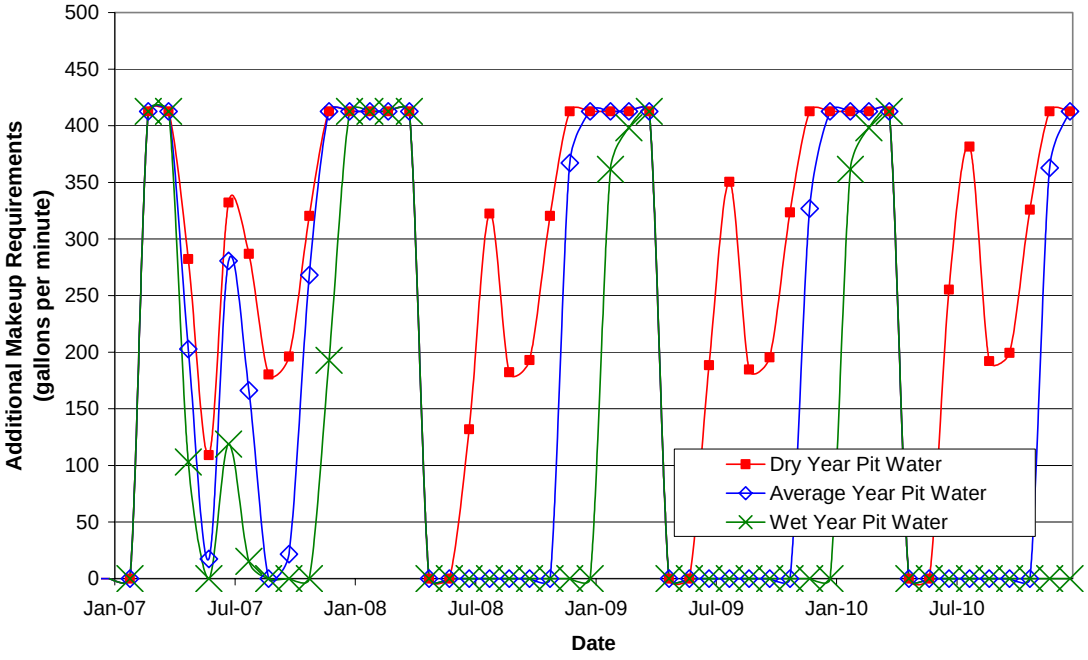


Figure 7 – Pit Water Makeup Requirements



Appendix C
Thermal and Seepage Evaluation

THERMAL AND SEEPAGE EVALUATION

for the proposed

ROCK CREEK GOLD MINE
TAILINGS STORAGE FACILITY DAM
NOME, ALASKA

Prepared for:

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April 2006

1106-04

Executive Summary

Northern Geotechnical Engineering, Inc. was contracted by Smith Williams Consultants, Inc. to conduct a thermal and fluid seepage analysis for a rock fill tailings retention dam to be constructed as part of the proposed Rock Creek Gold Mine located north of Nome, Alaska. The focus of the evaluation was to determine the approximate seepage flow under the dam and to assess alternative designs for minimizing the seepage volume. Alternatives included 1) lining the upper face of the dam, 2) incorporating thermosyphons to create a frozen barrier to water flow and 3) extending the liner system into the weathered bedrock foundation.

The Rock Creek Project is a gold ore mining and extraction operation proposed to be constructed along the southwestern flank of Mt. Brynteson, approximately 6 miles north of Nome, Alaska. The project facilities will be constructed along both sides of Rock Creek and will consist of an open pit mine, ore processing and extraction facilities, tailings storage facility, and associated operation/administrative facilities.

Several subsurface exploration programs have been conducted at the site, and the subsurface conditions at the site have been characterized through the installation of multiple core holes, boreholes, and test pits located across the extent of the site. Data obtained from these exploration studies were used to develop material properties and subsurface profiles used for the modeling effort. Thermal data collected was used to calibrate the model material properties and boundary condition functions.

Numerical modeling of the tailing storage facility was conducted using thermal and fluid seepage analysis software applications (TEMP/W & SEEP/W) developed and produced by GeoSlope International, Ltd. TEMP/W and SEEP/W are two-dimensional, finite-element analysis software applications which can model (predict) thermal and hydraulic changes in specified materials due to environmental changes, construction, and/or demolition of structures which may alter the thermal and hydraulic regimes of the materials modeled. TEMP/W and SEEP/W can perform time-step analyses in concert with one another effectively modeling convective heat transfer to predict the real-time impact that groundwater seepage has on the freeze-thaw interface of specified materials,

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and to predict the volume of water that will seep through the dam and underling native materials over the course of time.

A scaled model of the proposed tailings storage facility and surrounding/underlying materials was first constructed in the software program's graphical user interface using the available design tools. A layered model was constructed which depicts the tailings stockpile and dam, as well as the underlying soils/bedrock. The model was constructed in a manner which incorporates all three phases of the proposed dam construction into one model. This design method allowed the thermal/seepage analysis to be executed in three separate phases corresponding to the three proposed phases of dam construction.

Once a functional and reasonable analysis procedure had been developed, several different scenarios were generated and analyzed which allowed for the investigation of the effects that differing material properties, boundary conditions, and heat removal systems could have on the thermal and hydraulic conditions of the tailing storage facility and native materials during and after tailings placement within the storage area. A total of seven different scenarios were analyzed using the fundamental three-phase model.

All seven scenarios were analyzed by the modeling software, and the results were then compared to one another to determine what effect differing material properties, boundary conditions, and heat removal systems would have on the tailings storage facility and surrounding native materials.

Flux sections, which are used to determine the amount of discharge occurring thorough individual elements within the model, were placed at the upstream and downstream toes of the dam to calculate the discharge rate that is predicted to occur in each phase of the analyses. A vertical flux section was placed across the elements through which subsurface flow is predicted to occur to calculate the instantaneous horizontal flow rates which occur through each of the specified elements within the models. The instantaneous flow rates for each time step in the analysis were obtained from the flux sections and averaged together to obtain an average discharge rate for each year-long analysis.

From the modeling analysis it appears that with a liner on the rock fill dam, the seepage flow is governed by the properties of the weathered bedrock. During the period of time that tails are being added to the system, the heat added to the system cannot be controlled by passive artificial cooling. Decreasing the flow volume through the dam by cutting off the top 2/3 of the weathered bedrock significantly reduces the seepage flow from the tails.

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Passive cooling of the upstream toe of the dam has little effect on the annual seepage flows if there is no cut off into the weathered bedrock. With a cutoff extending 2/3 of the way through the weathered bedrock, passive cooling is not necessary.

In itself, thawing of the permafrost will have no effect on the stability of the Tailing storage facility. Controlling seepage to control the transport of contaminants is needed from an environmental standpoint. The annual average temperature suggests that with passive cooling, a permafrost barrier could be achieved. Due to the seepage flow and thermal input from the warm tails, it appears to not be practical to achieve a frozen barrier with thermosyphons. As ambient air temperatures rise, the ability to sustain a frozen barrier is reduced. Seepage flow can be effectively controlled using an HDPE cutoff barrier than extends most of the way through the weathered bedrock.

A cutoff trench in the weathered bedrock is recommended to control seepage from the tails to the downstream toe of the dam. The dam and cutoff trench can be constructed in the summer or winter. Additionally, the cutoff trench should be allowed to freeze prior to placement of tails over the trench.

We greatly appreciate the opportunity to be of service to you. If you have any questions regarding the material presented in this report, please contact our office at your convenience.

Sincerely,

NORTHERN GEOTECHNICAL ENGINEERING, INC.

ACS

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Project Geologist

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Appendix G	Phase III Analysis Results
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1.0 INTRODUCTION

Northern Geotechnical Engineering, Inc (NGE) was contracted by Smith Williams Consultants, Inc. (SWC) to conduct a thermal and fluid seepage analysis for a rock fill tailings retention dam to be constructed as part of the proposed Rock Creek Gold Mine located north of Nome, Alaska. The focus of the evaluation was to determine the approximate seepage flow under the dam and to assess alternative designs for minimizing the seepage volume. Alternatives included 1) lining the upper face of the dam, 2) incorporating thermosyphons to create a frozen barrier to water flow and 3) extending the liner system into the weathered bedrock foundation.

The proposed dam design calls for a rock fill structure to be constructed at the mine site on top of frozen bedrock. The upstream side of the dam will be lined with a high density polyethylene (HDPE) geomembrane, which will inhibit the migration of fluids through the upstream face of the dam. The initial design proposed that the foundation of the dam would be maintained in a frozen state (possibly through the use of thermosyphons) which would further limit the amount of fluids which could be transmitted through the dam and native materials to the downstream toe of the dam. The goals of the thermal and fluid seepage analysis were to: 1) evaluate the impact that the introduction of the tailings slurry will have on the native frozen materials; 2) determine if (and where) any heat removal devices will need to be installed to maintain frozen ground conditions at upstream toe of the dam; and 3) estimate the amount of fluid flow-through that may occur beneath and/or through the dam over time.

The various evaluations conducted on several scenarios using thermosyphons indicated that the fluid flow through and under the dam was not significantly reduced by the extra cooling provided. The distribution of the fluid flow was altered however the total fluid flow on an annual basis was not significantly reduced. Based on these results, a second model was developed to simulate extending the HDPE liner part way through the weathered bedrock where the fluid flow was concentrated.

The thermal and ground water seepage analysis was conducted using numerical modeling software applications developed by Geo-Slope International (TEMP/W and SEEP/W). A scaled model of the proposed dam and underlying strata was constructed in the software application using material properties measured at the site, as well as documented values for similar materials. Climatological and geographical data for the region were also acquired and incorporated into analysis. The model was constructed in three separate phases to correspond with the three proposed phases of dam construction. The analysis results of each preceding phase were subsequently applied as initial conditions in the analysis for each succeeding phase to effectively model the long-term effects of the dam and stored tailings on the frozen ground. Heat removal requirements were also examined in the analysis, and thermosyphon placement and size were estimated to maintain the frozen regime of the upstream toe of the dam.

Results of the analyses indicate that the use of thermosyphons is not cost effective and that extending the cutoff liner through 2/3 of the weathered bedrock significantly reduces fluid flow. It is apparent that the introduction of warm tails (above freezing at the time they are pumped into the reservoir area) impacts the permafrost foundation area. The permeability of the weathered bedrock and the fluid flow with its accompanying heat transfer are high enough to prevent the thermosyphons from creating a complete barrier to fluid flow. As the flow section decreases during the winter, the fluid flow velocity increases with an increased head. This increased velocity increases the thermal erosion rate, transferring the cooled fluid downstream where it is ineffective for developing a permanent barrier.

The modeling effort was conducted in metric units to match the previous and continuing work being completed for the project. Table 1 presents conversions for all of the units used within the model.

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2.0 PROJECT LOCATION AND DESCRIPTION

The Rock Creek Project is a gold ore mining and extraction operation proposed to be constructed along the southwestern flank of Mt. Brynteson, approximately 6 miles north of Nome, Alaska (Figure 1). The proposed project site is located within Sections 14, 15, 22, 23, 24, 25, 26, and 33, T10N, R34W, Kateel River Meridian, Alaska. The project facilities will be constructed along both sides of Rock Creek (a drainage of Mt. Brynteson and a tributary of the Snake River), and will consist of an open pit mine, ore processing and extraction facilities, tailings storage facility, and associated operation/administrative facilities. The base of the site sits at an approximate elevation of 100 meters above mean sea level (msl) with approximately 135 meters of relief across the site. The terrain is gently sloping to near vertical and is vegetated with low lying grasses and shrubs, muskeg, and riparian alders. Figure 2 presents a map of the TSF portion of the project site as it is currently planned.

Nome is located in area of discontinuous permafrost. Areas that have been disturbed by mining activities, larger stream beds and lakes are typically underlain with thawed ground. Undisturbed areas typically are underlain with permafrost that extends from a few to about 100 feet below the surface. Permafrost temperatures are typically quite warm and usually greater than -3°C. Annual temperature/precipitation values range from -15°C to 10°C with an average of 42 cm of rainfall equivalent precipitation (including snowfall) falling each year (Norwest, 2003). The average annual temperature is below 0°C thus barely maintaining the existing permafrost.

Approximately 7.5 million tons of gold ore (approx. 6,000 tons per day) is projected to be removed from the Rock Creek mine over the projected operational life of the mine (approx. 3-4 years). The Rock Creek processing and extraction facility will also accommodate and additional 1000 tons of gold ore per day which will be transported to the site from the Big Hurrah open pit gold mine located approximately 30 miles east of Nome.

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The tailings produced from the gold extraction process will be in paste form (very thick slurry), with the majority of the processing solution/water removed to be reused in the extraction process prior to placing the tails in the reservoir area. A Tailing Storage Facility (TSF) will be constructed south of Rock Creek, and will consist of a homogenous rock-fill dam with a 60-mil HDPE geomembrane lining the upstream face of the dam. The Tailing Storage Facility Dam (TSFD) will be constructed in three stages to minimize initial construction costs. Figure 3 shows a cross section of the dam with the three phases indicated. Figure 4 shows the modified cross-section for the extended liner analysis. The tailings will be placed behind the TSFD using a gravity-fed HDPE pipeline distribution system which will place the tailings from bottom to top using a series of distribution towers, and proceed up slope as tailing placement continues. Once mining operations have ended and tailings placement ceased, the TSF surface will be reclaimed and have permanent surface drainage features emplaced.

3.0 PREVIOUS WORK

3.1 Preliminary Economic Study
(Norwest Corporation - August 2003)

NovaGold Resources Inc. (NovaGold) contracted Norwest Corporation (Norwest) to conduct a preliminary economic study, mine plan, and cost estimate for the Rock Creek Project in the spring of 2003. The report provides a general description of the project site and project objectives. It also provides a fairly detailed account of the regional and local geology, mineral resource, and evaluates the potential recoverable gold based on a series of cores drilled across the extent of the site. The report provides recommendations for pit and rock dump dimensions, and initial recommendations for the TSF and impoundment dam construction. The report concludes the need for an in-depth geotechnical assessment of the site, and recommends additional core holes, boreholes, and test pits be installed across the site to better characterize the subsurface materials and aid in the refinement of the designs for the pit walls, rock dump foundations, TSF and TSFD, drainage system, and processing facility foundations.

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3.2 Draft Geotechnical Site Investigation
(Golder Associates - February 2004)

NovaGold contracted Golder Associates (Golder) to conduct geotechnical explorations at the Rock Creek Project site in the fall of 2003. The explorations were aimed at characterizing the subsurface conditions which exist beneath the proposed mine pit, TSF, processing facility site, and rock waste dumps. The explorations consisted of the installation of multiple core holes, boreholes, and test pits across the site (graphical logs were provided in the appendix of the Golder report). Appropriate rock and soil samples were collected and submitted for a suite of geotechnical analyses. The report details the subsurface conditions at each respective location, and provides a brief description of the permafrost and ground water conditions encountered across the site.

3.3 Geotechnical Site Investigation
(Smith Williams Consultants - April 2005)

Alaska Gold Company (Alaska Gold) contracted Smith Williams Consultants, Inc. (SWC) to conduct geotechnical explorations at the Rock Creek Project site in the summer and fall of 2004. The explorations were conducted in two phases due to issues which arose regarding equipment availability, site access, and facility design reconfigurations. Phase I was conducted in August of 2004 and consisted of the advancement of four core holes along the extent of the proposed TSFD and the excavation of a total of 34 test pits at selected locations across the site corresponding to proposed facility locations. Representative rock and soil samples were collected and submitted for a suite of geotechnical analyses. Grab samples of existing placer tailings located along Glacier Creek were also collected for geotechnical analyses to determine their suitability for use as drainage and bedding materials. Vibrating-wire piezometers and thermister strings were installed into all four of the core holes drilled during phase one of the explorations.

Phase two of the explorations were conducted in November of 2004 and consisted of excavating a total of 28 additional test pits at areas located across the site which either: 1) encountered refusal during phase one of the explorations due to frozen conditions; 2)

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were inaccessible during phase one of the explorations due to thawed surface conditions; or 3) which corresponded to facility design reconfigurations which were enacted after phase one of the explorations were completed. Representative rock and soil samples were collected and submitted for a suite of geotechnical analyses.

A summary of the subsurface conditions encountered at each of the facility sites and recommendations concerning building foundations and retaining structures is provided within. Graphical logs for the core holes and test pits installed during both phases of the explorations, results of the laboratory analyses, and data recorded from the thermister strings were all included in the appendices of the SWC report.

3.4 Feasibility Design Study
(Smith Williams Consultants - June 2005)

SWC completed a feasibility design study for the Rock Creek Project following the geotechnical explorations they conducted at the site in the fall of 2004 for Alaska Gold. The study accounts for all of the available information collected from the previous explorations conducted at the site, as well as all of the design changes enacted since the conception of the project, and presents a comprehensive evaluation of the existing site conditions and present comprehensive design recommendations for all of the proposed project facilities.

As part of the study, SWC conducted a preliminary seepage analysis for the proposed TSF using SEEP/W finite seepage analysis software) to estimate seepage flows, head distribution, and water levels within the TSFD. Estimates obtained from the preliminary analysis indicate that approximately 120,000 m^3 of fluid seepage may occur each year through the TSFD. The analysis also indicated that the stability of the TSFD should not be affected by the volume of fluids which is predicted to exist within the TSFD under normal operating procedures and average climatic conditions. The analysis indicated that even with total liner failure, the stability of the TSFD should not be compromised.

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To this date, this is the most current and comprehensive report detailing the existing conditions identified at the site and the proposed design for the project. This study is the basis for the all of the design dimensions and subsurface conditions used to construct the model of the TSFD used in our thermal and fluid seepage analyses.

4.0 SUBSURFACE CONDITIONS

As mentioned in Section 3.0, several subsurface exploration programs have been conducted at the site, and the subsurface conditions at the site have been characterized through the installation of multiple core holes, boreholes, and test pits located across the extent of the site. A complete description of the subsurface conditions encountered across the site is not included in this report, and the focus will only be on the subsurface conditions observed beneath the proposed TSF and TSFD. For a complete description of the subsurface conditions across the remaining portion of the site, please refer to the reports listed in Section 3.0.

The entire TSF footprint is overlain by a thin organic mat ranging from 0.05 meters to 0.15 meters in thickness. Low-lying areas and drainages located within the limits of the proposed TSF are typically underlain by differing thicknesses of sand, silt and gravel mixtures overlying which overlie fractured bedrock. These areas are typically characterized at the surface by shrub and willow thickets and represent thawed soil zones with subsurface water flow. The remaining portions of the proposed TSF footprint are underlain by finer-grained silts and sandy silts which are saturated, ice-rich, and overlay frozen bedrock. The ice-rich materials display moisture contents up to, and exceeding 100 percent of the total sample mass. These areas are characterized at the surface by low-lying sedge and tundra.

The footprint of the TSFD is also overlain by a thin tundra mat ranging from 0.09 meters to 0.12 meters in thickness. It is subsequently underlain by a 0.5 meter thick layer of saturated silts, which in turn is underlain by zero to six meters of silt and sandy silt which are saturated and ice-rich (permafrost). The ice-rich materials display moisture contents up to, and exceeding 100 percent of the total sample mass. The surficial sediments are

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underlain by a graphic schist bedrock containing visible sulfides, significant quartz veining, and substantial evidence of calcite. The condition of the schist ranges from decomposed or rubblized to competent at depths of 0.6 to 6.1 meters. The weathered bedrock material is frozen to depth, except along the Rock Creek drainage, where the material is thawed. Core samples reveal that the bedrock is moderately to highly fractured at depth. Data collected from thermister strings placed in core holes located along the centerline of the proposed TSFD indicate that temperatures within the bedrock range from -1/7°C to -1.2 °C at the bedrock surface (5-6 meters bgs) to -1.3°c to -1.2°C at a depth of 25 meters bgs. Permeability testing conducted in the four boreholes located along the centerline of the TSFD indicates that the bedrock has permeabilities ranging from 1.2×10^{-3} to 4.1×10^{-6} m/s, with higher permeabilities observed near the Rock Creek drainage and along the southern extent of the TSFD. The increased permeabilities are thought to represent areas of highly fractured bedrock, and where the fractures are relatively open and ice-free.

Based on the subsurface information derived from the several previous studies, a generalized cross-section was developed as shown in Figures 3 and 4. As with all sites, there was a range of material parameters for each unit, details of which are presented in the following Section 5.2.3.

5.0 COMPUTER ANALYSIS

5.1 Brief Overview of Numerical Modeling

Numerical modeling is a technique which utilizes mathematics to simulate actual physical processes. Numerical modeling has only recently become a viable industry tool with the advent of high-speed microprocessors and advanced software design, which can efficiently process the complex calculations involved. While computers and associated numerical modeling software have made the modeling process a more accessible and less expensive alternative to physical modeling and actual field testing, they have not eliminated the need for user understanding and expertise. The modeling program is only a glorified calculator; the model design, material properties, and analysis settings and

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results must still be evaluated and deemed reasonable by a competent and knowledgeable user.

Numerical modeling is a non-invasive and relatively expeditious technique which allows the user to manipulate initial site conditions and forecast (predict) future site conditions. However, because the model analysis is based on user defined material properties, the results generated are only as accurate as the data that is initially input. Furthermore, averaged values for material properties are often used in the modeling process to limit the complexity of the model, and allow for a more manageable data set. These generalizations do not account for the small-scale variations (both vertical and lateral) which often occur in earth materials. Therefore, results obtained from numerical models should not be viewed as real-world solutions, but should instead be used along with other site-specific data to help guide future site design.

5.2 Modeling Procedure

Numerical modeling of the TSFD was conducted using thermal and fluid seepage analysis software applications (TEMP/W & SEEP/W) developed and produced by GeoSlope International, Ltd. TEMP/W & SEEP/W are two-dimensional, finite-element analysis software applications which can model (predict) thermal and hydraulic changes in specified materials due to environmental changes, construction, and/or demolition of structures which may alter the thermal and hydraulic regimes of the materials modeled. Furthermore, TEMP/W & SEEP/W can perform time-step analyses in concert with one another effectively modeling convective heat transfer to predict the real-time impact that groundwater seepage has on the freeze-thaw interface of specified materials, and to predict the volume of water that will seep through the dam and underling native materials over the course of time.

For this project 2 models were developed because the model using thermosyphons to restrict water flow under the dam appeared to be relatively ineffective. The second model was created to assess the effectiveness of extending the HDPE liner part way through the weathered bedrock. A total of 7 scenarios were run. Details of each are presented in Section 5.4.

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5.2.1 Model Generation

A scaled model of the proposed TSFD (and surrounding/underlying materials) was first constructed in the software program's graphical user interface using the available design tools. A layered model was constructed which depicts the tailings stockpile and associated TSFD, as well as the underlying soils/bedrock depicted in Figures 3 and 4. The model was constructed in a manner which incorporates all three phases of the proposed TFSD construction into one model. This design method allowed the thermal/seepage analysis to be executed in three separate phases corresponding to the three proposed phases of dam construction (Phases I-III). Figure 5 presents a flow chart of the analysis procedures used for each of the 7 scenarios.

Furthermore, the three phase model allowed for the calculation of site conditions predicted to exist at the scheduled initiation of Phases II and III of dam construction. The three-phase model addresses this concern since the TSF (as well as the TSFD and surrounding/underlying materials) will not have reached equilibrium by the scheduled initiation of succeeding phases of dam construction.

Therefore, the results of the analysis for each preceding phase of the model were subsequently incorporated as initial conditions for each succeeding phase of dam construction to effectively model the impact of the changing configuration. Long-term effects of the TSF following completion of the mining operations could then be modeled using the final configuration and applying the boundary conditions for multiple years.

5.2.2 Mesh Configuration

Before any thermal/seepage analysis could be performed, the model had to be divided into individual units known as "regions". The region dimensions are designated by the user, and allow the user to assign material properties to the model (Discussion of material properties is provided in Section 5.2.3). Figure 6 shows the regions used for the thermosyphon analysis and Figure 7 shows the regions used for the extended liner analysis. The regions are subsequently divided into smaller units known as "elements" during a process known as "meshing. The software application generates an "element mesh" (a.k.a. grid), which allows the program to relate information contained within each

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element to the surrounding elements during the temporal analyses. Each element is composed of the most basic model units known as "nodes" (i.e. corner points), which link each element to one another within each region, and between surrounding regions.

The physical configuration of the element mesh generated for all three phases of the thermosyphon model is displayed in Figure 8. Figure 9 shows a detail of the thermosyphon node placement. A similar mesh was developed for the extended liner and is shown in Figure 10. The comprehensive model (Phase III) of the thermosyphon analysis included a total of 8803 nodes comprising a total of 8513 elements which were arranged in both structured and unstructured quad meshes across a total of 86 regions. The liner extension model was similar in size.

All of the elements located along the vertical downstream extent of the model were assigned as "infinite elements", and extended laterally to infinity (Figures 8 and 10). Infinite elements allow the user to extend the effective influence of the boundary conditions (in either the X or Y direction, or both) without actually extending the mesh. Thus reducing the number of nodes/elements that would otherwise be required to extend the model to a distance far enough away from the TSFD so as not to influence the results of the analysis near the area of interest.

5.2.3 Material Properties

The model generated for the proposed TSFD is comprised of six different materials which represent the five earth materials and the HDPE liner that are proposed to be used in the construction of the TSF (See Sections 2.0 and 4.0). The six materials include: 1) Fractured bedrock; 2) Weathered/decomposed bedrock; 3) Native topsoil; 4) Mine tailings (paste); 5) Rock fill used for dam construction; and 6) HDPE geomembrane used to line the upstream face of the TSFD.

The two natural processes simulated in this study are: 1) the transfer of heat energy through earth materials (thermal analysis); and 2) the movement of water through earth materials (seepage analysis). These processes are evaluated based on certain physical properties inherent to each earth material. The thermal and hydraulic properties for each

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of the six materials comprising the model were obtained and/or derived from a combination of: 1) site specific field data; 2) established values documented in existing literature for similar materials; and 3) from previously defined material properties listed in the TEMP/W & SEEP/W. Table 2 summarizes the material properties used.

Appendix A defines and presents the thermal functions used in the modeling effort (Thermal Conductivity and Unfrozen Water Content). Similarly Appendix B defines and presents the hydraulic functions used (Hydraulic Conductivity and Volumetric Water Content).

5.2.4 Boundary Conditions

Boundary conditions are used to define the external conditions that affect the temperature and seepage within the model, and are in essence what define the direction that energy or fluids will move within the system. Boundary conditions are used by the program to calculate the gradient within a problem set, whether it be heat energy flux into or out of a system, or ground water flow through a system. Boundary conditions are user defined, and are usually based on real-world data (i.e. climate data, elevation data, geothermal data, etc.).

The boundary conditions used for this model included air temperature coupled with modifiers, precipitation, and wind. Details of these functions are presented in Appendix C.

5.2.5 Thermosyphons

Thermosyphons are gas filled sealed tubes that through phase change in the gas are capable of transferring heat from a warm location to a colder location. Typically the tubes are filled with pressurized Carbon Dioxide (CO_2). The pressure used defines the temperature at which the CO_2 changes from a gas to a liquid. To maintain permafrost, the liquid needs to boil and change to a gas at a temperature below the freezing temperature of water. The gas will then revert to a liquid at a lower temperature. Within a sealed tube, the gas will rise to the top where a radiator is located. When the air temperature is low enough to remove the latent heat of the gas, it turns into a liquid and flows back down the

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tube. The warm earth temperatures then boil the liquid absorbing heat from the ground. The gas then floats to the radiator, repeating the cycle.

To model the thermosyphon function, the model needs to assess the temperature difference between the ground adjacent to the thermosyphon (See Figure 9 for locations) and the air temperature. The amount of heat that can be removed is a function of the radiator size in relation to the thermosyphon pipe size (length) and the efficiency of the radiator. The radiator efficiency is a function of the wind speed, air temperature and configuration of the piping in the ground.

The efficiency of the thermosyphon configuration in the ground was developed from data provided by the manufacturer and input into the model. The configuration used for the model represents nearly the minimum efficiency for thermosyphons due to the nearly flat configuration of the piping in the ground. The model does not represent the extreme length or flatness of thermosyphons that have been installed and function.

For this model, the thermosyphon length and ground configuration are constants and the air temperature and wind speed functions are input. For this design, it was assumed that the thermosyphon would run along the base of the dam with radiators at both ends. The length input was taken as ½ of the total length of the dam at the end of Phase III. The only remaining variable is the size of the radiator, which is measured in surface area of the fins. Two different sizes were modeled, 1) a radiator size of 50 m^2 being a normal large radiator consisting of 3 or 4 fin sets attached to the top of each thermosyphon, and 2) a radiator size of 200m^2 representing a likely extreme size radiator set on each end of the thermosyphon.

5.3 Analysis Procedure

As discussed in the model set up in section 5.1, the analysis uses a multi-step procedure to account for the anticipated out-of-equilibrium conditions that exist at the beginning of each Phase of construction. Figure 5 presents the flow chart used for the analysis of each phase.

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Seven different scenarios were analyzed to assess different conditions. These scenarios can be grouped into 3 sets based on the initial conditions assumed. They are:

- Group 1, Current Conditions
    1. Scenario 1. Current conditions, no thermosyphons
    2. Scenario 3. Current conditions with small thermosyphons
    3. Scenario 4. Current conditions with large thermosyphons
- Group 2, Elevated Conditions
    1. Scenario 5. Elevated boundary conditions without thermosyphons
    2. Scenario 6. Elevated boundary conditions with small thermosyphons
    3. Scenario 7. Elevated boundary conditions with large thermosyphons
- Group 3, Current Conditions with an extended liner

Details of the phase analyses are presented in the sections below. The scenario analysis discussions are presented in Section 5.4

5.3.1 Phase I

Before any transient analyses could be performed, an initial conditions file had to be generated (through a steady state analysis) which established the subsurface thermal and hydraulic conditions of the native materials located within the footprint of the proposed TSF. The steady-state analysis was performed to establish the initial thermal and hydraulic conditions of the native materials at equilibrium (as measured in the field), prior to the addition or removal of any materials at the surface of the model (i.e. addition of dam material, tailings, or removal of native overburden). This was accomplished by applying a series of lateral thermal boundary conditions which defined the thermal gradient of the native materials prior to TSFD construction. The boundary condition temperatures were adjusted until the vertical thermal gradient produced by the steady state analysis effectively represented the actual subsurface conditions measured at the site (i.e. thermistor values from core holes along the TSFD centerline).

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The initial hydraulic conditions of the native materials were defined by applying pressure head boundary conditions to each node along the surface of the weathered bedrock layer (which is where ground water table is reported to exist). This boundary condition essentially assigns a hydraulic head pressure to each node based on the Y-coordinate of the node (*i.e.* node elevation above msl).

The results of these steady state analyses represent the initial thermal and hydraulic conditions predicted to exist at the TSF site at the proposed start of TSFD construction in January of 2006 (designated as Jan:01).

The results of the steady state analyses (thermal and hydraulic) were then used as the initial conditions for a transient thermal analysis aimed at predicting the thermal and hydraulic conditions of the TSFD and underlying native materials during construction of Phase I of the TSFD, but prior to initial tailings placement. Results of the analyses for the three groups are presented in Appendix D.

Before the transient analysis was performed, the regions within the model which represent the fist phase of the TSFD were activated, and each node within these regions was assigned a thermal boundary condition equal to -5.8°C (the average air temperature between January and August), estimated temperature of rock fill used to construct the TSFD. A transient analysis then was run for one, 24-hour time step to establish the initial thermal and hydraulic conditions of the TSFD. The results were then saved as the initial conditions for the following transient analysis which predicts the impact of the TSFD on the thermal and hydraulic conditions of the native materials the course of the following 8 months. (Jan:01 to Aug:01).

A transient analysis (using connective heat transfer analysis w/ SEEP/W) was then initiated which ran from January (of the first year of TSFD construction – designated Jan:01) to August (of the first year of TSFD construction – designated as Aug:01), using an individual time-step of 24 hours. The result of the transient analysis is the predicted thermal and hydraulic conditions of the first phase of TSFD construction (and underlying native materials) prior to tailings placement. The results of this analysis were then saved as the initial conditions for the following the transient analysis which analyzes the impact

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of Phase I of tailings placement on the thermal and hydraulic conditions of the TSFD and native materials.

Results of the analyses prior to placement of the Phase I tails are presented in Appendix D.

The regions representing Phase I of tailings placement were then activated within the model. Each node within these regions was assigned a constant thermal boundary condition of 2°C (assumed average temperature of tailings as they are placed behind the TSFD). Also, a hydraulic boundary condition was placed along all of the nodes which define the bottom of the tailings (i.e. the tailings interface w/ the underlying native materials and the upstream face of the TSFD) which assigned a potential head to all of the selected nodes equal to the maximum height of the tailings along the TSFD face (i.e. maximum potential head of water stored within the tailings). A transient analysis then was run for one, 24-hour time step to establish the initial thermal and hydraulic conditions of the tailings. The results were then saved as the initial conditions for the following transient analysis which predicts the impact of the stored tailings on the thermal and hydraulic conditions of the native materials and TSFD over the course of the next 365 days. (Aug:01 to Aug:02).

The ensuing transient analysis was run for 365 days with 24 hours time steps. The results of this transient analysis display the predicted thermal and hydraulic conditions of the TSFD and native materials after one year of operation (Aug:02). The results of this year-long analysis then subsequently saved as the initial conditions for Phase II of TSF construction/operation.

Results of the Phase I analysis for the 7 scenarios are presented in Appendix E.

5.3.2 Phase II

The results of the year-long, Phase I transient analysis (Aug:01 to Aug:02) were subsequently applied as the initial conditions for a transient analysis of Phase II of TSFD construction and tailings placement. The regions representing Phase II of the TSFD and

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tailings placement were then activated within the model (as was performed in Phase I) and every node located within the newly activated TSFD regions was assigned a boundary condition equal to 2.2°C, and every node within Phase II of the tailings was assigned a thermal boundary condition of 2°C (See Section 5.3.1). A transient analysis was then executed for one, 24-hour time step to establish the thermal and hydraulic conditions of the second phase of TSFD construction and tailings placement. The results were then saved as the initial conditions for a transient analysis which predicts the impact of the stored tailings on the thermal and hydraulic conditions of the TSFD and native materials over the course of the ensuing 365 days (up to Aug:03). The transient analysis was carried out for 365 days with 24 hours time steps. The results of this transient analysis display the predicted thermal and hydraulic conditions of the TSFD and native materials after two years of operation.

Results of the Phase II analyses for the seven scenarios are presented in Appendix F.

5.3.3 Phase III

The results of the year-long, Phase II transient analysis (Aug:02 to Aug:03) were subsequently applied as the initial conditions for a transient analysis of Phase III of TSFD construction and tailings placement. The regions representing Phase III of the TSFD and tailings placement were then activated within the model (as was performed in Phase I and II) and every node located within the newly activated TSFD regions was again assigned a boundary condition equal to 2.2°C, and every node within Phase II of the tailings was assigned a thermal boundary condition of 2°C. A transient analysis was then executed for one, 24-hour time step to establish the thermal and hydraulic conditions of the third and final phase of TSFD construction and tailings placement. The results were then saved as the initial conditions for a transient analysis which predicts the impact of the stored tailings on the thermal and hydraulic conditions of the TSFD and native materials over the course of the ensuing 365 days (up to Aug:04). The transient analysis was carried out for 365 days with 24 hours time steps. The results of this transient analysis display the calculated predicted thermal and hydraulic conditions of the TSFD and native materials after three years of operation.

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Results of the analyses at the end of Phase III are presented in Appendix G for all seven scenarios.

5.3.4. Extended Analysis (9 year)

The results of the Phase III analysis were then saved as the initial conditions for a final transient analysis which predicts the impact of the stored tailings on the thermal and hydraulic conditions of the TSFD and native materials over an extended period of time after TSF closure has occurred (up to Aug:13). The transient analysis was carried out for a total of 3290 days (9 years) using 24 hour time steps. The results of this transient analysis display the predicted thermal and hydraulic conditions of the TSFD and native materials nine years after TSF operations cease.

Results of the extended analyses for the seven scenarios are presented in Appendix H.

5.4 Analysis Scenarios

Once a functional and reasonable analysis procedure had been developed, several different scenarios were generated and analyzed which allowed for the investigation of the effect(s) that differing material properties, boundary conditions, and heat removal systems could have on the thermal and hydraulic conditions of the TSFD and native materials during and after tailings placement within the TSF. A total of seven different scenarios were analyzed using the fundamental three-phase model described in Section 5.3.

5.4.1 Scenario 1

Current Site Conditions

Scenario 1 analyzes the fundamental three-phase model of the TSFD using material property functions derived from data obtained from the site and from published values for similar materials. Appendices A and B along with Table 2 list the material property functions for all 6 materials used in Scenario 1. The climatic boundary condition function used Scenario 1 is based on recent average ambient air temperatures and precipitation for the Nome area (Appendix C).

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The material properties and boundary conditions used for this scenario were used without alteration for scenarios 2, 3, and 4.

5.4.2 Scenario 2

Current Site Conditions w/ Extended Liner

Scenario 2 analyzes the fundamental three-phase model of the TSFD using the material property functions for scenario 1. Results from scenario 1 showed that most of the water flow from the tails toward the downstream toe went through the weathered bedrock. To reduce this flow, the liner used to prevent fluid flow through the rock fill dam was extended about 2/3 of the way through the weathered bedrock.

5.4.3 Scenario 3

Current Site Conditions w/ Heat Removal System (50 m^2 Radiator)

Scenario 3 is based off scenario 1 and analyzes the potential effect that a heat removal system could have on the thermal and hydraulic conditions of the TSFD and native materials. The heat removal system consists of two thermosyphons which were placed at two nodes, just downstream of the upstream toe of the TSFD, and immediately beneath the geomembrane liner material as shown in Figure 9. The heat removal capacity of each thermosyphon is based on a total condenser radiator area of 50 square meters (average maximum size for condenser radiators used in similar applications) per thermosyphon. All other boundary conditions and material property functions remain unchanged from Scenario 1.

5.4.4. Scenario 4

Current Site Conditions w/ Heat Removal System (200 m^2 Radiator)

Scenario 4 applies the same conditions as Scenario 3 (See Section 5.4.3.) except that the total condenser radiator area was increased to 200 square meters per thermosyphon. All other material property functions remain unchanged. The results of this analysis were compared with the results from Scenario 3 to determine the effect that increased

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condenser radiator size would have on the thermal and hydraulic conditions of the TSFD and native materials.

5.4.5. Scenario 5

Elevated Temperatures and Hydraulic Conductivity

Scenario 5 analyzes the potential effect that a five-fold increase in the hydraulic conductivity function for the native weathered bedrock material would have and the thermal and hydraulic conditions of the TSFD and native materials. The average annual air temperature was increased by 3°C, representing a major increase in global temperature. Appendix C discusses the boundary conditions used. All other boundary conditions and other material property functions remain unchanged from Scenario 1.

5.4.6. Scenario 6

Elevated Temperature and Hydraulic Conductivity and Heat Removal System ($50m^2$ Radiator)

Scenario 6 applies the same boundary conditions used in Scenario 5 with a thermosyphon system equal to that used in scenario 3. All other material property functions remain unchanged. The results of this analysis were compared with the results from Scenario 3 to determine the effect that increased permeability values would have on the thermal and hydraulic conditions of the TSFD and native materials. Scenario 5 was also compared to scenario 4 to assess the effect of the thermosyphons on the increased flow.

5.4.7. Scenario 7

Elevated Temperature and Hydraulic Conductivity Heat Removal System ($200m^2$ Radiator)

Scenario 7 applies the same conditions as in Scenario 5 (See Section 5.4.5.) and applying the extreme thermosyphon system used in scenario 4. All other boundary conditions remain unchanged. The results of this analysis were compared with the results from Scenario 5 to determine the effect that the thermosyphons have and to scenario 4 to assess the effects of the increased temperature and hydraulic conductivity.

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5.5 Analysis Results

All seven scenarios were analyzed by the modeling software, and the results were then compared to one another to determine what effect differing material properties, boundary conditions, and heat removal systems would have on the TSFD and surrounding native materials.

The first stage of analysis was to evaluate the mass balance of the fluids within the system. Figure 11 presents a schematic of the mass balance elements for the modeled system. Flux sections, which are used to determine the amount of discharge occurring thorough individual elements within the model, were placed at the upstream and downstream toes of the TSFD to calculate the discharge rate (Q) in cubic meters/hour that is predicted to occur in each phase of the analyses. A vertical flux section was placed across the elements through which subsurface flow is predicted to occur (i.e. the elements located above the frozen bedrock and below the geomembrane liner material and ground surface) to calculate the instantaneous horizontal flow rates which occur through each of the specified elements within the models. The instantaneous flow rates for each time step in the analysis were obtained from the flux sections and averaged together to obtain an average discharge rate for each year-long analysis.

Next, the cumulative hydraulic boundary flux for each node along the top and downstream face of the TSFD (which occurred over the course of each analysis) was calculated using the software. Using the flux volume and the total calculated precipitation volume, the amount of runoff and infiltration could be determined.

Ice melt and thaw was determined by calculating the change in the volumetric water content at each node. These changes were summed for the TSFD cross section, including the region of weathered bedrock between the flux sections. The ice melt includes changes in moisture content above the saturated region which also affects the water balance.

The water balance calculations for each phase of each scenario are presented in Table 3. The water balance and subsequent water outflow calculations are further complicated by the fact that all of the tails does not enter the facility at the beginning of each phase as

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modeled. Nor does the entire dam have a cross section equal to the maximum cross section modeled. To compensate for the actual conditions of continuous inflow of tails and variable dam height, the model calculated flows were adjusted. Figure 12 presents a schematic of the averaging scheme used.

It should be noted that the averaging factors for the precipitation, inflow, outflow and ice melt are not constant with each other or for each phase due to differences in the flux boundary geometries for each variable of the water balance. This was corrected by first calculating an approximate factor based on geometry and inputting the factors into all seven scenarios for each phase of analysis. The factors were then adjusted, with the largest adjustments going to the ice melt (as this factor was the least certain in our model data calculations) such that the difference between inflow and outflow for the seven scenarios combined was minimized.

Prior to adjustment, most of the calculated water balances were within 10% of each other, with the larger variations occurring in the late phases of the analysis. Based on the numerous assumptions made in developing the model, this variation was considered within the limits of the analysis. Following adjustments, the water balances between inflow and outflow were generally within about 5 percent.

From the calculations above, the predicted outflow from the base of the dam was calculated. The results are presented in Table 4. The calculated data also allowed calculation of the approximate percent volume of the outflow that is derived from infiltrated precipitation and ice melt. Where ice melt percentages are not tabulated on Table 4, the ice volume was either balanced or there was a net ice accumulation, resulting in no outflow component. Ice accumulation occurs when the inflow to the flux section exceeds the net outflow.

Due to temperature changes the monthly flow distribution is not uniform with most of the outflow occurring in August, September and October. The thermosyphons tended to grow ice in the winter months which then melted out in the summer further concentrating the flow. Table 5 presents the percent of flow per month for the different scenarios. Where

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the flow distributions were similar, the scenarios were lumped together into one set of data.

The seven scenarios were compared to each other. The end result of each phase was compared for the seven scenarios. Plots of the temperature and hydraulic conditions were grouped by phase and are presented in Appendices D through H. A discussion for each scenario is presented below.

Additional review was completed for each scenario by reviewed intermediate time steps throughout the 3 phases and extended analysis. Time step plots for scenario 2 Phase III are presented in Appendix I. All of the phases and scenarios could have time step plots made.

5.5.1. Scenario 1

Scenario 1 represents the base conditions assumed for the model. These assumptions were made based on the field data, existing environmental data base, published literature and initial calibration runs used to establish a pre-construction equilibrium for the model. During the year for all of the phases (See 5.5.2 for detailed discussion of analysis of Appendix I data) of scenario 1, some ice growth was observed in the winter with subsequent thawing the following year. Introduction of the tails into the system increased temperatures throughout the system with water seepage carrying heat downstream.

Water accumulation was observed on the liner during the initial third of the phase. This water eventually flowed to the toe of the liner and into the weathered bedrock. Ice erosion was noticed, especially in the early summer while the winter ice accumulation still had the flow path somewhat restricted, which increased the flow velocities by keeping the upstream head high.

Each addition of tails for each new phase increased the water supply into the system. Because the water was generally warmer than the tails below and under the dam, a thermal plume could be seen. During the winter months, the water in the dam foundation started to freeze back, loosing its heat to warm up, but not thaw the ice below the dam.

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After completion of the tails impoundment at the end of Phase III, a general cooling of the tails and dam foundation was observed. Additionally, with no additional water derived from the tails, water flow decreased. Eventually, the water flow would approximate the precipitation input to the TSF. This equilibrium was not achieved in the two year extended analysis.

5.5.2. Scenario 2

Scenario 2 was developed following review of the model results from the thermosyphon analyses (Scenarios 3 and 4). It is clear from the results of scenario 1 that a vast majority of water seeping under the dam flows through the weathered bedrock. To reduce the water flow, an artificial cutoff was modeled with the liner extending about 2/3 of the way through the modeled weathered bedrock zone. See Figures 4 and 7.

Cutting off the majority of the water flow in the weathered bedrock had a significant effect on the total outflow measured downstream. This in turn resulted in cooler temperatures within the permafrost below the dam, higher retained moisture within the tails and less ice melt.

In the long-term runs (See Appendix H), the differences between scenario 1 and 2 become less, although it is apparent that there is more water remaining in the tails in scenario 2.

5.5.3. Scenario 3

Scenario 3 uses the material properties and boundary conditions from Scenario 1 with thermosyphons added at the upstream toe of the dam. Cooling of the soil below the liner was evident in the fall and winter months, however the fluid flow was never cut off completely. Heat carried from the tails through the weathered bedrock flowed over the frozen section up into the dam rock fill material. The majority of the head loss realized was due to the rise in elevation to flow over the frozen bulb.

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In the spring when the thermosyphons were no longer active (the ground temperature immediately surrounding the thermosyphon was lower than the air temperature), the frozen bulb that had developed over the winter begins to shrink. By the beginning of August, the increased flow from the thawing tails, the thawing freeze bulb, and thermal erosion from the fluid flow combine to greatly increase the outflow at the toe of the dam.

By the time the thermosyphons again become active in late September, the thermal regime is essentially the same as the previous year. Following the phase III addition of tails, the flow rate begins to drop off as the heat and water supply diminish. The thermosyphons then begin to build a frozen bulb that increases each cooling season. It is expected that within several years the flow corridor through the weathered bedrock would seal off with a frozen barrier.

5.5.4. Scenario 4

Scenario 4 is similar to scenario 3 with additional cooling capacity. The additional cooling capacity was evident in the annual development of a frozen bulb. Each year the bulb would be slightly larger than that developed in Scenario 3. Each thawing season, the frozen bulb would melt out completely.

It appears that the decreased flow area increased the flow velocity, canceling the effect of freezing the weathered bedrock. Similar to Scenario 3, following the final tails placement, the flow area trended toward freezing a blockage. The growth of the frozen bulb is slightly faster than noted in Scenario 3. It appears that the cooling rate at the thaw/frozen interface of the bulb is governed by the thermal conductivity of the frozen weathered bedrock surrounding the thermosyphon.

5.5.5. Scenario 5

Increasing the permeability of the weathered bedrock had a significant effect on the water flow at the downstream toe of the dam. The tails drained faster which also tended to erode the upstream permafrost under the tails. The increased temperature had less of an impact on the model. The thaw season was lengthened and the freezing season shortened, however at depth within the model, the material temperatures changed very little.

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The average annual temperature for the raised conditions is still below freezing. Discounting solar radiation gains, the permafrost would still be maintained by the ambient air conditions. With the solar gain it is possible that there will be a gradual degradation of the permafrost.

The increased flow through the weathered bedrock increases the thaw rate of the permafrost under the dam. Below the weathered bedrock there is slight rise in temperature although through the modeled time frame, the bedrock remains frozen.

5.5.6. Scenario 6

Scenario 6 is similar to scenario 3 but uses the model parameters developed for scenario 5. Cooling of the soil below the liner was evident in the fall and winter months, however the fluid flow was never cut off completely. As expected the cutoff was slightly less than that achieved in scenario 3. Heat carried from the tails through the weathered bedrock flowed over the frozen section up into the dam rock fill material. The majority of the head loss realized was due to the rise in elevation to flow over the frozen bulb.

In the spring when the thermosyphons were no longer active (the ground temperature immediately surrounding the thermosyphon was lower than the air temperature), the frozen bulb that had developed over the winter begins to shrink. By late July or the beginning of August, the increased flow from the thawing tails, the thawing freeze bulb, and thermal erosion from the fluid flow combine to greatly increase the outflow at the toe of the dam.

By the time the thermosyphons again become active in late September, the thermal regime is essentially the same as the previous year. Following the phase III addition of tails, the flow rate begins to drop off as the heat and water supply diminish. The thermosyphons then begin to build a frozen bulb that increases each cooling season. It is expected that within several years the flow corridor through the weathered bedrock would seal off with a frozen barrier.

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5.5.7. Scenario 7

Scenario 7 is similar to scenario 4 but uses the model parameters developed for scenario 5. The additional cooling capacity was evident in the annual development of a frozen bulb. Each year the bulb would be slightly larger than that developed in Scenario 6. Each thawing season, the frozen bulb would melt out completely.

It appears that the decreased flow area increased the flow velocity, canceling the effect of freezing the weathered bedrock. Similar to Scenario 6, following the final tails placement, the flow area trended toward freezing a blockage. The growth of the frozen bulb is slightly faster than noted in Scenario 6. It appears that the cooling rate at the thaw/frozen interface of the bulb is governed by the thermal conductivity of the frozen weathered bedrock surrounding the thermosyphon.

6.0 ANALYSIS CONCLUSIONS

Based on the results of the modeling effort several conclusions can be made regarding the control of seepage flow under the dam and out of the downstream toe.

- From the modeling analysis it appears that with a liner on the rock fill dam, the seepage flow is governed by the properties of the weathered bedrock.
- During the period of time that tails are being added to the system, the heat added to the system cannot be controlled by passive artificial cooling.
- Winter construction of the dam would likely have little effect on the seepage volumes, however allowing the cutoff trench to freeze before placement of tails on the dam face would likely have a long-term benefit for limiting seepage flow.
- Decreasing the flow volume through the dam by cutting off the top 2/3 of the weathered bedrock significantly reduces the seepage flow from the tails.
- Passive cooling of the upstream toe of the dam has little effect on the annual seepage flows if there is no cut off into the weathered bedrock.
- With a cutoff extending 2/3 of the way through the weathered bedrock, passive cooling is not necessary.

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- Thermosyphons alter the flow regime of the tails seepage and increase the thaw rate of existing ice present in the weathered bedrock.

7.0 ENGINEERING CONCLUSIONS

Disturbance of permafrost in the Nome area, particularly in areas where there is significant water flow has invariably resulted in a complete disappearance of the permafrost. It appears from the modeling effort that control of seepage volumes is key to reducing the permafrost degradation rate.

In itself, thawing of the permafrost will have no effect on the stability of the TSF. The dam itself will be founded on weathered bedrock which has sufficient strength to support the dam when thawed. Additional seepage will also have no effect on the dam stability.

Controlling seepage to control the transport of contaminants is needed from an environmental standpoint. Although the annual average temperature suggests that with passive cooling, a permafrost barrier could be achieved. Due to the seepage flow and thermal input from the warm tails, it appears to not be practical to achieve a frozen barrier. As ambient air temperatures rise, the ability to sustain a frozen barrier is reduced. Seepage flow can be effectively controlled using an HDPE cutoff barrier that extends most of the way through the weathered bedrock.

8.0 ENGINEERING DESIGN RECOMMENDATIONS

The design of the dam for the tailing storage facility as presented to NGE at the beginning of the modeling analysis is suitable for the proposed containment of paste tails. Thermosyphons used to cool the upstream toe have little to no effect on the control of seepage from the tails. A cutoff liner through the bedrock is effective and should be incorporated into the design. Allowing the cutoff region to freeze prior to placement of tails directly on the cutoff will likely have a long-term benefit controlling the downstream seepage.

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Due to inherent variability of the weathered bedrock, an experienced geotechnical engineer should be on site to evaluate the cutoff trench. It is expected that the trench depth required to inhibit seepage flow under the dam will vary considerably, especially if zones of highly fractured rock are encountered.

Placement of tails the first winter should be designed such that the tails are placed away from the dam face. This will leave the cutoff trench exposed to cooling and freezing. Allowing some water to flow into the trench area during the freezing period will be beneficial in forming a frozen barrier. The accumulated water depth should be limited to avoid forming a lake that will not completely freeze. A similar effect can be achieved by introducing excess water into the cutoff trench backfill during or shortly after construction. This recommendation may be overridden by the compaction and construction requirements for the trench backfill.

9.0 CLOSURE

Northern Geotechnical Engineering Inc. prepared this report exclusively for the use of *Smith Williams Consultants* for use in design of the proposed Tailings Storage Facility Dam. *Northern Geotechnical Engineering, Inc.* should be notified if significant changes are to occur in the nature, design, or location of the proposed structures in order that the conclusions presented in this report may be reviewed and, if necessary, modified to satisfy the proposed changes.

Due to the natural variability of earth materials, variations in material properties most likely exist across the project site. However, for modeling purposes, established material values were applied to the models, and therefore do not reflect any large scale variations in material properties which may occur across the site. It is therefore recommended that a qualified geotechnical engineer be on-site during construction activities to provide corrective recommendations for any unexpected conditions revealed during construction. Furthermore, the construction budget should allow for any unanticipated conditions which may be encountered during construction activities.

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Northern Geotechnical Engineering Inc. conducted this investigation following the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty expressed or implied is made.

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TABLES

Table 1
Unit Conversion Table

Parameter	Measurement	English Units	SI Units	Conversion Factor (SI to English)
Length	L	Feet (ft)	Meter (m)	1 m = 3.28 ft
Time	T	Hour (hr)	Hour (hr)	Same units
Force	F	Pound (lb)	KiloNewton (kN)	1 kN = 224.8 lb
Pressure	F/L^2	Pounds per Square Foot (PSF)	KiloPascal (kPa)	1 kPa = 20.89 psf
Unit Wt. of Water	F/L^3	Pounds per Cubic Foot (pcf)	kN/m^3	9.807 kN/m^3 = 62.4 pcf
Unit Wt.	F/L^3	Pounds per Cubic Foot (pcf)	kN/m^3	1 kN/m^3 = 6.363 pcf
Hydraulic Conductivity	L/t	ft/hr	m/hr	1 m/hr = 3.28 ft/hr
Hydraulic Head	L	ft	m	1 m = 3.28 ft
Hydraulic Nodal Flux	$Q=L^3/t$	ft^3/hr	m^3/hr	1 m^3/hr = 35.288 ft^3/hr
Hydraulic Flux Boundary	q=L/t	ft/hr	m/hr	1 m/hr = 3.28 ft/hr
Hydraulic Flux Section	L^3/t	ft^3/hr	m^3/hr	0.028 m^3/hr = 1 ft^2/hr
Volume	L^3	ft^3	m^3	1 m^3 = 35.288 ft^3
Heat	H	British Thermal Unit (BTU)	KiloJoules (kJ)	1.055 kJ = 1 BTU
Temperature	T	Degrees Farenheight (°F)	Degrees Celcius (°C)	1 °C = 1.6 °F
Latent Heat	H/L^3	BTU/ft^3	kJ/m^3	37.229 kJ/m^3 = 1 BTU/ft^3
Thermal Conductivity	H/(t)(L)(T)	BTU/hr ft °F	kJ/hr m °C	6.229 kJ/ hr m °C = 1 BTU/ hr ft °F
Volumetric Heat Capacity	$H/(L^3)(T)$	BTU/ft^3 °F	kJ/m^3 °C	67.07 kJ/m^3 °C = 1 BTU/ft^3 °F
Total Heat Flow	Q=H/t	BTU/hr	kJ/hr	1 kJ/hr = 0.948 BTU/hr
Unit Heat Flow	$Q=H/(t)(L^2)$	BTU/hr ft^2	kJ/hr m^2	11.35 kJ/hr m^2 = 1 BTU/hr ft^2

Table 2

Material Properties Used for Numerical Modeling of Rock Creek TSFD

Material	Volumetric Heat Capcity (frozen) kJ/m^3 °C	Volumetric Heat Capcity (unfrozen) kJ/m^3 °C	Volumetric Water Content	Hydraulic Conductivity at Saturation
Fractured Bedrock	1.88E+03	2.00E+03	5.00E-02	3.60E-02
Weathered Bedrock	1.88E+03	2.22E+03	1.50E-01	1.69E+01
Native Soils	1.91E+03	3.16E+03	5.00E-01	9.80E-01
Tailing Slurry	1.88E+03	3.10E+03	5.40E-01	2.40E-03
Rock Fill for TSFD	1.94E+03	1.94E+03	1.50E-01	6.67E+01
HPDE Liner	1.88E+03	3.10E+03	5.40E-01	5.00E-15

Table 3

Water Balance Calculations

Scenario #	PHASE I (AUG:01 to AUG:02)		PHASE II (AUG:02 to AUG:03)		PHASE III (AUG:03 to AUG:04)		EXTENDED RUN (AUG:04 to AUG:05)		EXTENDED RUN (AUG:05 to AUG:06)	
1	Instantaneous Inflow Rate (m^3/hr)	0.0177	Instantaneous Inflow Rate (m^3/hr)	0.0092	Instantaneous Inflow Rate (m^3/hr)	0.0138	Instantaneous Inflow Rate (m^3/hr)	0.0153	Instantaneous Inflow Rate (m^3/hr)	0.0054
	Instantaneous Outflow Rate (m^3/hr)	0.0159	Instantaneous Outflow Rate (m^3/hr)	0.0123	Instantaneous Outflow Rate (m^3/hr)	0.031	Instantaneous Outflow Rate (m^3/hr)	0.0262	Instantaneous Outflow Rate (m^3/hr)	0.0075
	Avg. Inflow Rate (m^3/yr)	155	Inflow (m^3/yr)	81	Inflow (m^3/yr)	121	Inflow (m^3/yr)	134	Inflow (m^3/yr)	47
	Avg. Outflow Rate (m^3/yr)	139	Outflow (m^3/yr)	108	Outflow (m^3/yr)	272	Outflow (m^3/yr)	230	Outflow (m^3/yr)	66
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	0.0222	Avg. Vol. Water Content Change (w/in Dam)	-0.0016	Avg. Vol. Water Content Change (w/in Dam)	-0.0174	Avg. Vol. Water Content Change (w/in Dam)	-0.0046	Avg. Vol. Water Content Change (w/in Dam)	0.0014
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	-0.0242	Avg. Vol. Water Content Change (Below Dam)	-0.0041	Avg. Vol. Water Content Change (Below Dam)	0.0015
	Amount of Water Stored as Ice (m^3)	24	Amount of Water Stored as Ice (m^3)	-4	Amount of Water Stored as Ice (m^3)	-112	Amount of Water Stored as Ice (m^3)	-26	Amount of Water Stored as Ice (m^3)	8
	% Difference Between Inflow & Outflow	8	% Difference Between Inflow & Outflow	9	% Difference Between Inflow & Outflow	4	% Difference Between Inflow & Outflow	12	% Difference Between Inflow & Outflow	20
2	Instantaneous Inflow Rate (m^3/hr)	0.0005	Instantaneous Inflow Rate (m^3/hr)	0.0003	Instantaneous Inflow Rate (m^3/hr)	0.0002	Instantaneous Inflow Rate (m^3/hr)	0.0002	Instantaneous Inflow Rate (m^3/hr)	0
	Instantaneous Outflow Rate (m^3/hr)	0.0028	Instantaneous Outflow Rate (m^3/hr)	0.008	Instantaneous Outflow Rate (m^3/hr)	0.0137	Instantaneous Outflow Rate (m^3/hr)	0.0201	Instantaneous Outflow Rate (m^3/hr)	0.0027
	Avg. Inflow Rate (m^3/yr)	4	Inflow (m^3/yr)	3	Inflow (m^3/yr)	2	Inflow (m^3/yr)	2	Inflow (m^3/yr)	0
	Avg. Outflow Rate (m^3/yr)	25	Outflow (m^3/yr)	70	Outflow (m^3/yr)	120	Outflow (m^3/yr)	176	Outflow (m^3/yr)	24
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	0.0049	Avg. Vol. Water Content Change (w/in Dam)	-0.0074	Avg. Vol. Water Content Change (w/in Dam)	-0.0105	Avg. Vol. Water Content Change (w/in Dam)	-0.0113	Avg. Vol. Water Content Change (w/in Dam)	0.0015
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	-0.0111	Avg. Vol. Water Content Change (Below Dam)	-0.0136	Avg. Vol. Water Content Change (Below Dam)	0.0019
	Amount of Water Stored as Ice (m3)	5	Amount of Water Stored as Ice (m3)	-18	Amount of Water Stored as Ice (m3)	-63	Amount of Water Stored as Ice (m3)	-70	Amount of Water Stored as Ice (m3)	9
	% Difference Between Inflow & Outflow	12	% Difference Between Inflow & Outflow	31	% Difference Between Inflow & Outflow	18	% Difference Between Inflow & Outflow	56	% Difference Between Inflow & Outflow	27
3	Instantaneous Inflow Rate (m^3/hr)	0.0178	Instantaneous Inflow Rate (m^3/hr)	0.0082	Instantaneous Inflow Rate (m^3/hr)	0.0095	Instantaneous Inflow Rate (m^3/hr)	0.007	Instantaneous Inflow Rate (m^3/hr)	0.0047
	Instantaneous Outflow Rate (m^3/hr)	0.0163	Instantaneous Outflow Rate (m^3/hr)	0.0144	Instantaneous Outflow Rate (m^3/hr)	0.0356	Instantaneous Outflow Rate (m^3/hr)	0.0236	Instantaneous Outflow Rate (m^3/hr)	0.0046
	Avg. Inflow Rate (m^3/yr)	156	Inflow (m^3/yr)	72	Inflow (m^3/yr)	83	Inflow (m^3/yr)	61	Inflow (m^3/yr)	41
	Avg. Outflow Rate (m^3/yr)	143	Outflow (m^3/yr)	126	Outflow (m^3/yr)	312	Outflow (m^3/yr)	207	Outflow (m^3/yr)	40
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	0.0228	Avg. Vol. Water Content Change (w/in Dam)	-0.003	Avg. Vol. Water Content Change (w/in Dam)	-0.018	Avg. Vol. Water Content Change (w/in Dam)	-0.0115	Avg. Vol. Water Content Change (w/in Dam)	0.0048
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0	Avg. Vol. Water Content Change (Below Dam)	-0.0134	Avg. Vol. Water Content Change (Below Dam)	0.0068
	Amount of Water Stored as Ice (m3)	25	Amount of Water Stored as Ice (m3)	-7	Amount of Water Stored as Ice (m3)	-116	Amount of Water Stored as Ice (m3)	-71	Amount of Water Stored as Ice (m3)	31
	% Difference Between Inflow & Outflow	6	% Difference Between Inflow & Outflow	12	% Difference Between Inflow & Outflow	35	% Difference Between Inflow & Outflow	22	% Difference Between Inflow & Outflow	17
4	Instantaneous Inflow Rate (m^3/hr)	0.0176	Instantaneous Inflow Rate (m^3/hr)	0.0062	Instantaneous Inflow Rate (m^3/hr)	0.0114	Instantaneous Inflow Rate (m^3/hr)	0.0059	Instantaneous Inflow Rate (m^3/hr)	0.0022
	Instantaneous Outflow Rate (m^3/hr)	0.0157	Instantaneous Outflow Rate (m^3/hr)	0.0137	Instantaneous Outflow Rate (m^3/hr)	0.037	Instantaneous Outflow Rate (m^3/hr)	0.0235	Instantaneous Outflow Rate (m^3/hr)	0.0048
	Avg. Inflow Rate (m^3/yr)	154	Inflow (m^3/yr)	54	Inflow (m^3/yr)	100	Inflow (m^3/yr)	52	Inflow (m^3/yr)	19
	Avg. Outflow Rate (m^3/yr)	138	Outflow (m^3/yr)	120	Outflow (m^3/yr)	324	Outflow (m^3/yr)	206	Outflow (m^3/yr)	42
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	0.0219	Avg. Vol. Water Content Change (w/in Dam)	-0.0058	Avg. Vol. Water Content Change (w/in Dam)	-0.017	Avg. Vol. Water Content Change (w/in Dam)	-0.0118	Avg. Vol. Water Content Change (w/in Dam)	-0.0026
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0	Avg. Vol. Water Content Change (Below Dam)	-0.0138	Avg. Vol. Water Content Change (Below Dam)	-0.0039
	Amount of Water Stored as Ice (m3)	24	Amount of Water Stored as Ice (m3)	-14	Amount of Water Stored as Ice (m3)	-107	Amount of Water Stored as Ice (m3)	-72	Amount of Water Stored as Ice (m3)	-17
	% Difference Between Inflow & Outflow	9	% Difference Between Inflow & Outflow	17	% Difference Between Inflow & Outflow	33	% Difference Between Inflow & Outflow	28	% Difference Between Inflow & Outflow	61

Table 3 - Continued

Water Balance Calculations

Scenario #	PHASE I (AUG:01 to AUG:02)		PHASE II (AUG:02 to AUG:03)		PHASE III (AUG:03 to AUG:04)		EXTENDED RUN (AUG:04 to AUG:05)		EXTENDED RUN (AUG:05 to AUG:06)	
5	Instantaneous Inflow Rate (m^3/hr)	0.0259	Instantaneous Inflow Rate (m^3/hr)	0.0525	Instantaneous Inflow Rate (m^3/hr)	0.0743	Instantaneous Inflow Rate (m^3/hr)	0.0695	Instantaneous Inflow Rate (m^3/hr)	0.0226
	Instantaneous Outflow Rate (m^3/hr)	0.0268	Instantaneous Outflow Rate (m^3/hr)	0.0492	Instantaneous Outflow Rate (m^3/hr)	0.0744	Instantaneous Outflow Rate (m^3/hr)	0.0502	Instantaneous Outflow Rate (m^3/hr)	0.0185
	Avg. Inflow Rate (m^3/yr)	227	Inflow (m^3/yr)	460	Inflow (m^3/yr)	651	Inflow (m^3/yr)	609	Inflow (m^3/yr)	198
	Avg. Outflow Rate (m^3/yr)	235	Outflow (m^3/yr)	431	Outflow (m^3/yr)	652	Outflow (m^3/yr)	440	Outflow (m^3/yr)	162
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.001	Avg. Vol. Water Content Change (w/in Dam)	0.0277	Avg. Vol. Water Content Change (w/in Dam)	0.0025	Avg. Vol. Water Content Change (w/in Dam)	0.0042	Avg. Vol. Water Content Change (w/in Dam)	-0.0001
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0.007	Avg. Vol. Water Content Change (Below Dam)	0.0076	Avg. Vol. Water Content Change (Below Dam)	0.0008
	Amount of Water Stored as Ice (m3)	-1	Amount of Water Stored as Ice (m3)	68	Amount of Water Stored as Ice (m3)	21	Amount of Water Stored as Ice (m3)	30	Amount of Water Stored as Ice (m3)	1
	% Difference Between Inflow & Outflow	6	% Difference Between Inflow & Outflow	1	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	28	% Difference Between Inflow & Outflow	33
5	Instantaneous Inflow Rate (m^3/hr)	0.0244	Instantaneous Inflow Rate (m^3/hr)	0.0618	Instantaneous Inflow Rate (m^3/hr)	0.077	Instantaneous Inflow Rate (m^3/hr)	0.0754	Instantaneous Inflow Rate (m^3/hr)	0.0207
	Instantaneous Outflow Rate (m^3/hr)	0.0274	Instantaneous Outflow Rate (m^3/hr)	0.0644	Instantaneous Outflow Rate (m^3/hr)	0.0784	Instantaneous Outflow Rate (m^3/hr)	0.0656	Instantaneous Outflow Rate (m^3/hr)	0.0188
	Avg. Inflow Rate (m^3/yr)	214	Inflow (m^3/yr)	541	Inflow (m^3/yr)	675	Inflow (m^3/yr)	661	Inflow (m^3/yr)	181
	Avg. Outflow Rate (m^3/yr)	240	Outflow (m^3/yr)	564	Outflow (m^3/yr)	687	Outflow (m^3/yr)	575	Outflow (m^3/yr)	165
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.0015	Avg. Vol. Water Content Change (w/in Dam)	-0.0027	Avg. Vol. Water Content Change (w/in Dam)	-0.011	Avg. Vol. Water Content Change (w/in Dam)	0.0046	Avg. Vol. Water Content Change (w/in Dam)	-0.0009
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	-0.0155	Avg. Vol. Water Content Change (Below Dam)	0.0082	Avg. Vol. Water Content Change (Below Dam)	-0.0005
	Amount of Water Stored as Ice (m3)	-2	Amount of Water Stored as Ice (m3)	-7	Amount of Water Stored as Ice (m3)	-71	Amount of Water Stored as Ice (m3)	32	Amount of Water Stored as Ice (m3)	-5
	% Difference Between Inflow & Outflow	1	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	29
7	Instantaneous Inflow Rate (m^3/hr)	0.0235	Instantaneous Inflow Rate (m^3/hr)	0.0184	Instantaneous Inflow Rate (m^3/hr)	0.0882	Instantaneous Inflow Rate (m^3/hr)	0.0816	Instantaneous Inflow Rate (m^3/hr)	0.0046
	Instantaneous Outflow Rate (m^3/hr)	0.0258	Instantaneous Outflow Rate (m^3/hr)	0.0285	Instantaneous Outflow Rate (m^3/hr)	0.0907	Instantaneous Outflow Rate (m^3/hr)	0.0922	Instantaneous Outflow Rate (m^3/hr)	0.008
	Avg. Inflow Rate (m^3/yr)	206	Inflow (m^3/yr)	161	Inflow (m^3/yr)	773	Inflow (m^3/yr)	715	Inflow (m^3/yr)	40
	Avg. Outflow Rate (m^3/yr)	226	Outflow (m^3/yr)	250	Outflow (m^3/yr)	795	Outflow (m^3/yr)	808	Outflow (m^3/yr)	70
	Cum. Bound Flux (m^3/yr)	22	Cum. Bound Flux (m^3/yr)	33	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45	Cum. Bound Flux (m^3/yr)	45
	Avg. Vol. Water Content Change (w/in Dam)	-0.0035	Avg. Vol. Water Content Change (w/in Dam)	-0.0198	Avg. Vol. Water Content Change (w/in Dam)	-0.0135	Avg. Vol. Water Content Change (w/in Dam)	-0.0138	Avg. Vol. Water Content Change (w/in Dam)	-0.0012
	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	N/A	Avg. Vol. Water Content Change (Below Dam)	0	Avg. Vol. Water Content Change (Below Dam)	-0.0217	Avg. Vol. Water Content Change (Below Dam)	-0.0011
	Amount of Water Stored as Ice (m3)	-4	Amount of Water Stored as Ice (m3)	-49	Amount of Water Stored as Ice (m3)	-95	Amount of Water Stored as Ice (m3)	-92	Amount of Water Stored as Ice (m3)	-7
	% Difference Between Inflow & Outflow	2	% Difference Between Inflow & Outflow	3	% Difference Between Inflow & Outflow	14	% Difference Between Inflow & Outflow	6	% Difference Between Inflow & Outflow	26

Table 4
Predicted Water Outflow

Annual Flow Calcs
cubic meters per year

	Base Conditions Scenario 1			Extended Liner Scenario 2			Thermosyphons Scenarios 3, 4			High Perm and Temp Scenario 5		
	Outflow	% rain	% ice melt	Outflow	% rain	% ice melt	Outflow	% rain	% ice melt	Outflow	% rain	% ice melt
Phase I	68000	21		12000	98		68000	21		121000	11	1
Phase II	96000	26	3	45000	63	17	96000	30	13	368000	7	
Phase III	275000	13	34	121000	29	66	275000	13	30	693000	5	
Year 4	219000	18	12	108000	32	30	189000	22	40	559000	5	
Year 5	72000	51		44000	79		45000	81		207000	18	

Table 5
Monthly Flow Distribution

Monthly Seepage Flow, No heat pipes
Percent of total flow for phase — Scenarios 1, 2, 5

	Phase 1	Phase 2	Phase 3
Jan			7
Feb			2
Mar			
Apr			
May	4	2	1
Jun	6	2	1
Jul	8	4	2
Aug	17	32	39
Sep	37	24	19
Oct	27	18	10
Nov	1	12	10
Dec		6	9

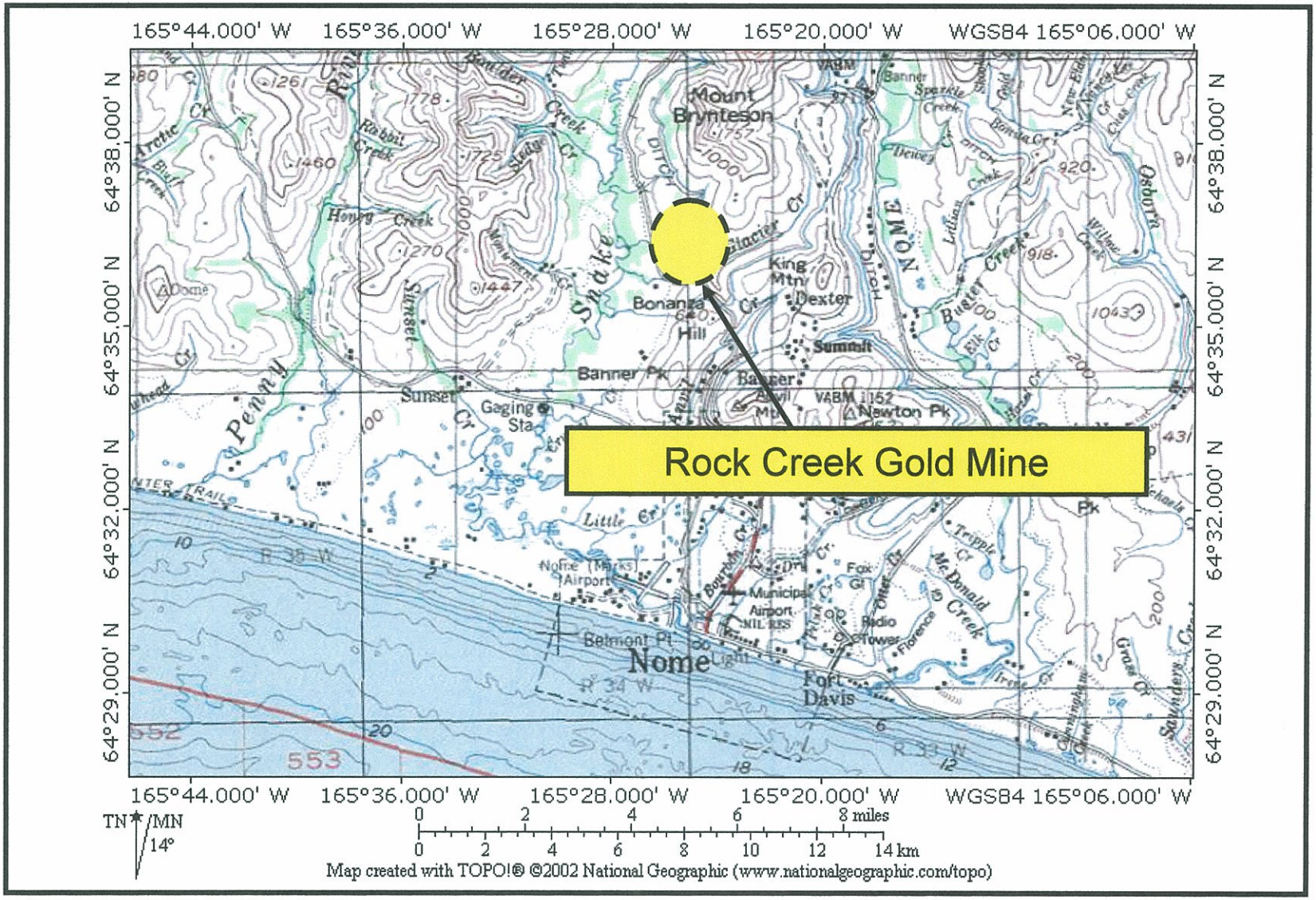
Monthly Seepage Flow, heat pipes 50 square meter radiators
Percent of total flow for phase — Scenarios 3, 6

	Phase 1	Phase 2	Phase 3
Jan			2
Feb			
Mar			
Apr			
May	5		
Jun	3		
Jul	5		1
Aug	14	44	53
Sep	39	18	13
Oct	29	22	13
Nov	5	11	9
Dec		5	9

Monthly Seepage Flow, heat pipes 200 square meter radiators
Percent of total flow for phase — Scenarios 4, 7

	Phase 1	Phase 2	Phase 3
Jan		1	3
Feb			1
Mar			
Apr			
May	3		
Jun	5		
Jul	5	2	2
Aug	14	41	53
Sep	42	17	12
Oct	30	22	11
Nov	2	11	9
Dec		7	9

FIGURES

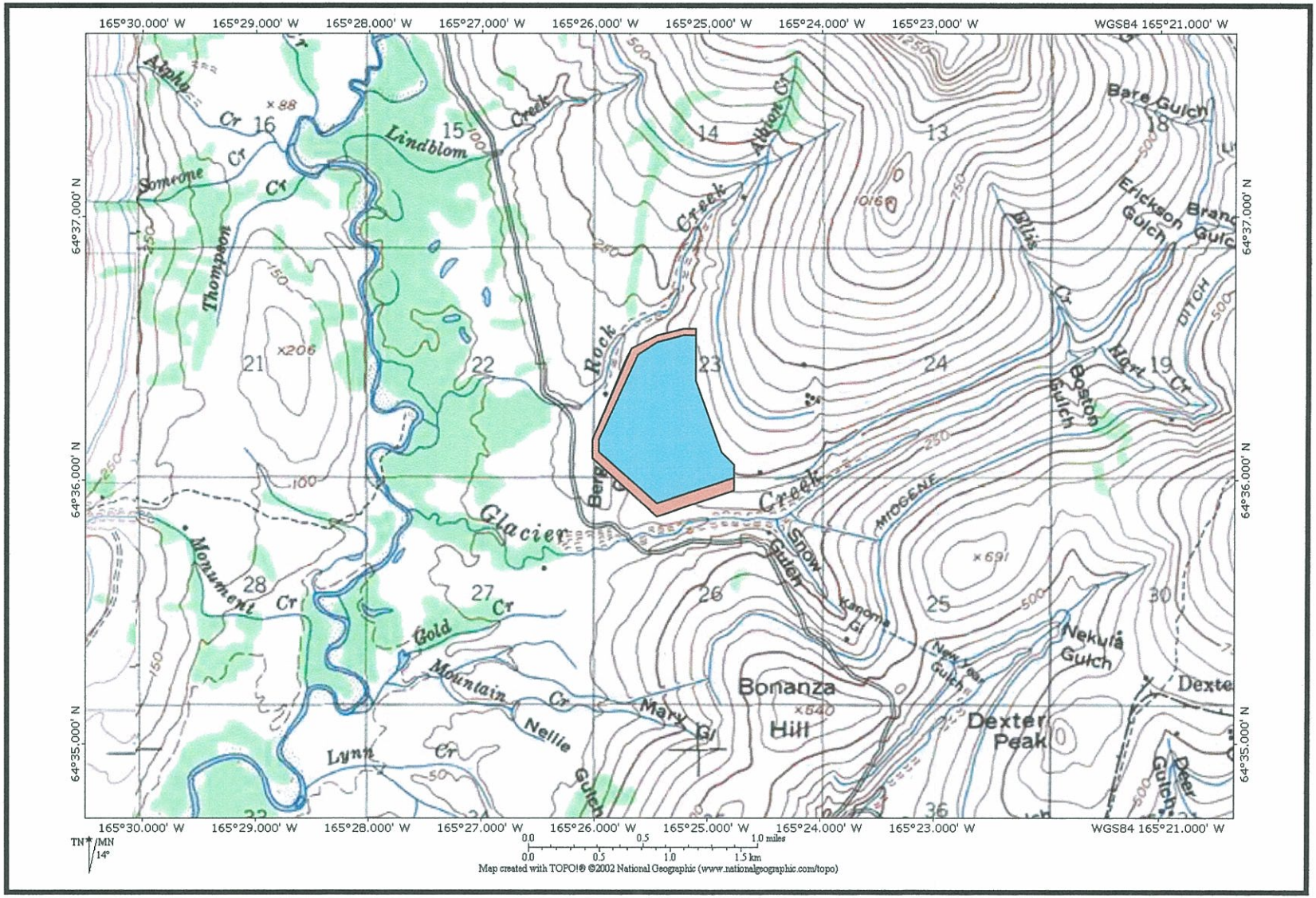


NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

REGION LOCATION MAP

Rock Creek Dam,
Nome, Alaska

FIG 1



= Tailings Storage Facility Dam

= Tailings

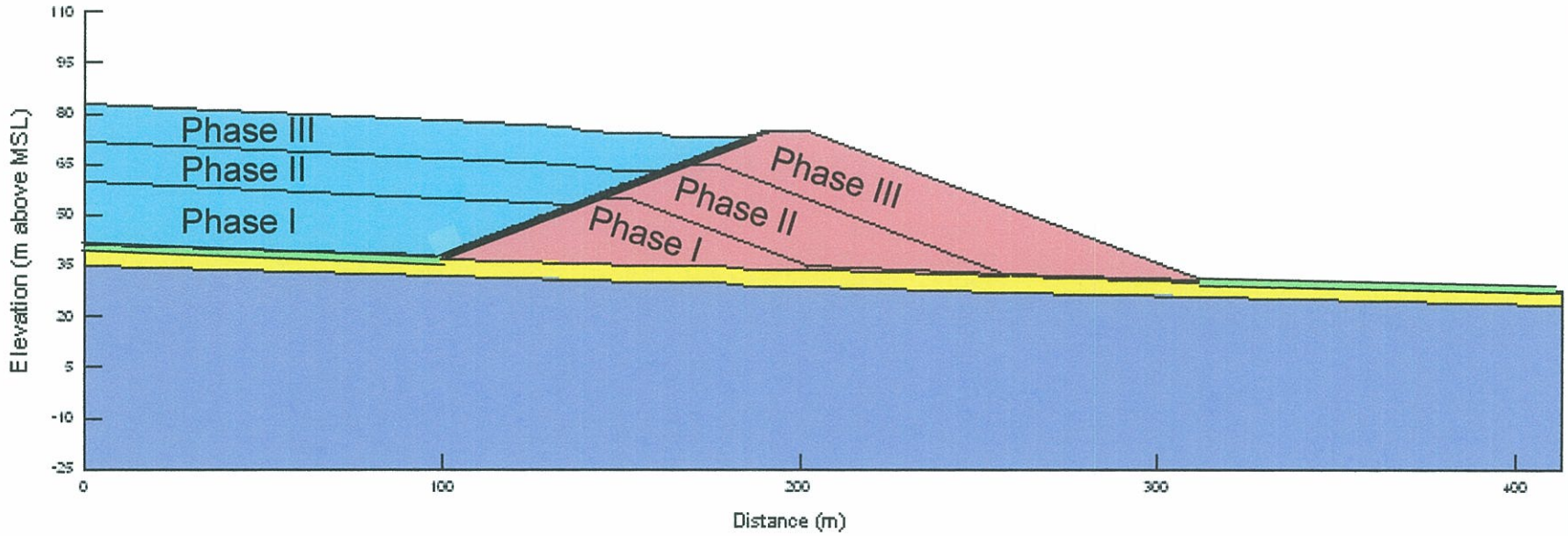
*Approximate size and location

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

SITE LOCATION MAP

Rock Creek Dam,
Nome, Alaska

FIG 2



= Tailings Slurry

= Native Soils

= Native Bedrock

= Rock Fill Dam Material

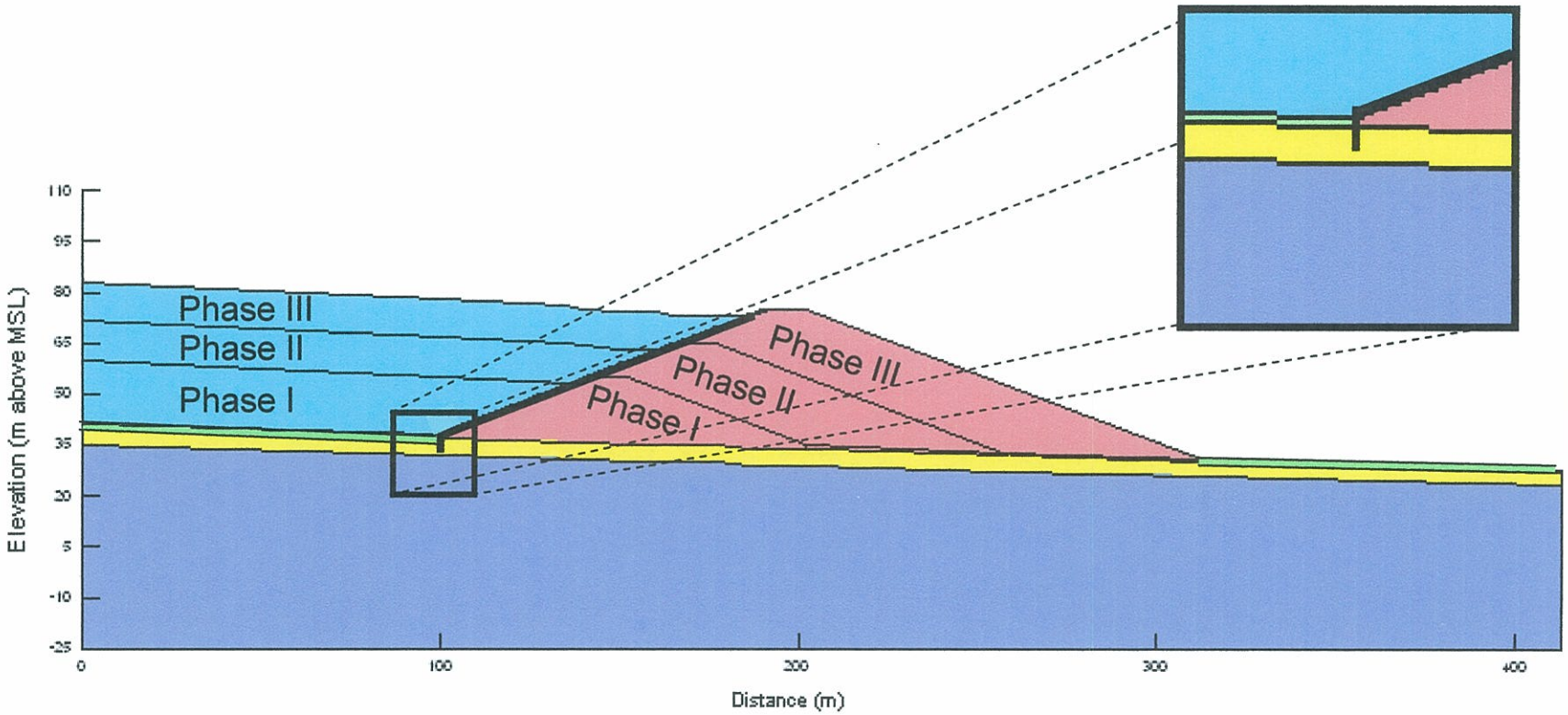
= Native Weathered Bedrock

= Liner Material

CROSS-SECTION OF COMPUTER MODEL SHOWING ALL THREE PHSES OF TSF CONSTRUCTION

Rock Creek Dam,
Nome, Alaska

FIG 3



= Tailings Slurry

= Native Soils

= Native Bedrock

= Rock Fill Dam Material

= Native Weathered Bedrock

= Liner Material

CROSS-SECTION OF COMPUTER MODEL SHOWING SCENARIO 2 W/ LINER EXTENDED INTO THE WEATEHRED BEDROCK

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Rock Creek Dam,
Nome, Alaska

FIG 4

PHASE I ANALYSIS

Initial Conditions

- Independent steady-state thermal/hydraulic analysis to establish Initial site conditions Jan:01 (No Dam or tailings)
- Initial thermal/hydraulic conditions - Jan:01 (w/ Phase I of TSFD, no tails)
- Initial thermal/hydraulic conditions - Aug:01 (Phase I of TSFD, no tails)
- Initial thermal/hydraulic conditions - Aug:01 (Phase I of TSFD, no tails)

Transient

- Convective heat analysis to establish conditions w/ Ph 1 of TSFD constructed Jan:01 (1 time step w/ (Phase I of TSFD, no tails)
- Convective heat analysis Jan:01 to Aug:01 (24 hr time steps w/ Phase I of TSFD, no tails)
- Convective heat transfer analysis one 24 hour time step to establish thermal/hydraulic conditions Aug:01(Phase I of TSFD w/ tails)
- Convective heat transfer analysis Aug:01 to Aug:02 (6 hr time steps w/ Phase I of TSFD and tails)

PHASE II ANALYSIS

Initial Conditions

- Initial conditions (Phase I of TSFD and tails) Aug:02
- Initial thermal/hydraulic conditions - Aug:02 (Phase II of TSFD and tails)

Transient

- Convective heat analysis one 24 hour time step to establish thermal/hydraulic conditions Aug:02 (Phase II of TSFD and tails added)
- Convective heat transfer analysis Aug:02 to Aug:03 (6 hr time steps w/ Phase II of TSFD and tails)

PHASE III ANALYSIS

Initial Conditions

- Initial conditions (Phase II of TSFD and tails) Aug:03
- Initial thermal/hydraulic conditions - Aug:03 (Phase III of TSFD and tails)

Transient

- Convective heat analysis one 24 hour time step to establish thermal/hydraulic conditions Aug:03 (Phase III of TSFD and tails added)
- Convective heat transfer analysis Aug:03 to Aug:04 (6 hr time steps w/ Phase III of TSFD w/ tails)

EXTENDED ANALYSIS

Initial Conditions

- Initial conditions (Phase III of TSFD and tails) Aug:04

Transient

- Convective heat transfer analysis Aug:04 to Aug:06 (6 hr time steps w/ Phase III of TSFD w/ tails)

→ = Analysis results saved as initial conditions for ensuing analysis

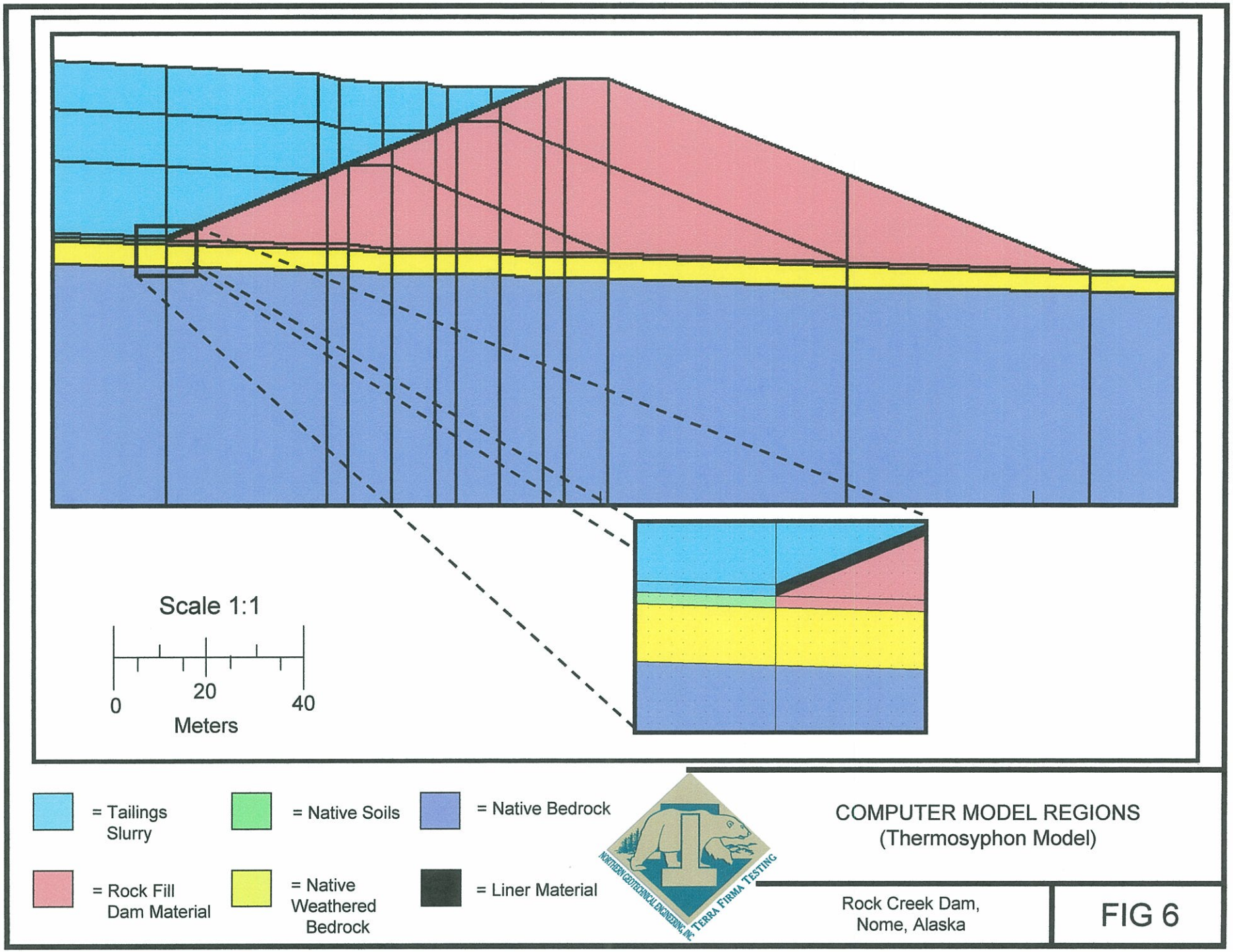
⏟ = Initial conditions used for transient analysis

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

THERMAL/SEEPAGE ANALYSIS FLOW CHART

Rock Creek TSFD
Nome, Alaska

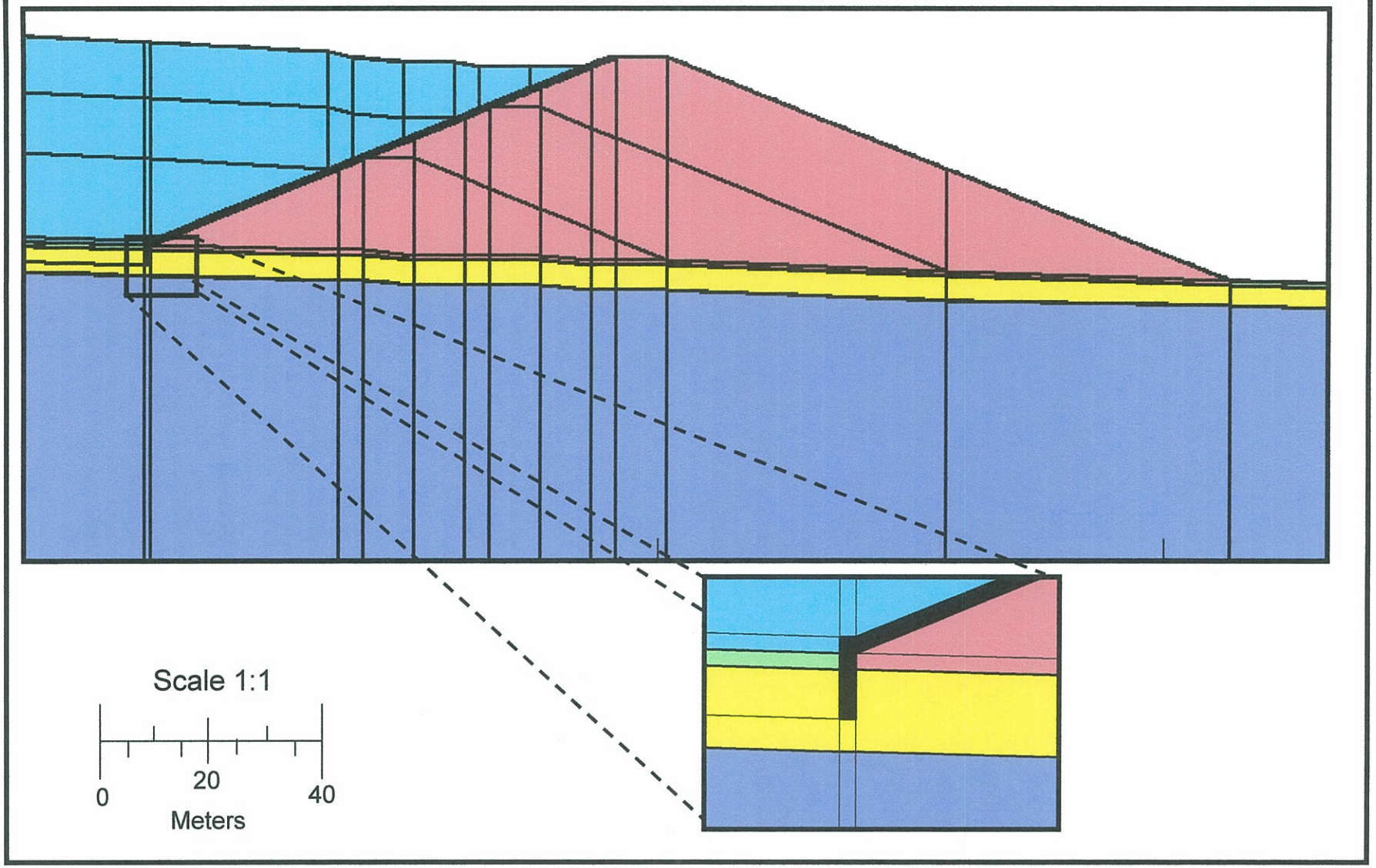
FIG 5



COMPUTER MODEL REGIONS
(Thermosyphon Model)

Rock Creek Dam,
Nome, Alaska

FIG 6



= Tailings Slurry

= Rock Fill Dam Material

= Native Soils

= Native Weathered Bedrock

= Native Bedrock

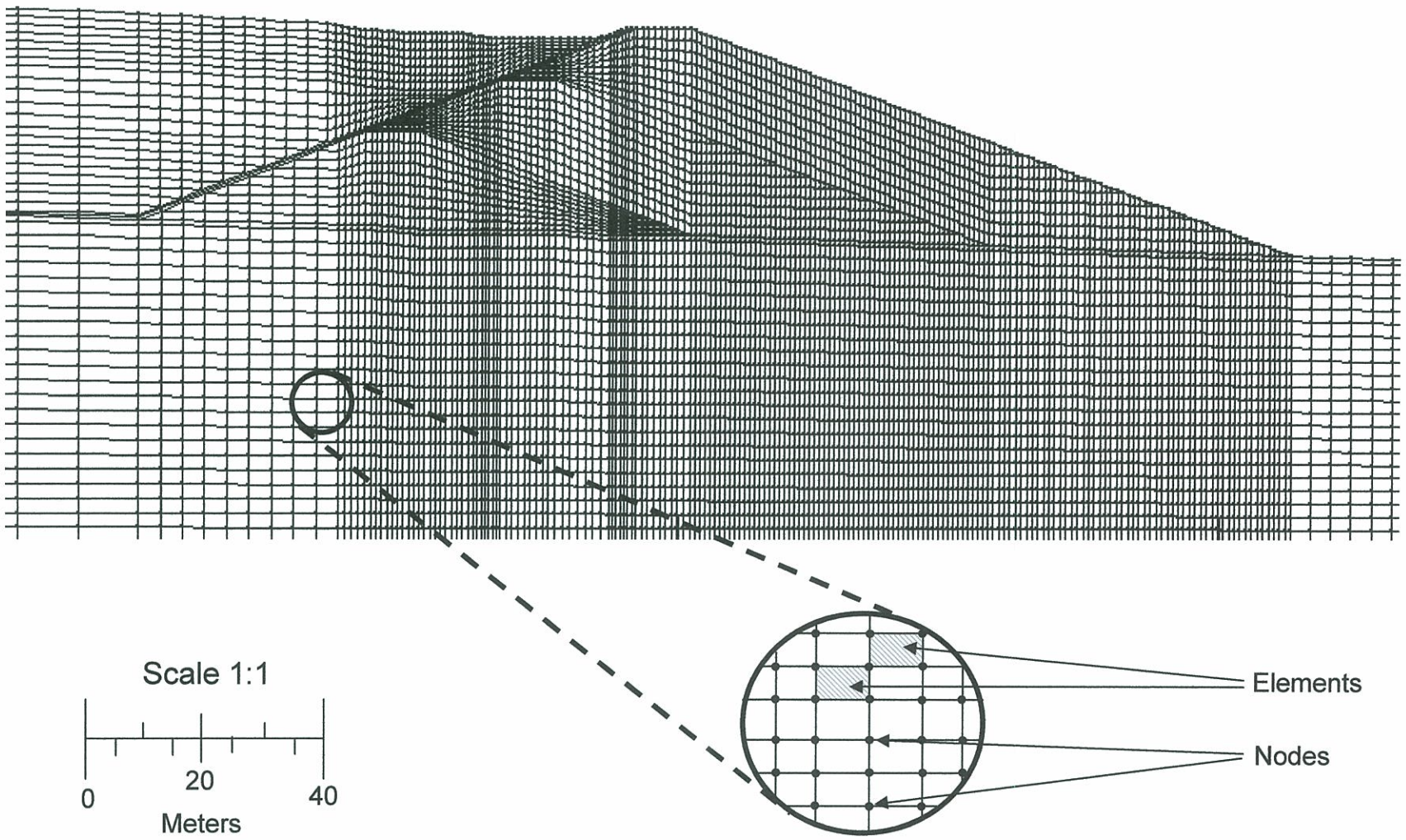
= Liner Material

NORTHERN GEOTECHNICAL ENGINEERING, INC.
TERRA FIRMA TESTING

COMPUTER MODEL REGIONS
(EXTENDED LINER MODEL)

Rock Creek Dam,
Nome, Alaska

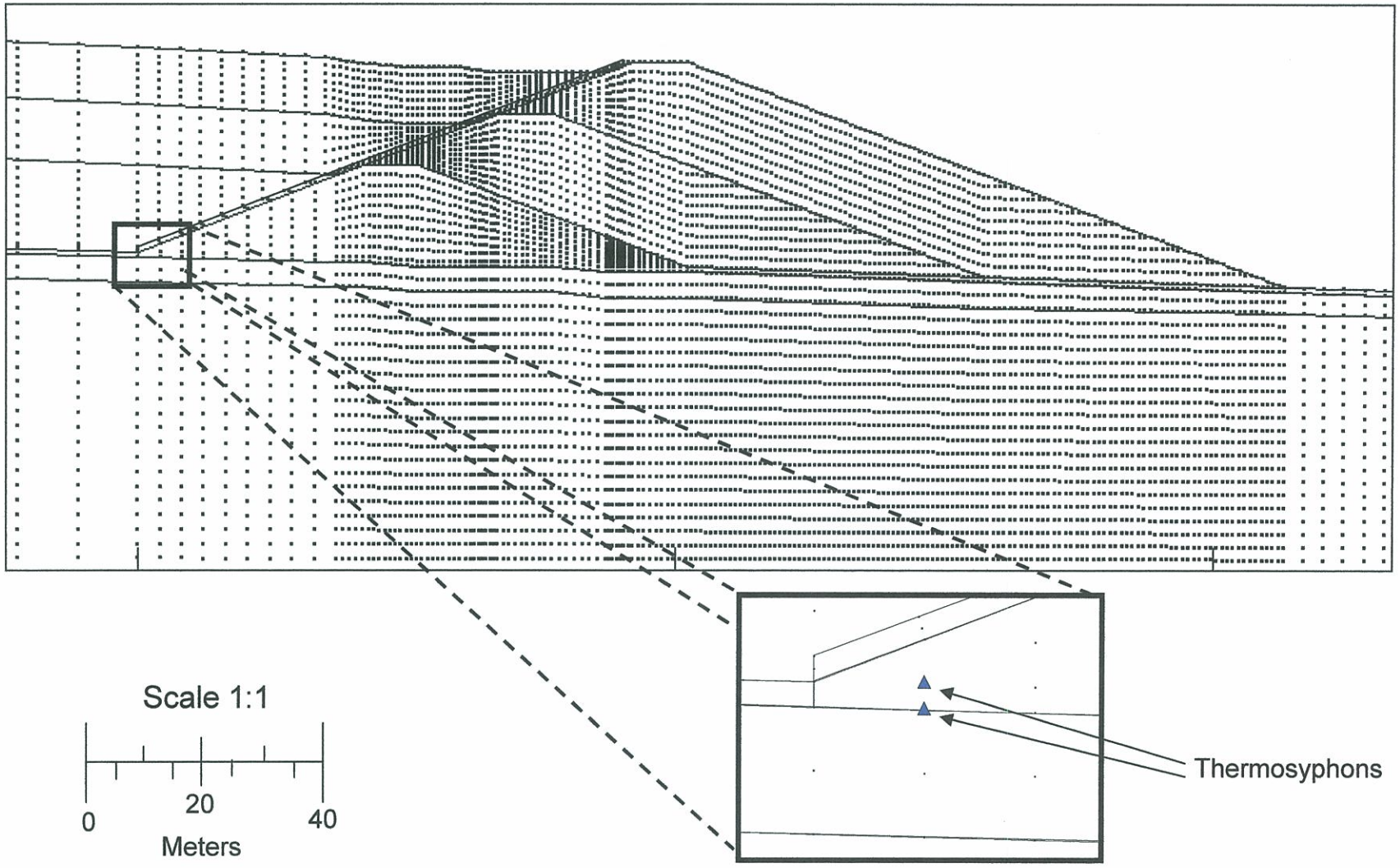
FIG 7



COMPUTER MODEL ELEMENTS AND NODES

Rock Creek Dam,
Nome, Alaska

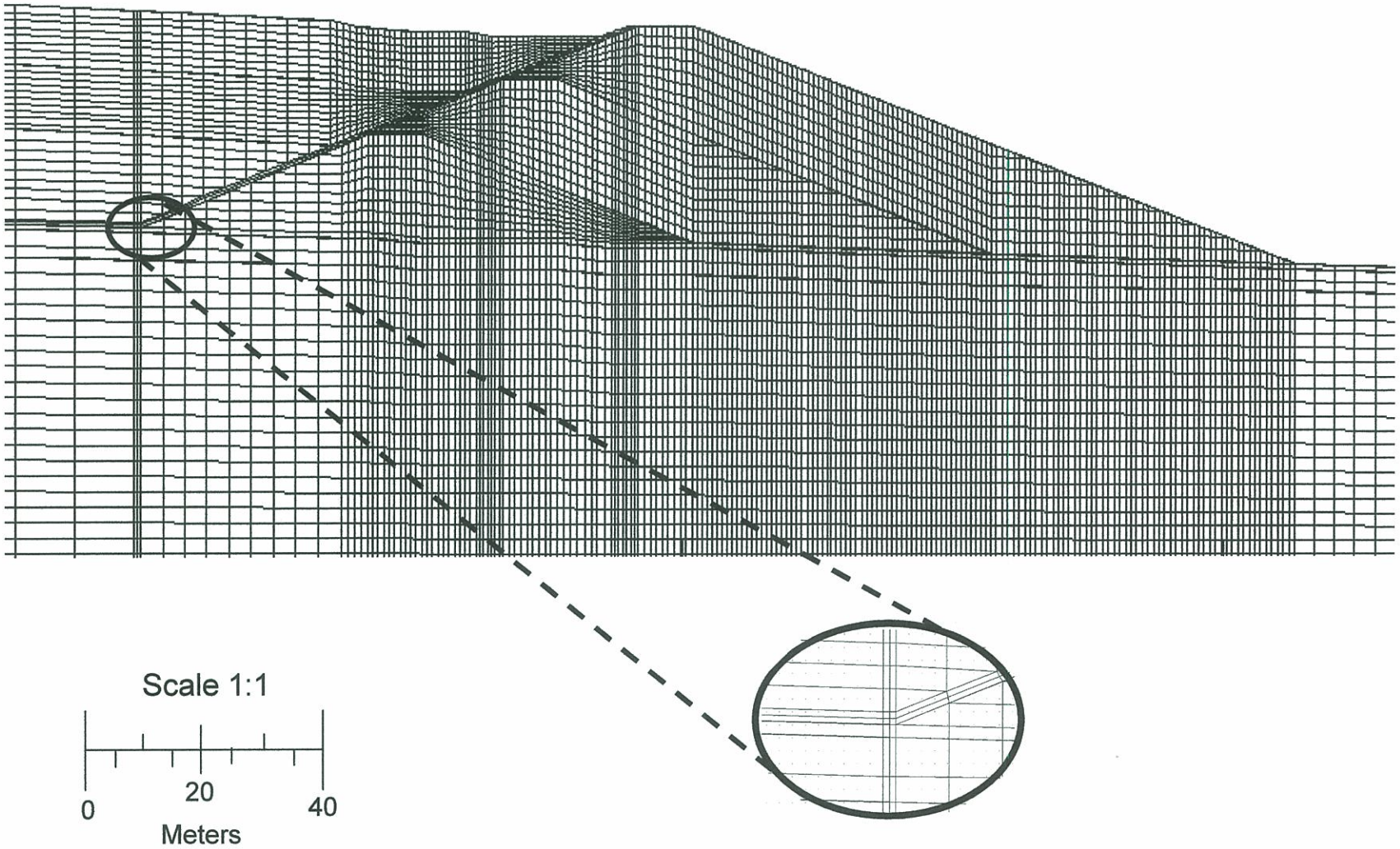
FIG 8



THERMOSYPHON PLACEMENT

Rock Creek Dam,
Nome, Alaska

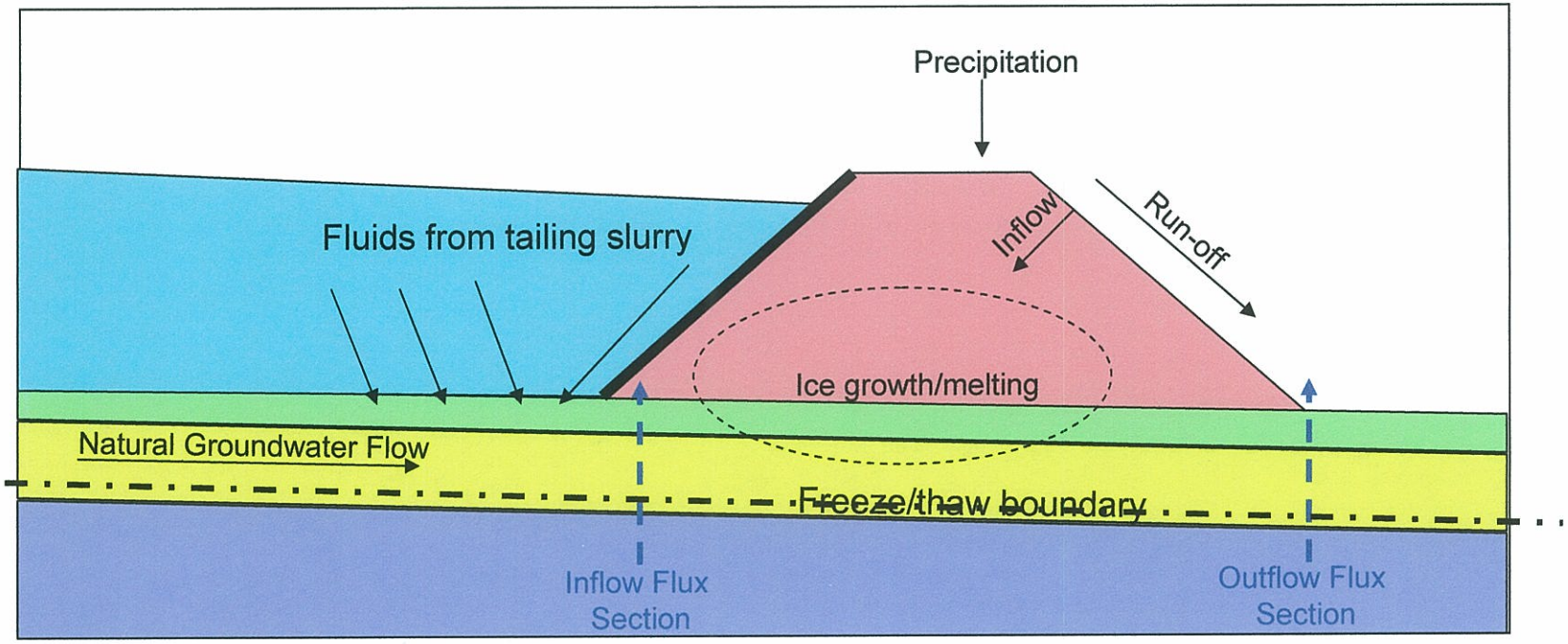
FIG 9



COMPUTER MODEL ELEMENTS
AND NODES
(EXTENDED LINER MODEL)

Rock Creek Dam,
Nome, Alaska

FIG 10



*Model dimensions have been exaggerated to show detail

= Tailings Slurry

= Native Soils

= Native Bedrock

= Rock Fill Dam Material

= Native Weathered Bedrock

= Liner Material

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

WATER BALANCE DIAGRAM

Rock Creek Dam,
Nome, Alaska

FIG 11

Total Average Annual Discharge from the TSF expressed as: $(Q_A) = F_A * F_T * Q_C$

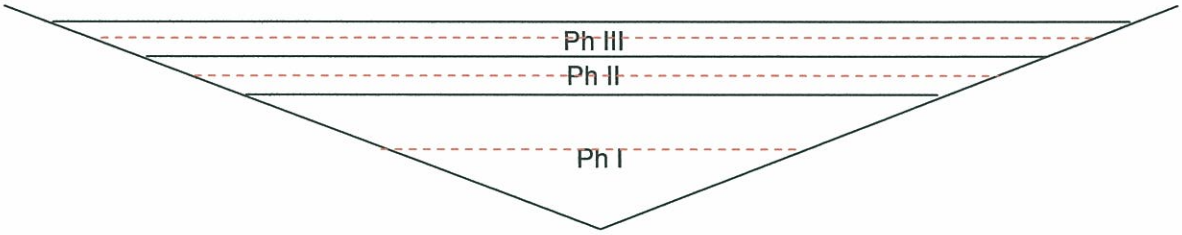
$Q_C = V * L * 8760$ hours

Where: V = Total discharge measured from flux sections for entire length of analysis
L = Effective discharge length of TSFD toe
8760 = # of hours in one year

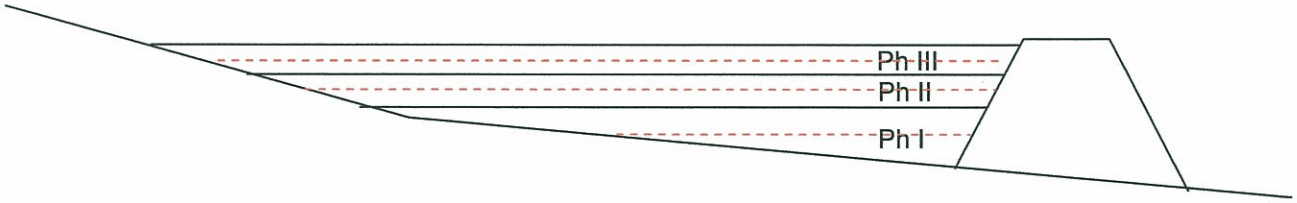
F_A = Correction factor for the average level of tailings within the TSF based on area

F_T = Correction factor for the average level of tailings in TSF based on time

Cross-Section of TSF Along Axis of TSFD



Cross-Section of TSF Perpendicular to Topography



- - - - - - - - - - = Average height of tailings

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

TSF ANNUAL DISCHARGE DETERMINATION

Rock Creek Dam,
Nome, Alaska

FIG 12

APPENDIX A

THERMAL PROPERTY FUNCTIONS

APPENDIX A
THERMAL PROPERTIES

TEMP/W requires input of thermal properties for each of the different materials used in the model. Each region is defined as a material type and the model references each material type to assigned properties. Where the thermal properties are a function dependent on other variables in the system, a graphical representation of the property is needed. The thermal properties defined for each material in the model include:

1) Latent heat: Thermal energy given off or absorbed by a material during a phase change. In this case the material experiencing the phase change is the ground water/soil water. The amount of thermal energy released/absorbed within a particular material is dependent on the Volumetric Water Content (defined in Appendix B). The latent heat of water is pre-programmed into the model with options to select the correct units. The units of measure used in the model for latent heat are kJ/m^3.

2) Thermal conductivity: The ability of a soil/rock to transmit heat energy by conduction. The thermal conductivity is a function of the mineral type, water content, and temperature. Graphs of the thermal conductivity vs. temperature are presented in Figures A-1 through A-5. The functions represent saturated conditions for the material. The thermal conductivity of the liner was assumed to be the same as the tails so the thermal model of the liner is for a line, not the 2 meter thick unit used in the model. Unit of thermal conductivity used in the model are kJ/hr m ^{o}C.

3) Unfrozen water content: The percentage of water within a material (i.e. soil/rock) that remains unfrozen at a given temperature. It is expressed as a percentage and is a function of temperature. Unfrozen water occurs at below freezing temperatures in soil due to tensile stresses derived from capillarity. A thin coat of liquid water will also remain on the surface of soil particles, dependent on the mineral type, particle size and temperature. The unfrozen water content functions used for the 5 soil types are presented in Figures A-6 through A-10. The unfrozen water content of the liner was taken to be the same as that

for the tails, again to model the liner as a line and not a 2 meter thick unit. Units used in the model for the unfrozen water content are %.

4) Volumetric heat capacity: The quantity of heat energy required to raise the temperature of a specified volume of a material by a unit degree. The volumetric heat capacity is a function of the mineral properties, water content and temperature. Ice has a different heat capacity than water. The model uses a frozen and thawed volumetric heat capacity. Values used are presented in Table 2 of the main report. Units used in the model for volumetric heat capacity are $kJ/m^3/°C$.

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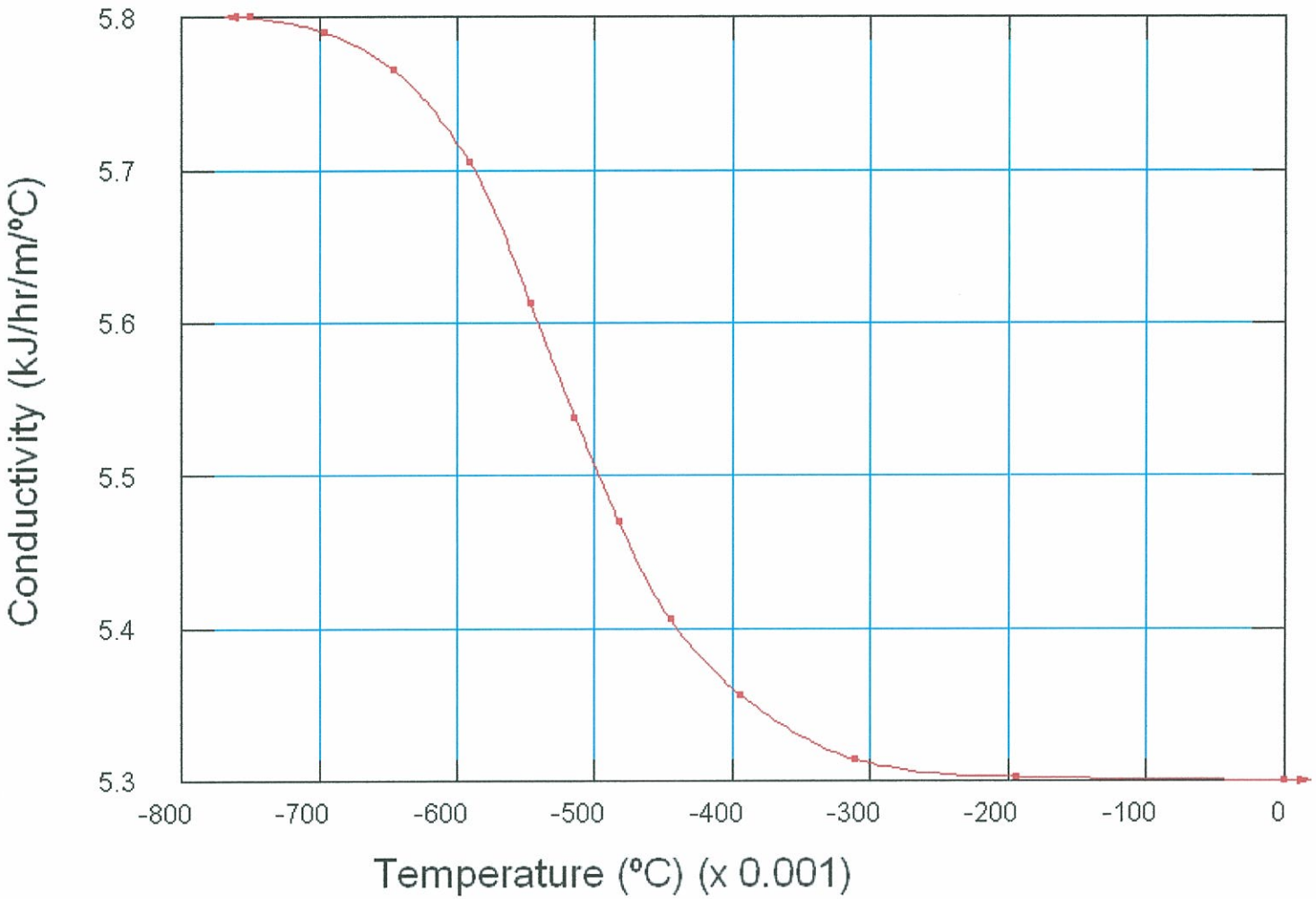
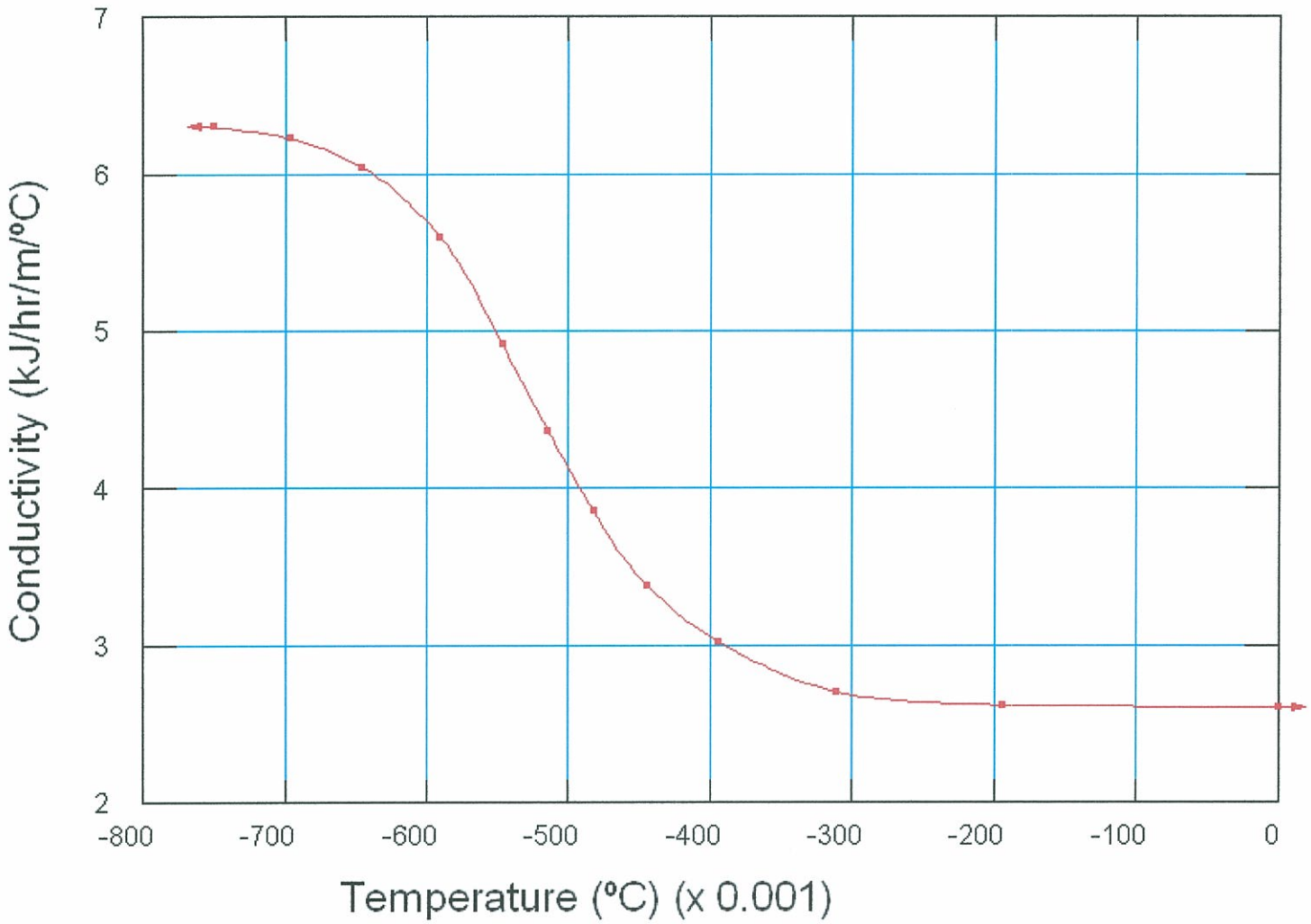


THERMAL CONDUCTIVITY FUNCTION
FOR THE BEDROCK

Rock Creek Dam,
Nome, Alaska

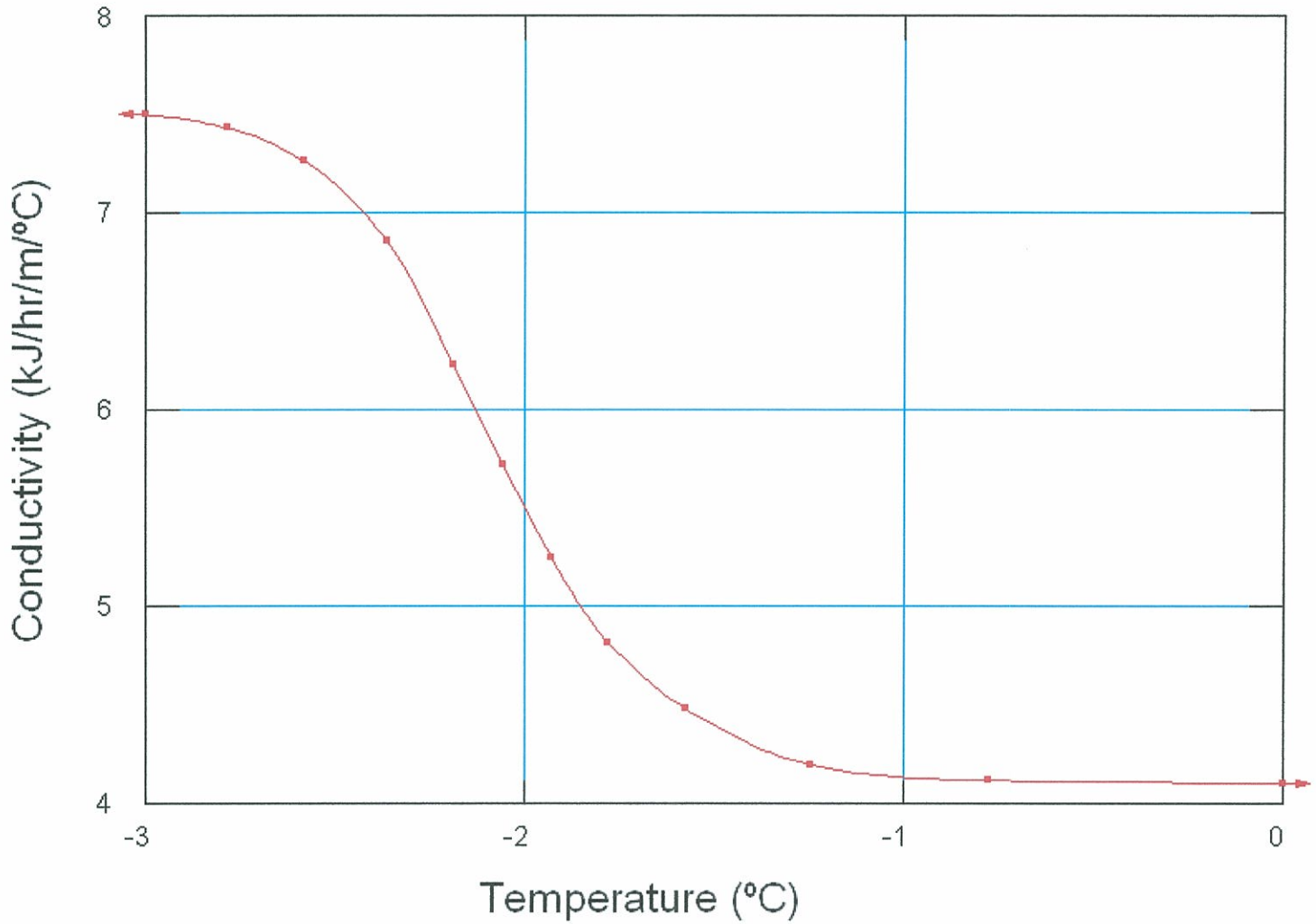
A-1



THERMAL CONDUCTIVITY FUNCTION FOR THE ROCK FILL DAM MATERIAL

Rock Creek Dam,
Nome, Alaska

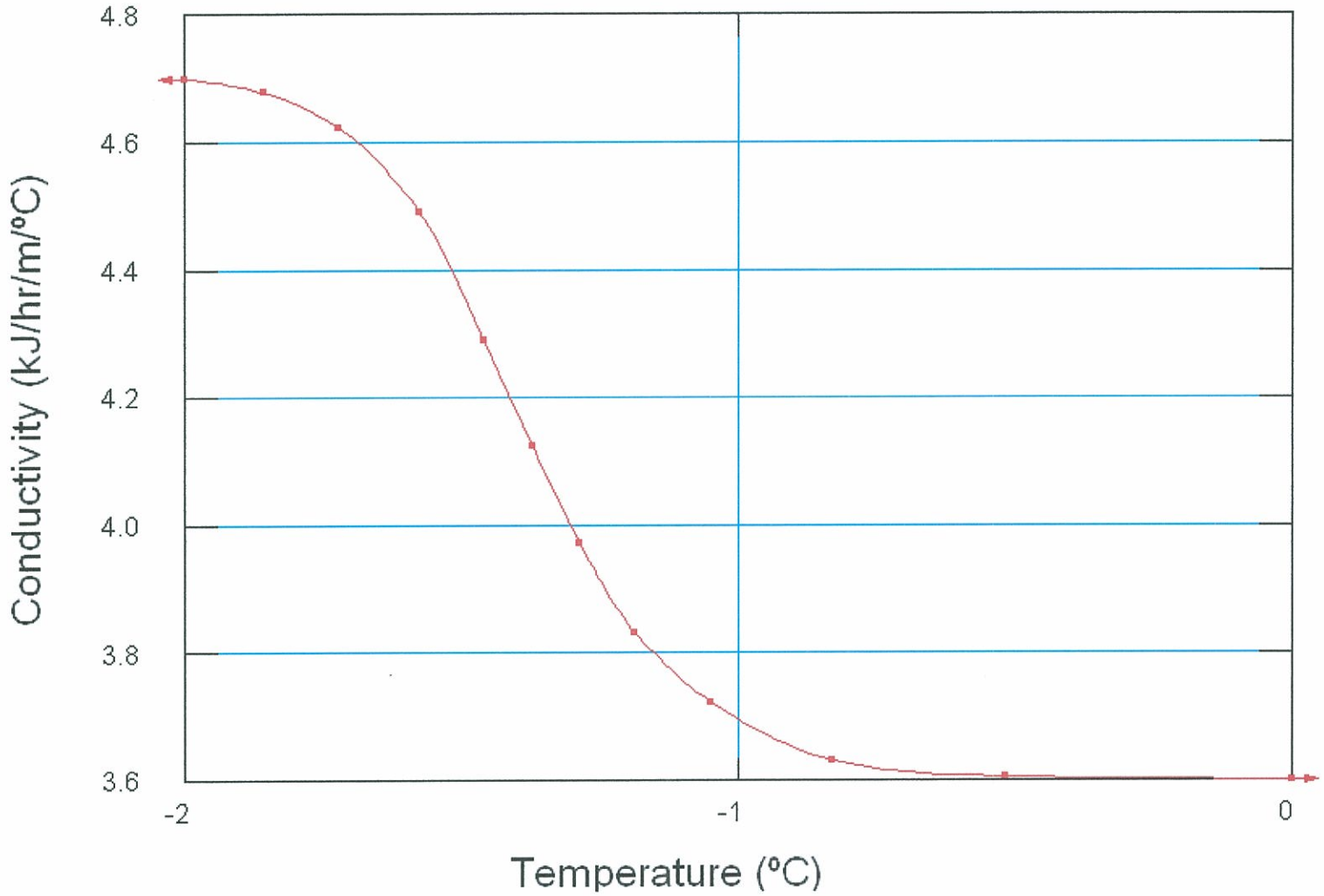
A-2



THERMAL CONDUCTIVITY FUNCTION
FOR THE TAILINGS

Rock Creek Dam,
Nome, Alaska

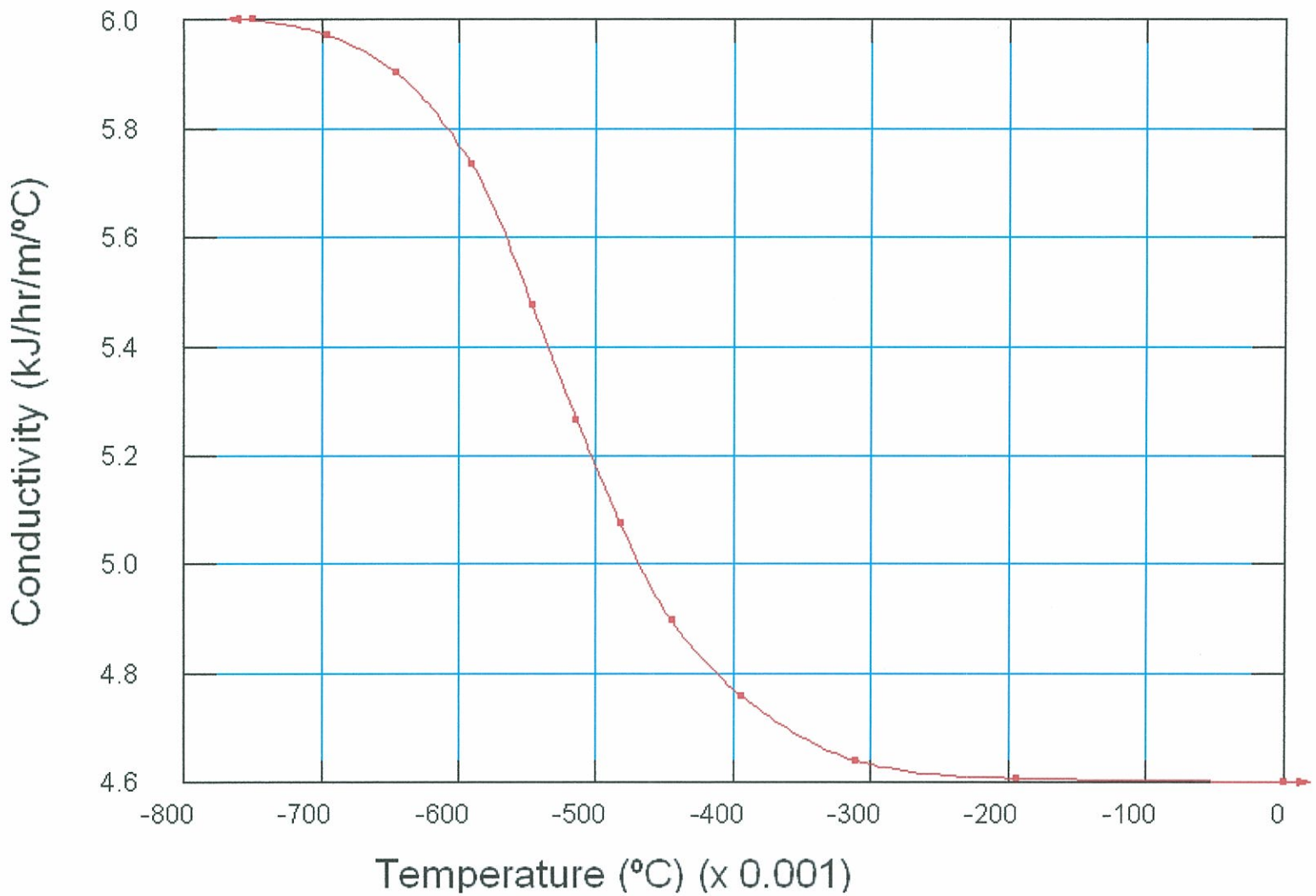
A-3



THERMAL CONDUCTIVITY FUNCTION FOR THE NATIVE SURFICAL SOILS

Rock Creek Dam,
Nome, Alaska

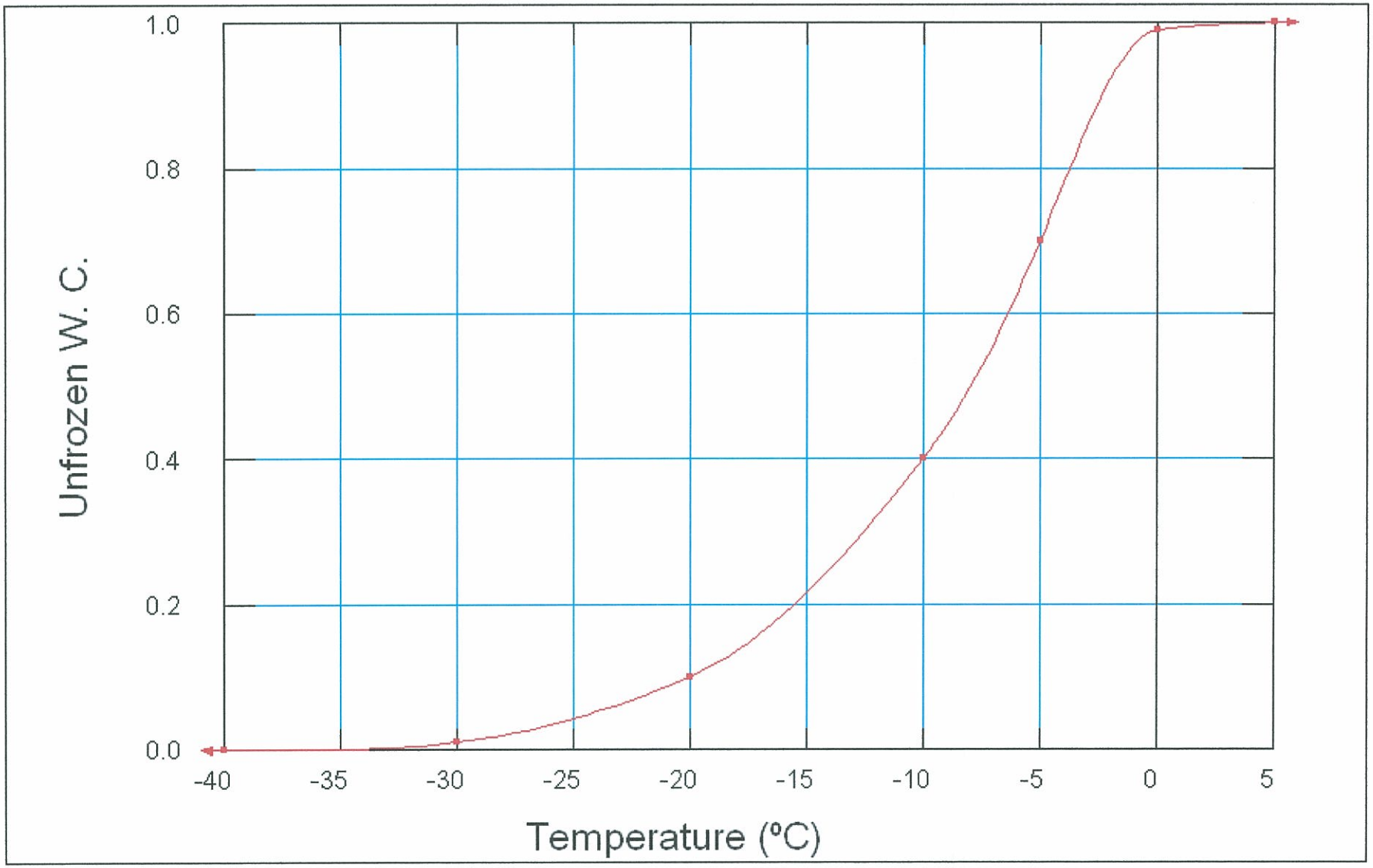
A-4



THERMAL CONDUCTIVITY FUNCTION FOR THE NATIVE WEATHERED BEDROCK

Rock Creek Dam,
Nome, Alaska

A-5

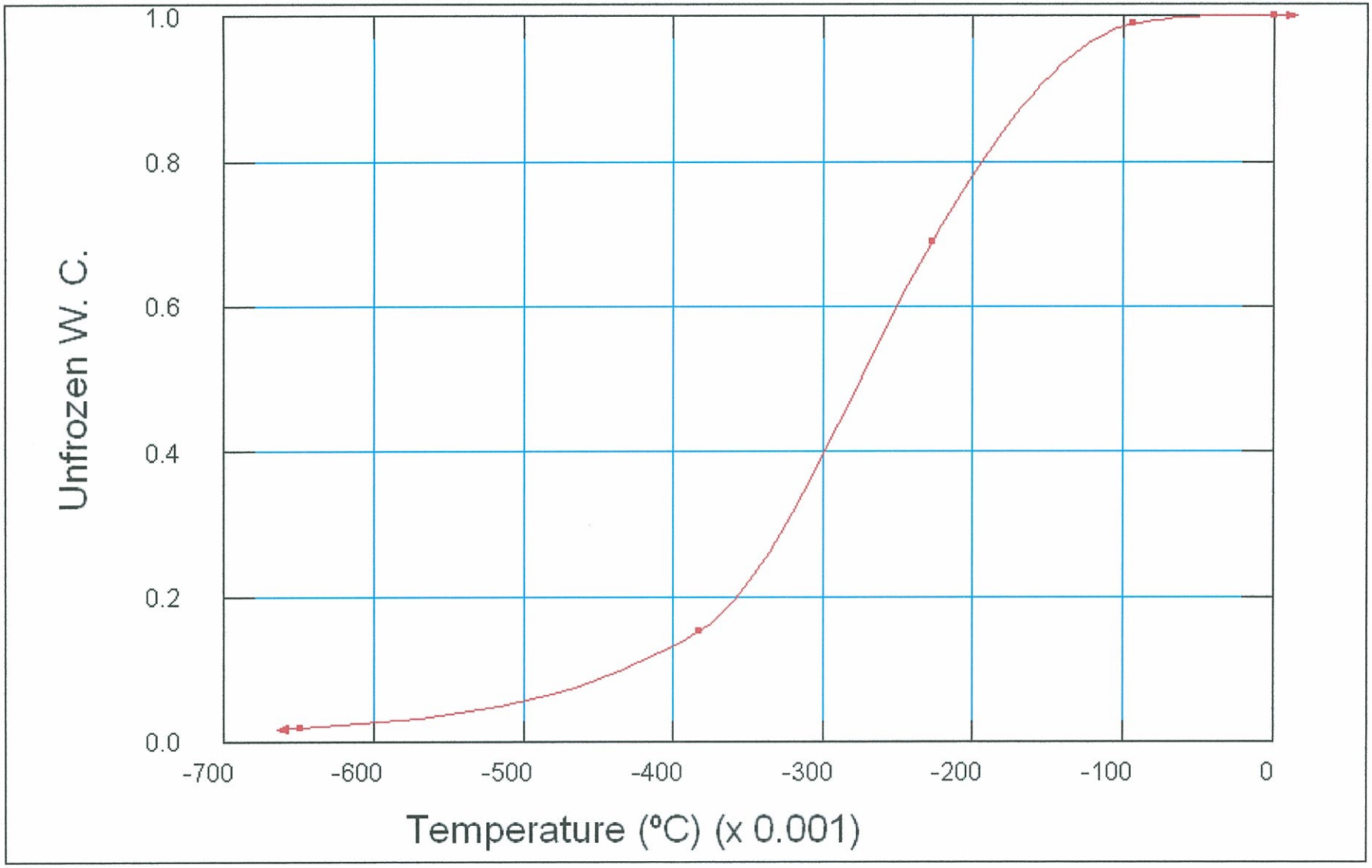


UNFROZEN WATER CONTENT FUNCTION
FOR THE TAILINGS

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Rock Creek Dam,
Nome, Alaska

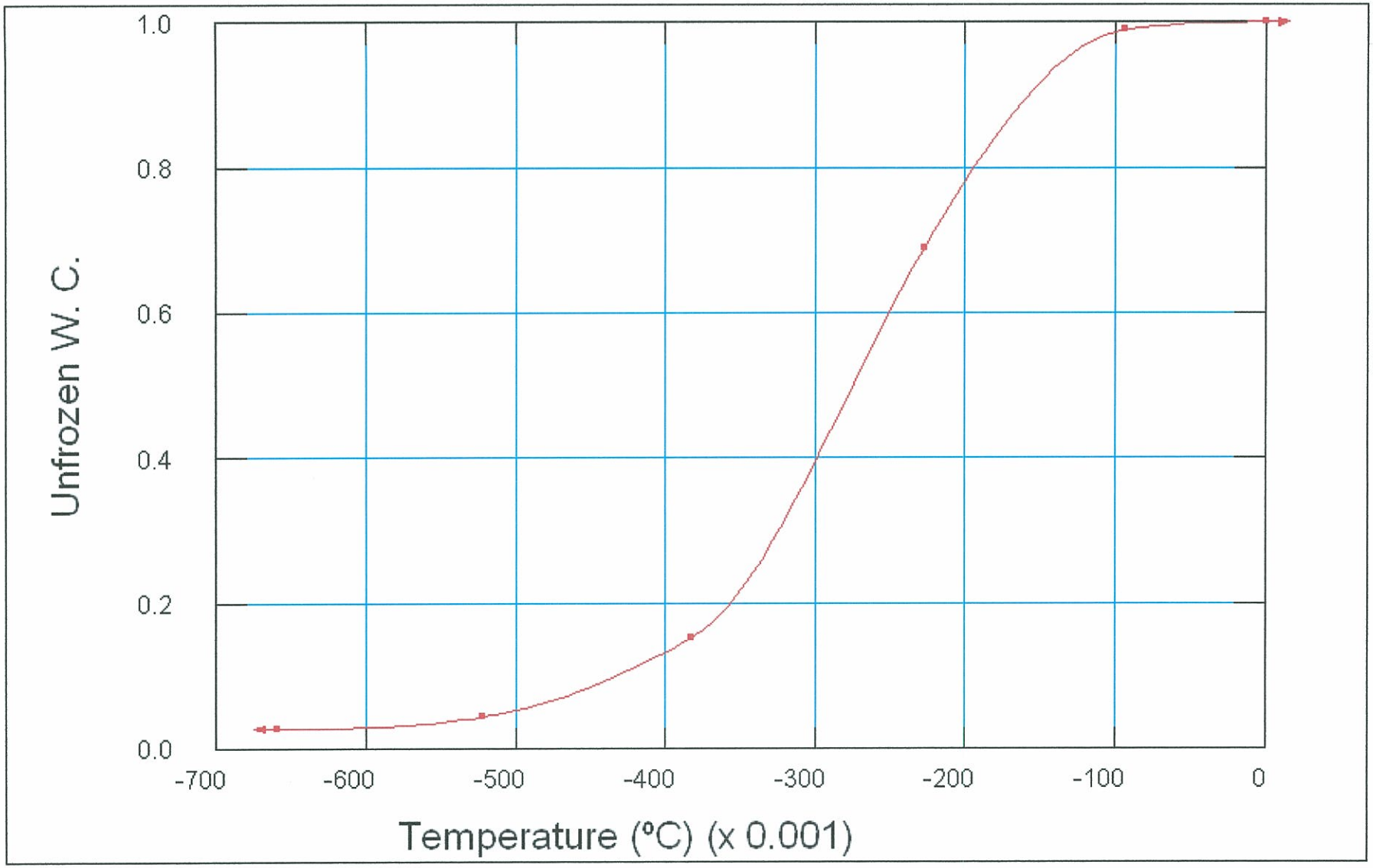
A-6



UNFROZEN WATER CONTENT FUNCTION
FOR THE NATIVE WEATHERED BEDROCK

Rock Creek Dam,
Nome, Alaska

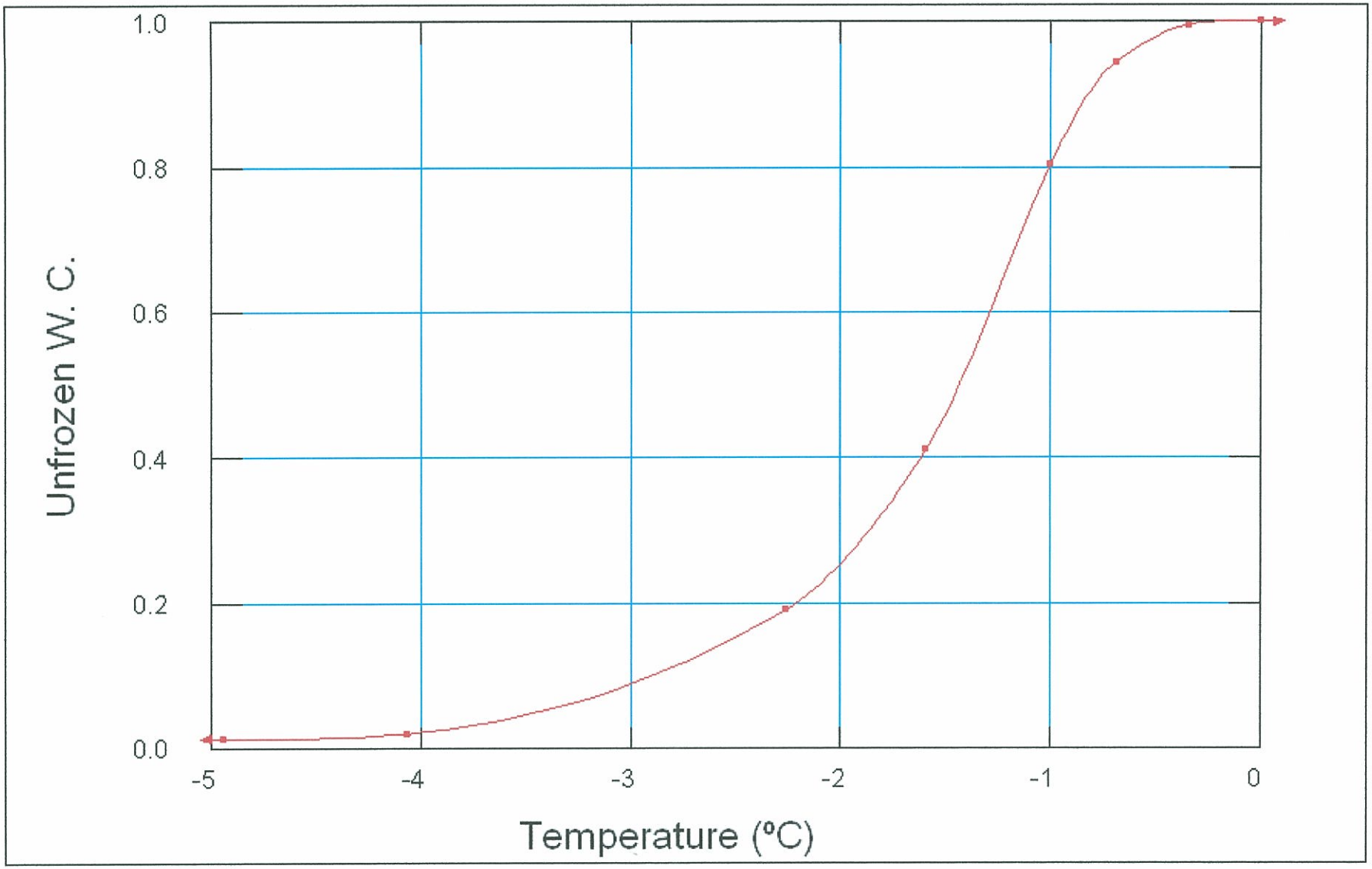
A-7



UNFROZEN WATER CONTENT FUNCTION
FOR THE NATIVE BEDROCK

Rock Creek Dam,
Nome, Alaska

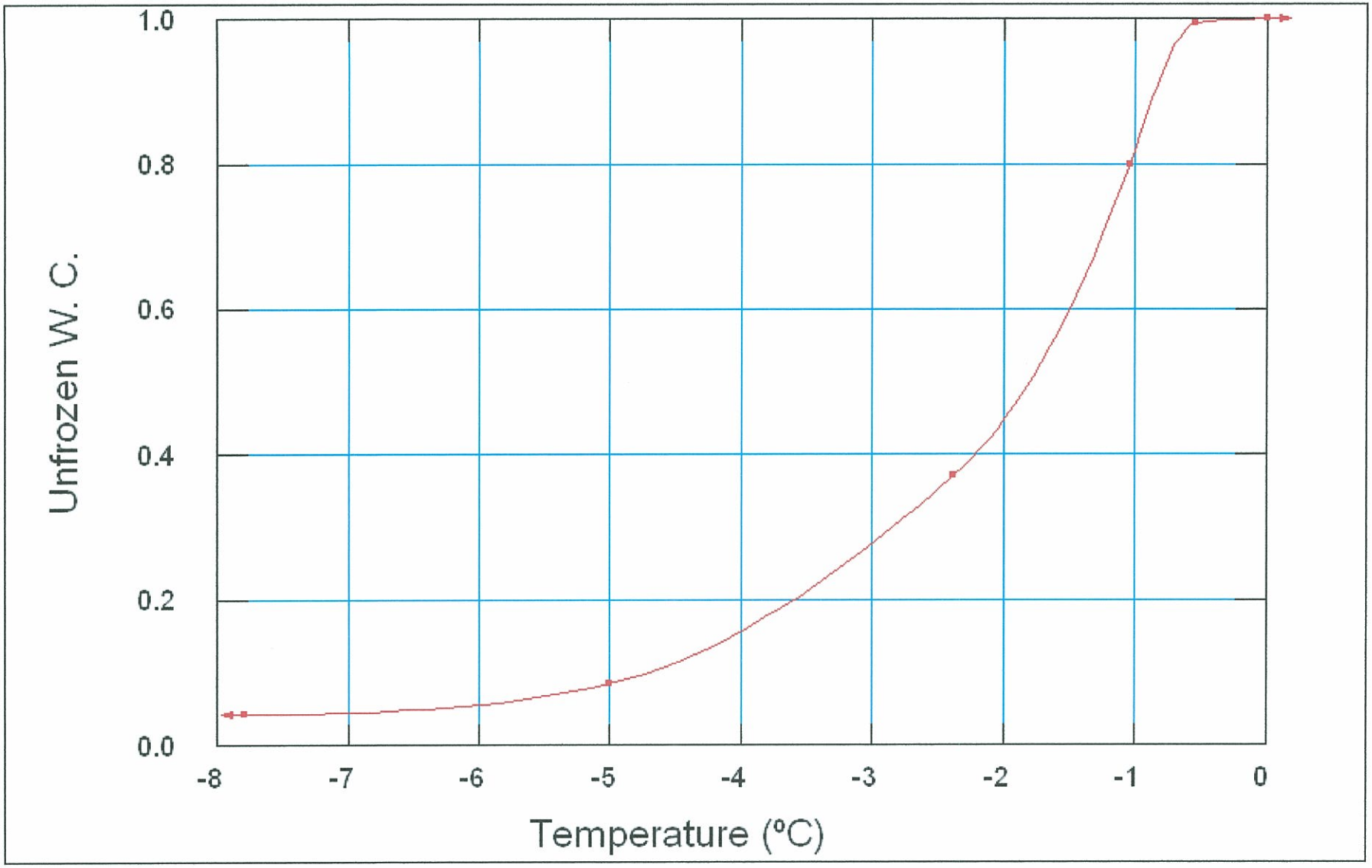
A-8



UNFROZEN WATER CONTENT FUNCTION
FOR THE ROCK FILL DAM MATERIAL

Rock Creek Dam,
Nome, Alaska

A-9



UNFROZEN WATER CONTENT FUNCTION
FOR THE NATIVE SURFICIAL SOILS

Rock Creek Dam,
Nome, Alaska

A-10

APPENDIX B

HYDRAULIC PROPERTY FUNCTIONS

APPENDIX B
HYDRAULIC PROPERTIES

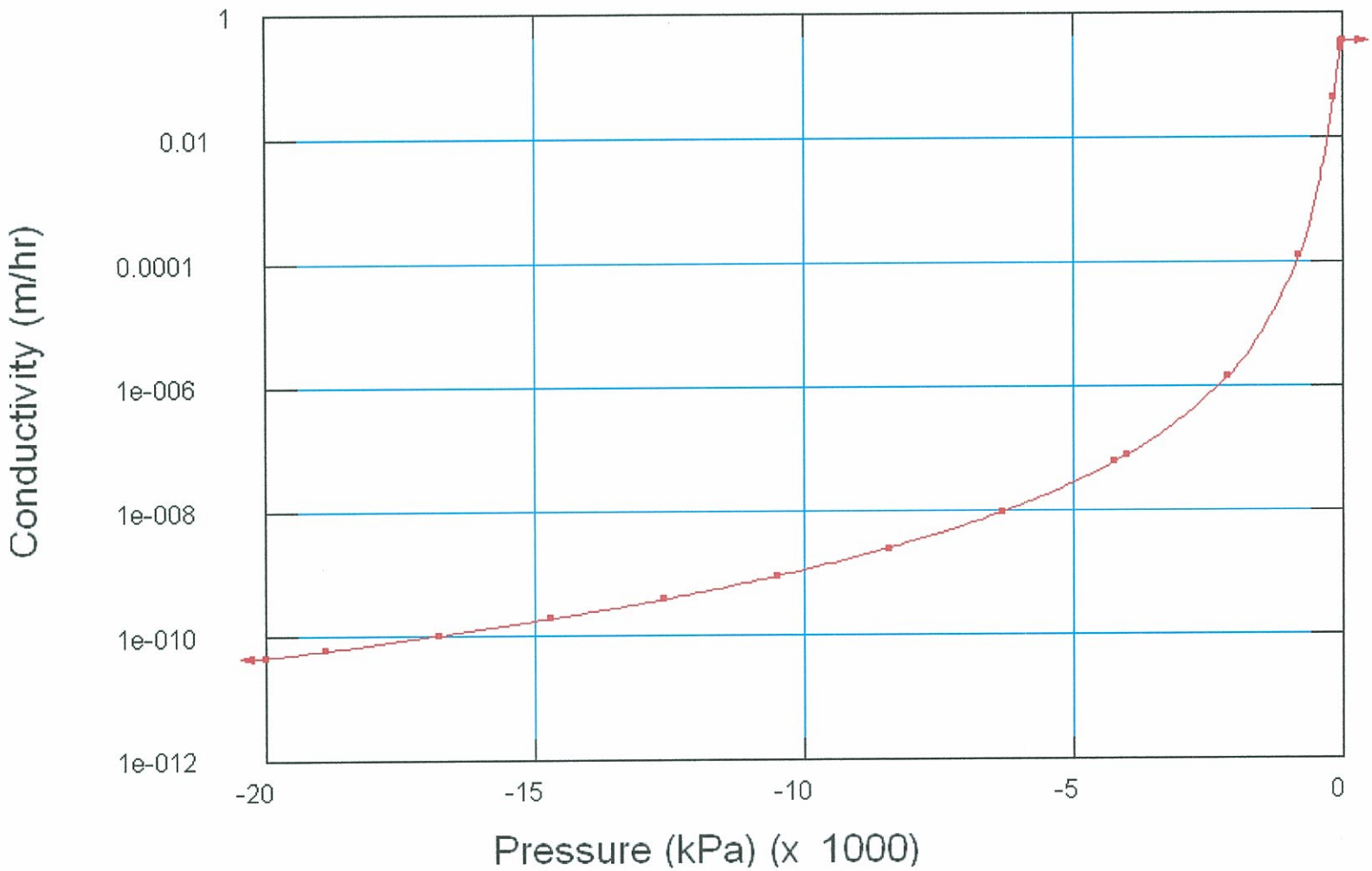
SEEP/W requires input of hydraulic properties for each of the different materials used in the model. Each region is defined as a material type and the model references each material type to assigned properties. Where the hydraulic properties are a function dependent on other variables in the system, a graphical representation of the property is needed. The hydraulic properties defined for each material in the model include:

1) Hydraulic conductivity: The ability of a material to transport or conduct water under both saturated and unsaturated conditions. With unsaturated conditions, the hydraulic conductivity decreases as a function of the head. Because the phreatic surface is below the node in question, a suction pressure is created. The functions are presented in Figures B- through B-6. The units used for the model are m/hr.

The liner hydraulic conductivity was derived from the permeability of the HDPE liner and calculated for an equivalent permeability using a 2 meter thick region. This was required as the liner in essence is a hydraulic discontinuity, but it is not a thermal discontinuity. For the coupled analysis using TEMP/W and SEEP/W, the hydraulic discontinuity needed to be modeled such that heat transfer could be calculated.

2) Volumetric water content: The volume of water which occupies the void spaces within a material. It is expressed as a percentage of water-filled voids to air-filled voids, with 100% indicating saturation. The saturated volumetric water content is defined for each material as shown in Table 2. In unsaturated conditions, the volumetric water content is a function of the suction pressure. These functions are presented in Figures B-7 through B-12. Units used in the model are %.

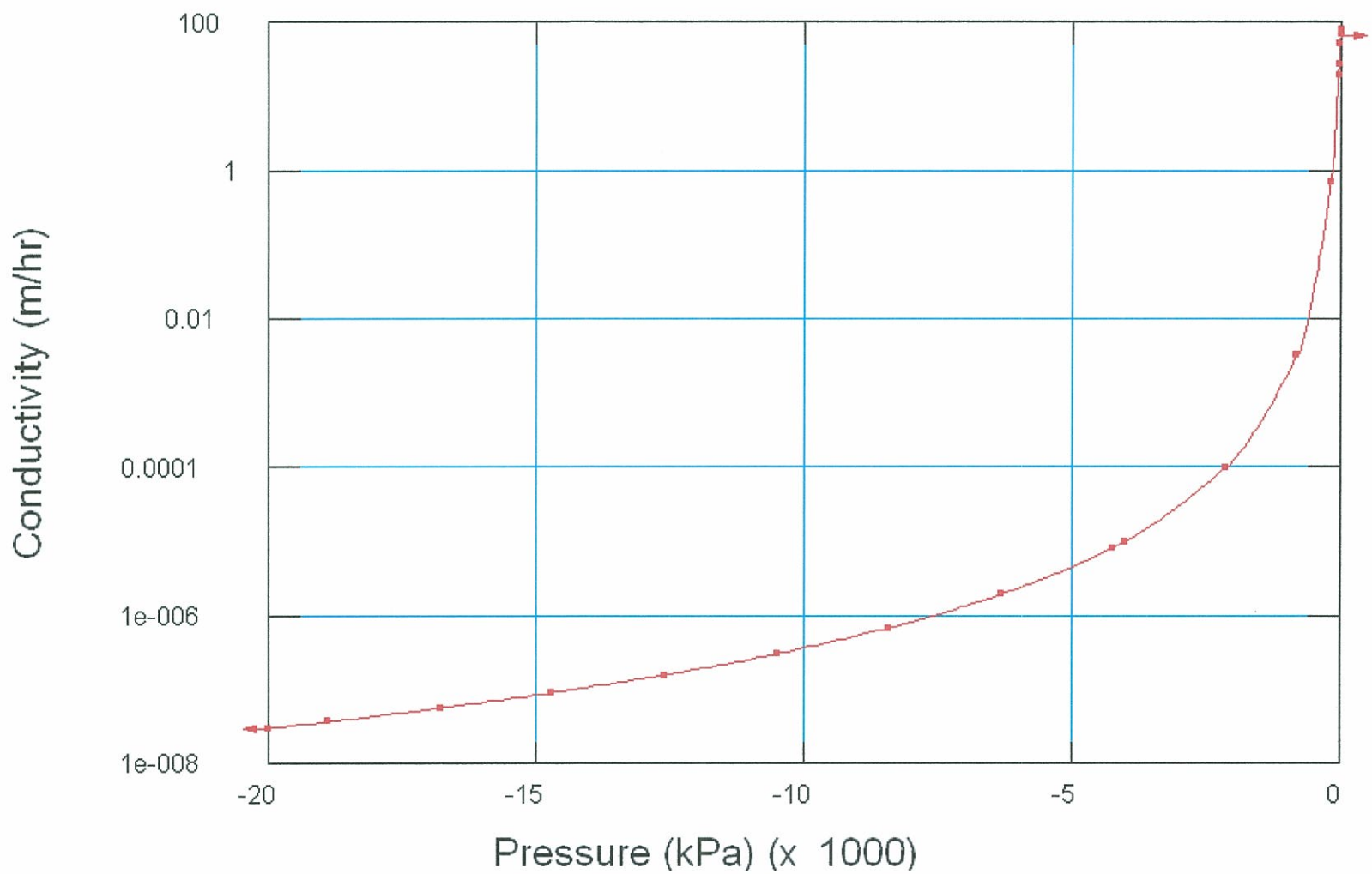
During the seepage analysis, the program calculates the actual volumetric water content in the unsaturated zone based on the calculated suction pressure. This in turn affects the permeability.



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE NATIVE BEDROCK

Rock Creek Dam,
Nome, Alaska

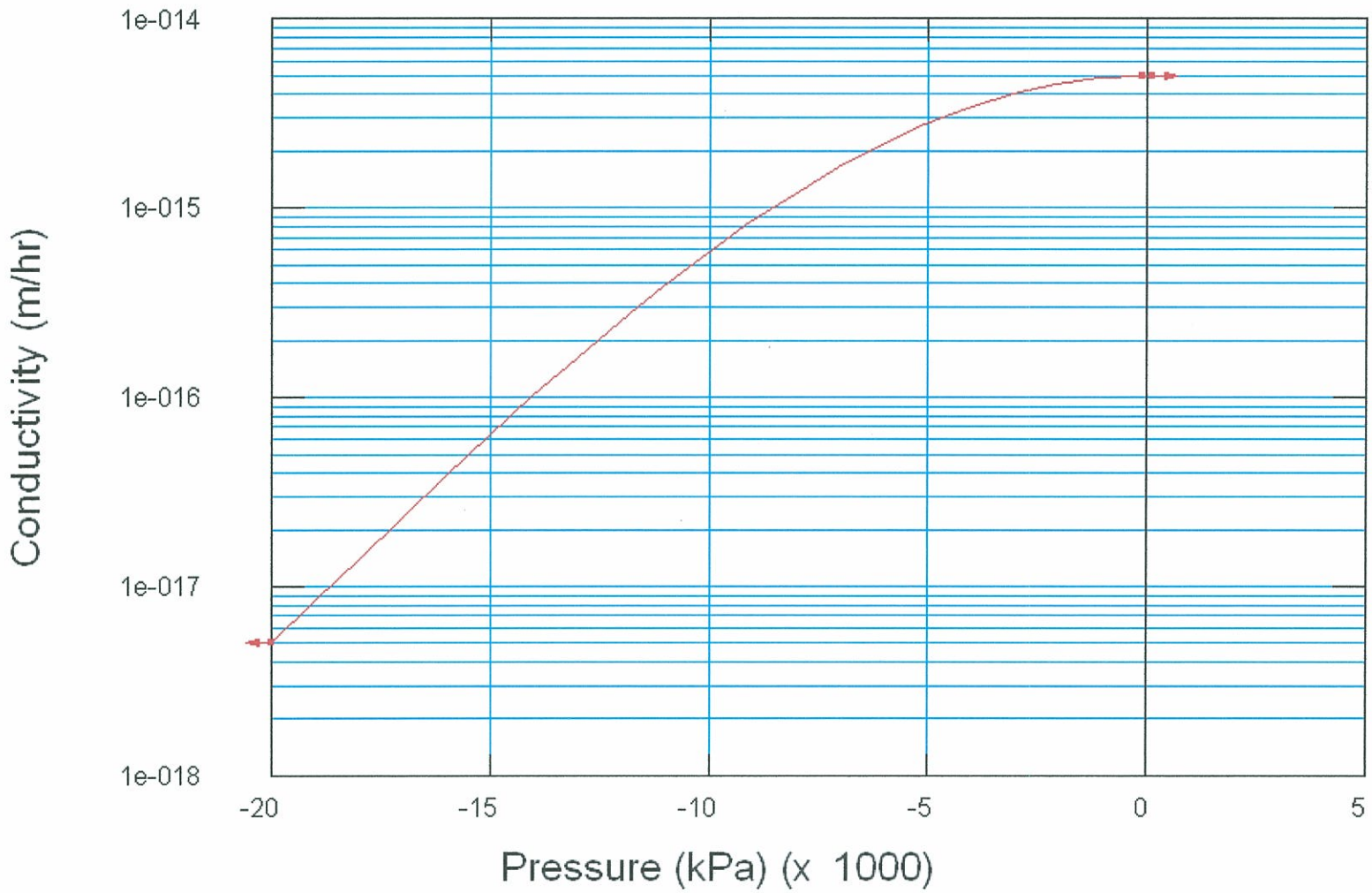
B-1



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE ROCK FILL DAM MATERIAL

Rock Creek Dam,
Nome, Alaska

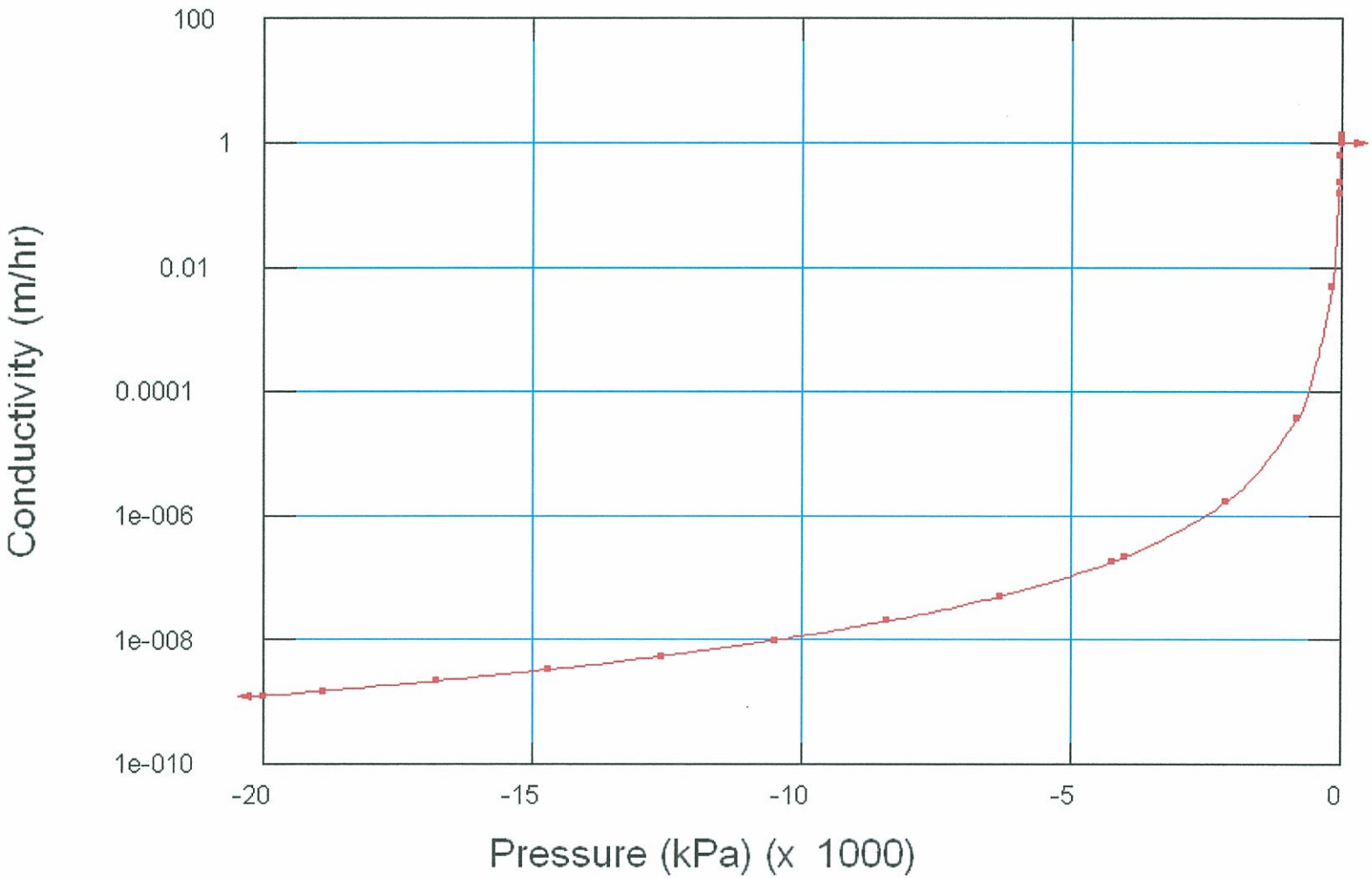
B-2



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE LINER MATERIAL

Rock Creek Dam,
Nome, Alaska

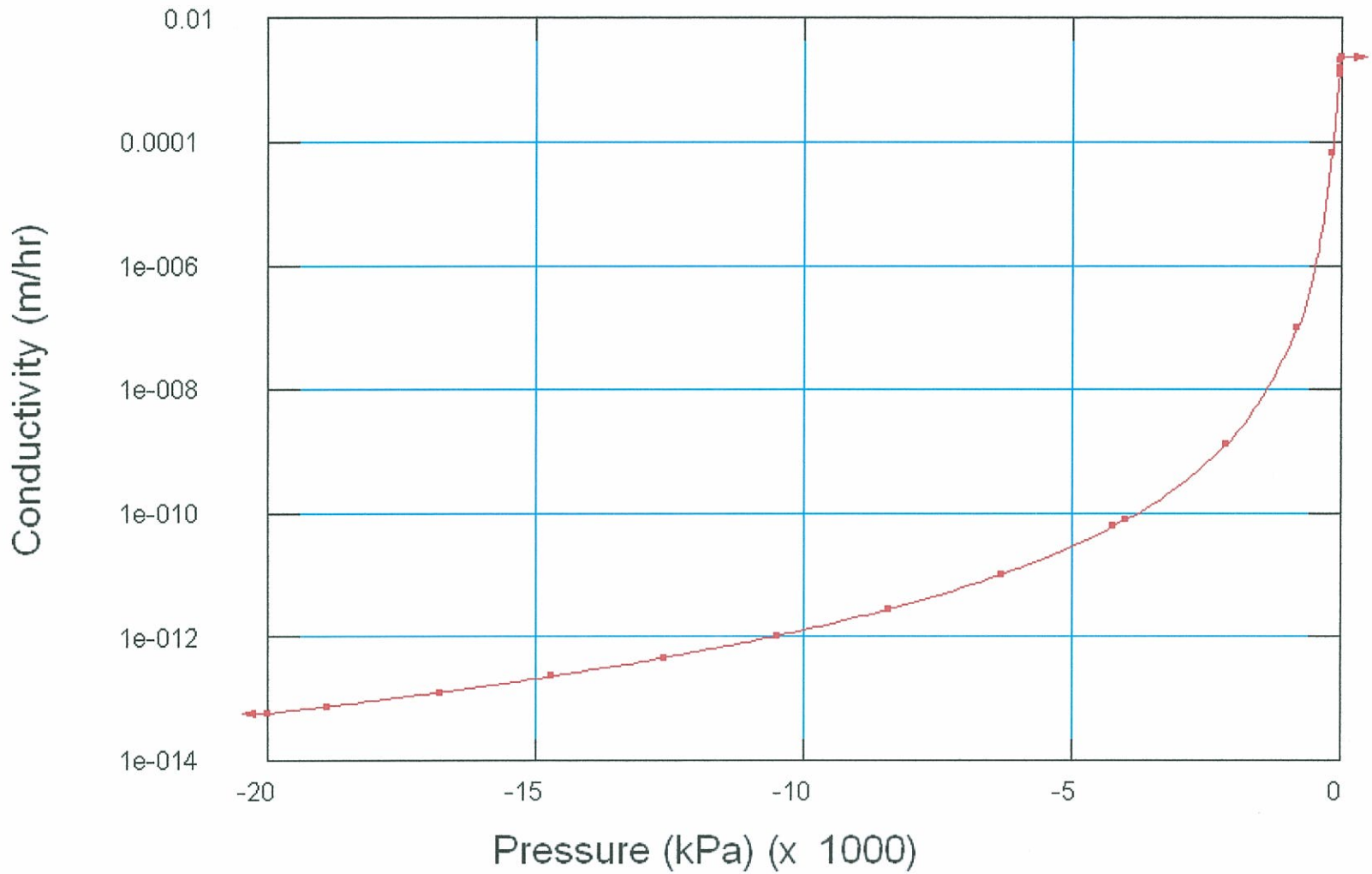
B-3



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE NATIVE SURFICIAL SOILS

Rock Creek Dam,
Nome, Alaska

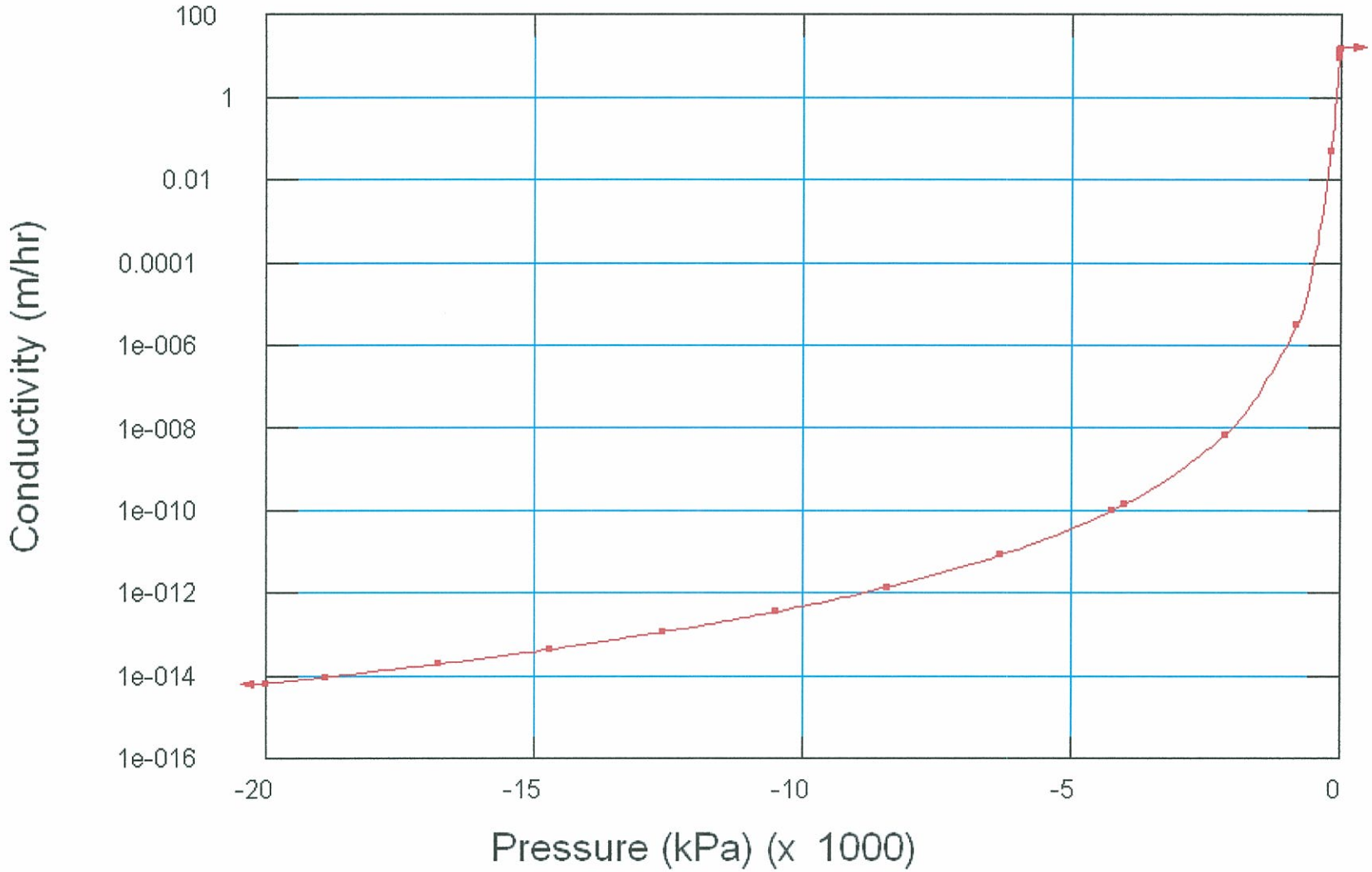
B-4



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE TAILINGS

Rock Creek Dam,
Nome, Alaska

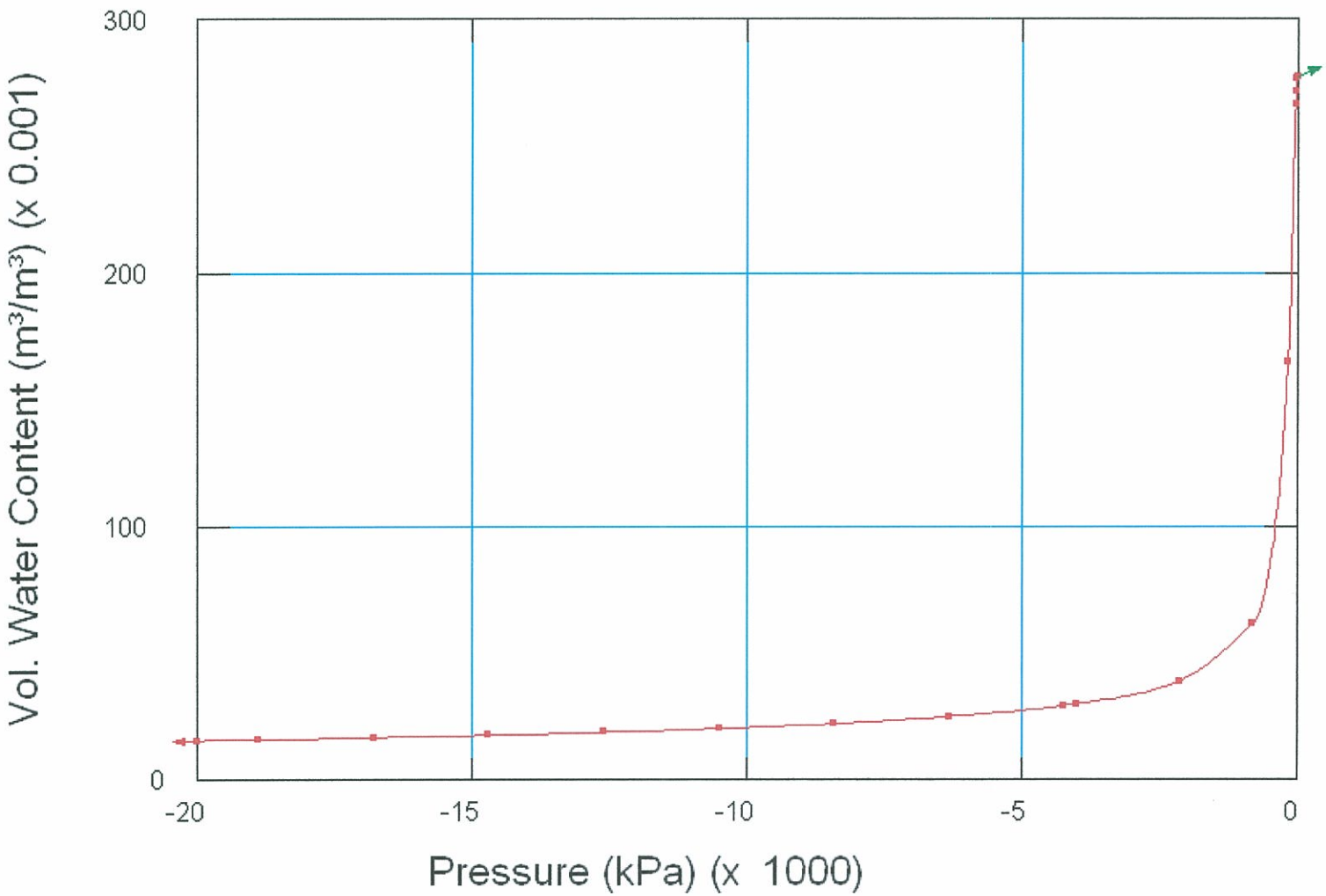
B-5



HYDRAULIC CONDUCTIVITY FUNCTION
FOR THE NATIVE WEATHERED BEDROCK

Rock Creek Dam,
Nome, Alaska

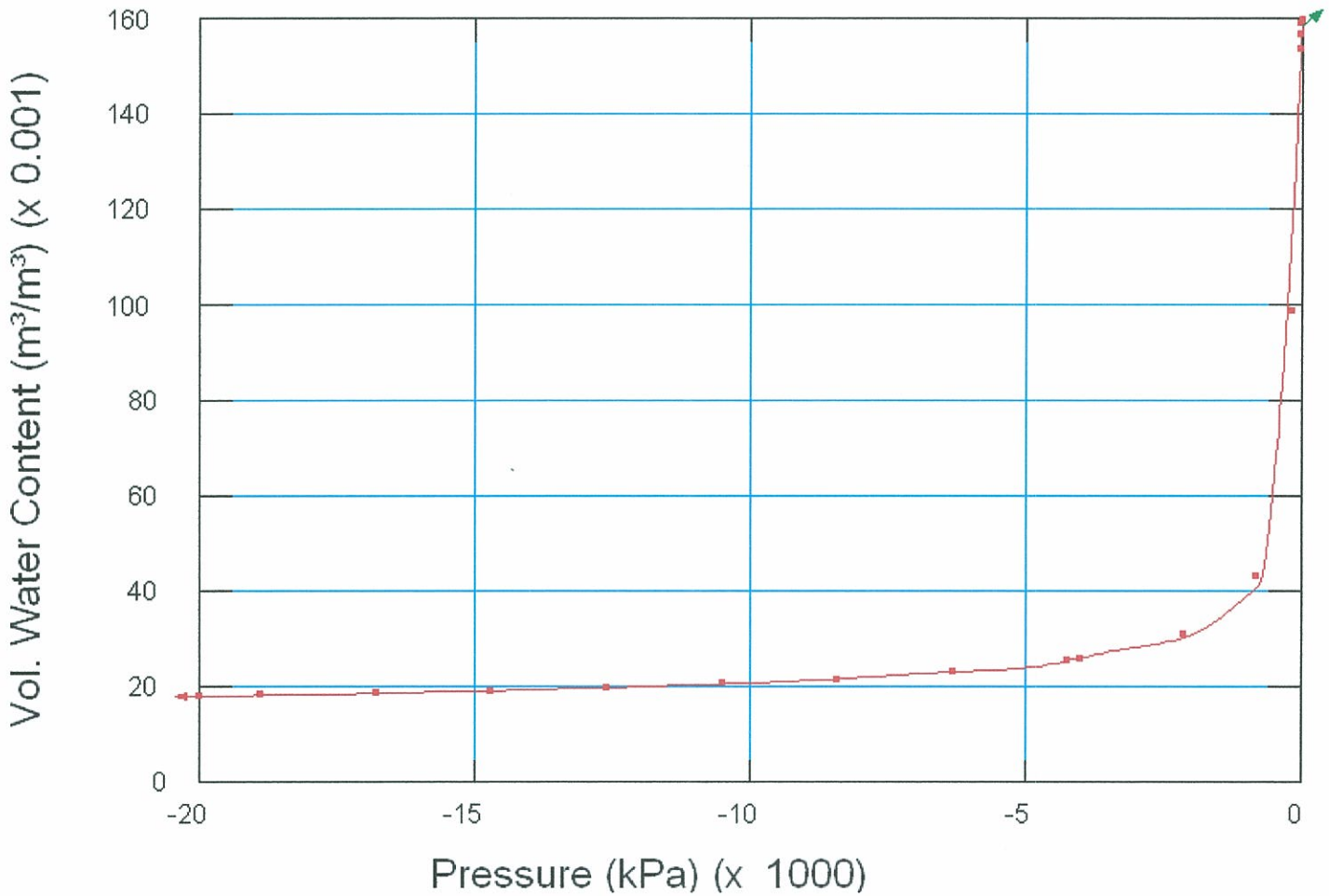
B-6



VOLUMETERIC WATER CONTENT
FUNCTION FOR THE
ROCK FILL DAM MATERIAL

Rock Creek Dam,
Nome, Alaska

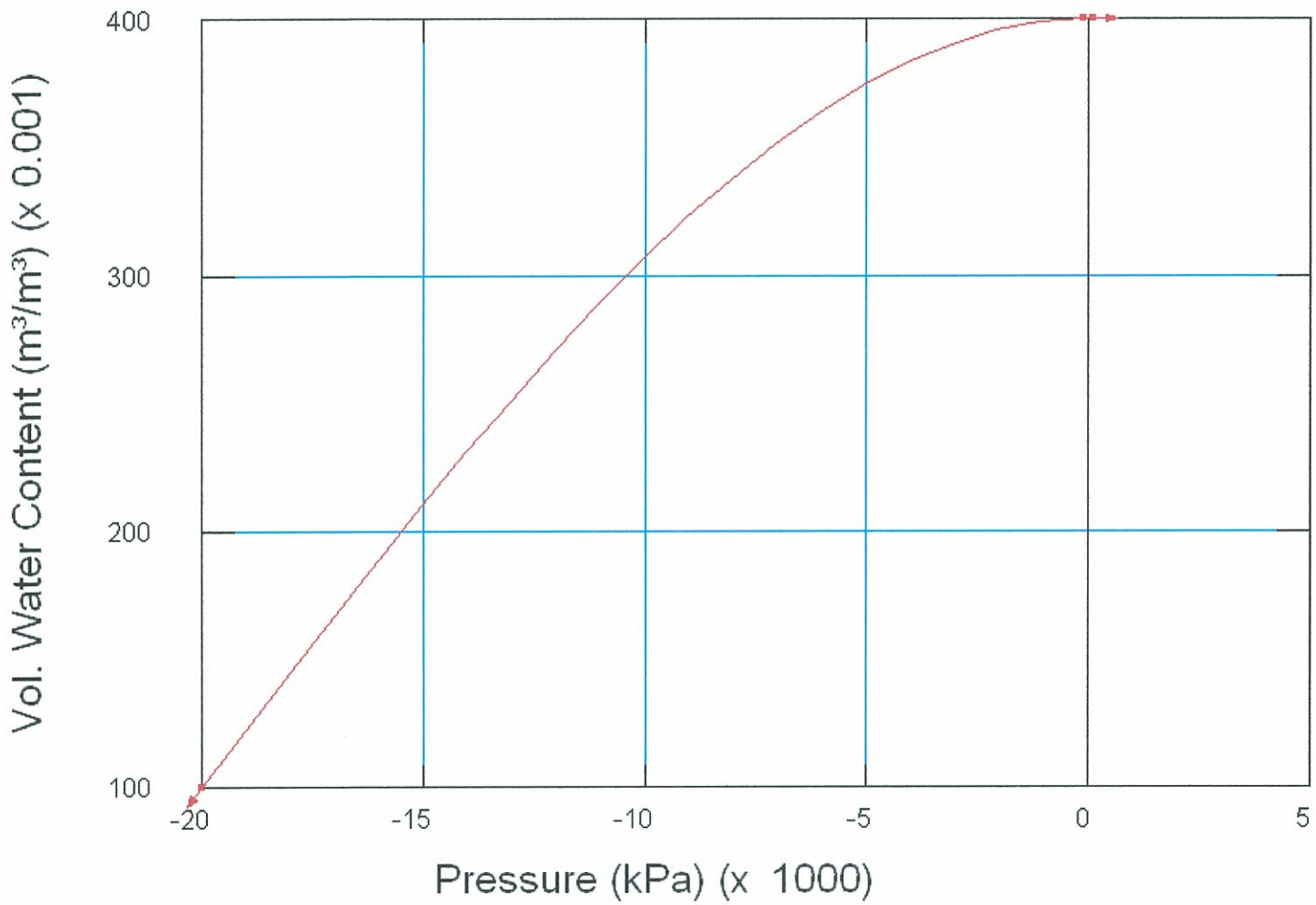
B-7



VOLUMETERIC WATER CONTENT FUNCTION FOR THE NATIVE BEDROCK

Rock Creek Dam,
Nome, Alaska

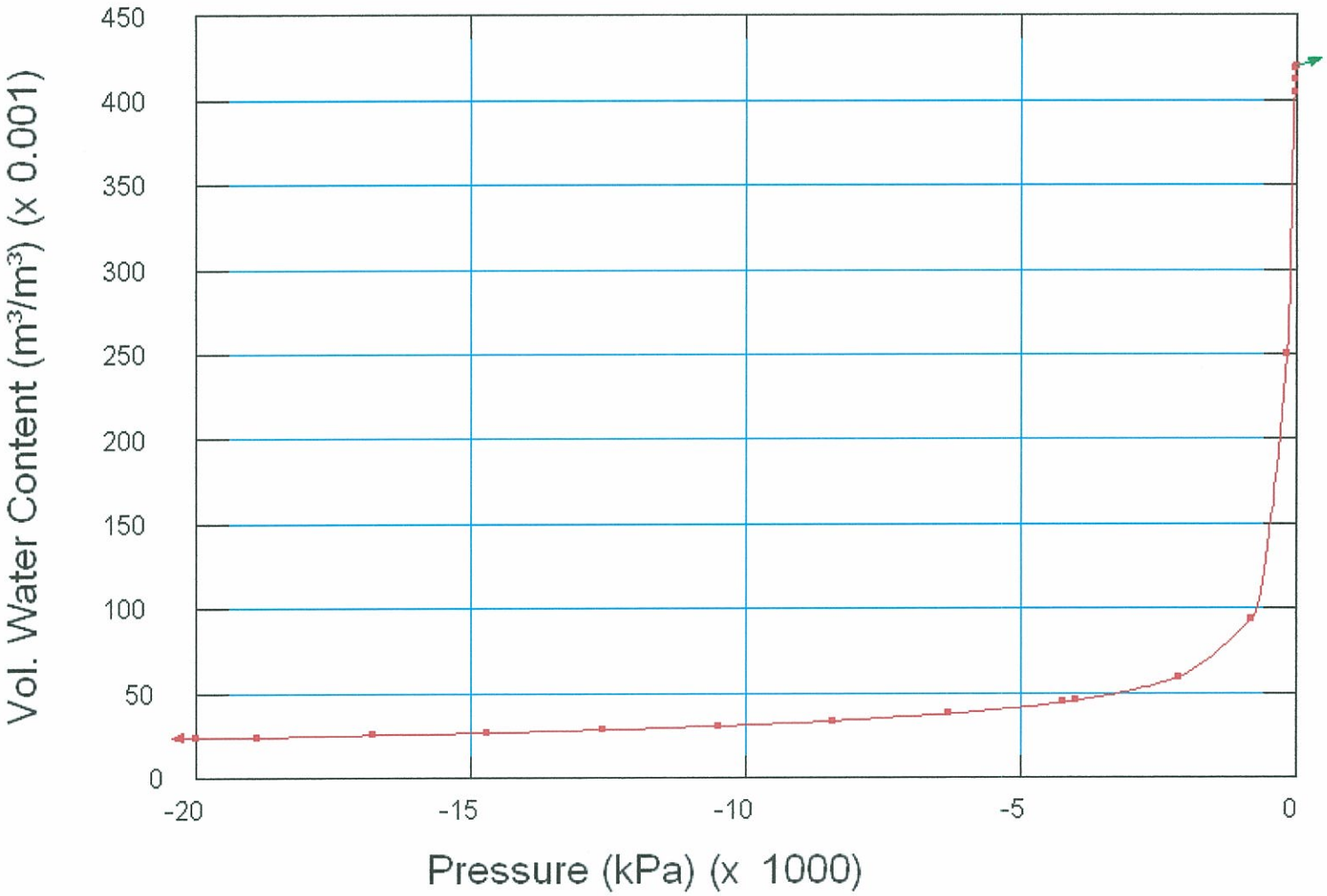
B-8



VOLUMETERIC WATER CONTENT
FUNCTION FOR THE LINER MATERIAL

Rock Creek Dam,
Nome, Alaska

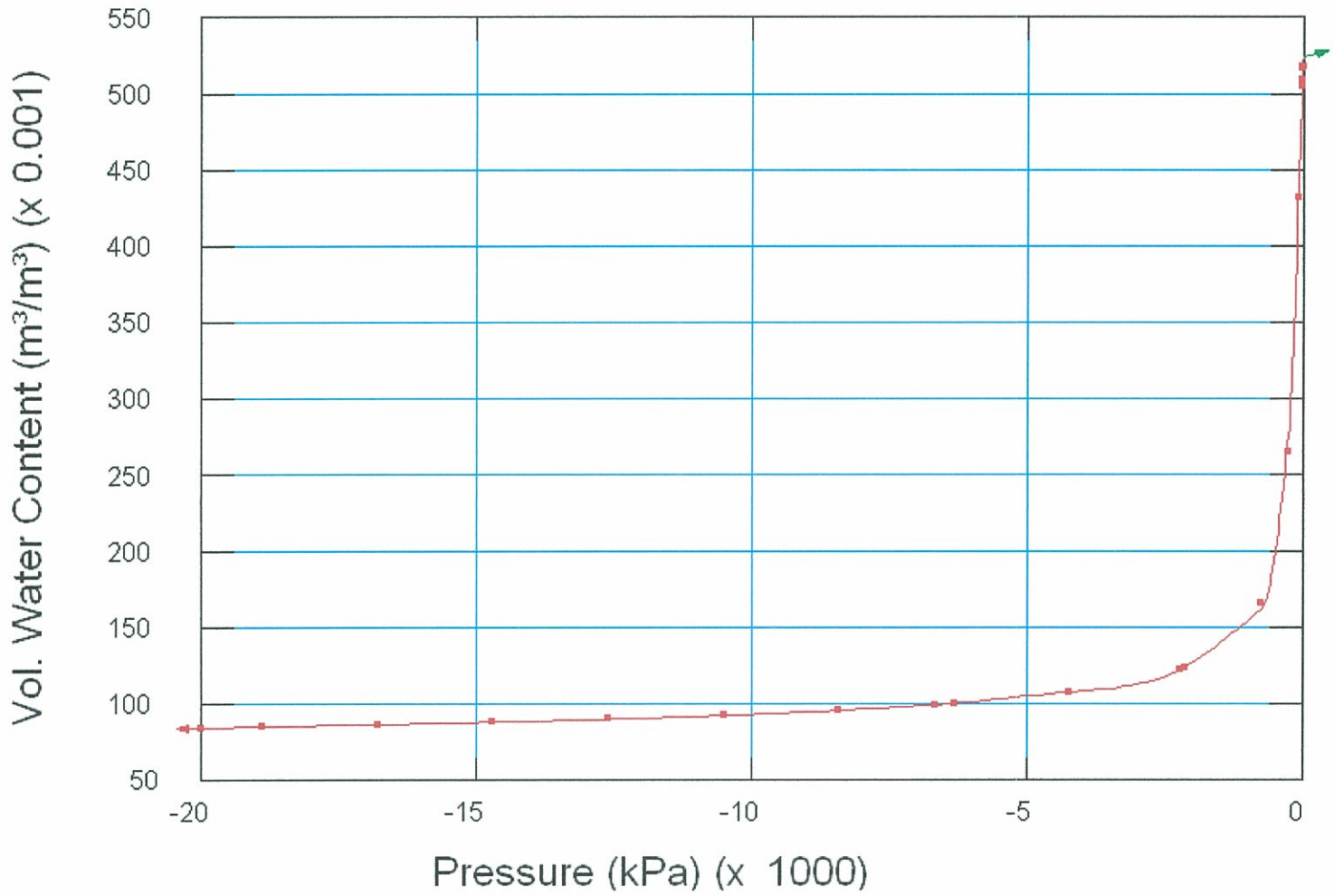
B-9



VOLUMETERIC WATER CONTENT FUNCTION FOR THE NATIVE SURFICIAL SOILS

Rock Creek Dam,
Nome, Alaska

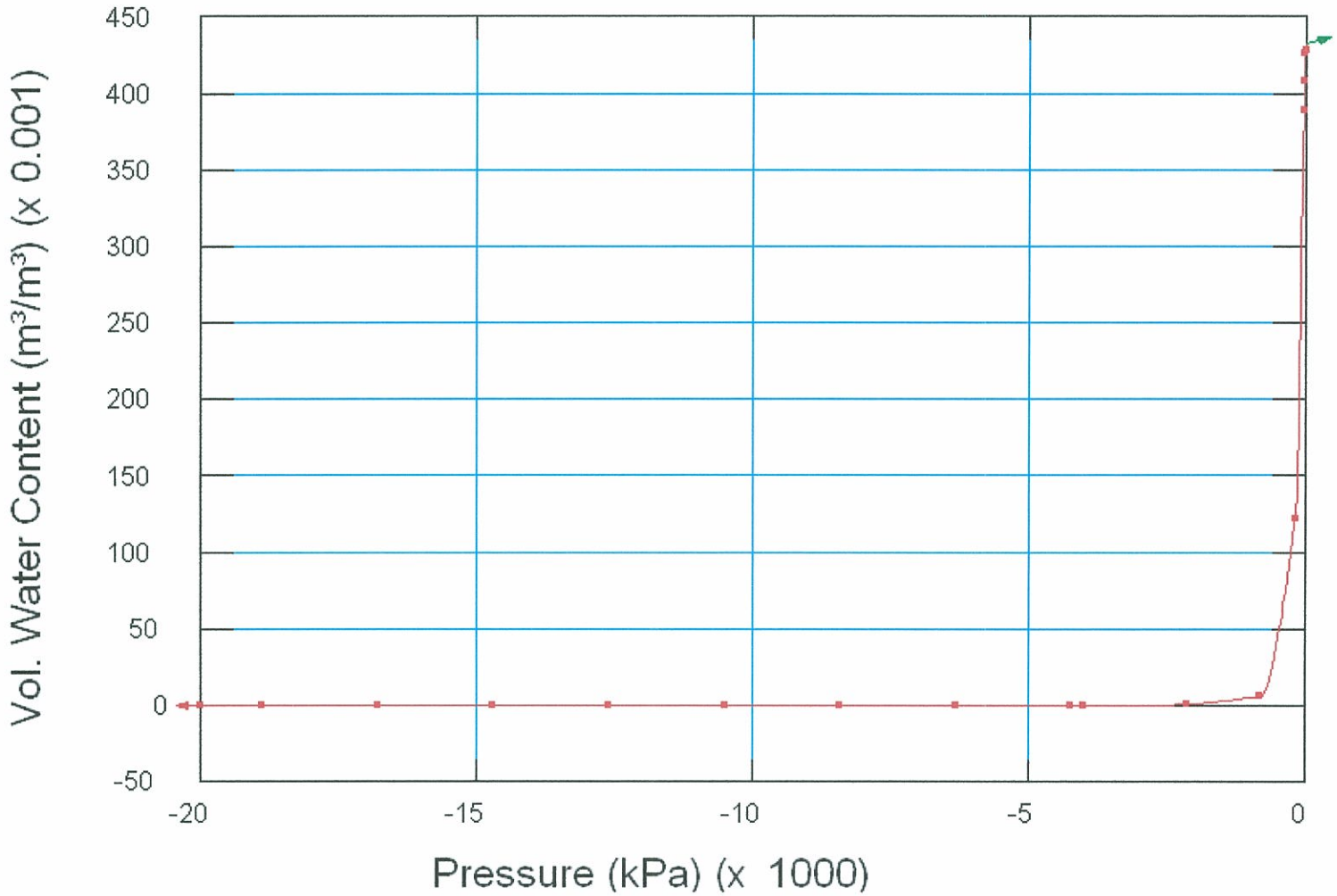
B-10



VOLUMETERIC WATER CONTENT FUNCTION FOR THE TAILINGS

Rock Creek Dam,
Nome, Alaska

B-11



VOLUMETERIC WATER CONTENT FUNCTION FOR THE NATIVE WEATHERED BEDROCK

Rock Creek Dam,
Nome, Alaska

B-12

APPENDIX C

BOUNDARY CONDITION FUNCTIONS

APPENDIX C

BOUNDARY CONDITIONS

Thermal Boundaries

Temperature Boundary

The thermal boundary conditions for the model used in this study were defined by either applying: 1) a constant temperature; or 2) a time-related temperature function to individual nodes along a defined boundary (ex. ground surface).

Constant thermal boundary conditions were used to apply site-specific temperature data (recorded in core holes along the TSFD centerline) to linear series of nodes at corresponding depths within the model. These boundary conditions were used in the initial steady state analyses to define the average thermal gradient of the subsurface materials as they currently exist.

A time-related temperature function was developed in the modeling software using ambient air temperature data acquired from the Nome Airport, which defined the annual average hourly change in air temperatures for the area (Figure C-1). This function was subsequently applied (during the transient analyses) to the nodes along the surface of the model to account for the hourly input/removal of thermal energy to/from the model as a result of contact with the ambient air at the site. This temperature function was used for scenarios 1 through 4.

Raised temperatures used in scenarios 5 through 7 to model an extreme global warming condition. The entire function shown in Figure C-1 was increased by 3°C for the entire modeling period. A more realistic model effort would have been to raise the temperature incrementally over the modeling period at the beginning of each phase. This was not completed due to time and budget constraints.

Thermal Modifier Functions

Correction factors, known as modifier functions, were developed for the surficial thermal boundary condition function (i.e. ambient air temperature) to account for differing rates of material heat gain/loss due to factors other than air temperature; such as snow

insulation, wind removal, solar incidence, ground cover, etc. The modifier functions are developed in the analysis software and are time-related correction factors which are applied to representative nodes at the time that a thermal boundary condition is applied to a node in the model. Three functions were developed to account for differences in the ground cover at various positions on the model surface.

Native Soil Function

The modifier function for the native soil is shown in Figure C-2. The value of less than 1 for the winter month reflects the insulation value from snow and native plant growth. Mathematically, the surface temperatures during the winter are warmer than the air temperature. During the summer months, the function is greater than 1 representing solar absorption. The factor is lower than for bare material as the plant growth evapo-transpiration and insulating characteristics reduces energy absorption into the ground.

Tailings Function

The modifier function for the tailings is shown in Figure C-3. During the winter the tails are expected to melt some snow and to accumulate in piles. As such some solar gain is expected and little to no insulating value from the snow is expected. The release of latent heat from the snow melt cannot be accommodated in the model as it is above the mesh surface, so a modifier value slightly greater than 1 was used. During the summer months solar gain will be significant with the wet tails on the surface able to absorb the incident heat.

Rock Fill Function

The modifier function for the rock fill to be used in the dam construction is shown on Figure C-4. Most of the downstream dam face points to the south and west. As such, it is expected that snow accumulation will be less, water from the snow melt will percolate deep into the dam, and incident solar radiation will be increased both from the orientation and the sloped face. During the summer months incident solar radiation will be high, however the dam face is expected to be dry, thus reducing the heat absorption.

Geothermal Gradient

A geothermal gradient exists over the entire earth's surface and is the result of heat from the core reaching the ground surface. The gradient is variable, dependent upon numerous

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factors. Lunardini (1981) suggested an order-of-magnitude value for the geothermal gradient. This value was used initially during the calibration phase of the modeling. With a 50 m thick model below the base of the dam, it can be assumed that the temperature of the base would not change during the first year of modeling. To achieve this, the geothermal gradient value was adjusted until thermal equilibrium was reached at depth. The value used for all seven scenarios was 0.21 kJ/hr/M and was applied to the nodes along the bottom the model.

Hydraulic Boundaries

The hydraulic boundary conditions for the model used in this study were defined by either applying: 1) a constant hydraulic head condition (a.k.a. potential head); 2) an elevation dependant hydraulic head condition (a.k.a. pressure head); or 3) a time-related meteoric water input function to individual nodes along the surface.

A hydraulic head boundary condition was used to apply estimated hydraulic head conditions to the nodes which represents the surface of the groundwater table as is reported to exist at the site (top of the weathered bedrock material). Each node was assigned a pressure head value corresponding to the node's elevation. These boundary conditions were used in the initial steady state analyses to define the average hydraulic gradient of the subsurface materials as they currently exist.

Once the initial hydraulic conditions of the native materials was established, Phase I of the TSFD and tailings were added to the model, and a pressure head boundary condition applied to the nodes along the surface of the tailings corresponding to the elevation of the tailing surface. This established the hydraulic gradient within the tailings and underlying native materials.

A time-related meteoric water input function was developed in SEEP/W using rainfall equivalence data acquired from the 2003 Norwest Report, which defined the annual average hourly water input to the site from precipitation (Figure C-5). This function was subsequently applied (during the transient analyses) to the nodes along the surface of the model to account for the hourly input of meteoric water into the model. The function was adjusted to account for the increased runoff which occurs during spring break-up, and the

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limited runoff/infiltration which occurs during winter months. The total annual precipitation accumulation was kept constant with the data used.

Thermosyphon Boundary Conditions

TEMP/W contains an application which allows the user to place a thermosyphon boundary condition at an individual node (or nodes) which represent a single thermosyphon, as if you were viewing the pipe in cross-section. The thermosyphon application within TEMP/W operates on four user-defined criteria: 1) pipe length (750 m); 2) maximum functioning air temperature (-1°C); 3) the minimum air/ground temperature difference that must exist in order for a phase change to occur within the thermosyphon system (3°C); and 4) the area of the thermosyphon's condenser radiator in square meters (variable). The thermosyphon application refers to a user-defined annual climate dataset to determine: 1) when the thermosyphon will be active during the course of the transient analysis; and 2) the heat removal capabilities of the thermosyphon based on air temperatures and wind speeds. For the purposes of this study, thermosyphon boundary conditions were applied to two nodes located downstream of the upstream toe of the TSFD, immediately beneath the liner material (Figure 9 in the main report).

Data used for the thermosyphon function included the 30-year average daily temperatures and 57-year average daily wind speeds were obtained from National Oceanographic and Atmospheric Administration (NOAA) databases. These data were input into the Thermosyphon Boundary Condition application to be used by the application to determine when the heat removal would occur through the thermosysphons.

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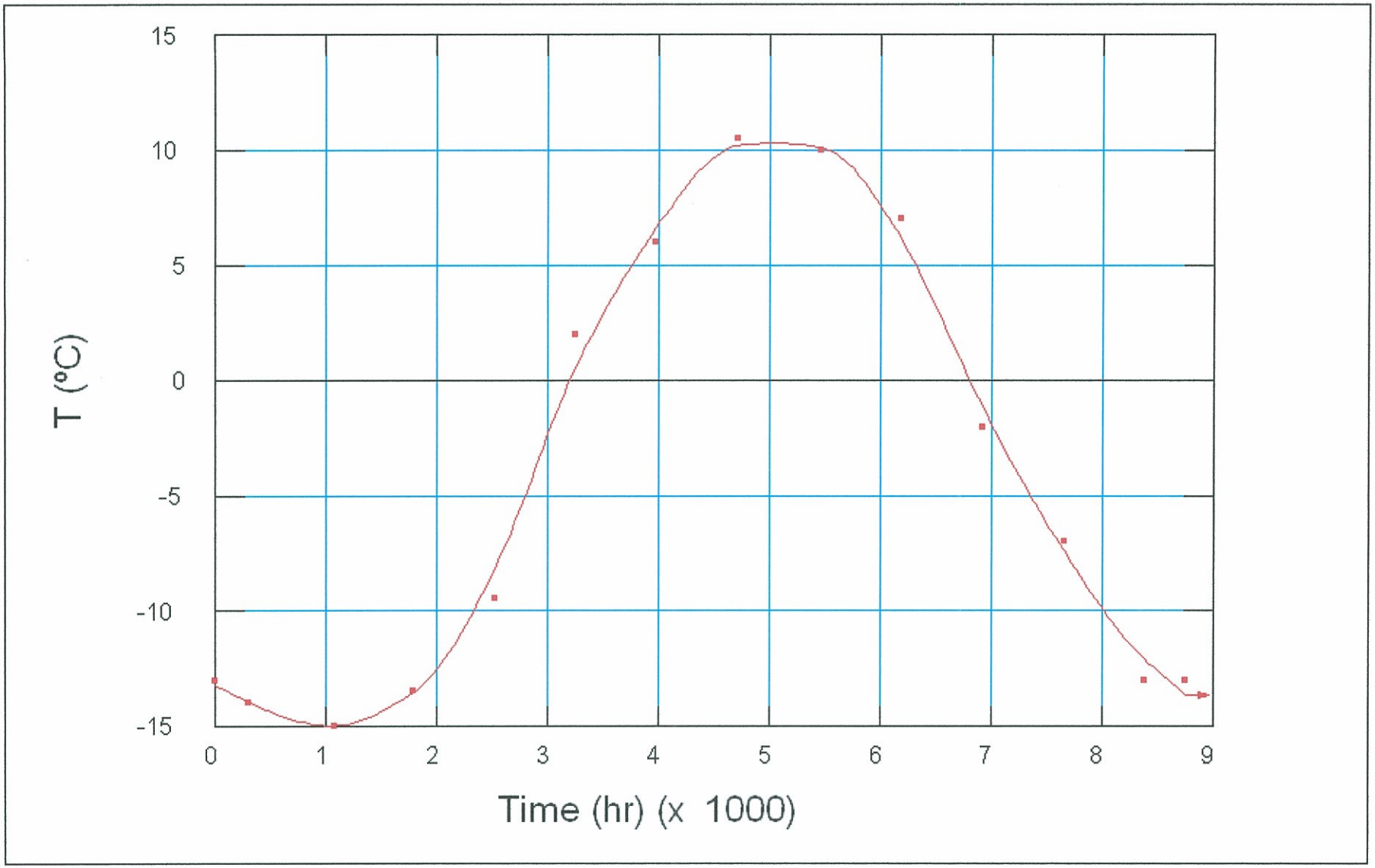
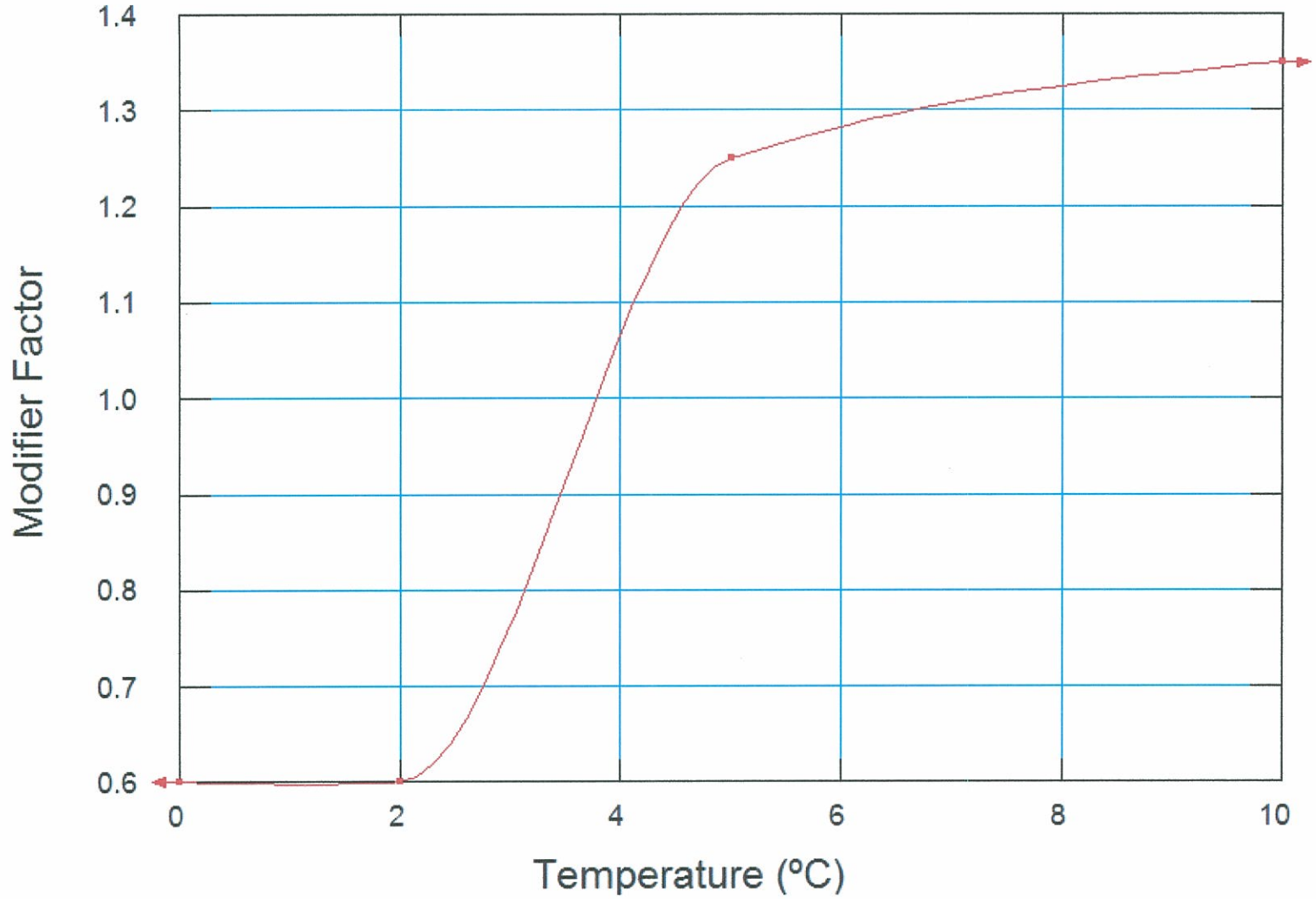


PLOT OF AVERAGE HOURLY
AIR TEMPERATURES FOR NOME, AK

Rock Creek Dam,
Nome, Alaska

C-1

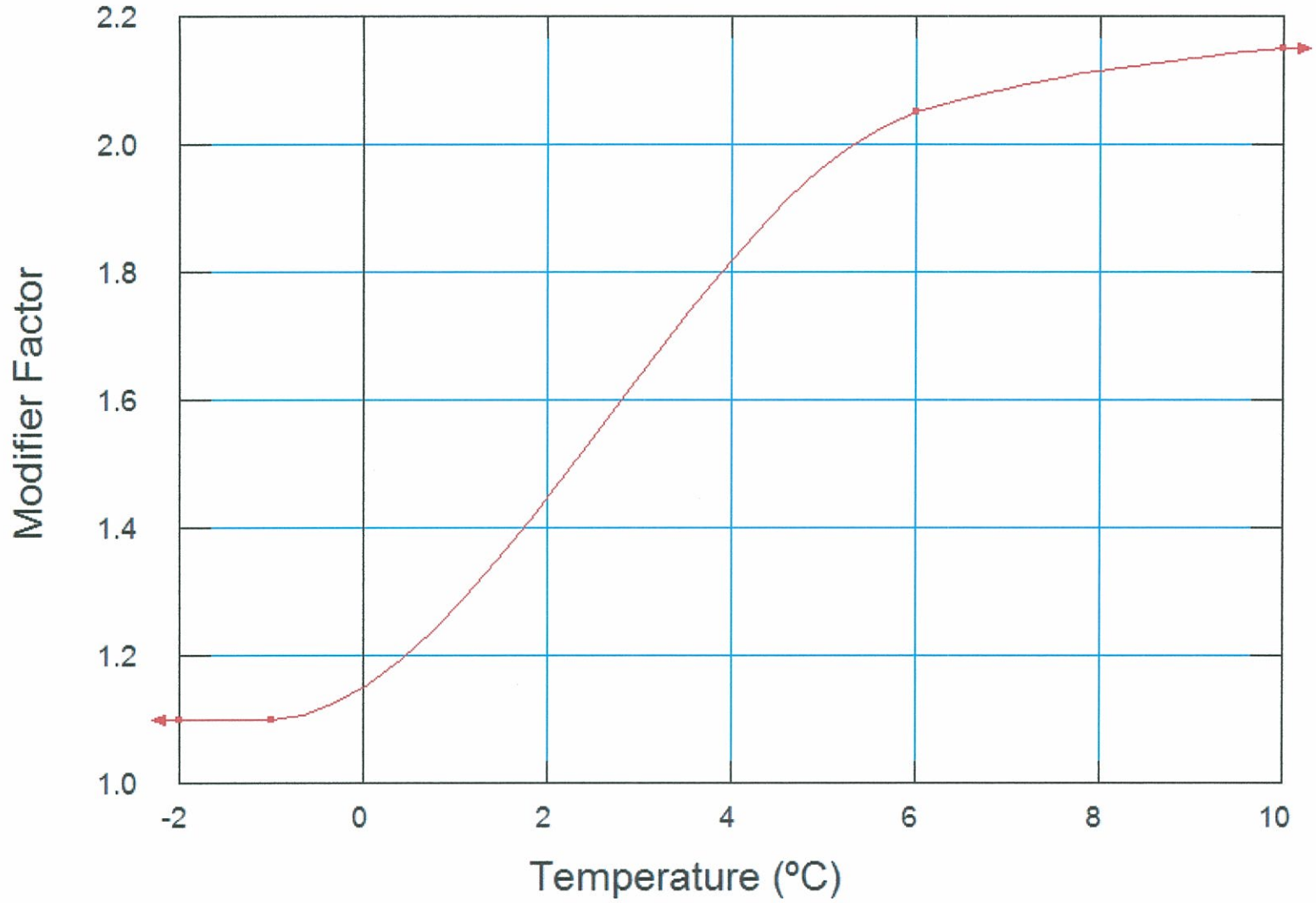


NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

THERMAL MODIFIER FUNCTION
FOR THE NATIVE SOILS

Rock Creek Dam,
Nome, Alaska

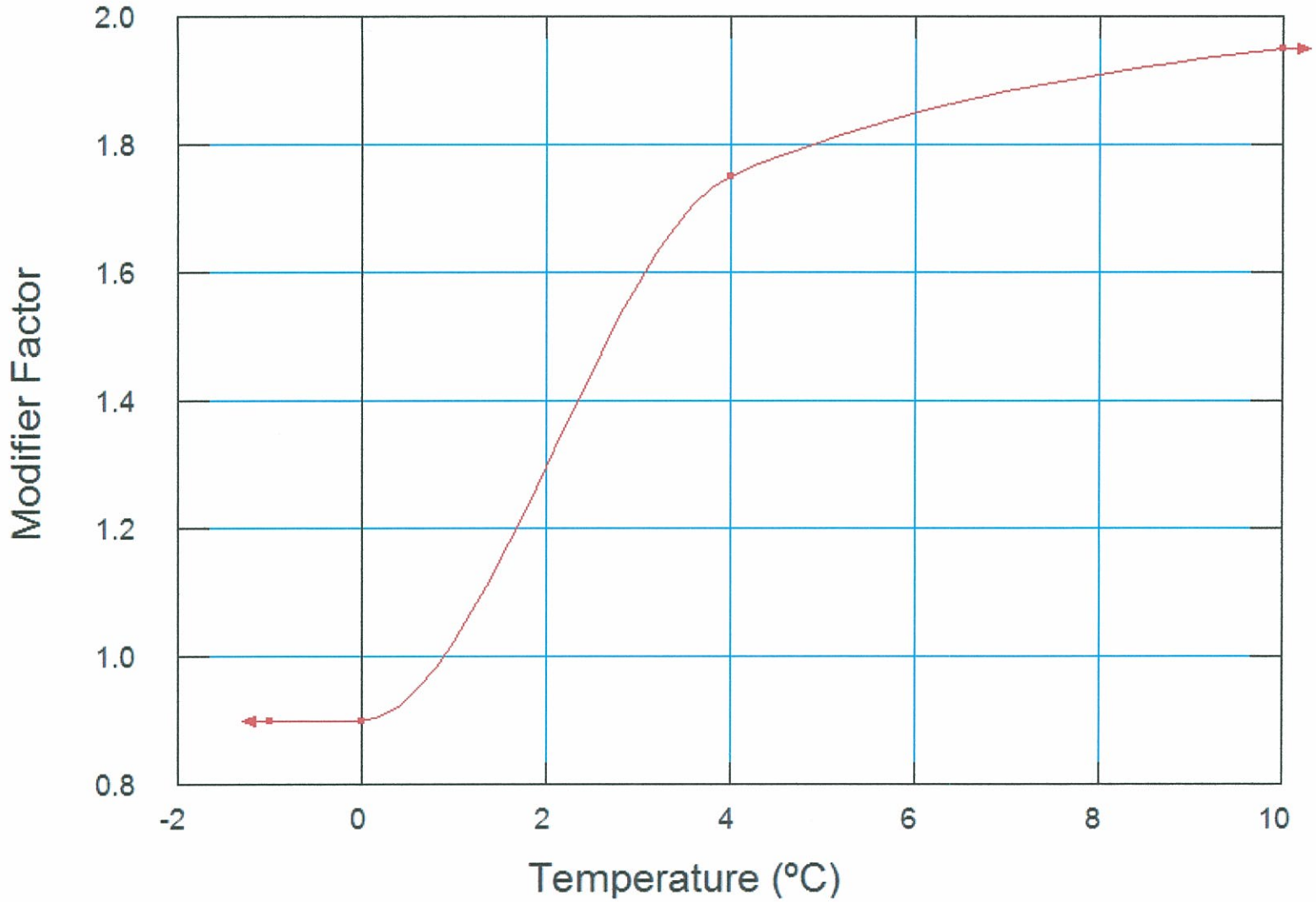
C-2



THERMAL MODIFIER FUNCTION
FOR THE TAILINGS

Rock Creek Dam,
Nome, Alaska

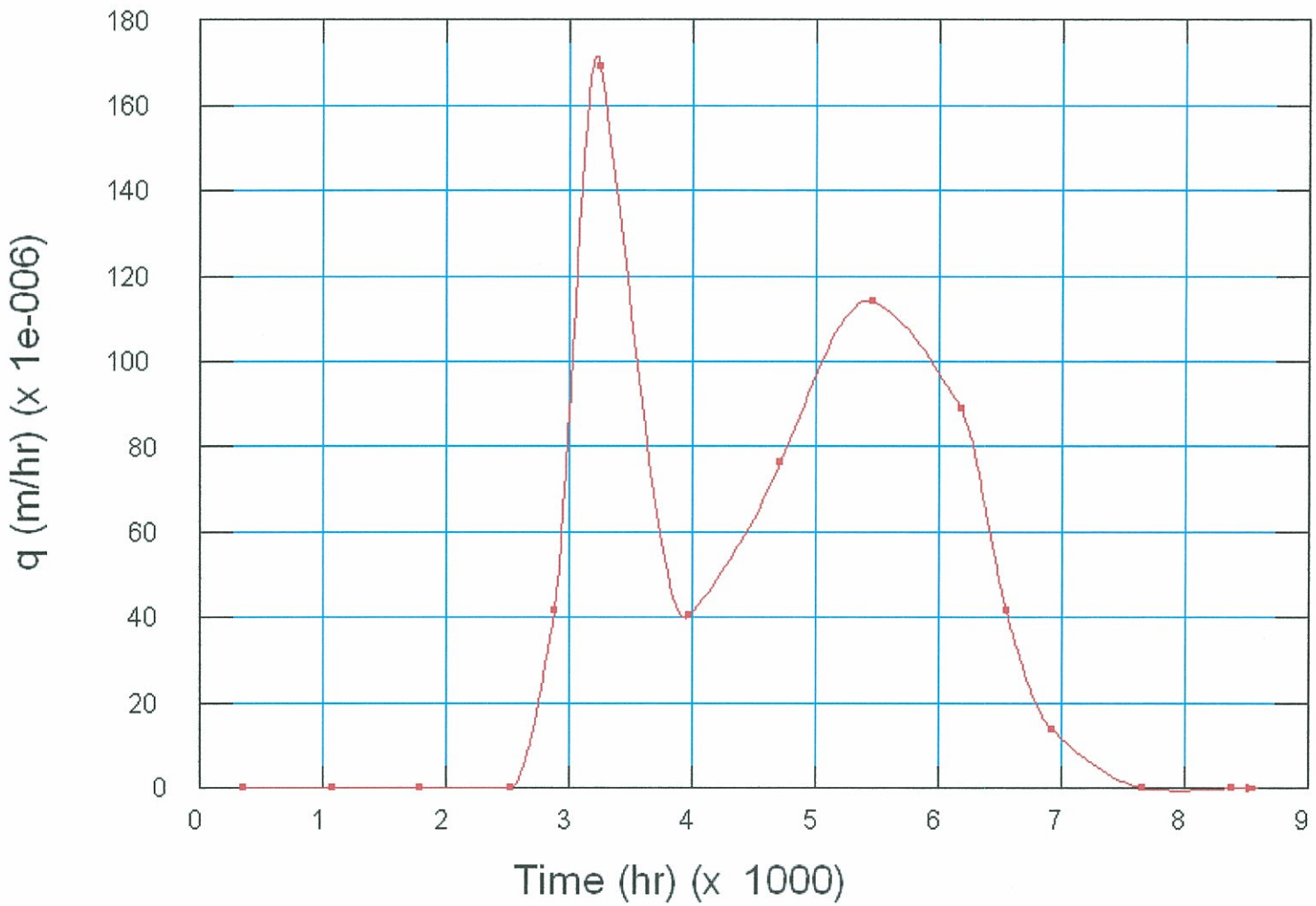
C-3



THERMAL MODIFIER FUNCTION
FOR THE ROCK FILL MATERIAL

Rock Creek Dam,
Nome, Alaska

C-4



PLOT OF AVERAGE HOURLY PRECIPITATION FOR NOME, AK

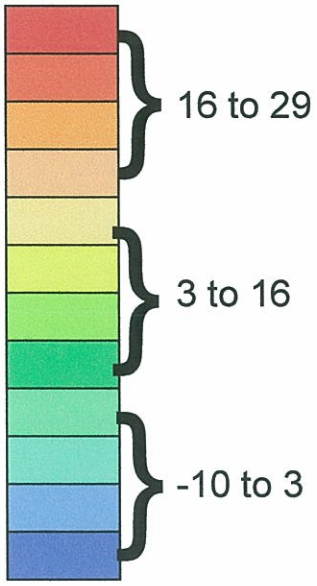
Rock Creek Dam,
Nome, Alaska

C-5

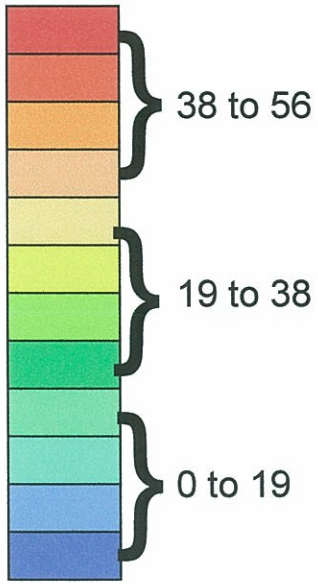
APPENDIX D

PHASE I DAM CONSTRUCTION ANALYSIS RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

= Contour Interval Line

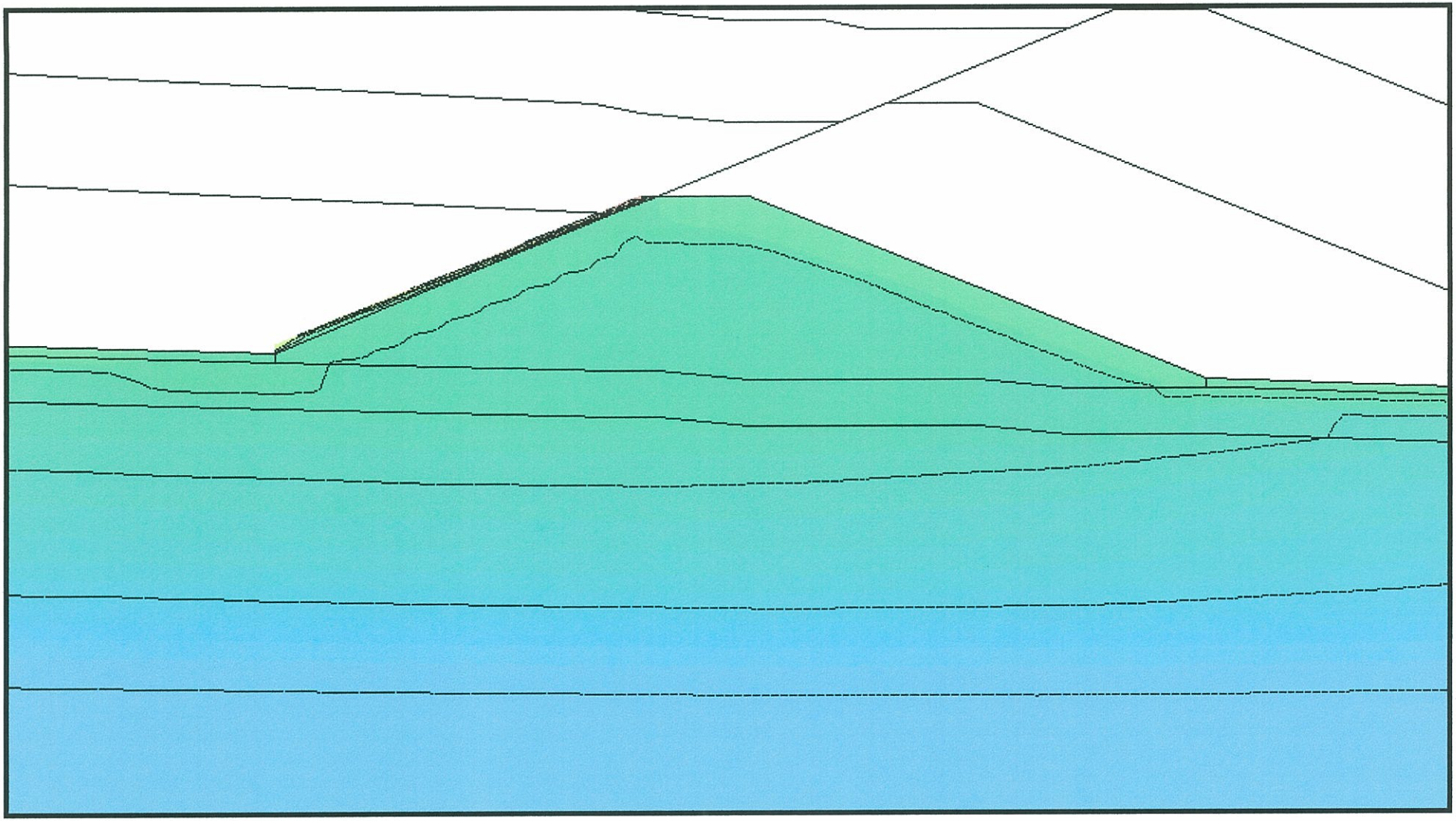
Scenario 1 = Current site conditions w/ no thermosyphons
Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons
Scenario 3 = Current site conditions w/ two thermosyphons and equipped w/ 50m^2 radiators
Scenario 4 = Current site conditions w/ two thermosyphons and equipped w/ 200m2 radiators
Scenario 5 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. No thermosyphons.
Scenario 6 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 50m^2 radiators
Scenario 7 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 200m^2 radiators

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

APPENDIX D KEY

Rock Creek Dam,
Nome, Alaska

D-0



Scale 1:1

0 20 40

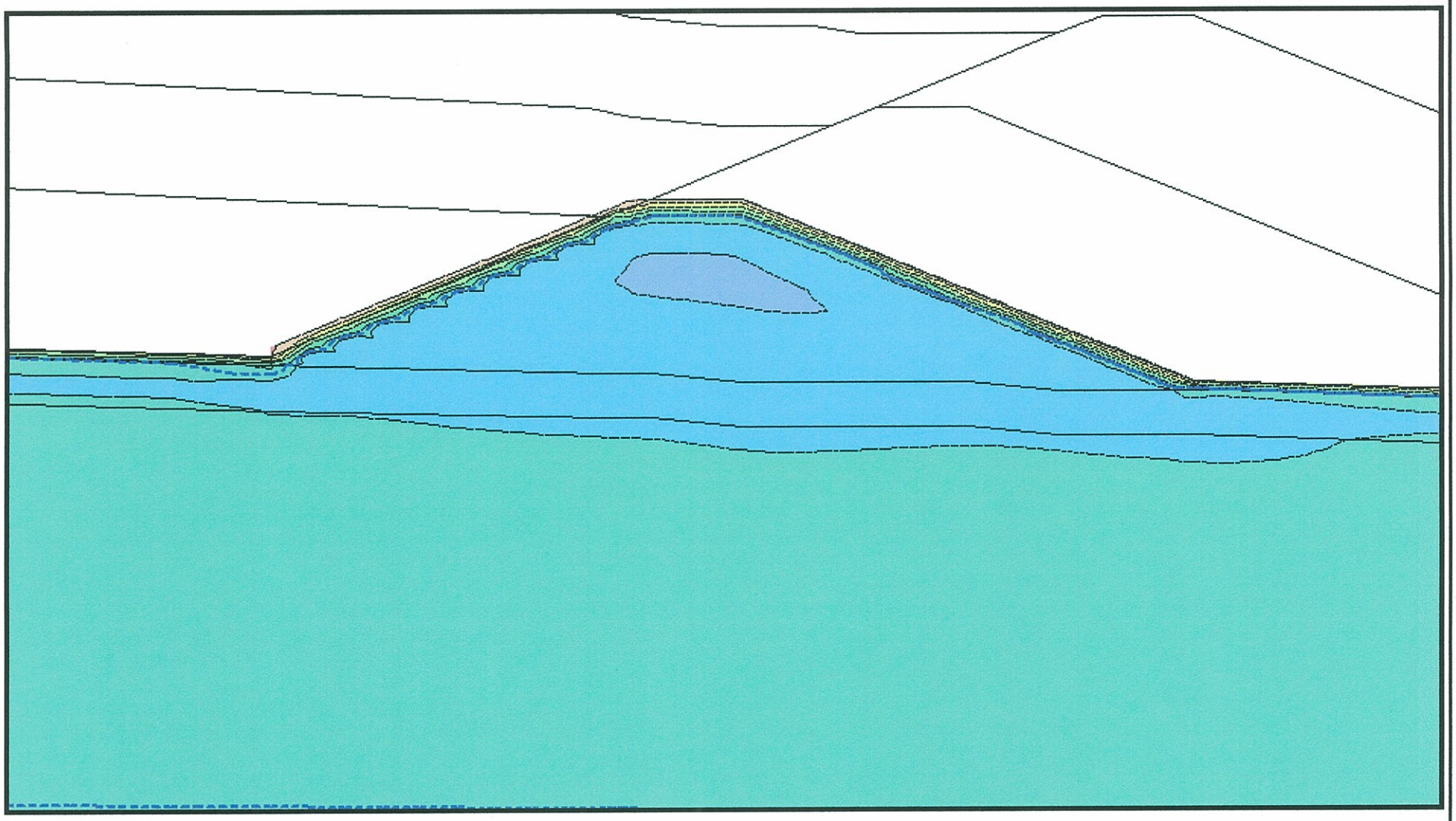
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic head Contour Map
Scenario 1 – Phase 1 – AUG 01

Rock Creek Dam,
Nome, Alaska

D-1h



Scale 1:1

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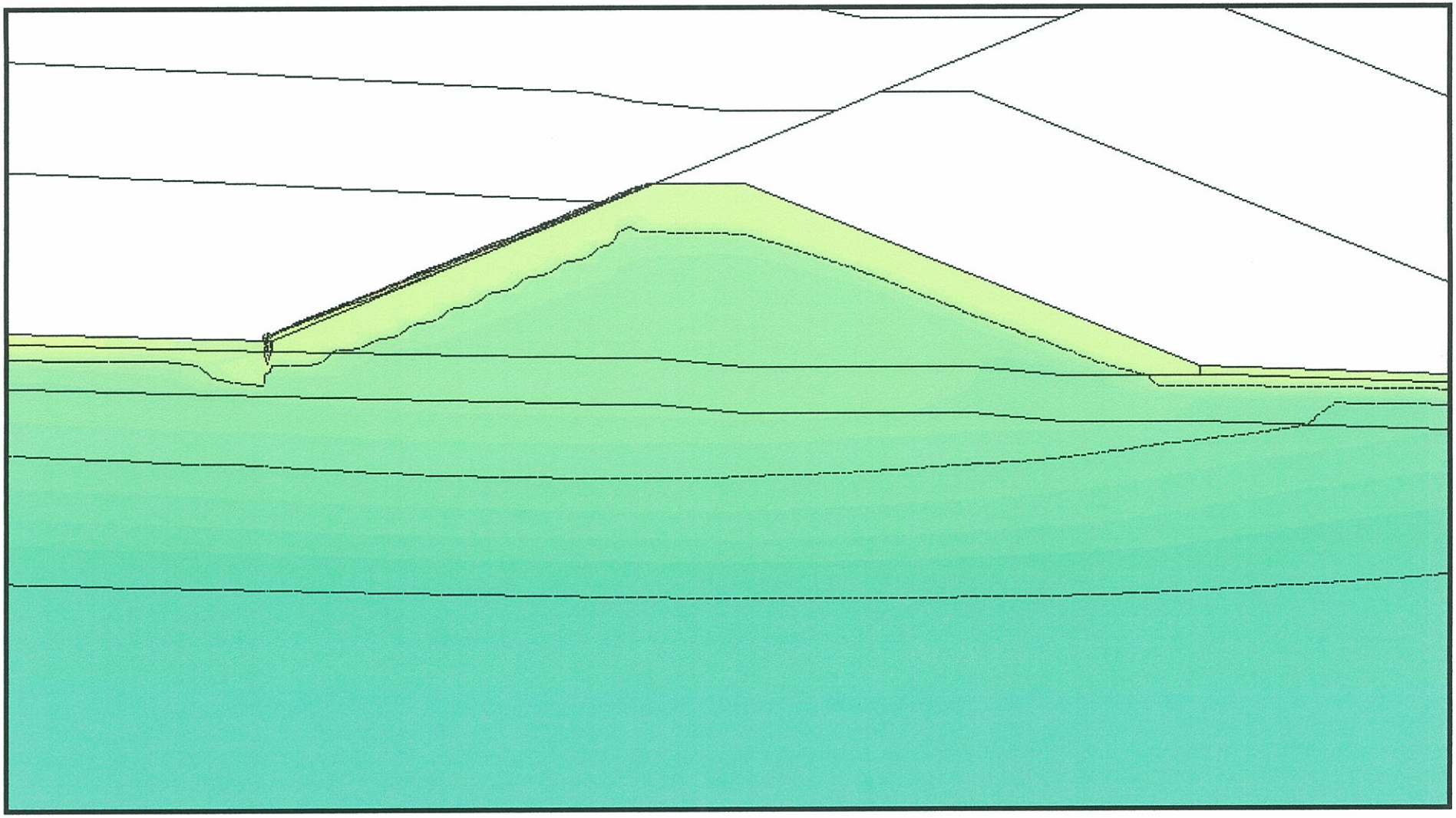
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 1 – Phase 1 – AUG 01

Rock Creek Dam,
Nome, Alaska

D-1t



Scale 1:1

0 20 40

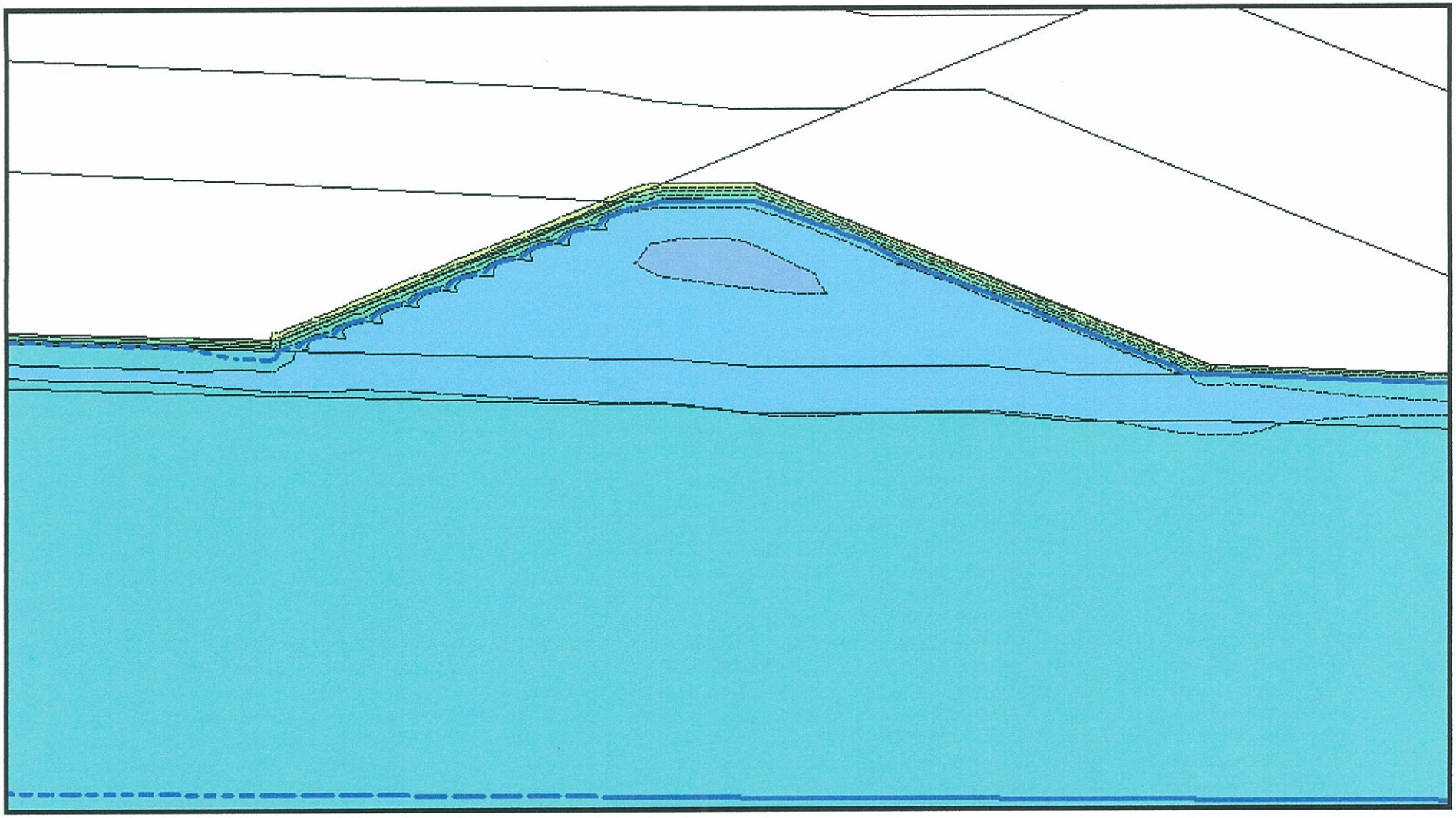
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Hydraulic head Contour Map
Scenario 2 – Phase 1 – AUG 01

Rock Creek Dam,
Nome, Alaska

D-2h



Scale 1:1

0 20 40

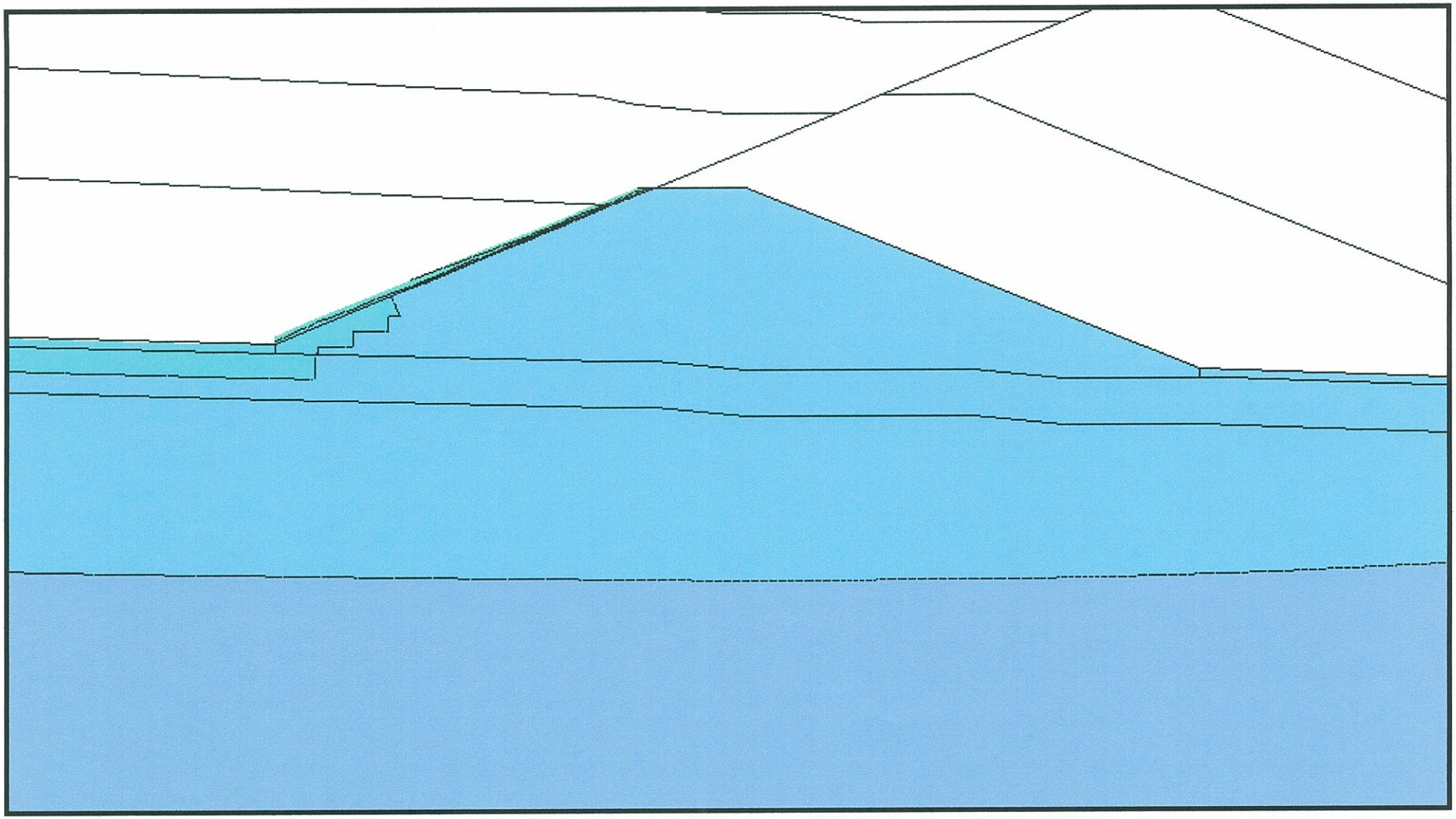
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 1 – AUG 01

Rock Creek Dam,
Nome, Alaska

D-2t



Scale 1:1

0 20 40

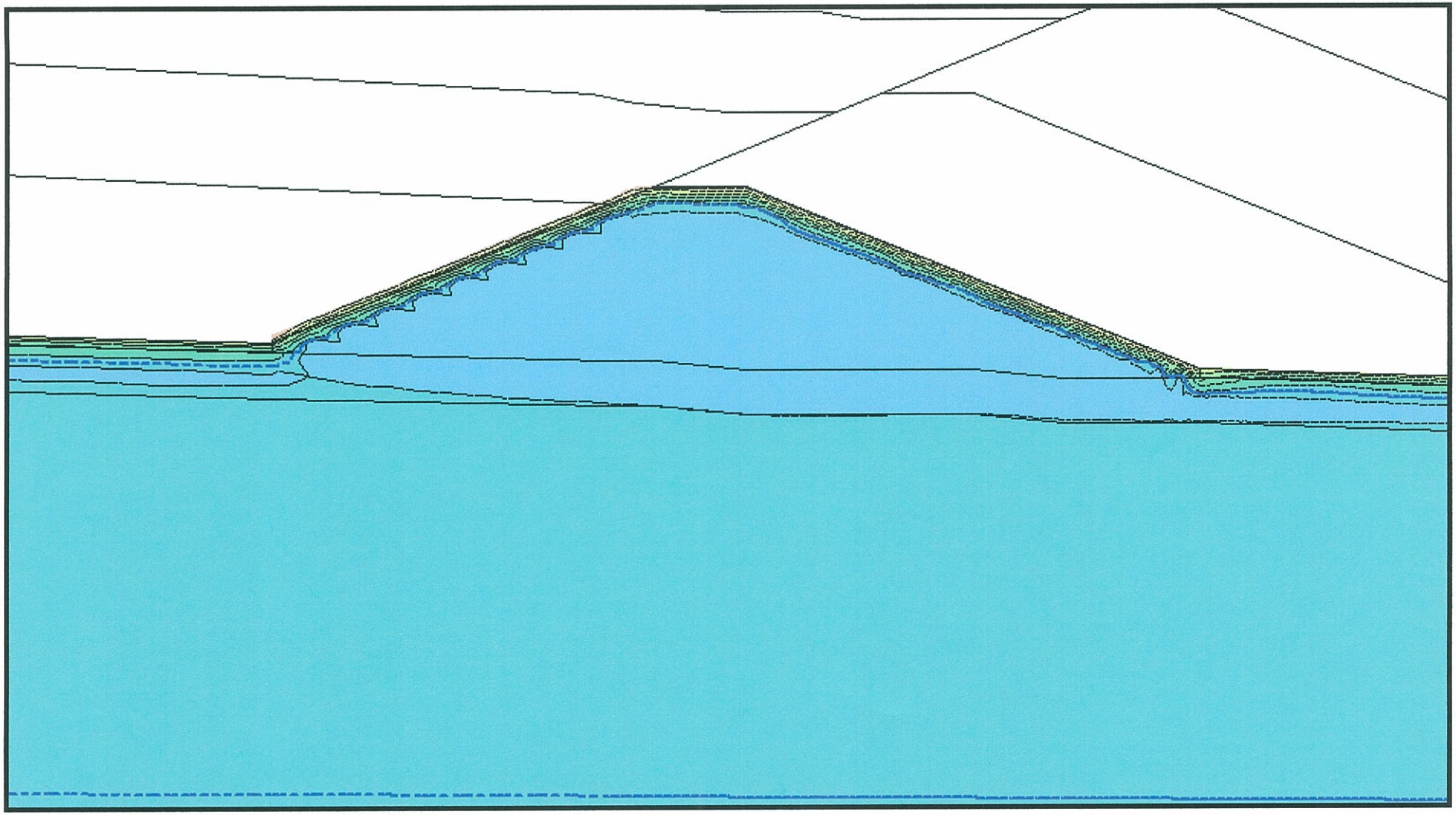
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic head Contour Map
Scenario 5 – Phase 1 – AUG 01

Rock Creek Dam,
Nome, Alaska

D-5h



Scale 1:1

0 20 40

Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 5 – Phase 1 – AUG 01

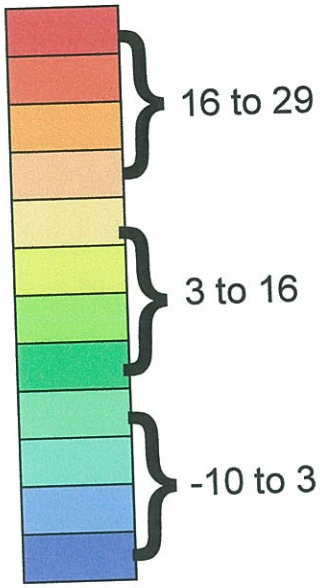
Rock Creek Dam,
Nome, Alaska

D-5t

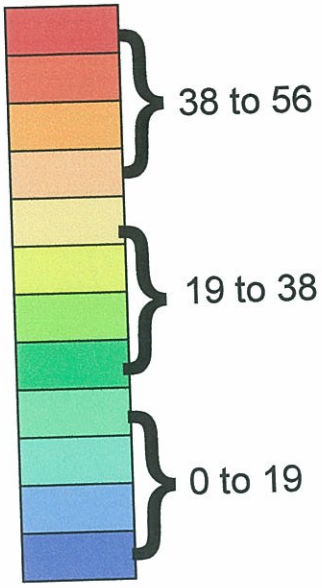
APPENDIX E

PHASE I TAILS ANALYSIS RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

= Contour Interval Line

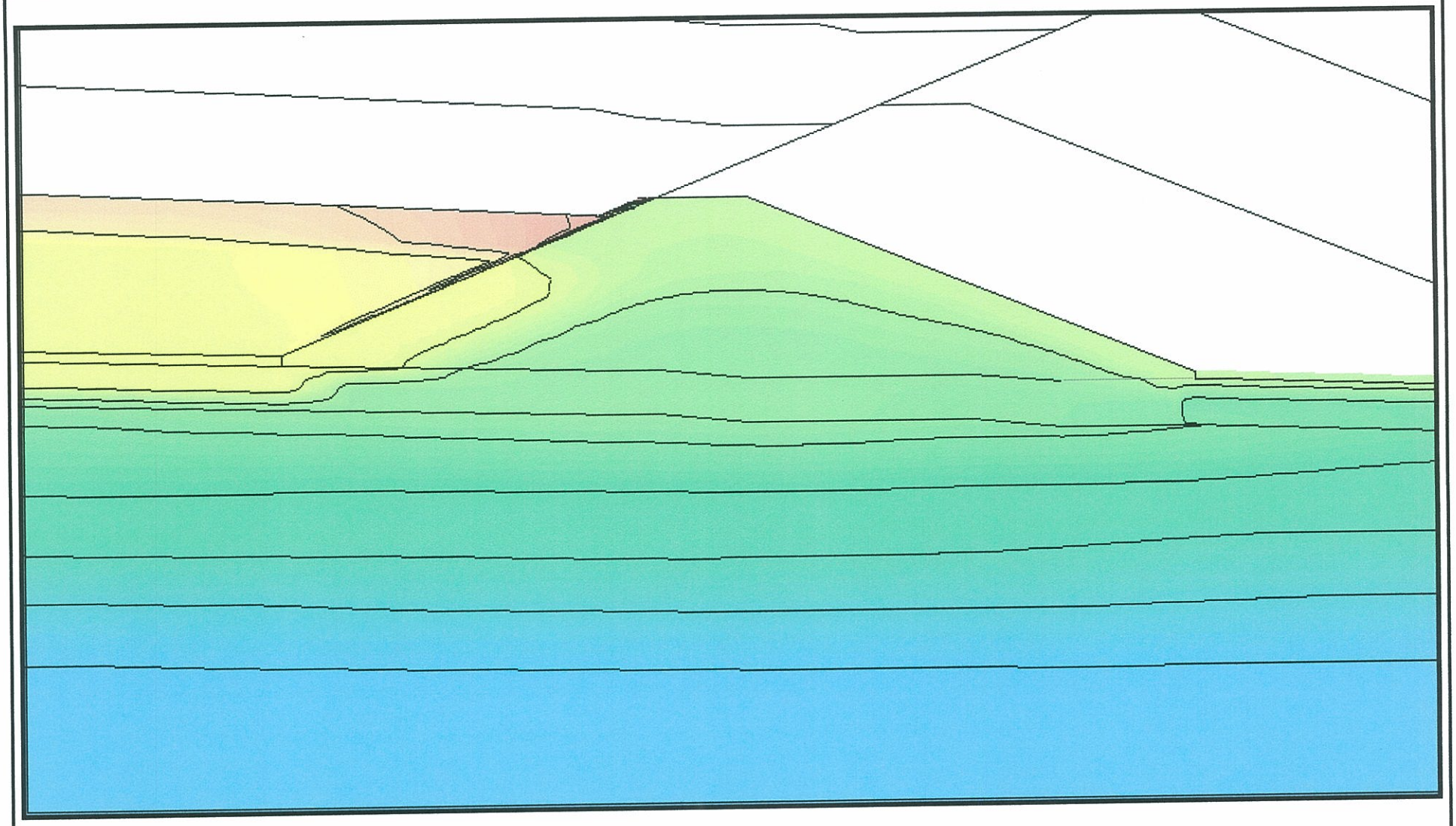
Scenario 1 = Current site conditions w/ no thermosyphons
Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons
Scenario 3 = Current site conditions w/ two thermosyphons and equipped w/ 50m^2 radiators
Scenario 4 = Current site conditions w/ two thermosyphons and equipped w/ 200m2 radiators
Scenario 5 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. No thermosyphons.
Scenario 6 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 50m^2 radiators
Scenario 7 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 200m^2 radiators

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

APPENDIX E KEY

Rock Creek Dam,
Nome, Alaska

E-0



Scale 1:1

0 20 40

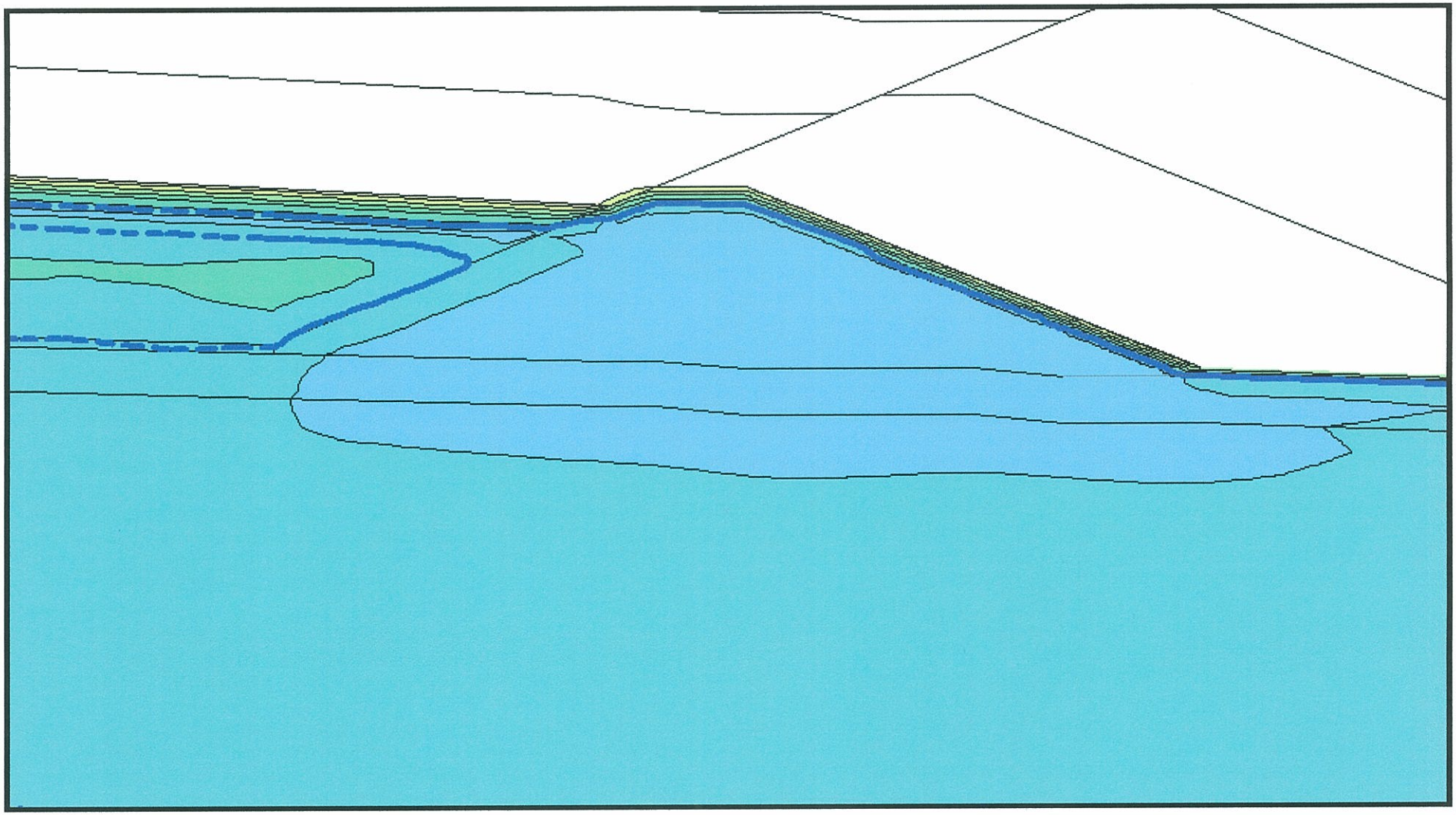
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 1 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-1h



Scale 1:1

0 20 40

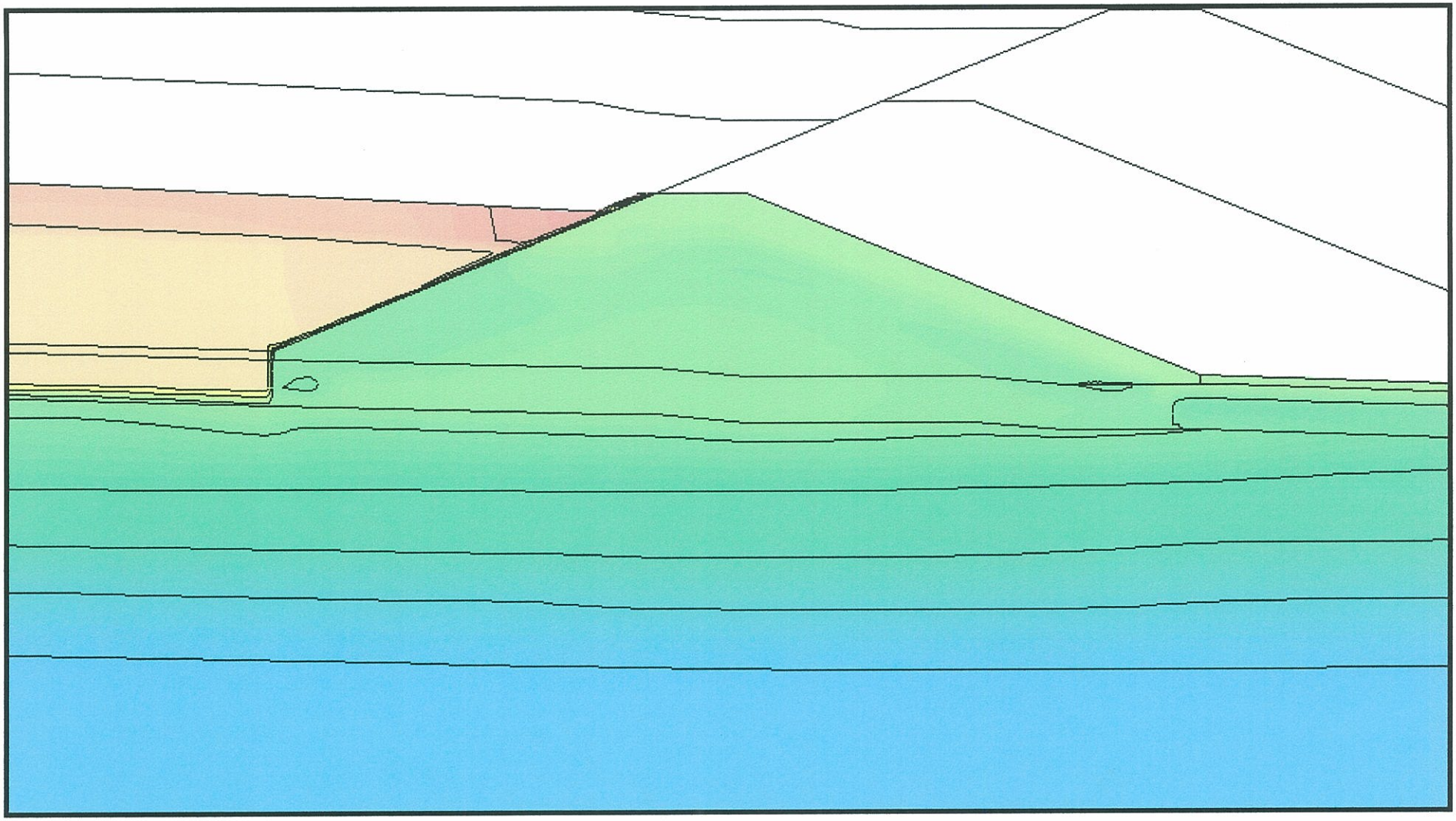
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 1 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-1t



Scale 1:1

0 20 40

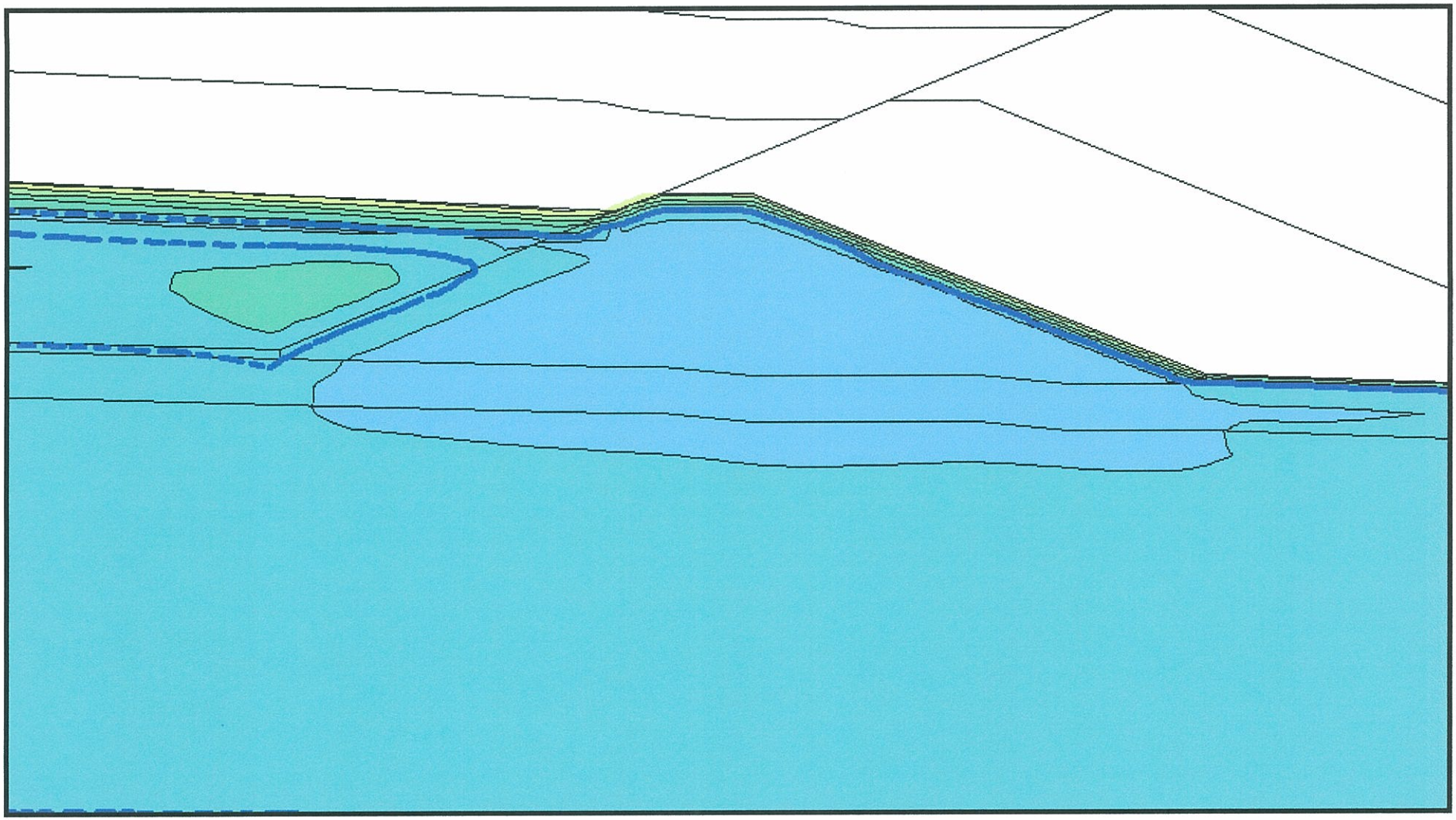
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-2h



Scale 1:1

0 20 40

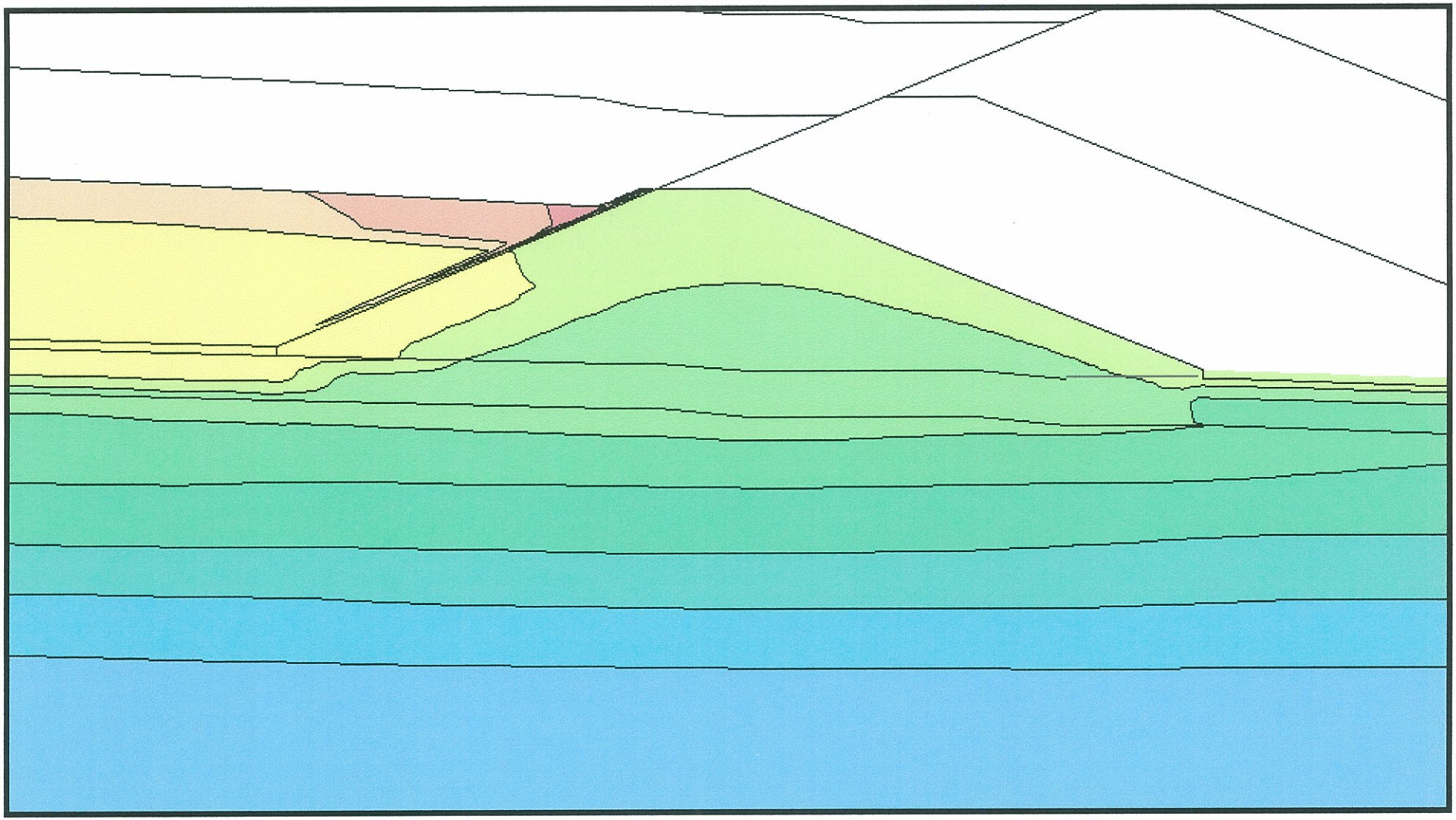
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-2t



Scale 1:1

0 20 40

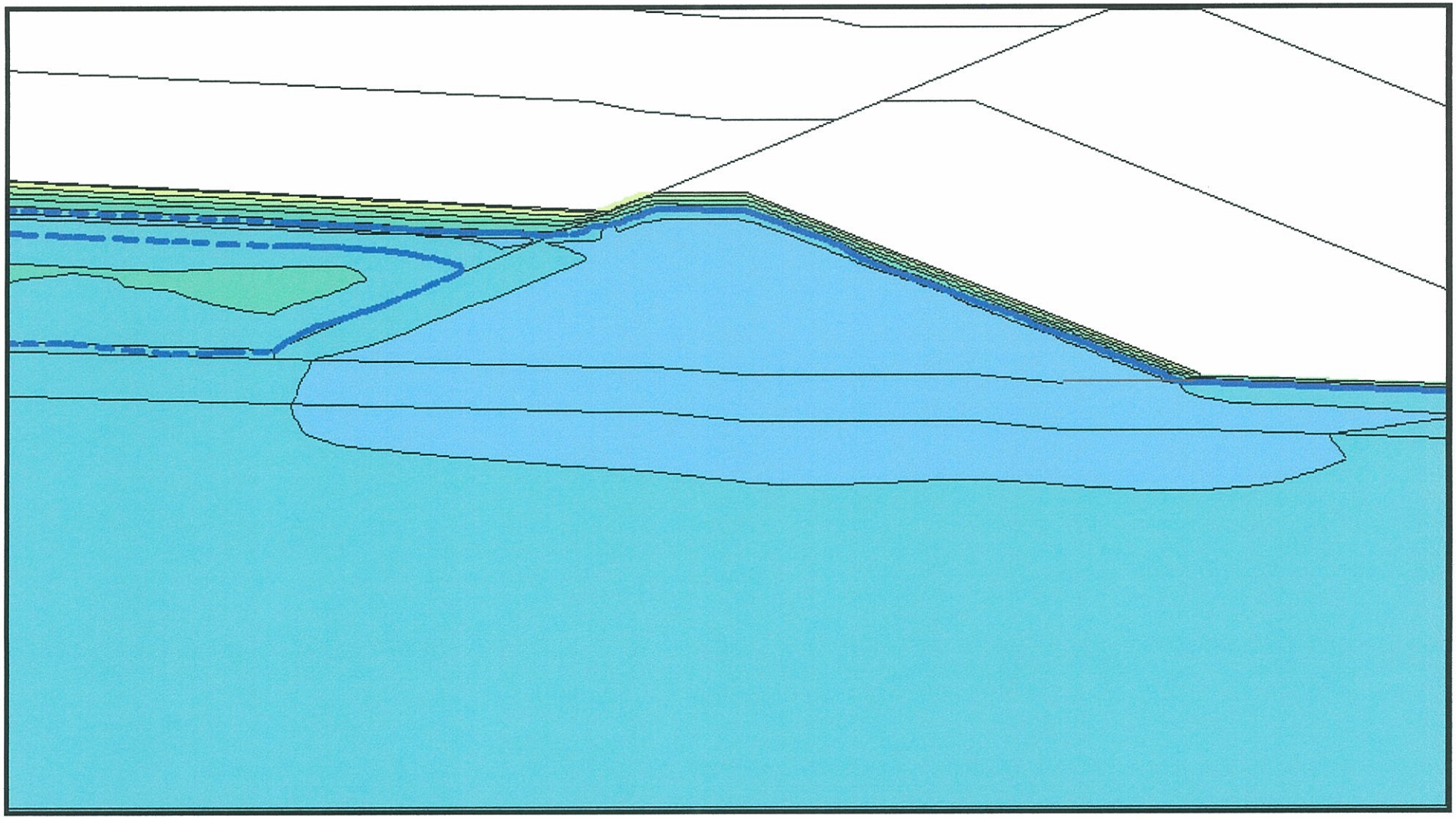
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 3 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-3h



Scale 1:1

0 20 40

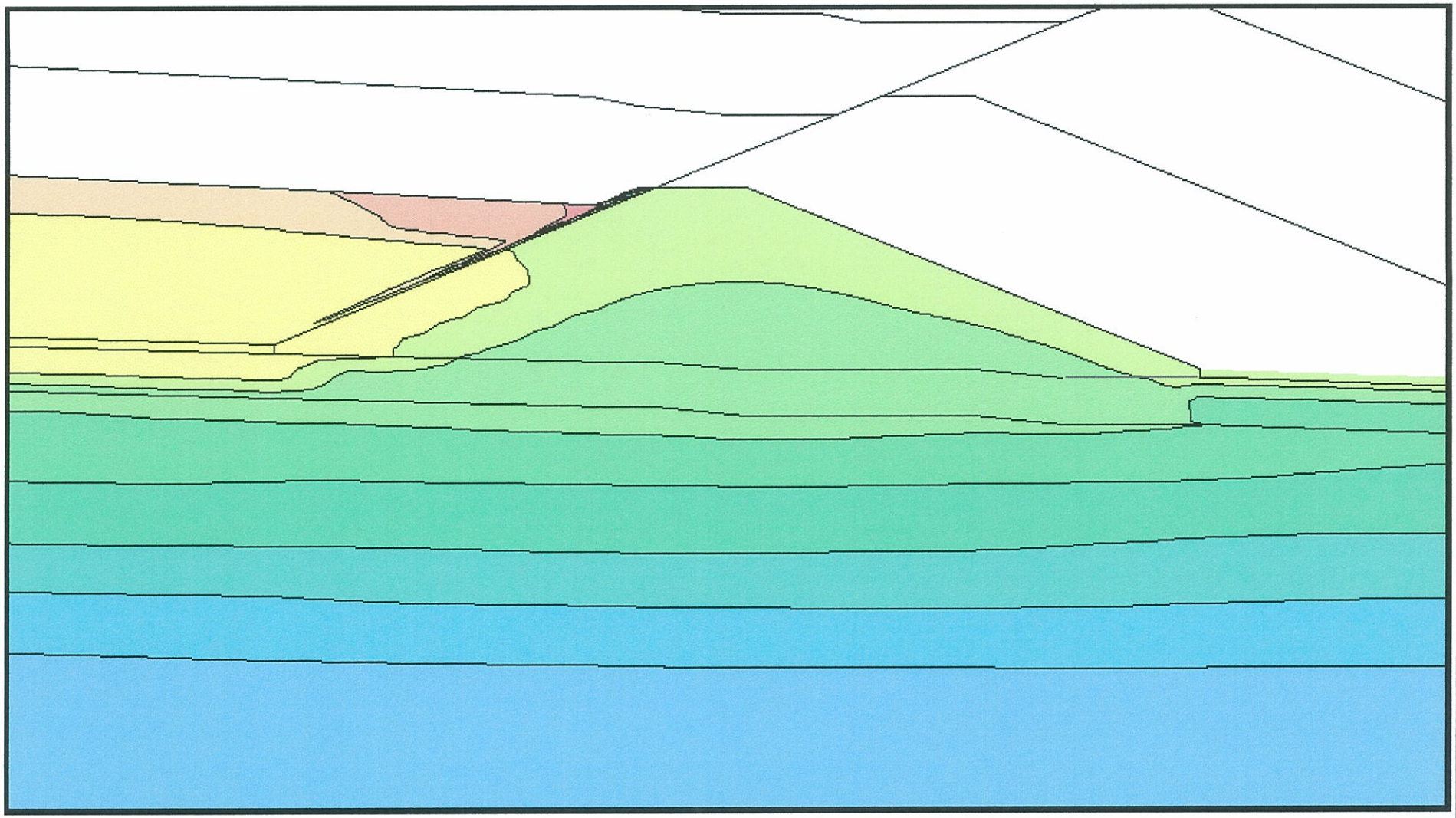
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 3 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-3t



Scale 1:1

0 20 40

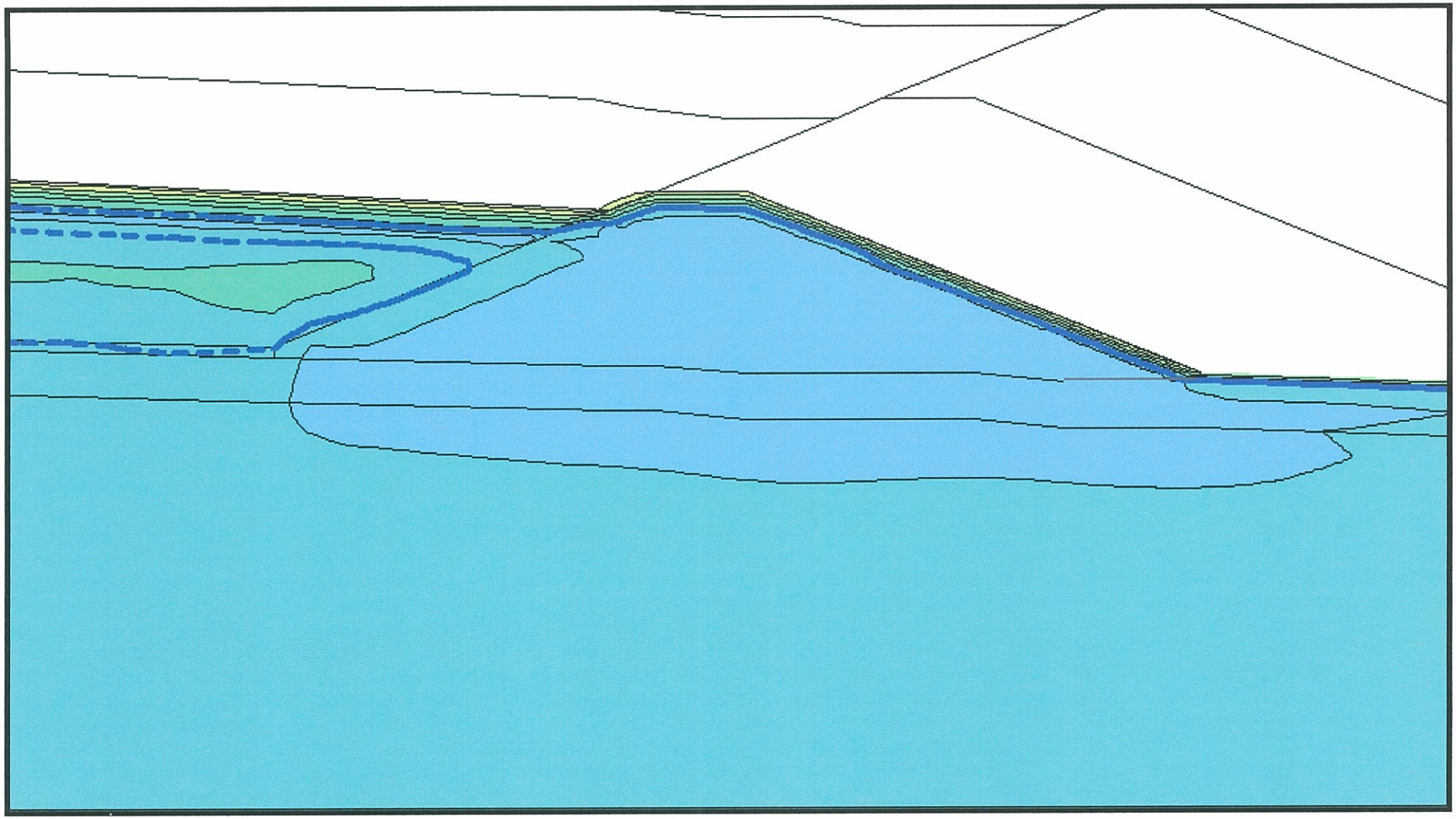
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 4 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-4h



Scale 1:1

0 20 40

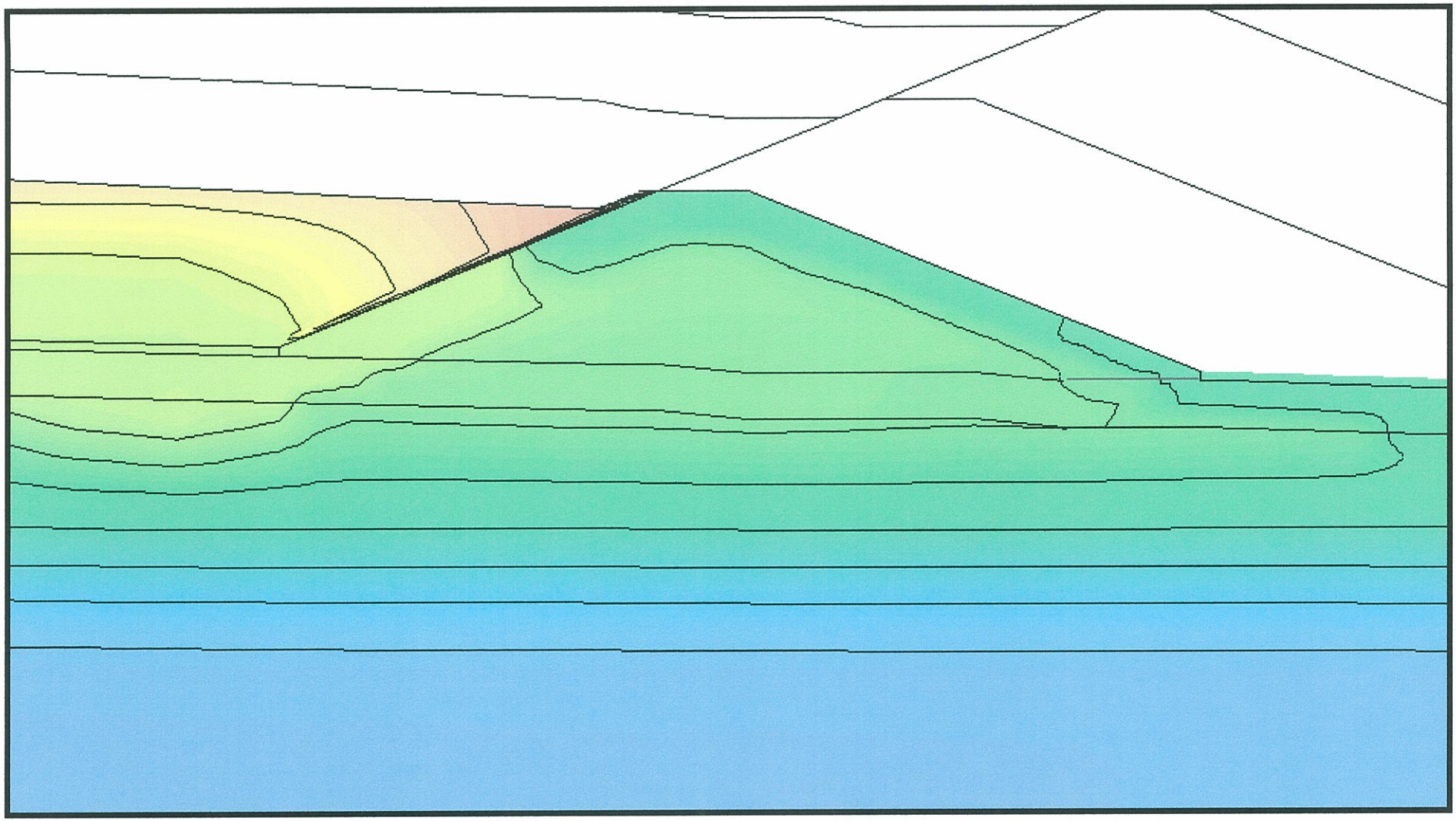
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 4 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-4t



Scale 1:1

0 20 40

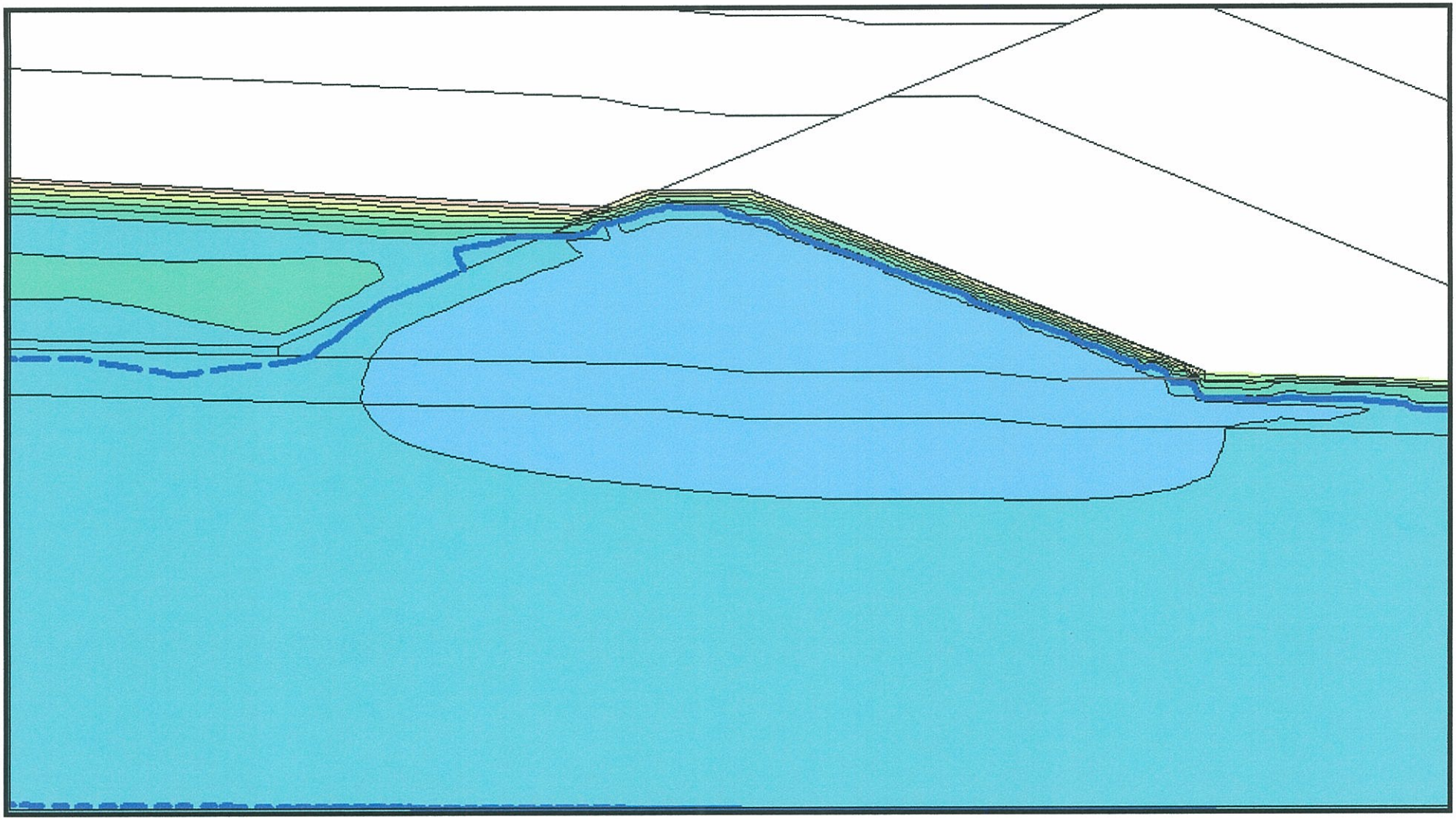
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 5 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-5h



Scale 1:1

0 20 40

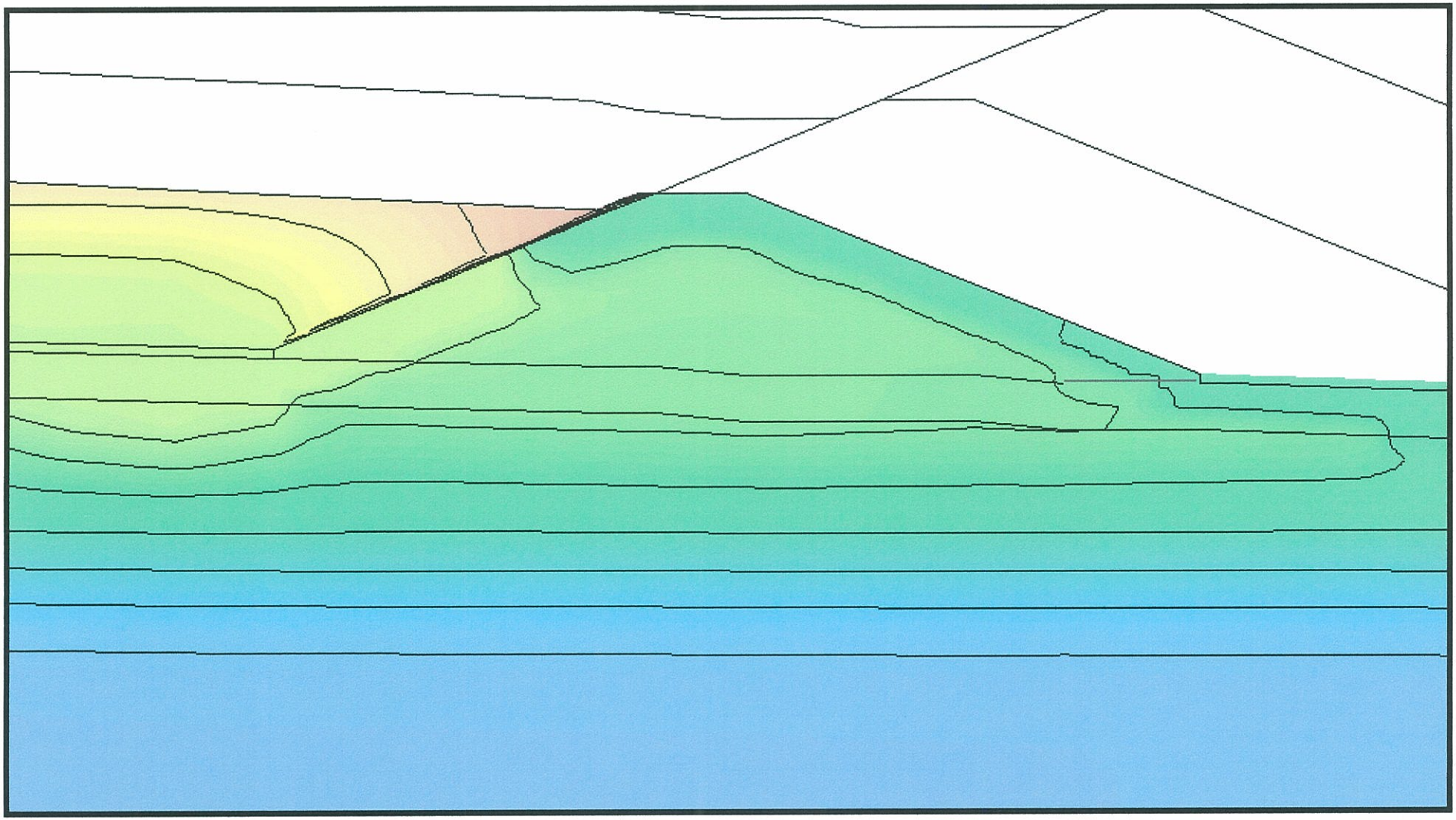
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 5 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-5t



Scale 1:1

0 20 40

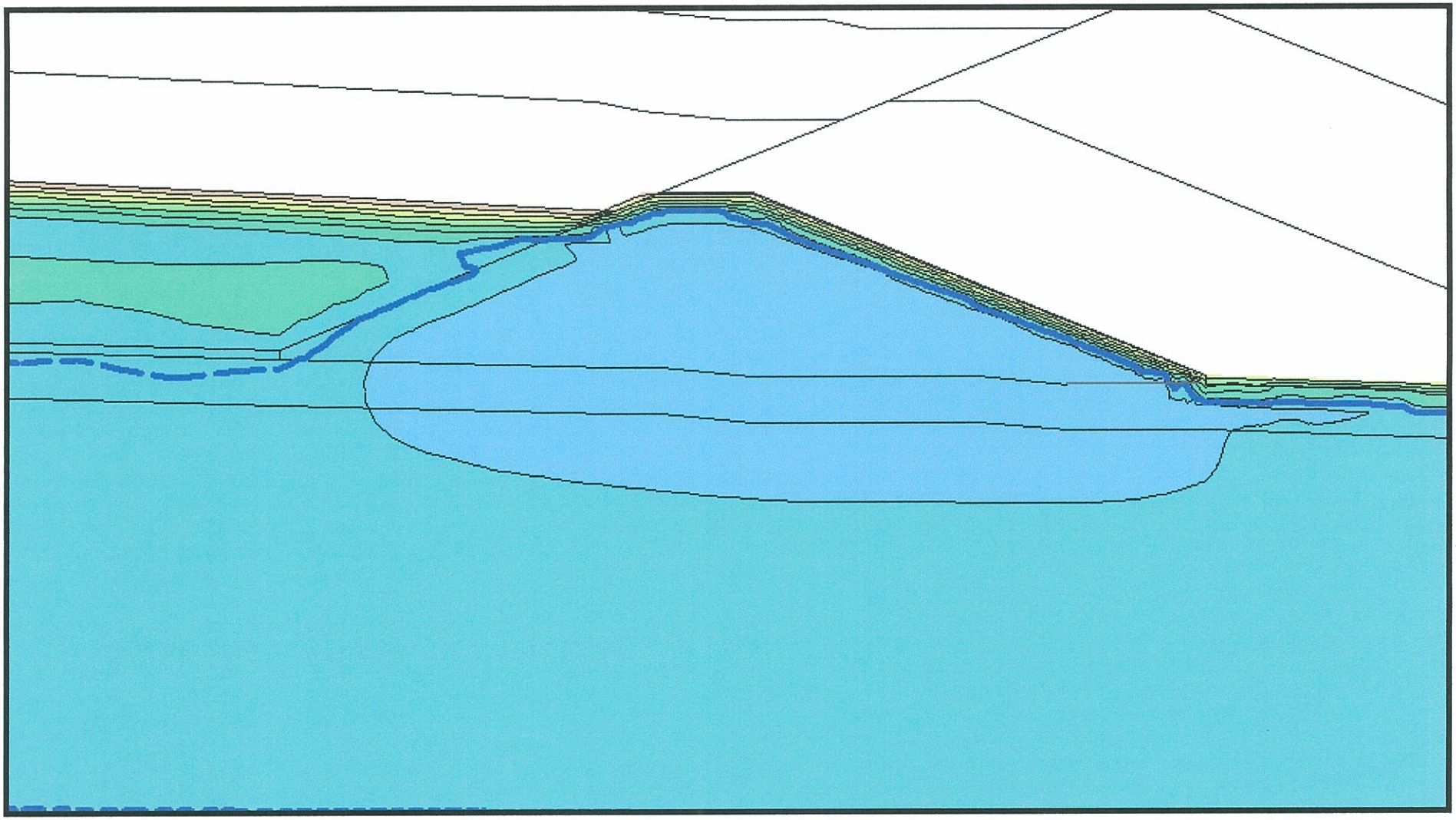
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 6 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-6h



Scale 1:1

0 20 40

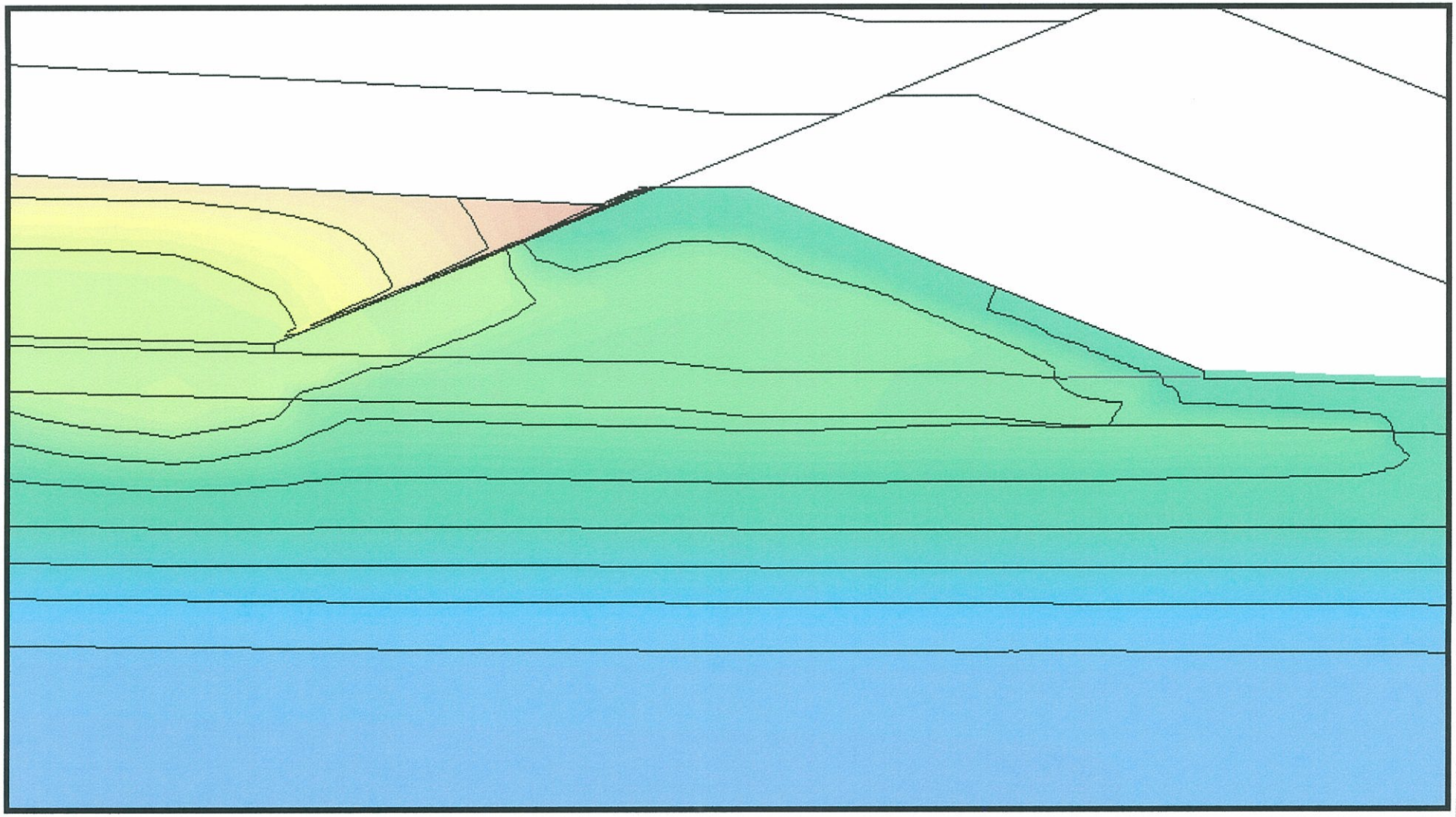
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 6 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-6t



Scale 1:1

0 20 40

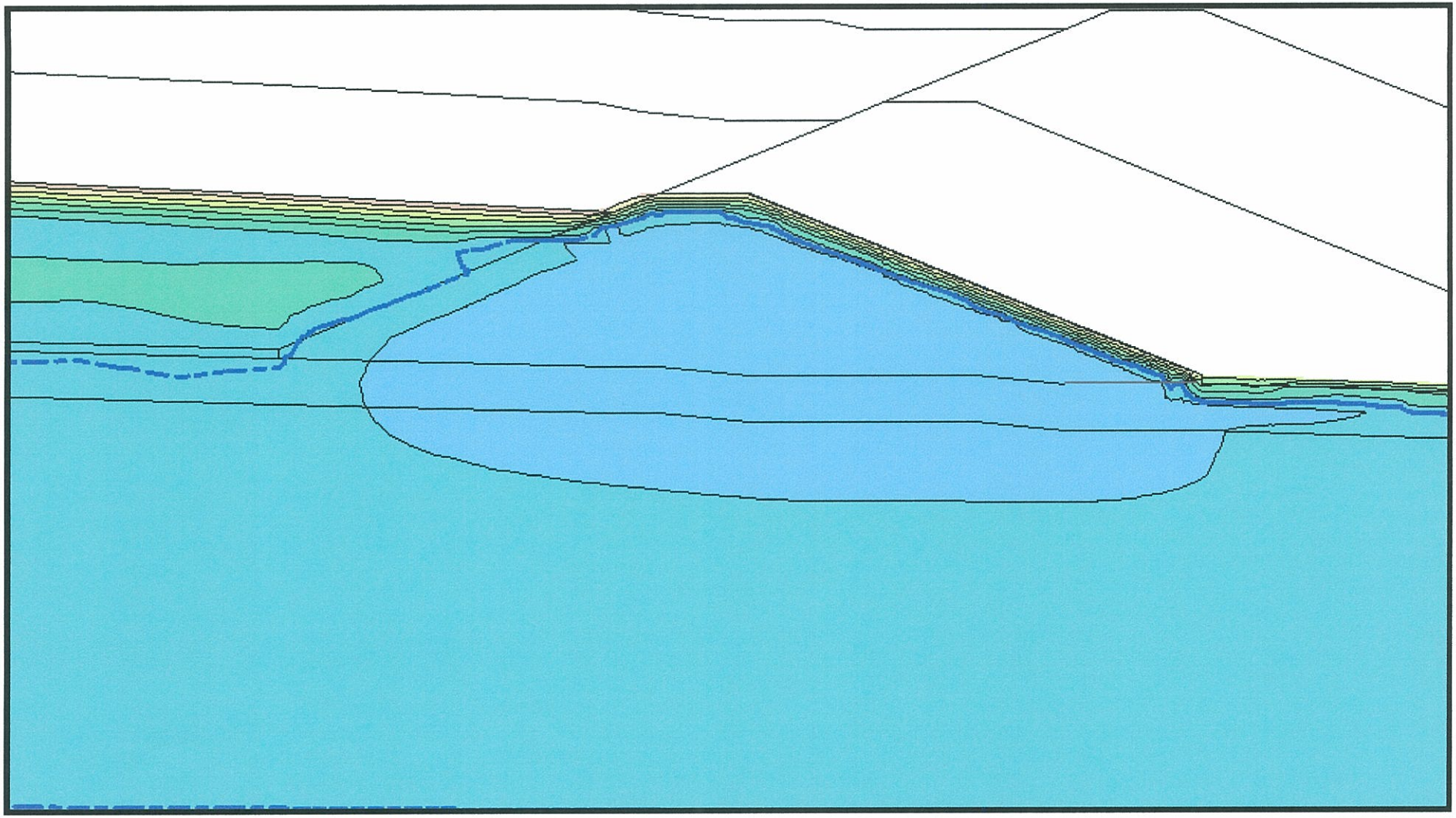
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 7 – Phase 1 – AUG 02

Rock Creek Dam,
Nome, Alaska

E-7h



Scale 1:1

0 20 40

Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 7 – Phase 1 – AUG 02

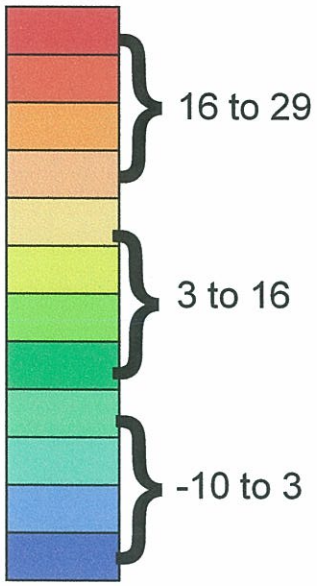
Rock Creek Dam,
Nome, Alaska

E-7t

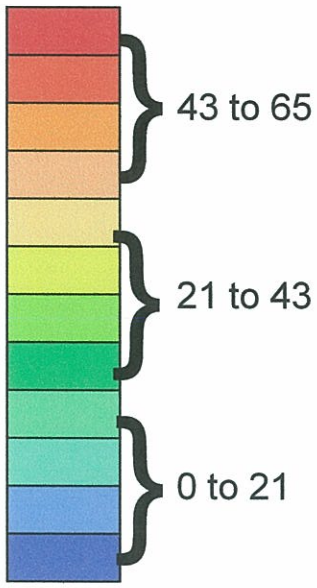
APPENDIX F

PHASE II ANALYSIS RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

= Contour Interval Line

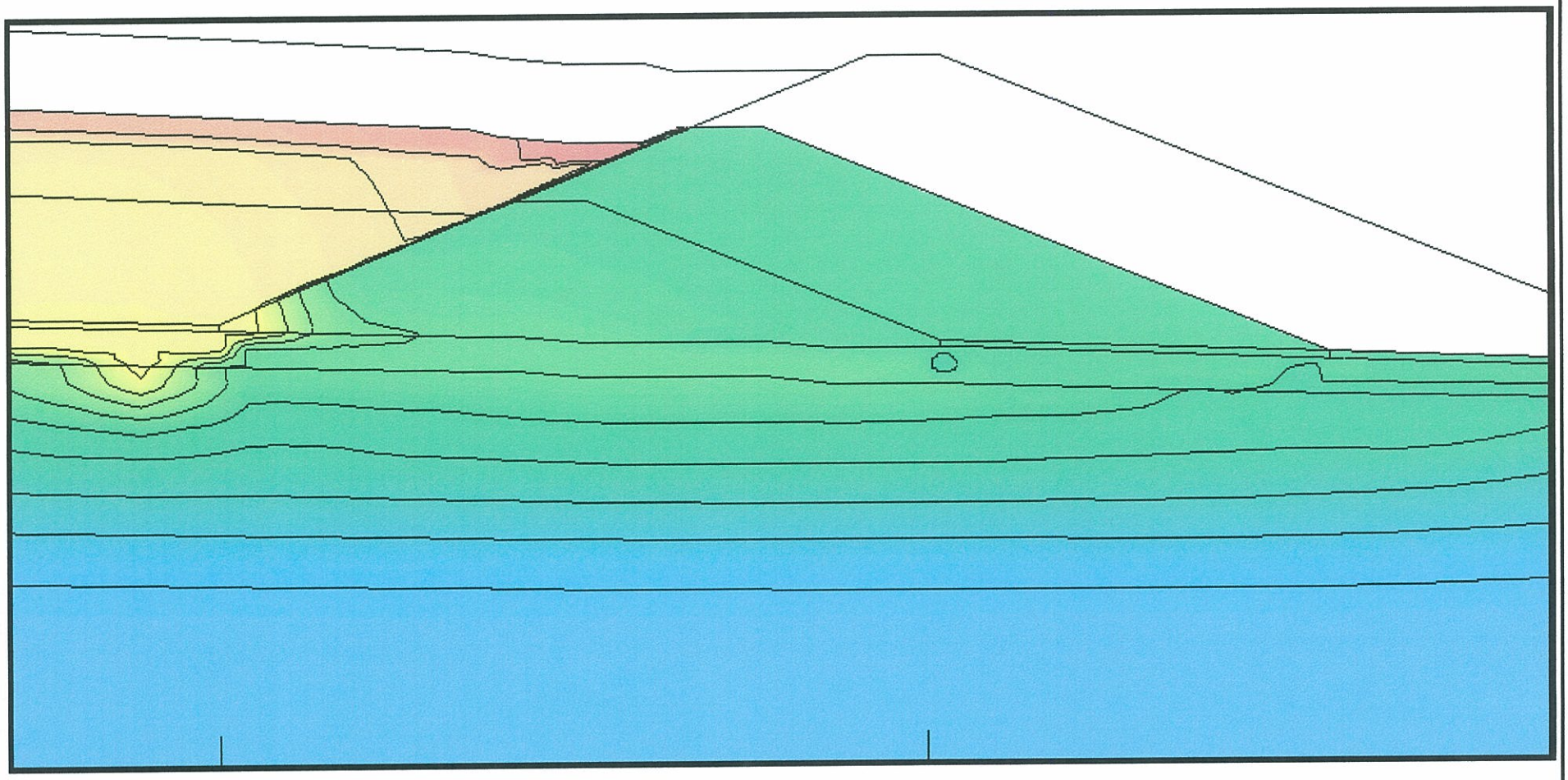
Scenario 1 = Current site conditions w/ no thermosyphons
Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons
Scenario 3 = Current site conditions w/ two thermosyphons and equipped w/ 50m^2 radiators
Scenario 4 = Current site conditions w/ two thermosyphons and equipped w/ 200m2 radiators
Scenario 5 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. No thermosyphons.
Scenario 6 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 50m^2 radiators
Scenario 7 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 200m^2 radiators

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

APPENDIX F KEY

Rock Creek Dam,
Nome, Alaska

F-0



Scale 1:1

0 20 40

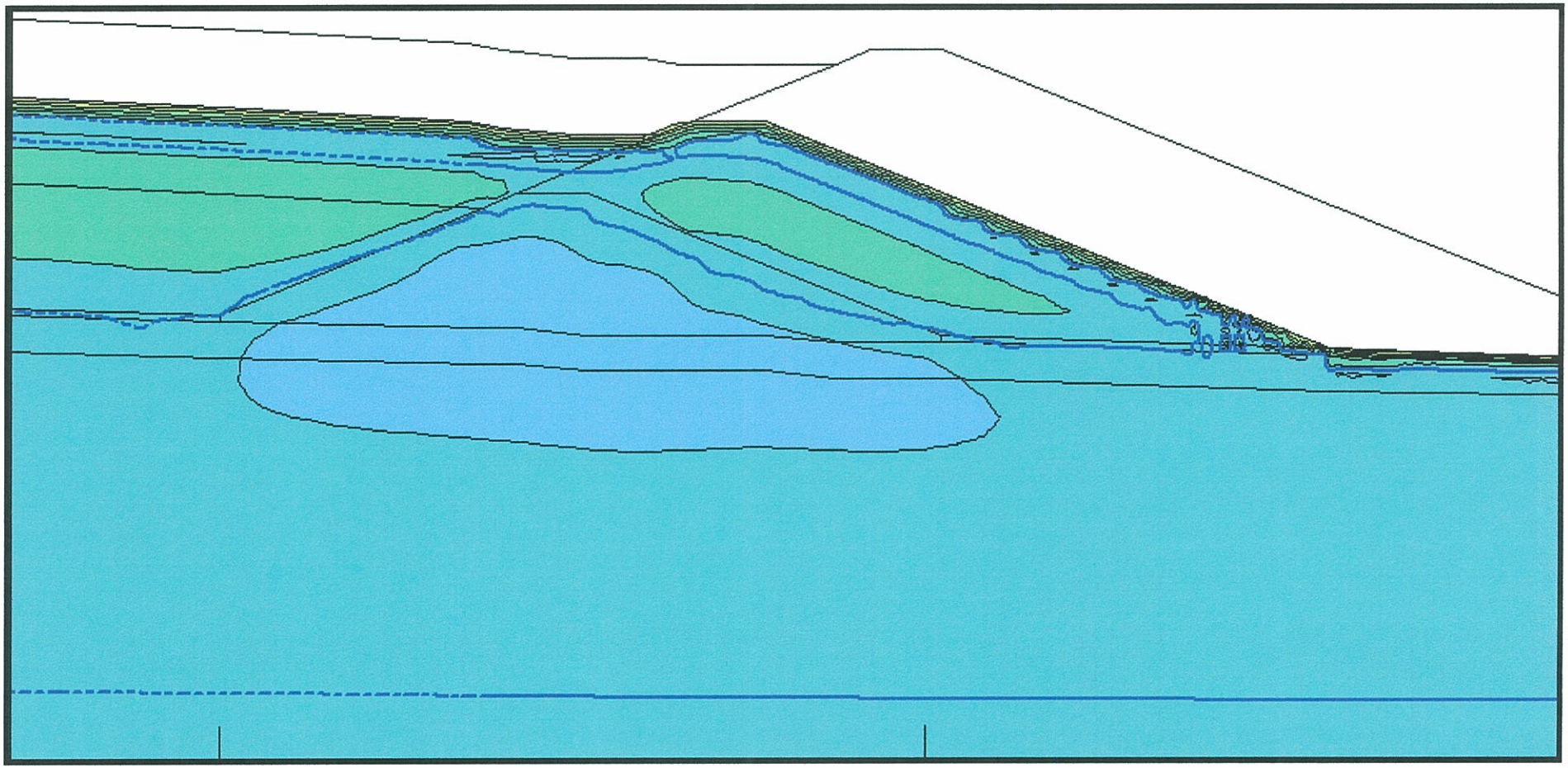
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 1 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-1h



Scale 1:1

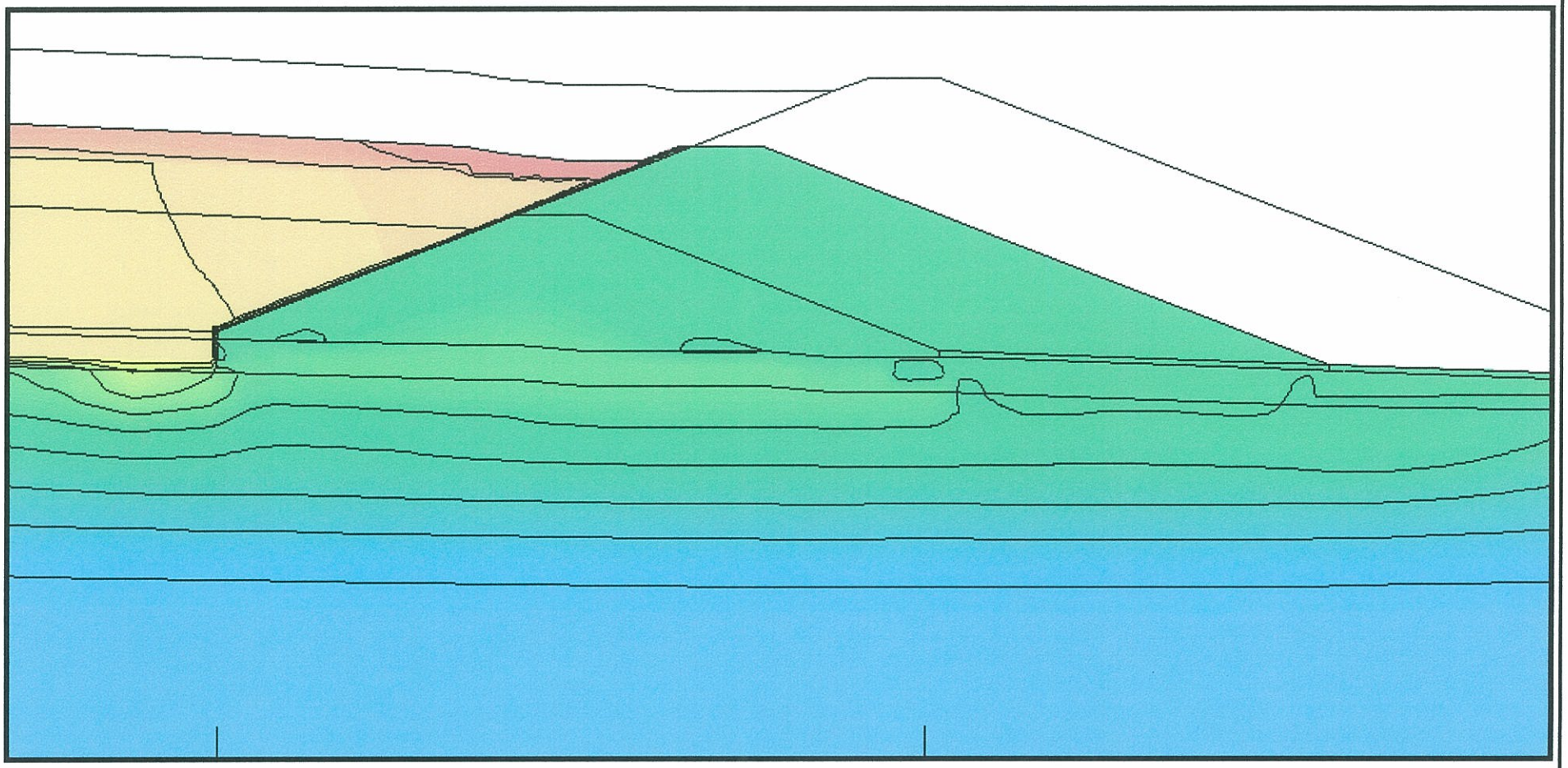
0 20 40

Meters

Thermal Contour Map
Scenario 1 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-1t



Scale 1:1

0 20 40

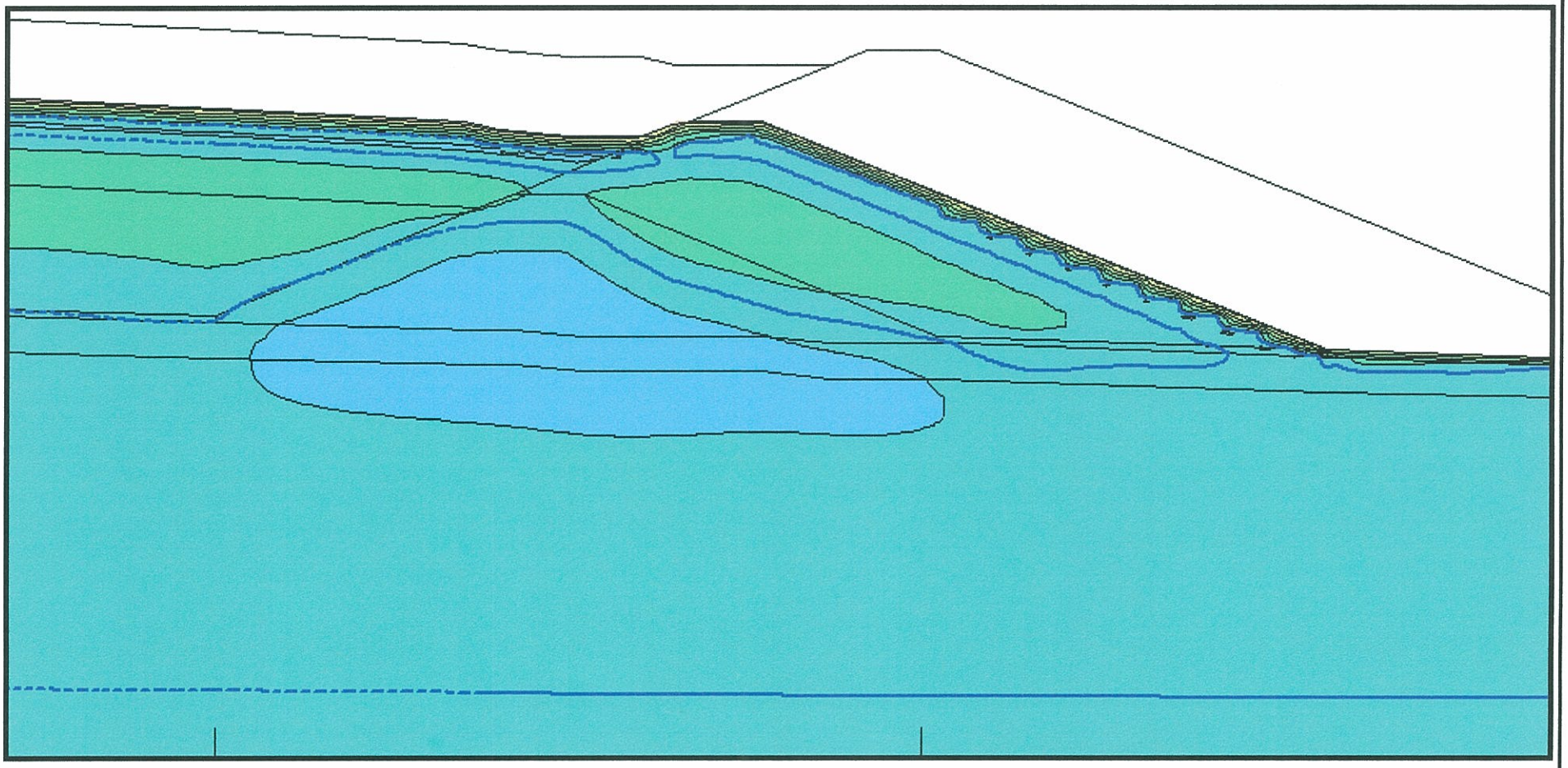
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-2h



Scale 1:1

0 20 40

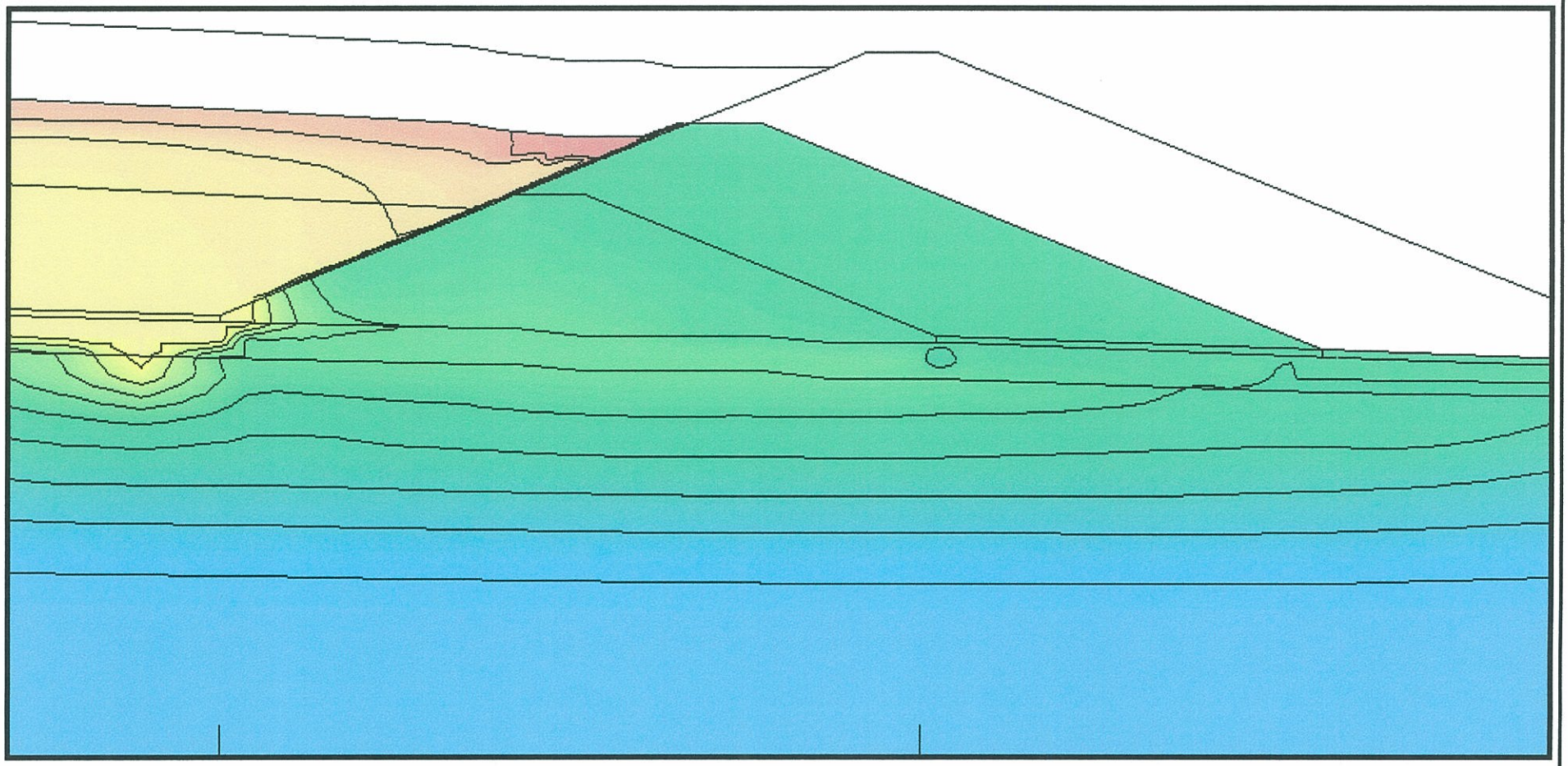
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. • TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-2t



Scale 1:1

0 20 40

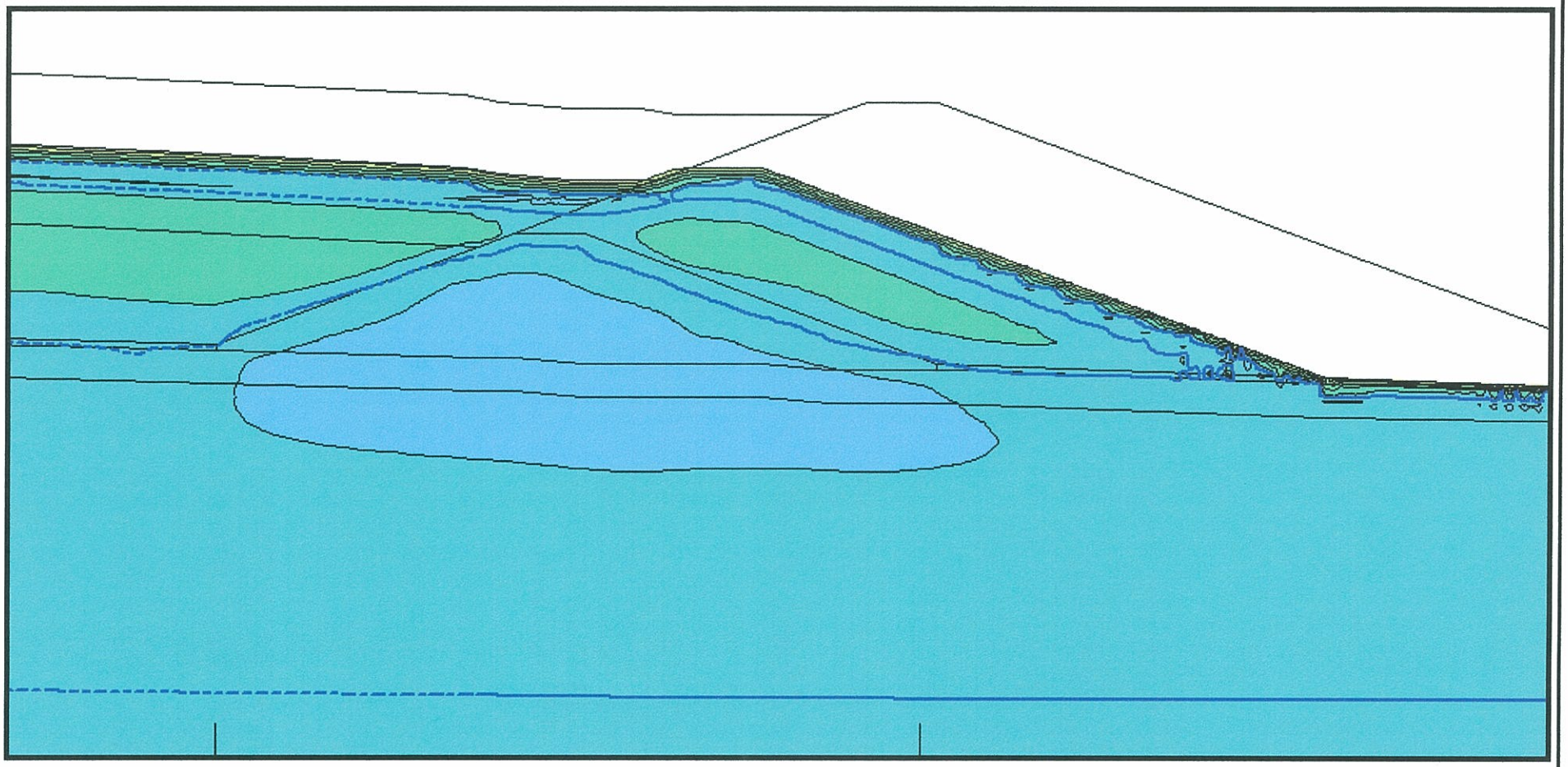
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 3 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-3h



Scale 1:1

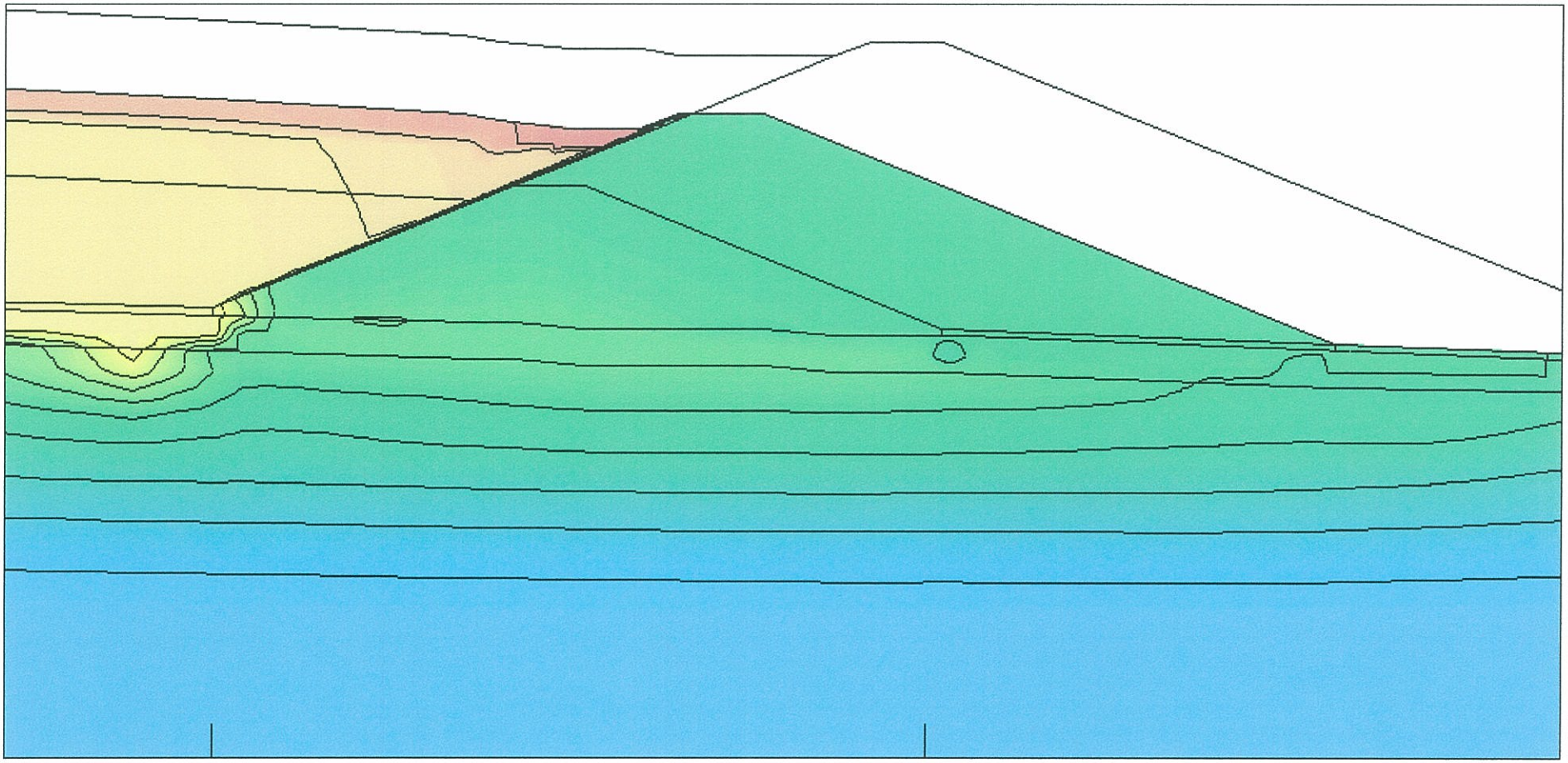
0 20 40

Meters

Thermal Contour Map
Scenario 3 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-3t



Scale 1:1

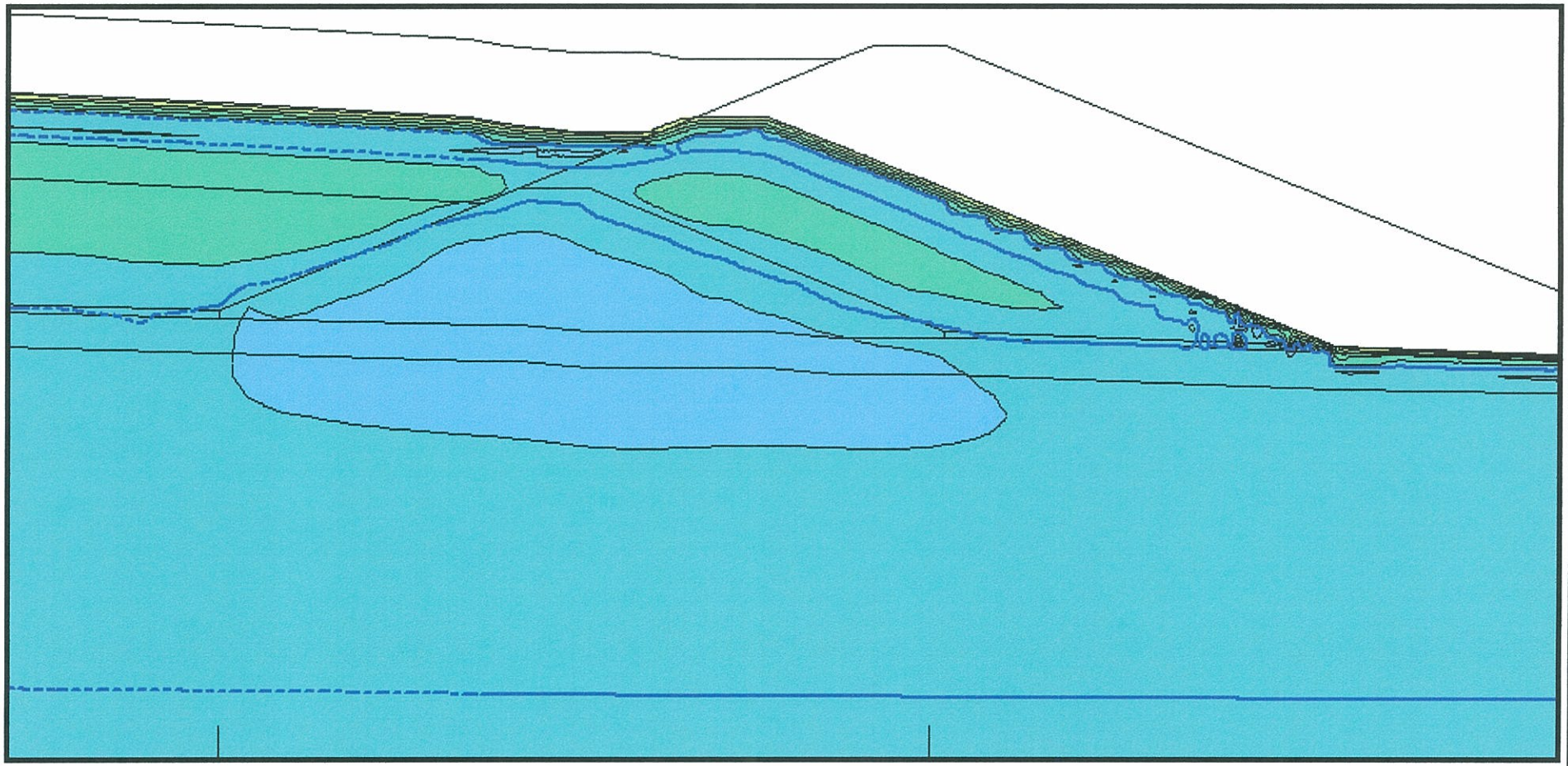
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 4 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-4h



Scale 1:1

0 20 40

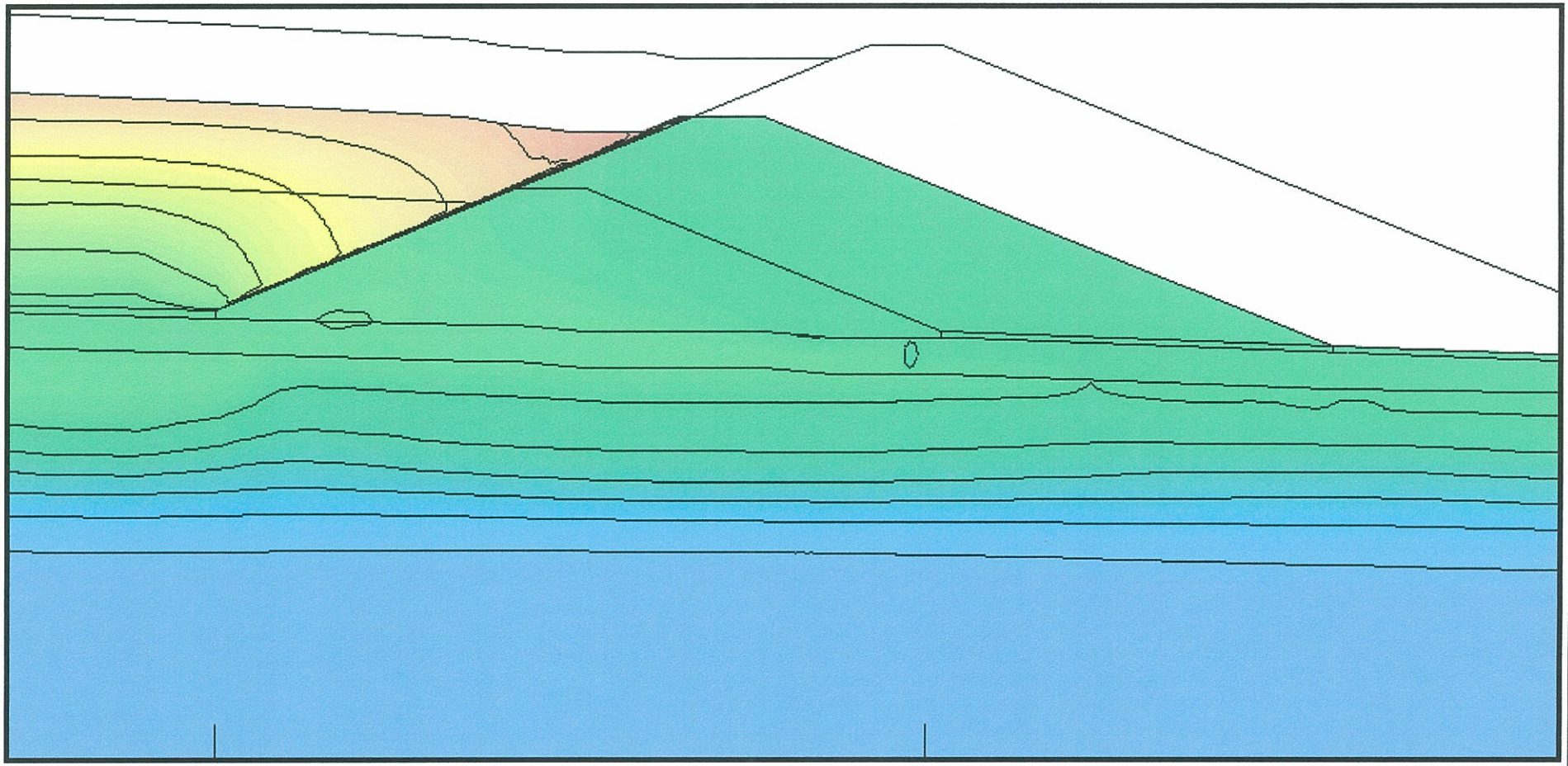
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 4 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-4t



Scale 1:1

0 20 40

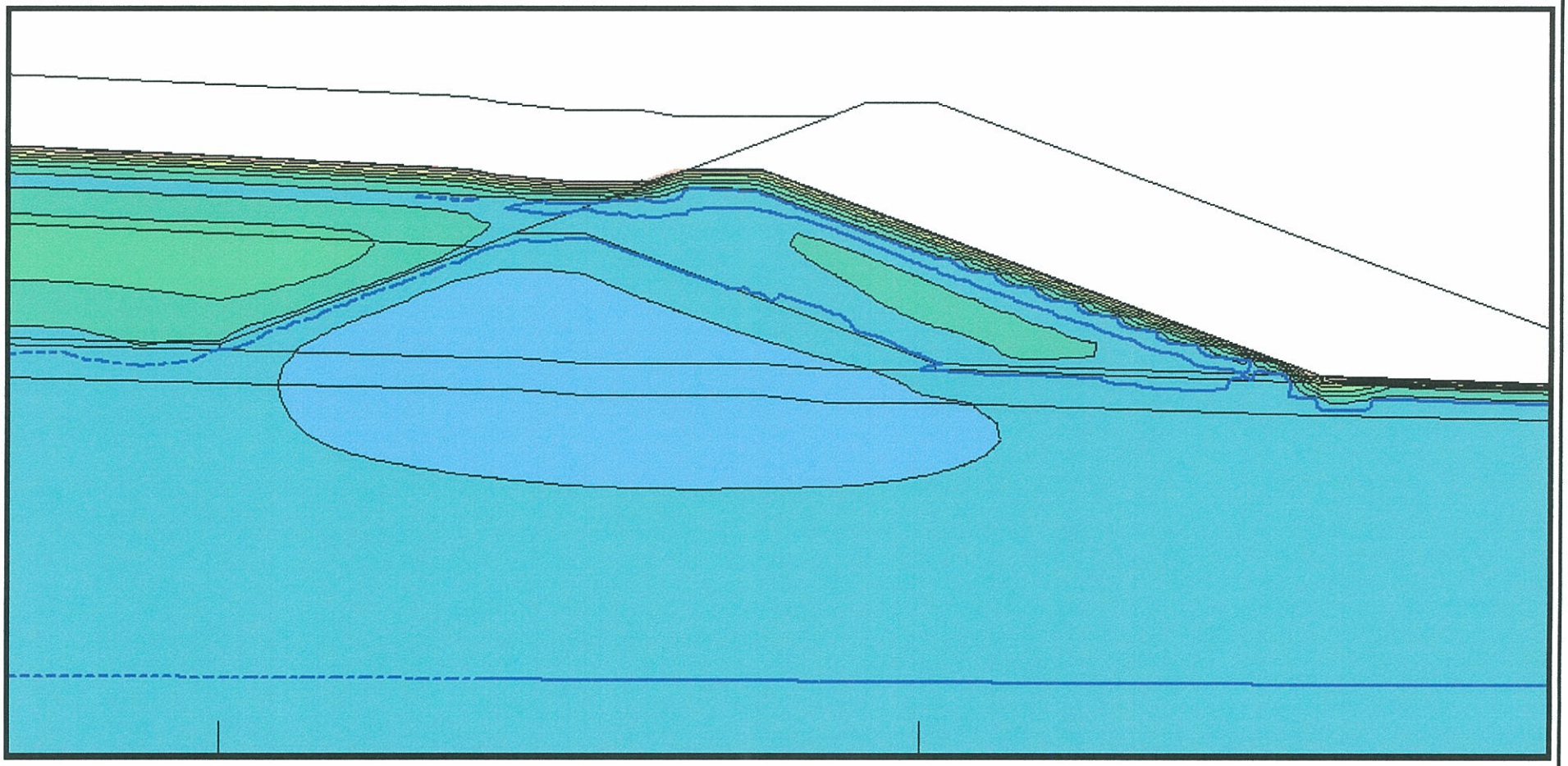
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 5 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-5h



Scale 1:1

0 20 40

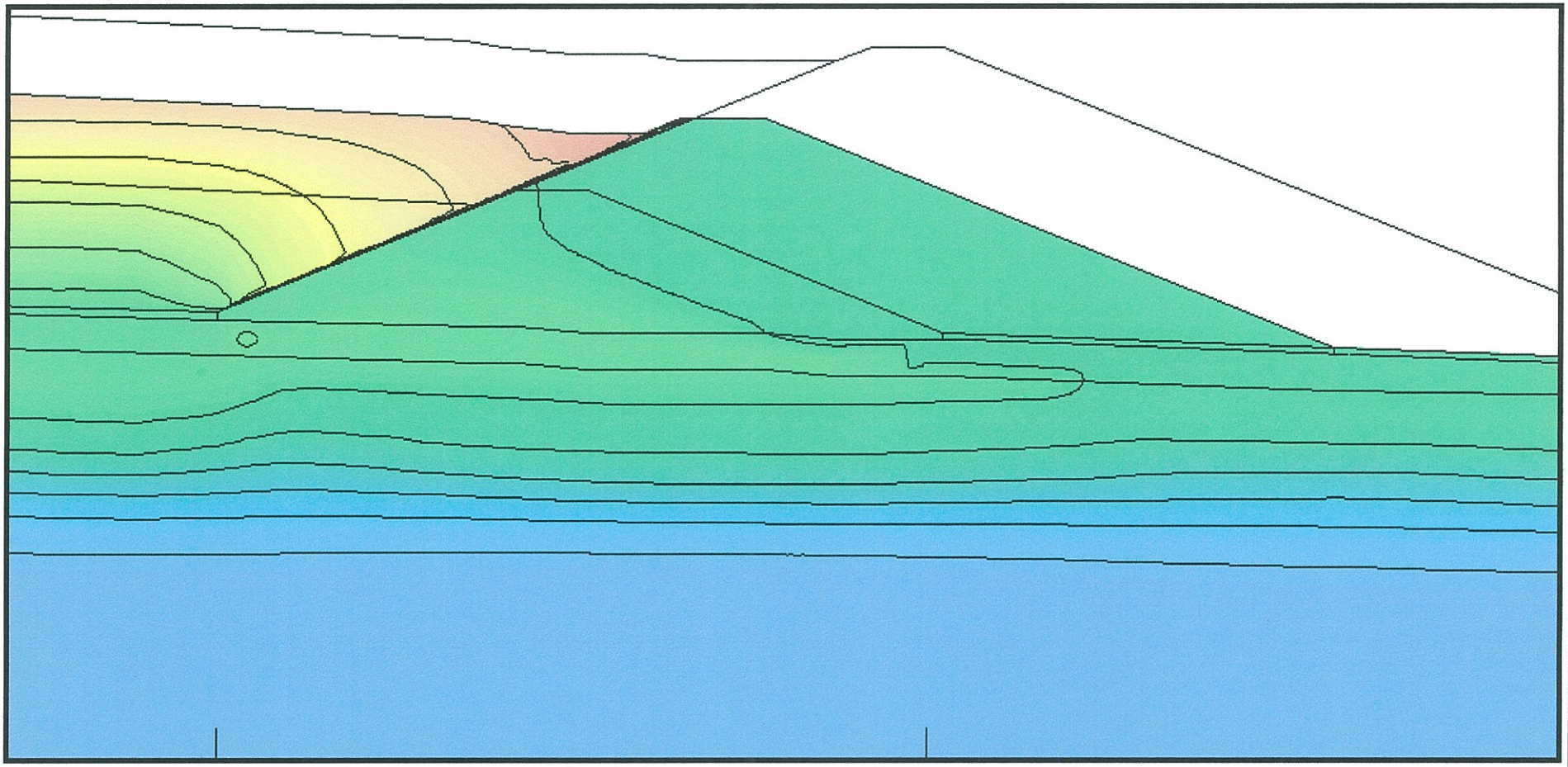
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 5 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-5t



Scale 1:1

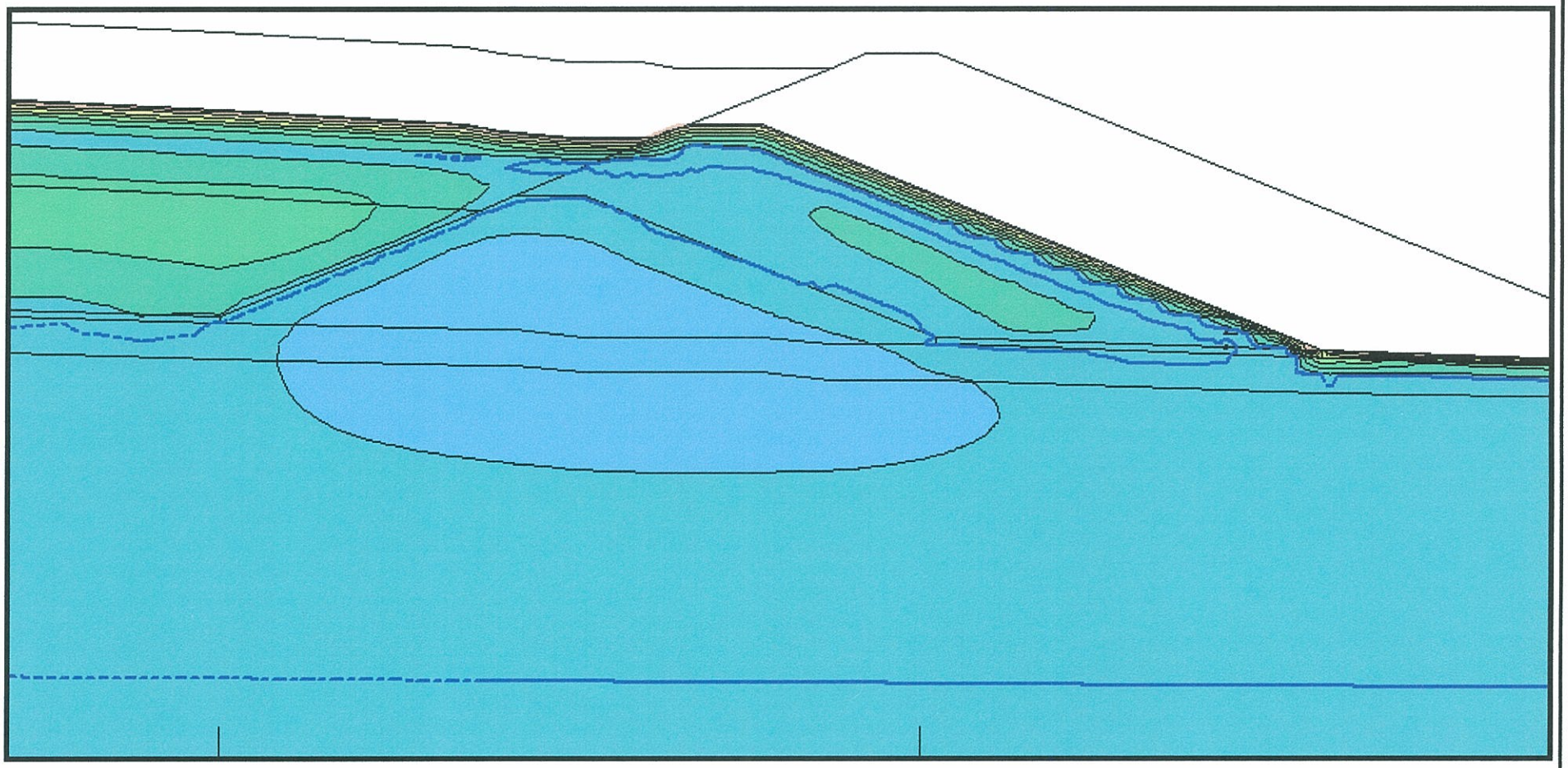
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 6 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-6h



Scale 1:1

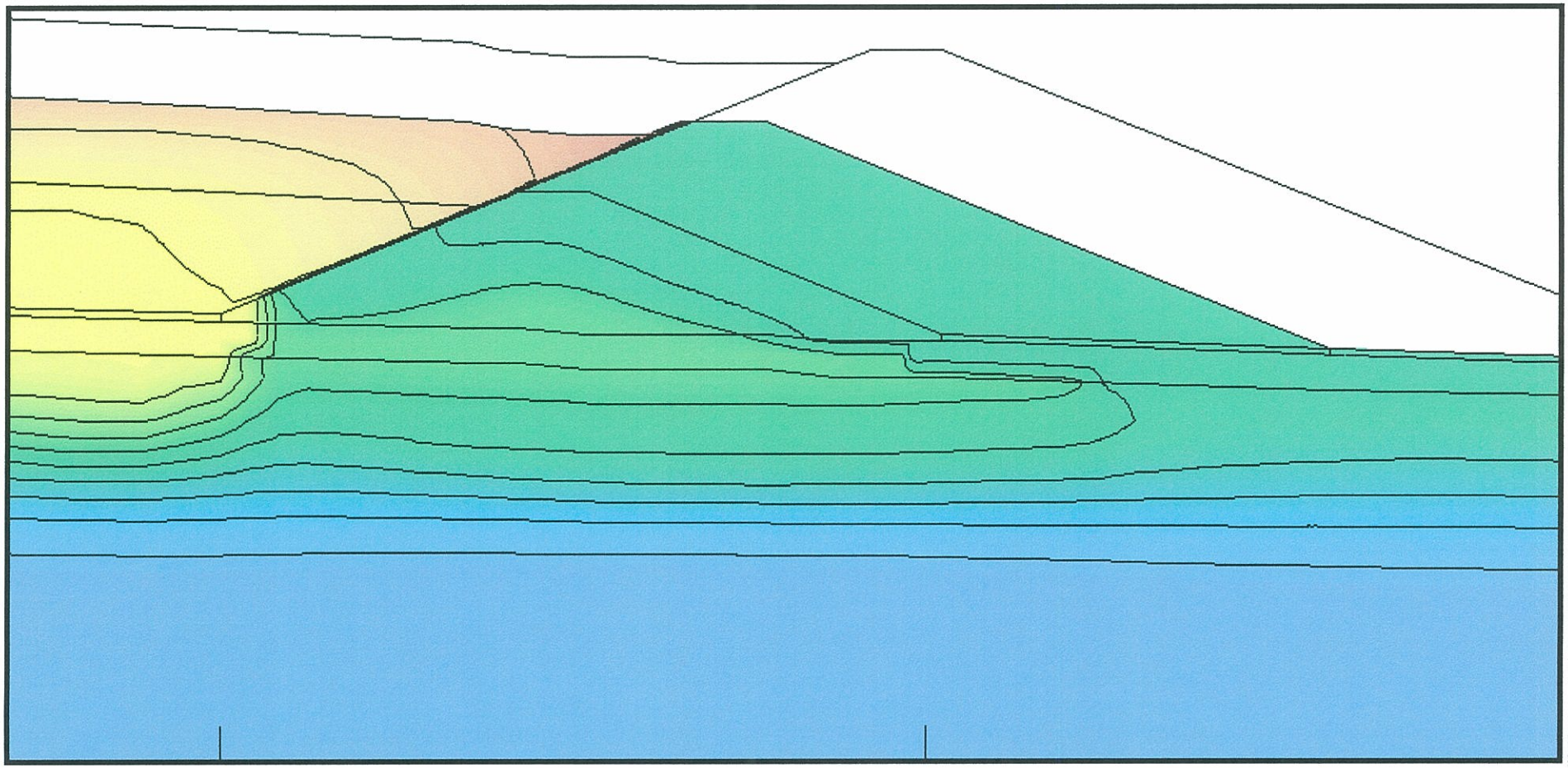
0 20 40

Meters

Thermal Contour Map
Scenario 6 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-6t



Scale 1:1

0 20 40

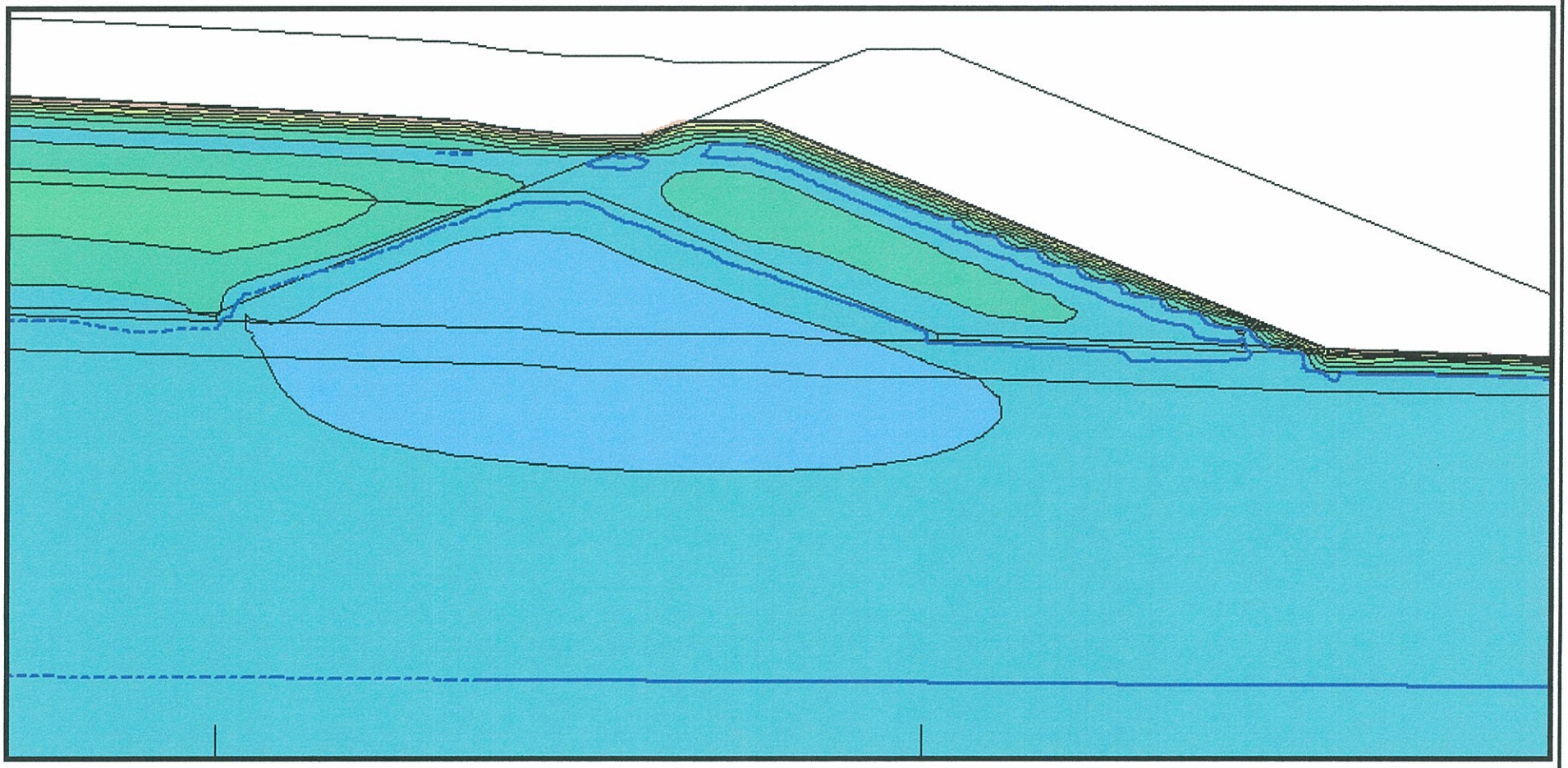
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 7 – Phase 2 – AUG 03

Rock Creek Dam,
Nome, Alaska

F-7h



Scale 1:1

0 20 40

Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 7 – Phase 2 – AUG 03

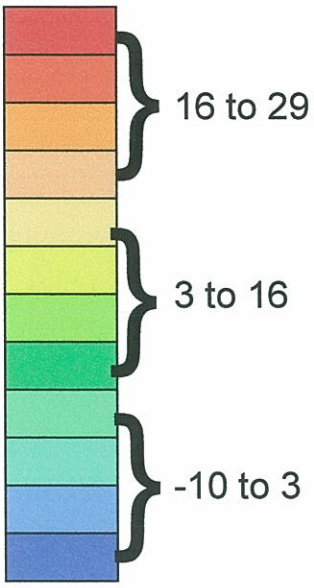
Rock Creek Dam,
Nome, Alaska

F-7t

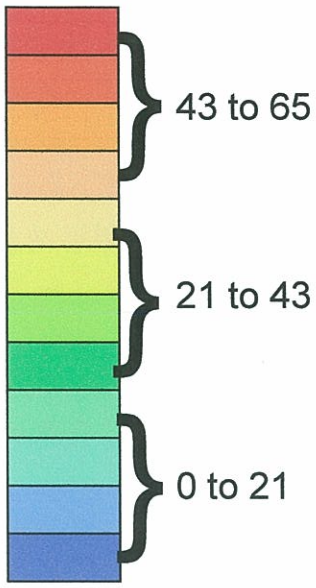
APPENDIX G

PHASE III ANALYSIS RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

= Contour Interval Line

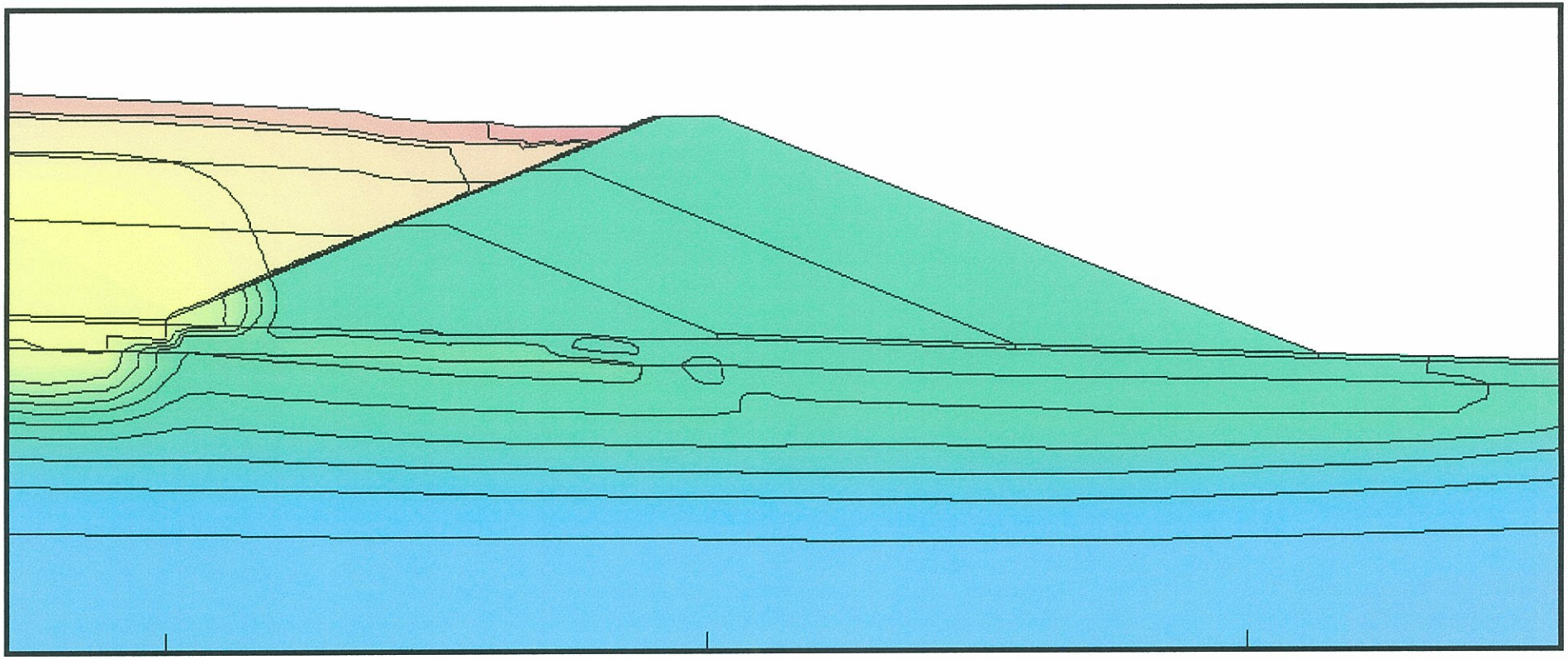
Scenario 1 = Current site conditions w/ no thermosyphons
Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons
Scenario 3 = Current site conditions w/ two thermosyphons and equipped w/ 50m^2 radiators
Scenario 4 = Current site conditions w/ two thermosyphons and equipped w/ 200m2 radiators
Scenario 5 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. No thermosyphons.
Scenario 6 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 50m^2 radiators
Scenario 7 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 200m^2 radiators

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

APPENDIX G KEY

Rock Creek Dam,
Nome, Alaska

G-0



Scale 1:1

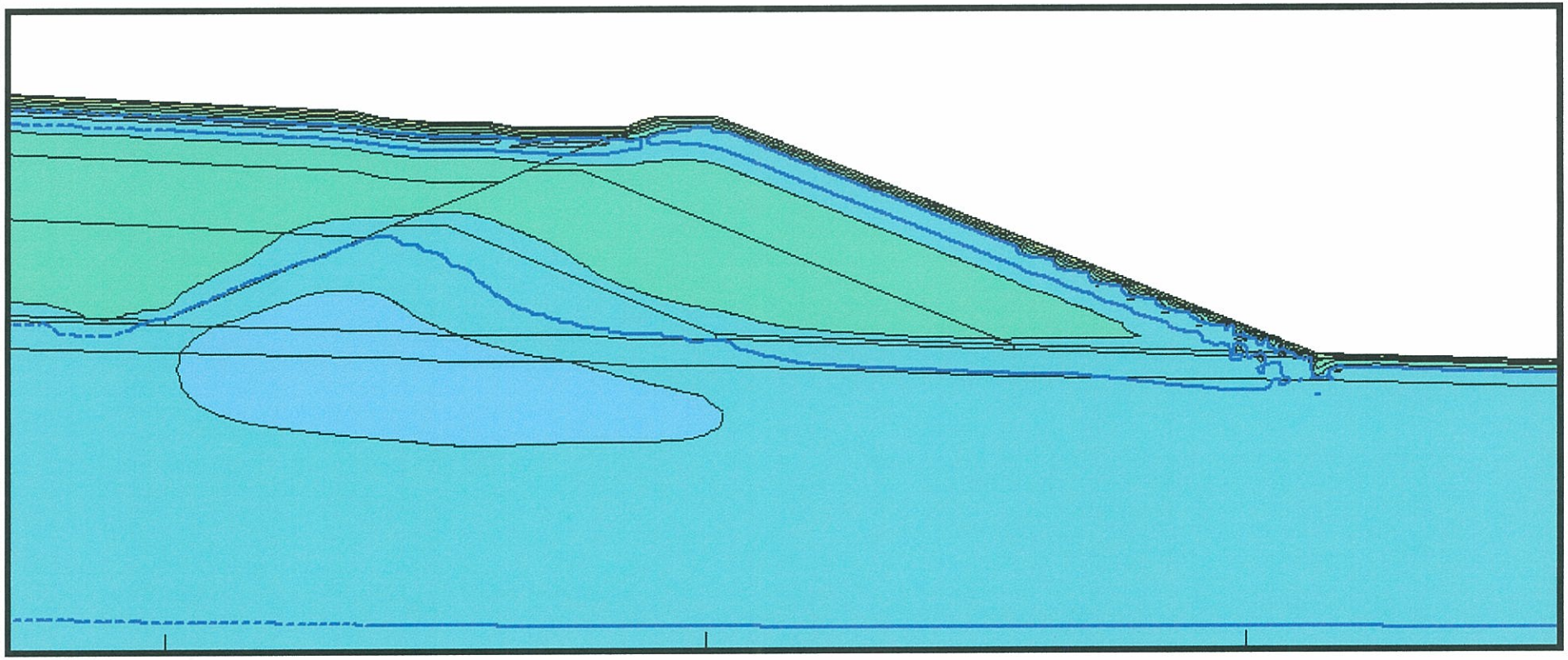
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 1 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-1h



Scale 1:1

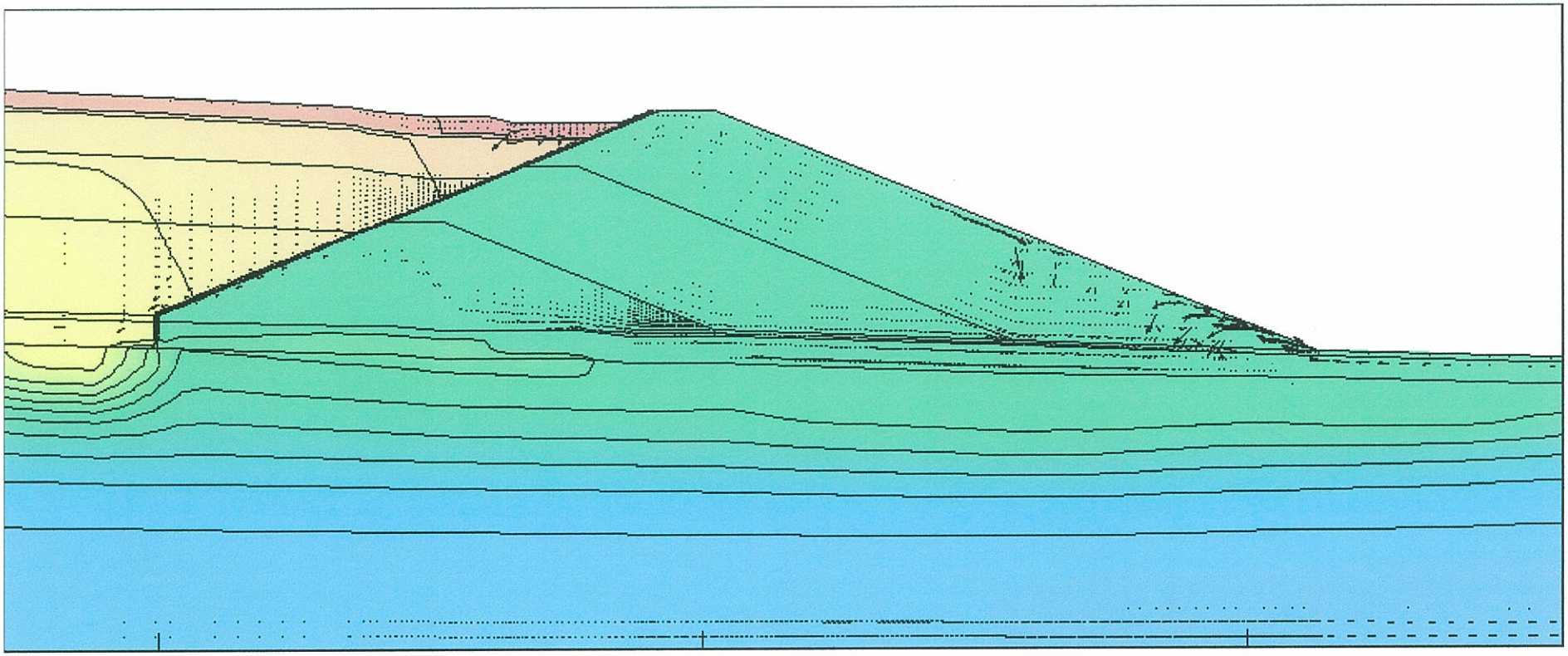
0 20 40

Meters

Thermal Contour Map
Scenario 1 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-1t



Scale 1:1

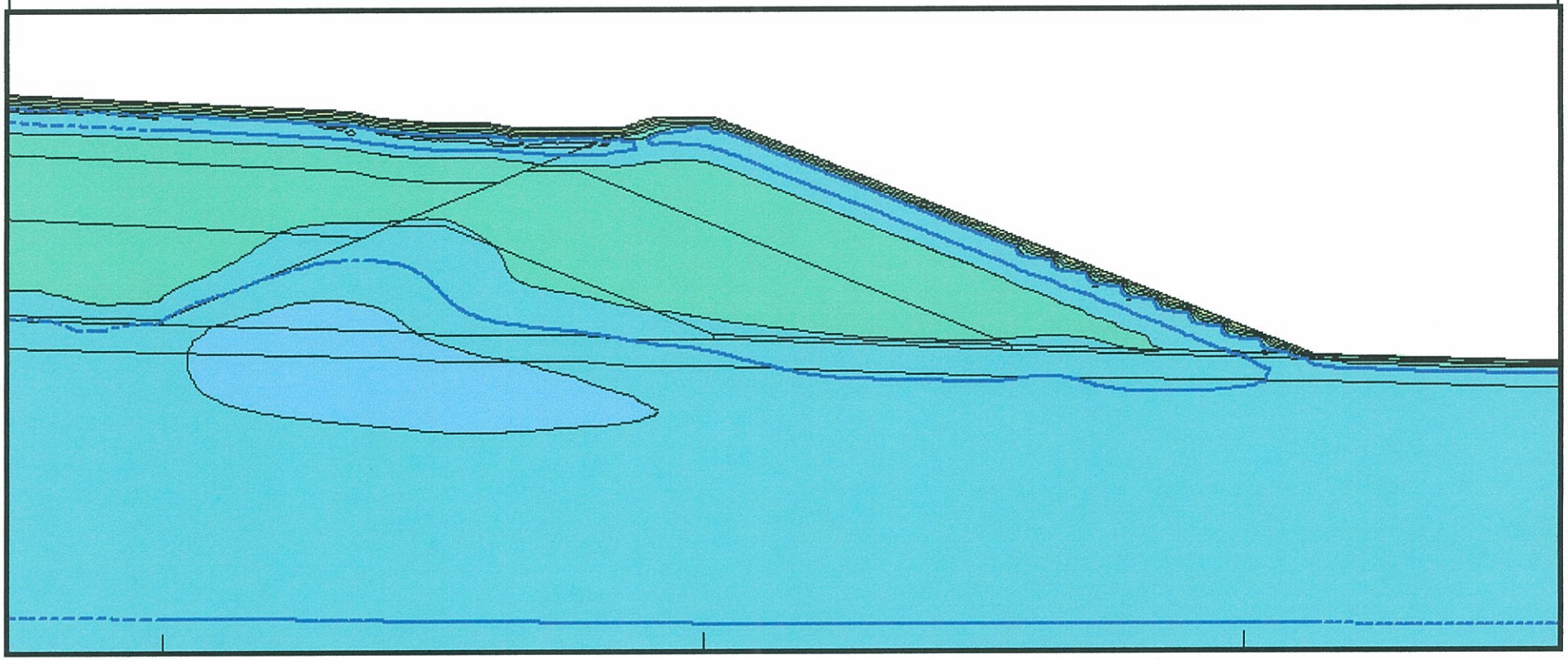
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-2h



Scale 1:1

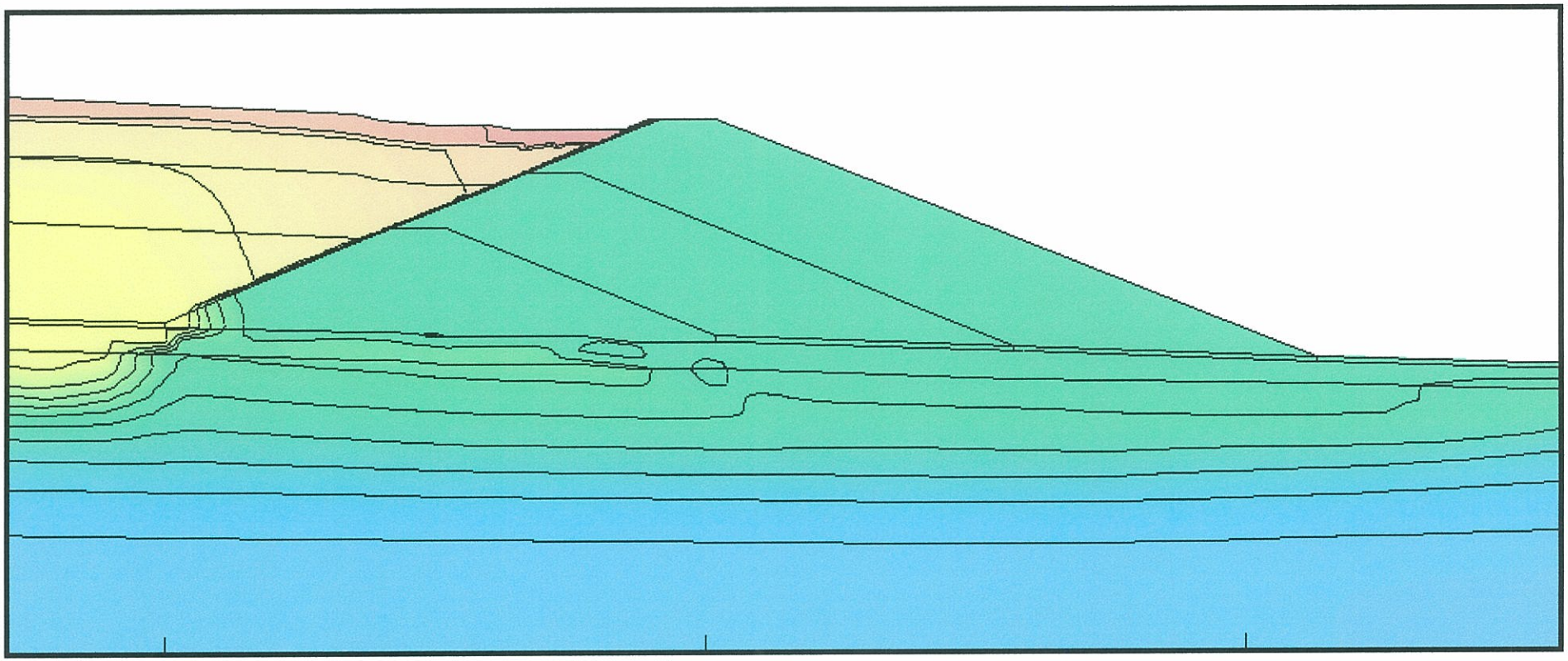
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-2t



Scale 1:1

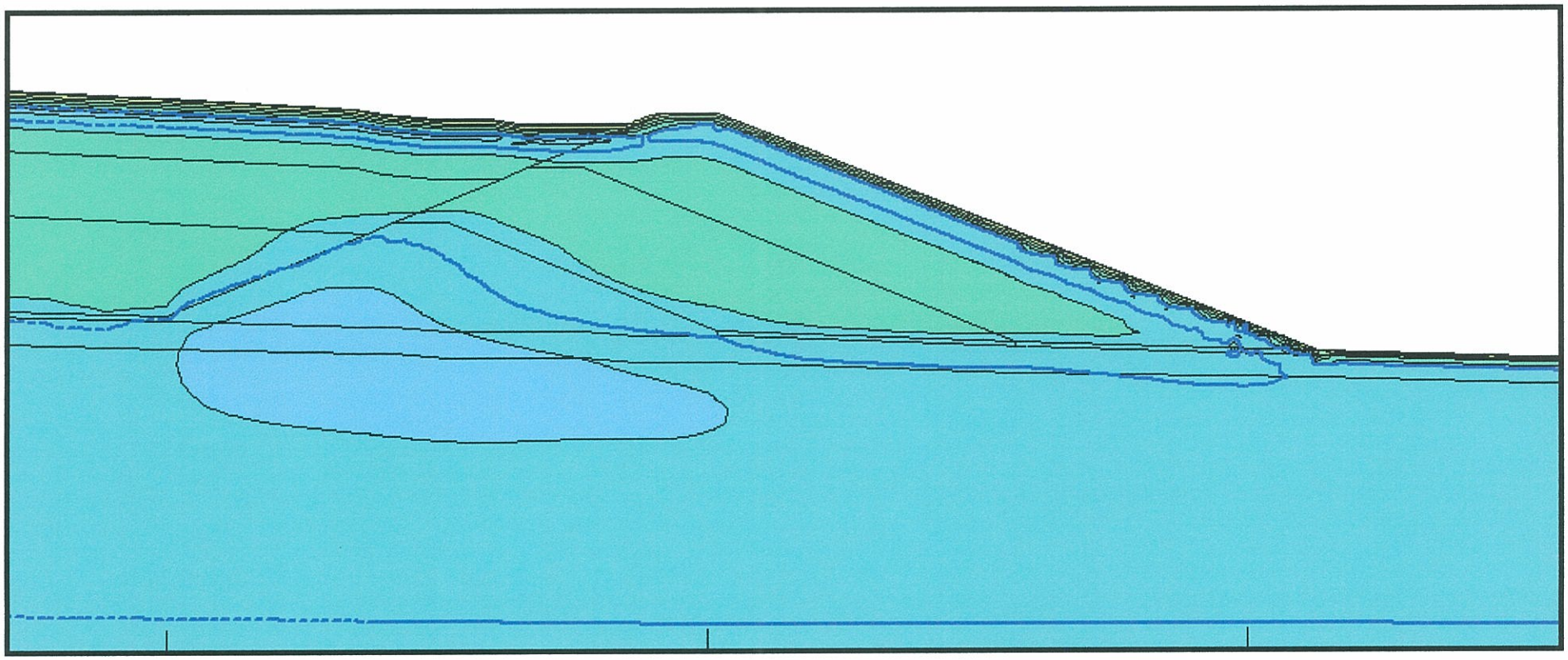
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 3 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-3h



Scale 1:1

0 20 40

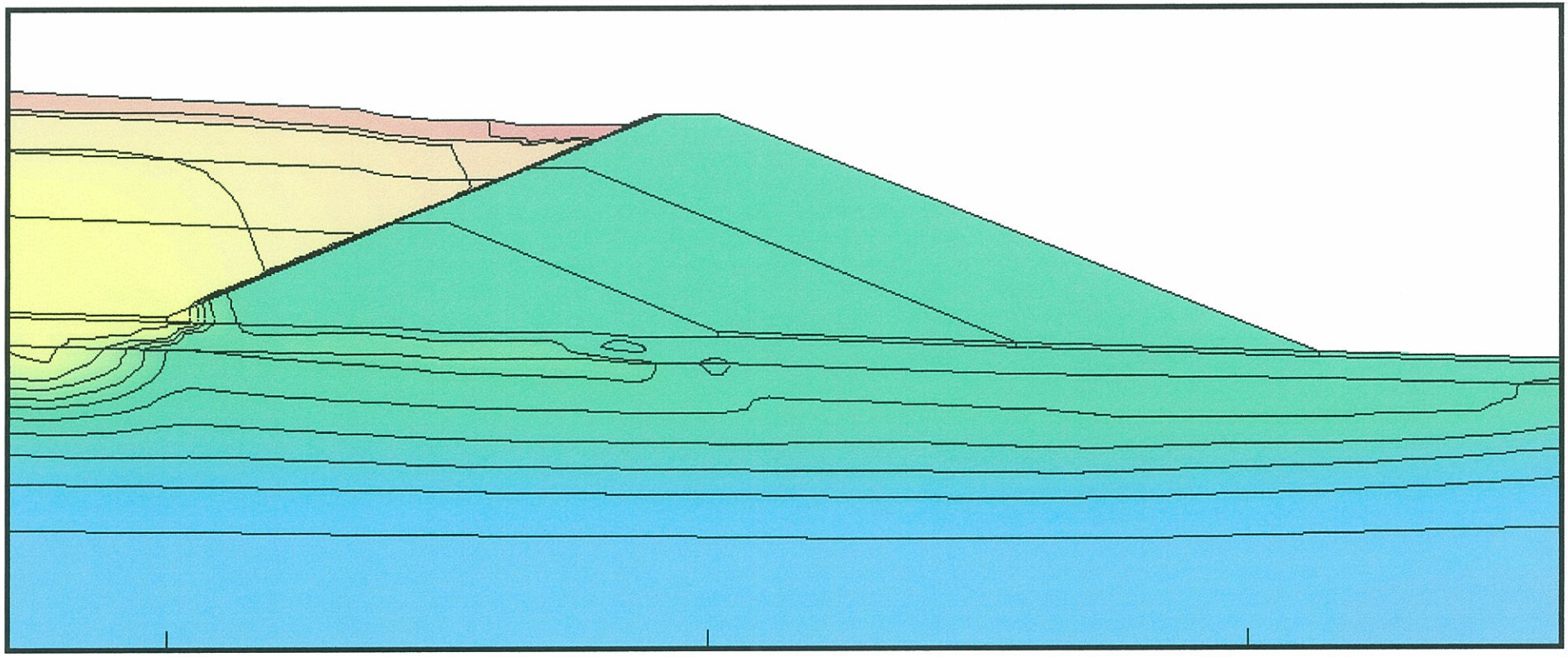
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 3 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-3t



Scale 1:1

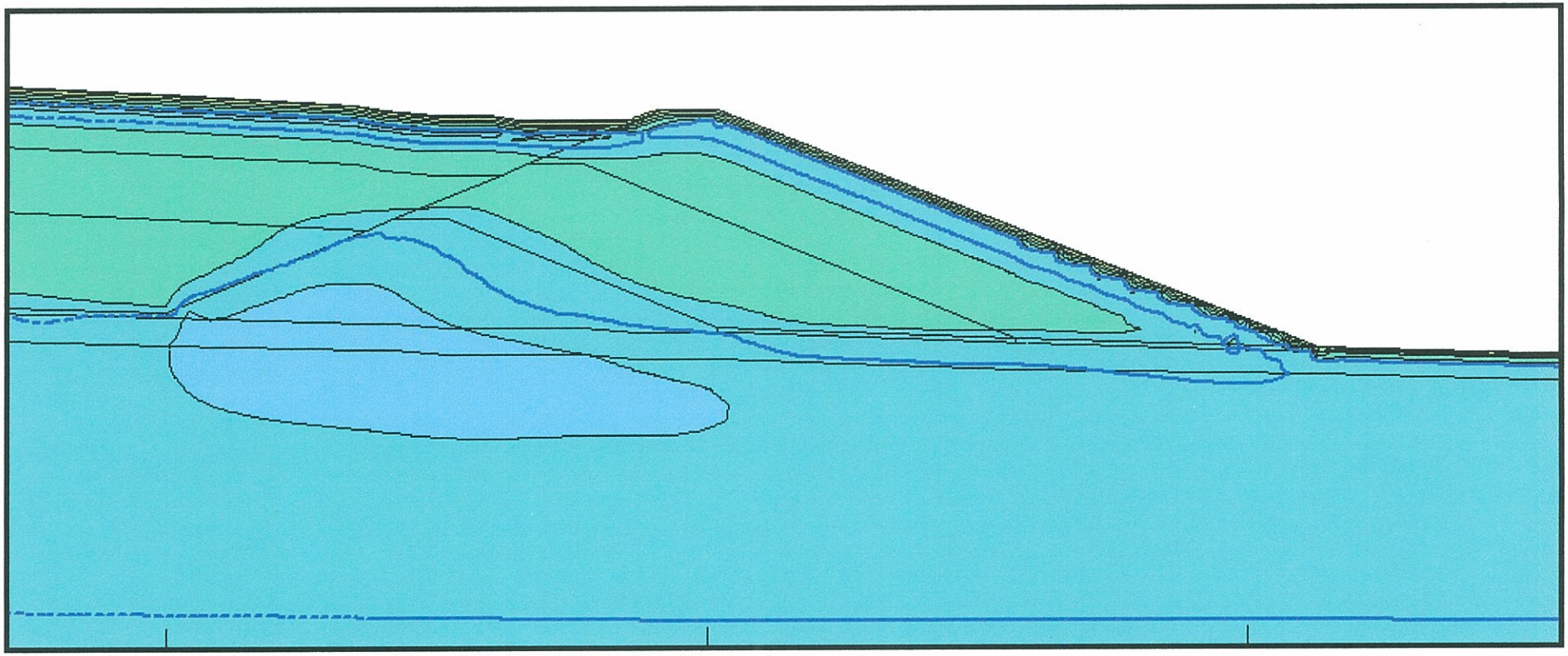
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 4 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-4h



Scale 1:1

0 20 40

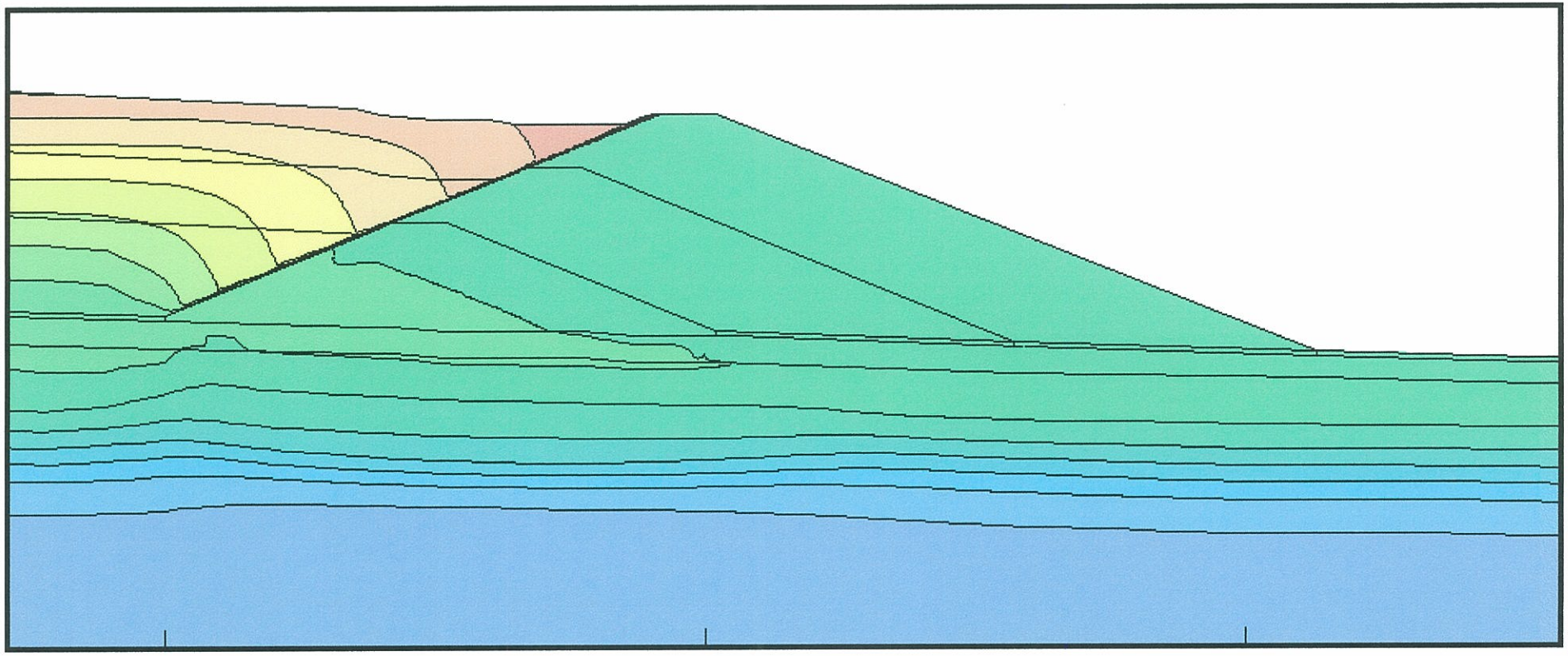
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 4 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-4t



Scale 1:1

0 20 40

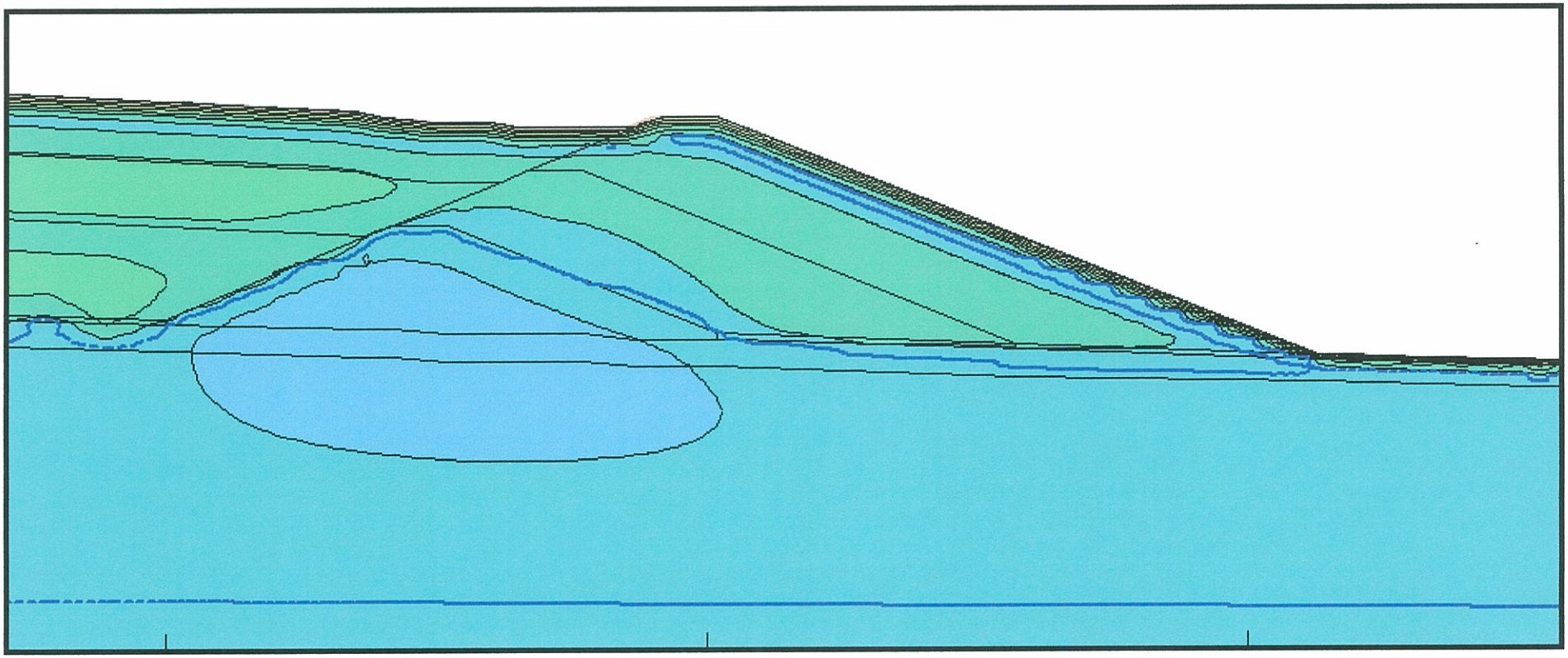
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 5 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-5h



Scale 1:1

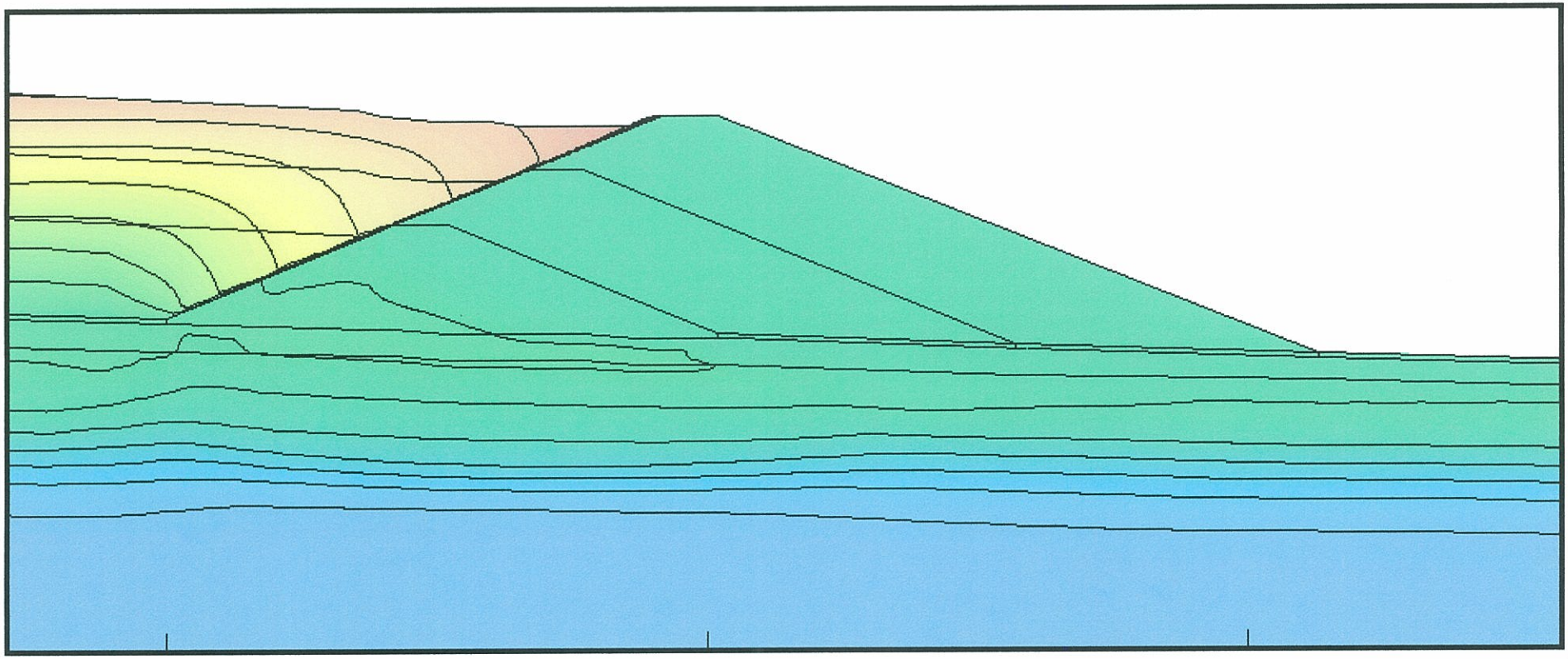
0 20 40

Meters

Thermal Contour Map
Scenario 5 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-5t



Scale 1:1

0 20 40

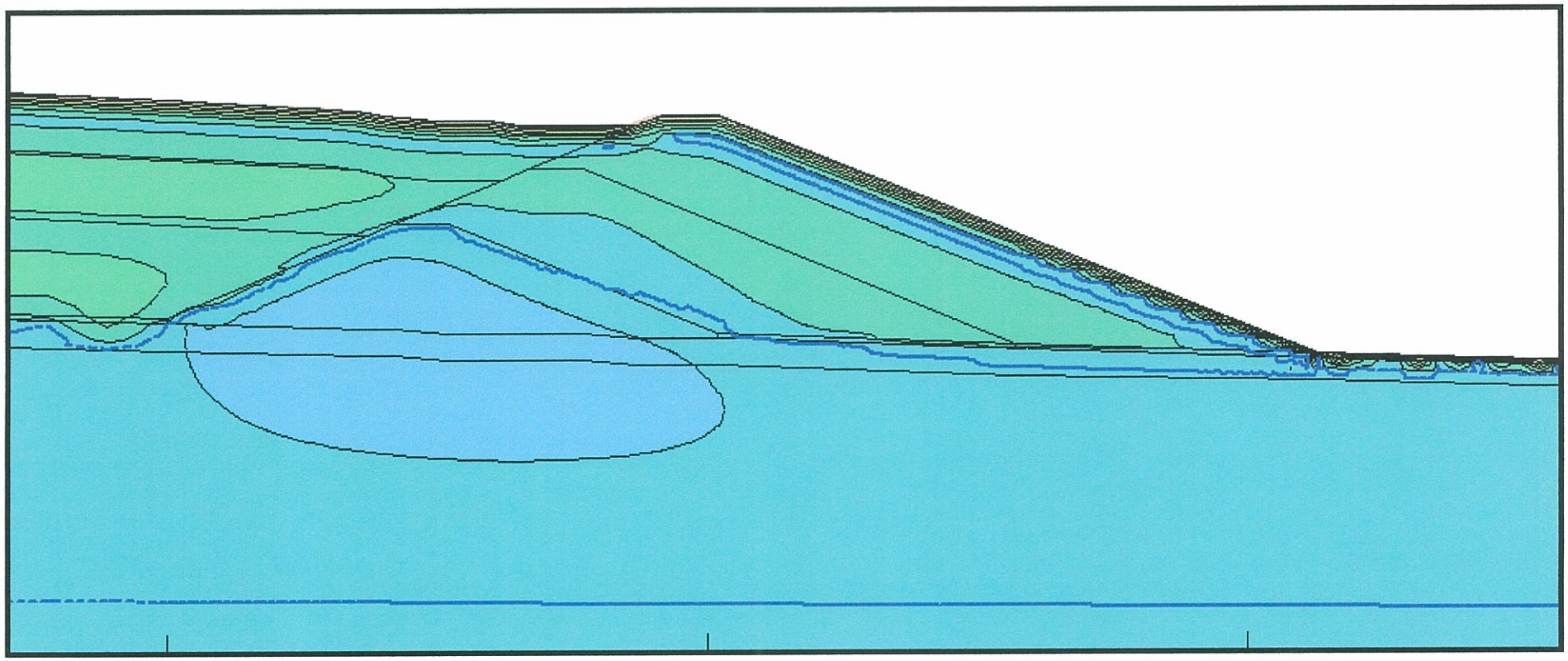
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 6 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-6h



Scale 1:1

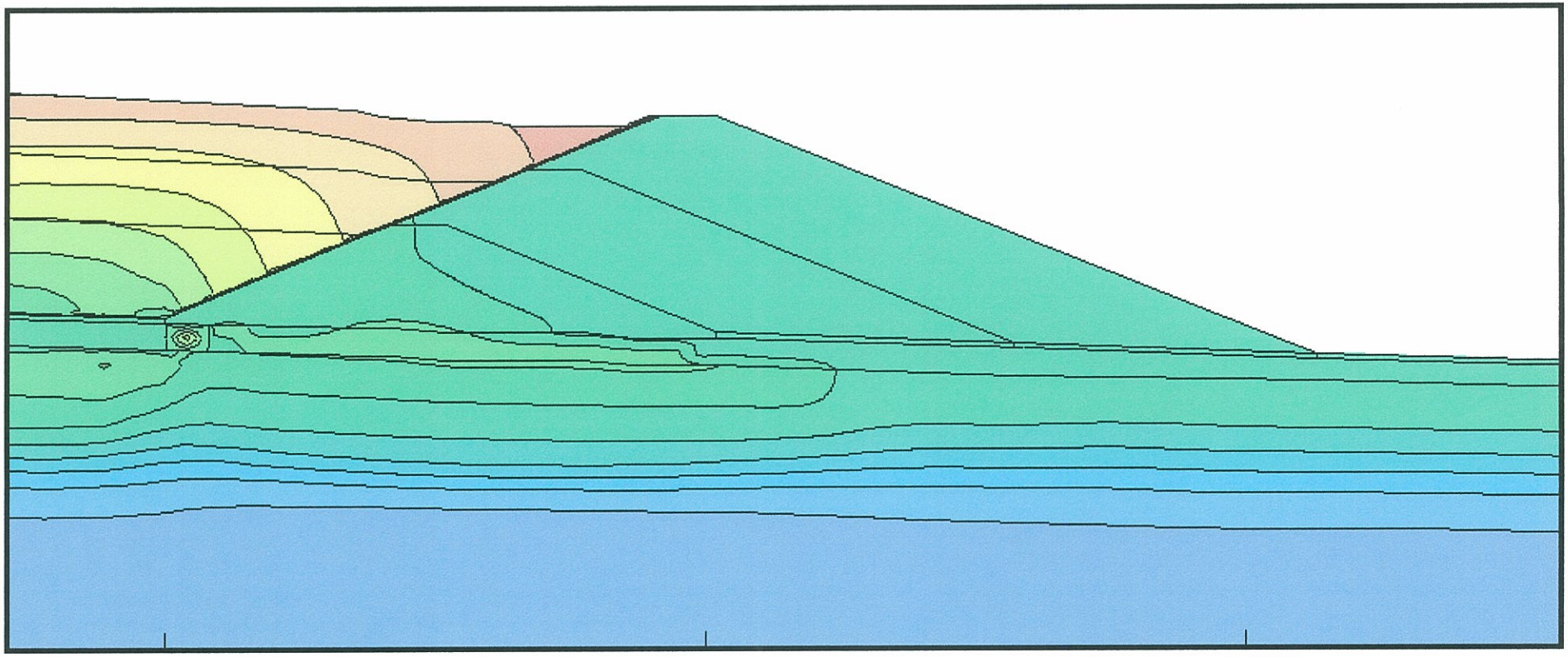
0 20 40

Meters

Thermal Contour Map
Scenario 6 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-6t



Scale 1:1

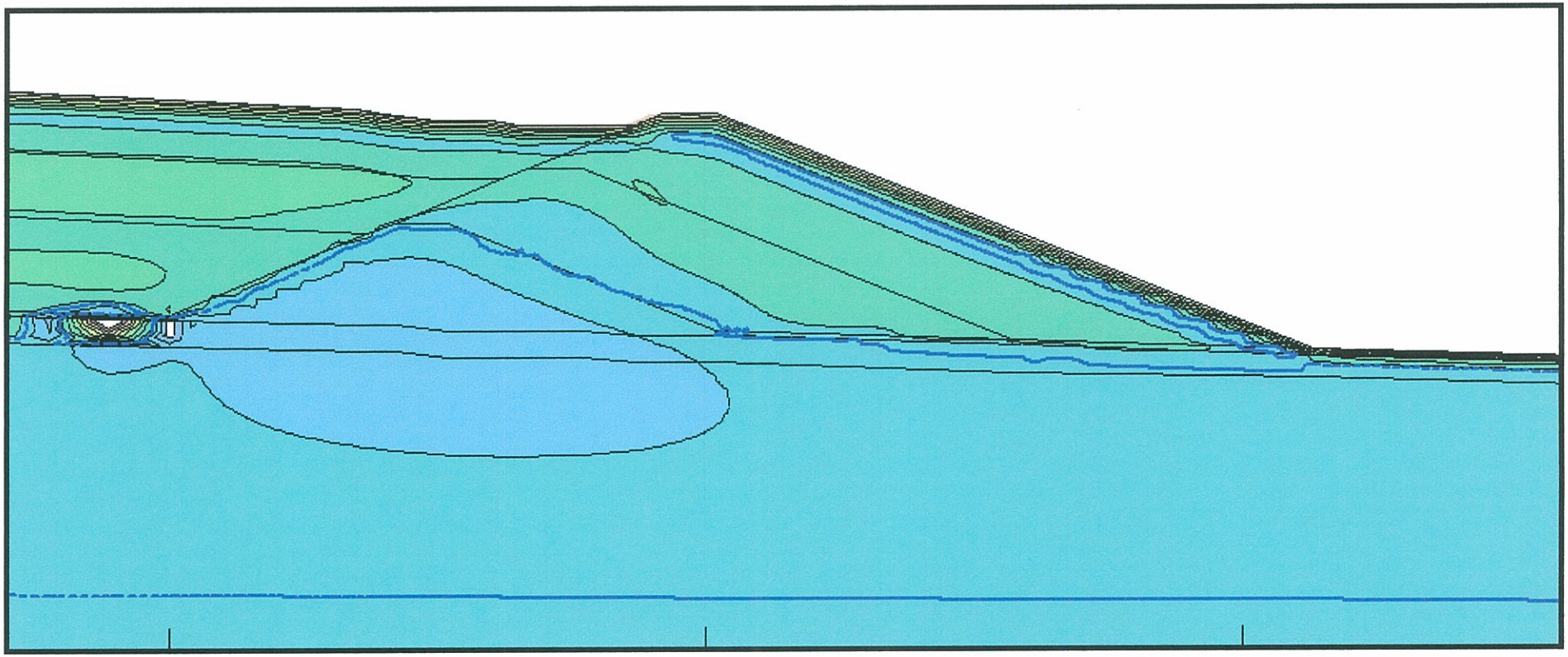
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 7 – Phase 3 – AUG 04

Rock Creek Dam,
Nome, Alaska

G-7h



Scale 1:1

0 20 40

Meters

Thermal Contour Map
Scenario 7 – Phase 3 – AUG 04

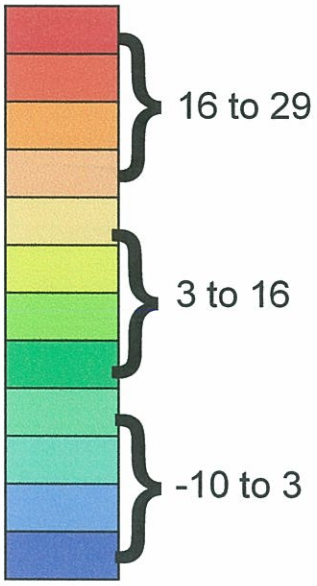
Rock Creek Dam,
Nome, Alaska

G-7t

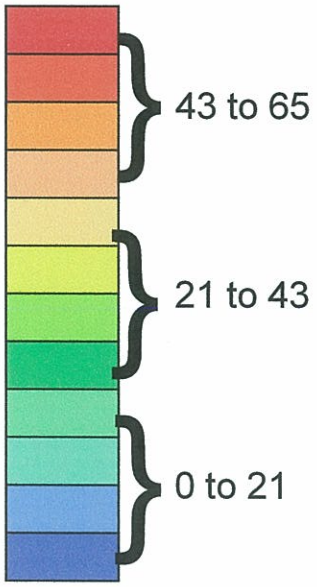
APPENDIX H

POST OPERATIONS ANALYSIS RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

= Contour Interval Line

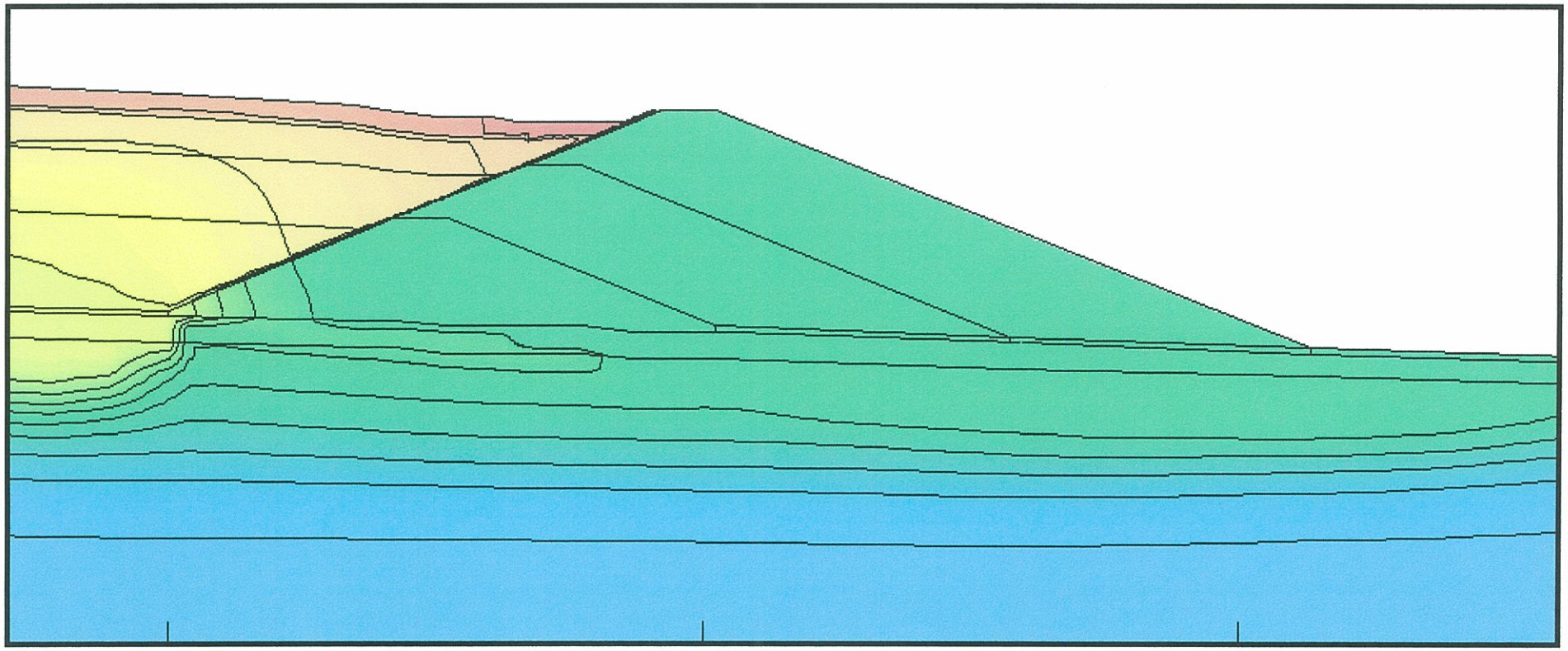
Scenario 1 = Current site conditions w/ no thermosyphons
Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons
Scenario 3 = Current site conditions w/ two thermosyphons and equipped w/ 50m^2 radiators
Scenario 4 = Current site conditions w/ two thermosyphons and equipped w/ 200m2 radiators
Scenario 5 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. No thermosyphons.
Scenario 6 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 50m^2 radiators
Scenario 7 = Elevated air temperatures (+3°C) and elevated hydraulic conductivity values (5x) for the weathered bedrock unit. Contains two thermosyphons w/ 200m^2 radiators

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

APPENDIX H KEY

Rock Creek Dam,
Nome, Alaska

H-0



Scale 1:1

0 20 40

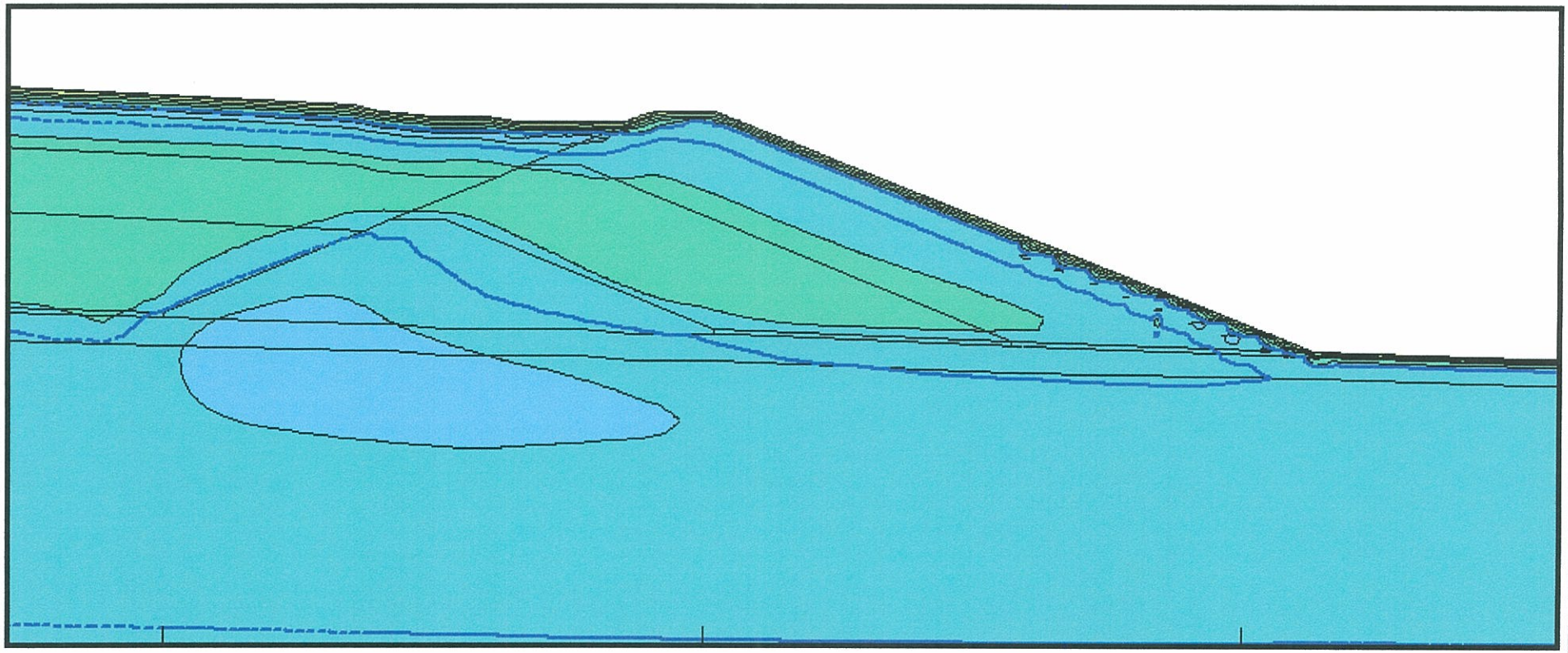
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 1 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-1h



Scale 1:1

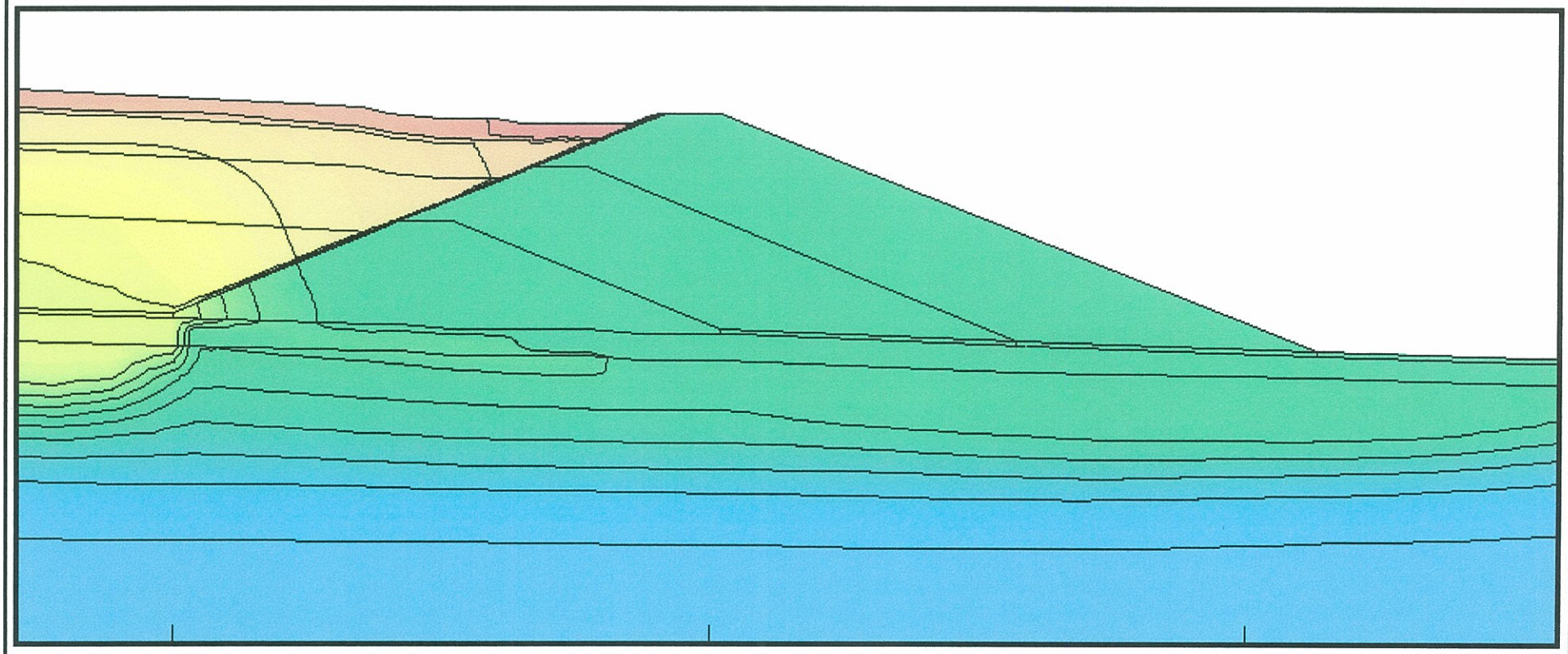
0 20 40

Meters

Thermal Contour Map
Scenario 1 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-1t



Scale 1:1

0 20 40

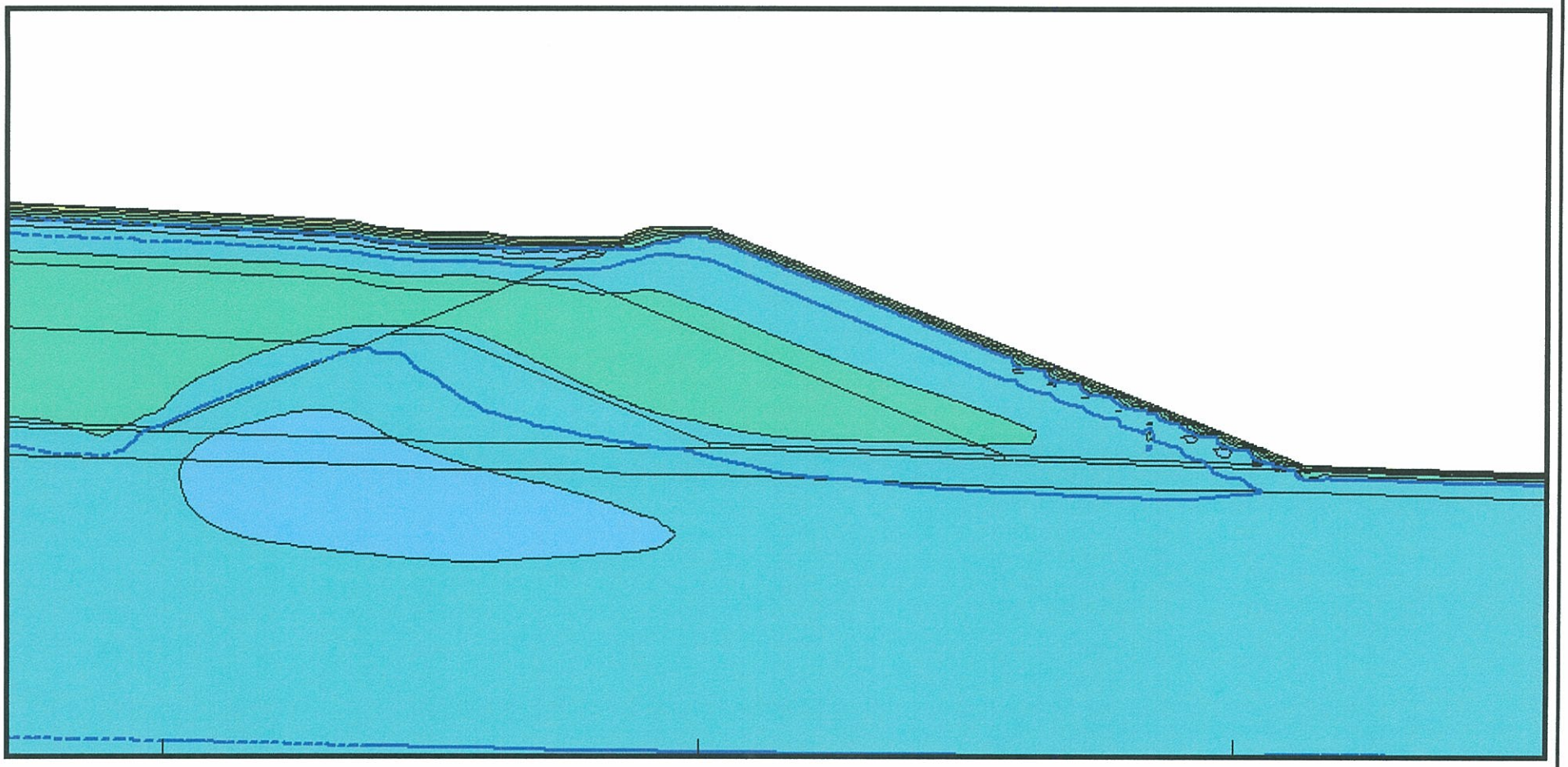
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-2h



Scale 1:1

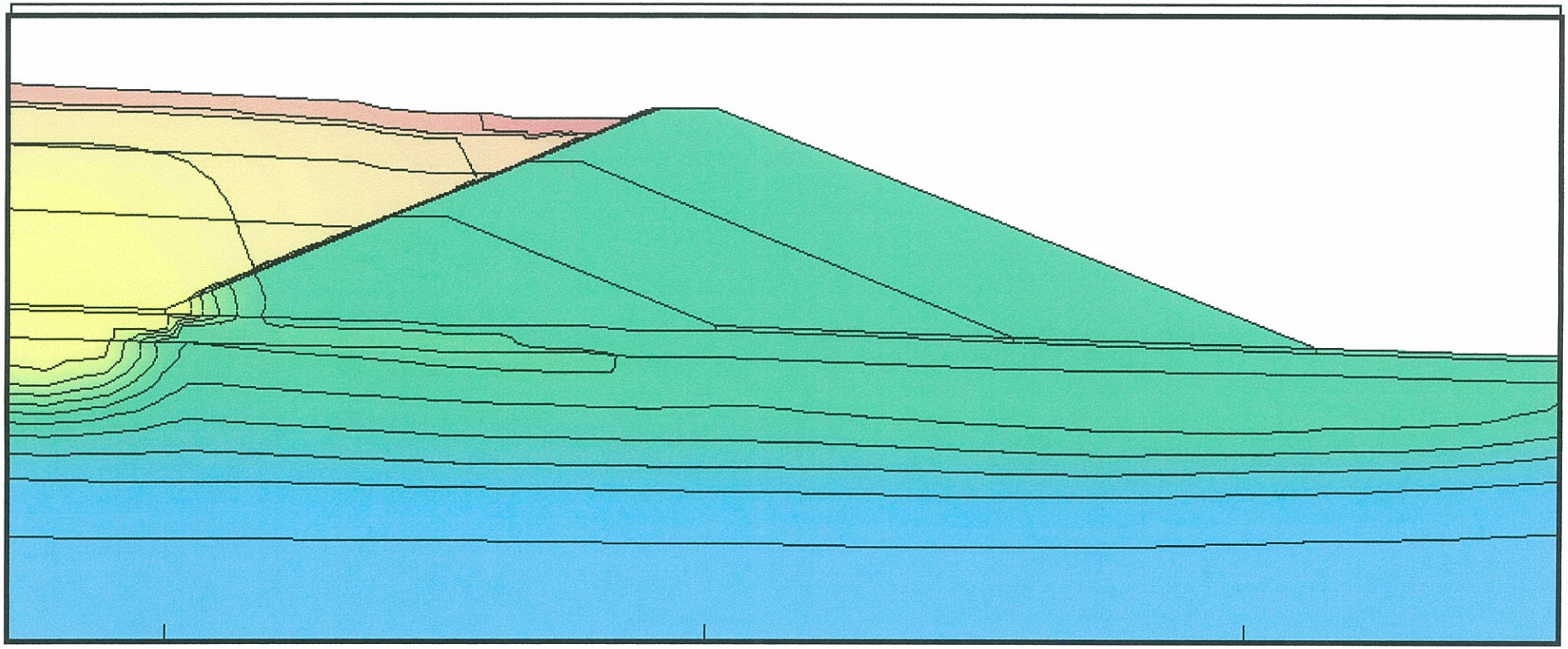
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-2t



Scale 1:1

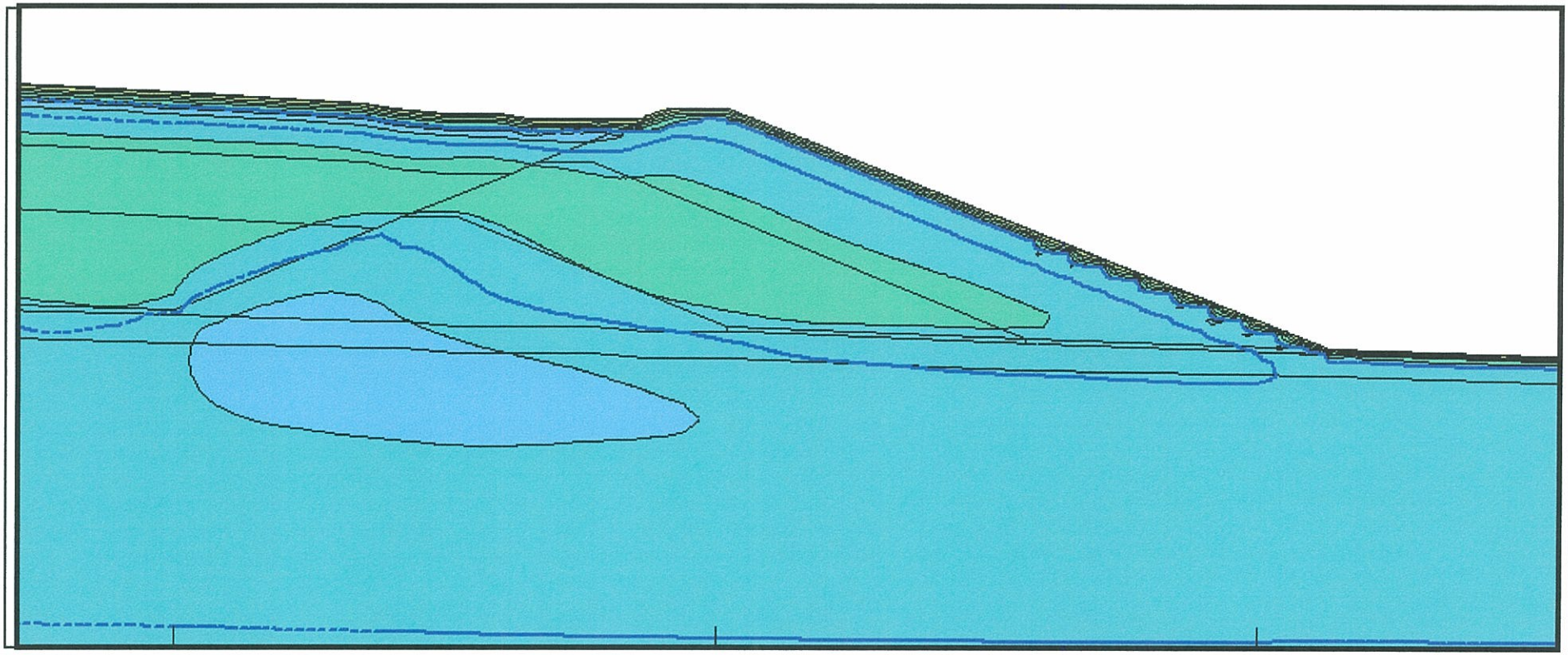
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 3 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-3h



Scale 1:1

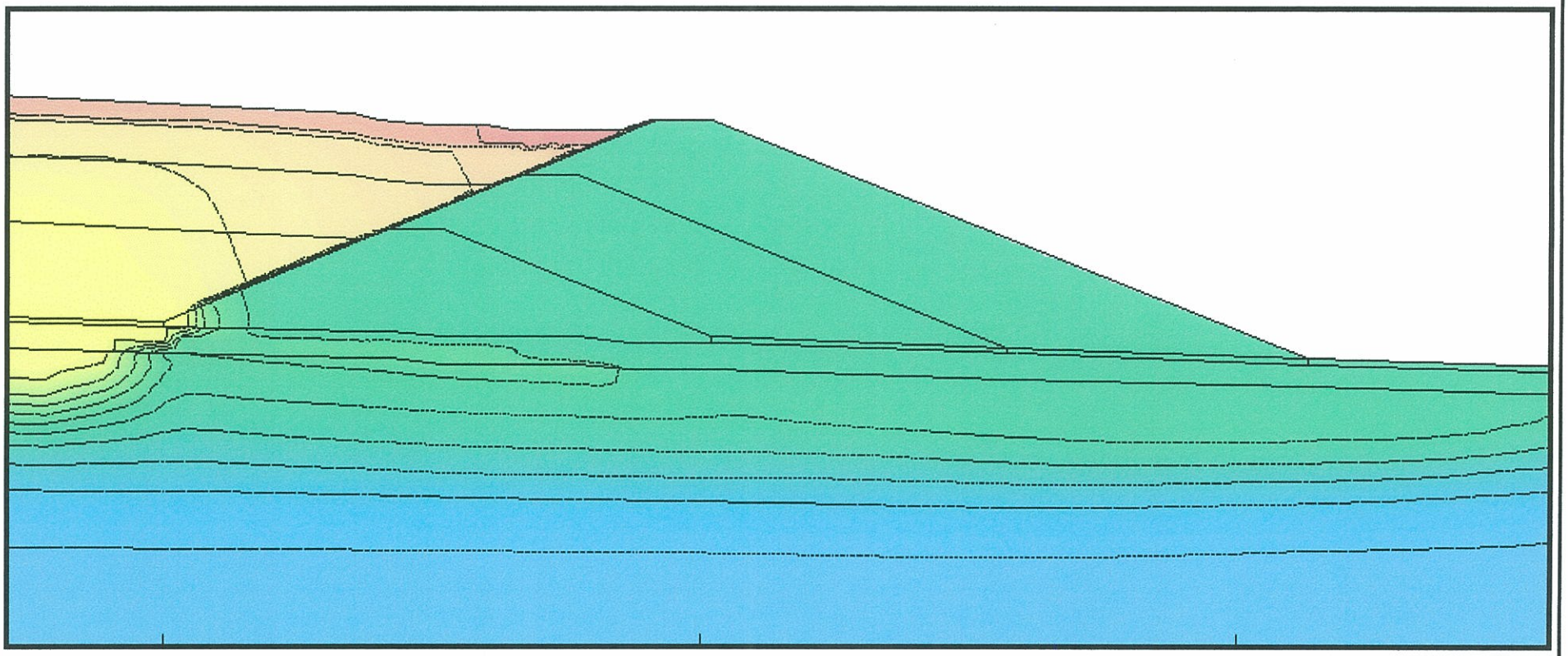
0 20 40

Meters

Thermal Contour Map
Scenario 3 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-3t



Scale 1:1

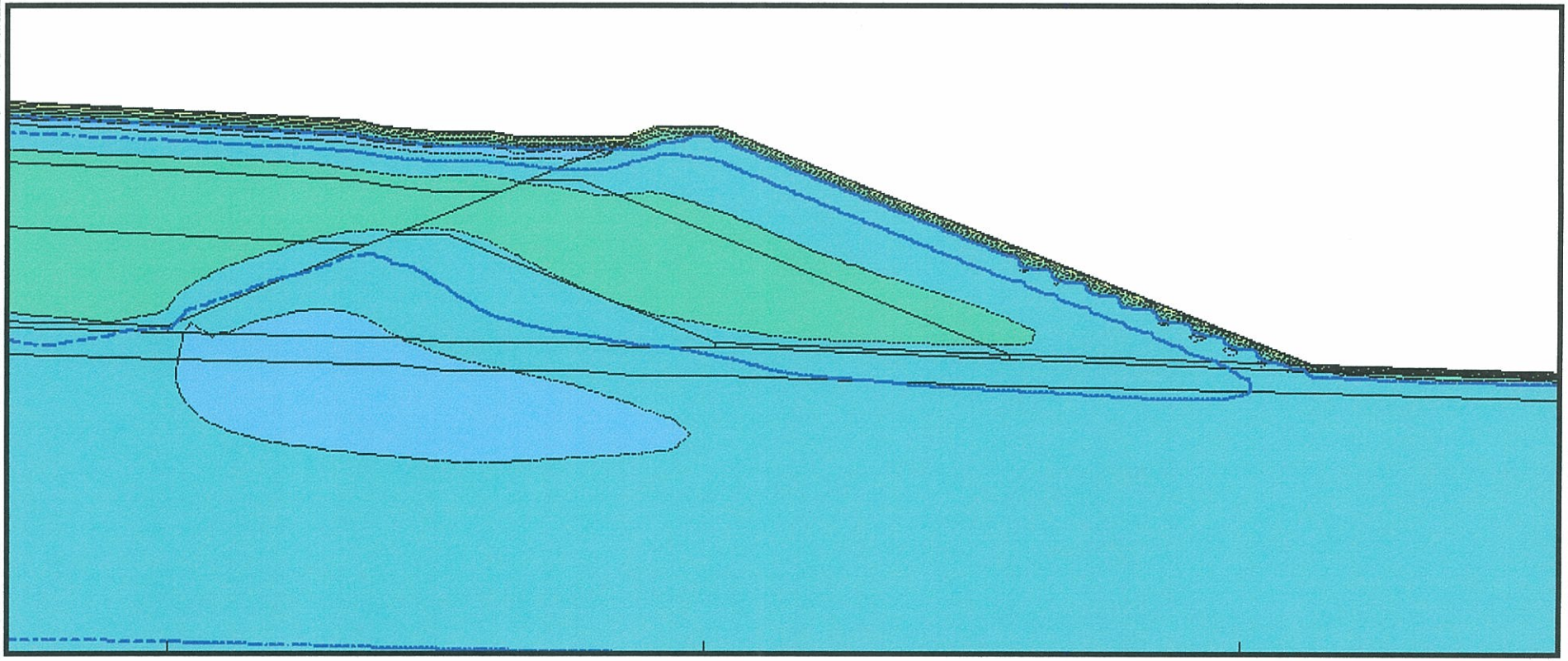
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 4 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-4h



Scale 1:1

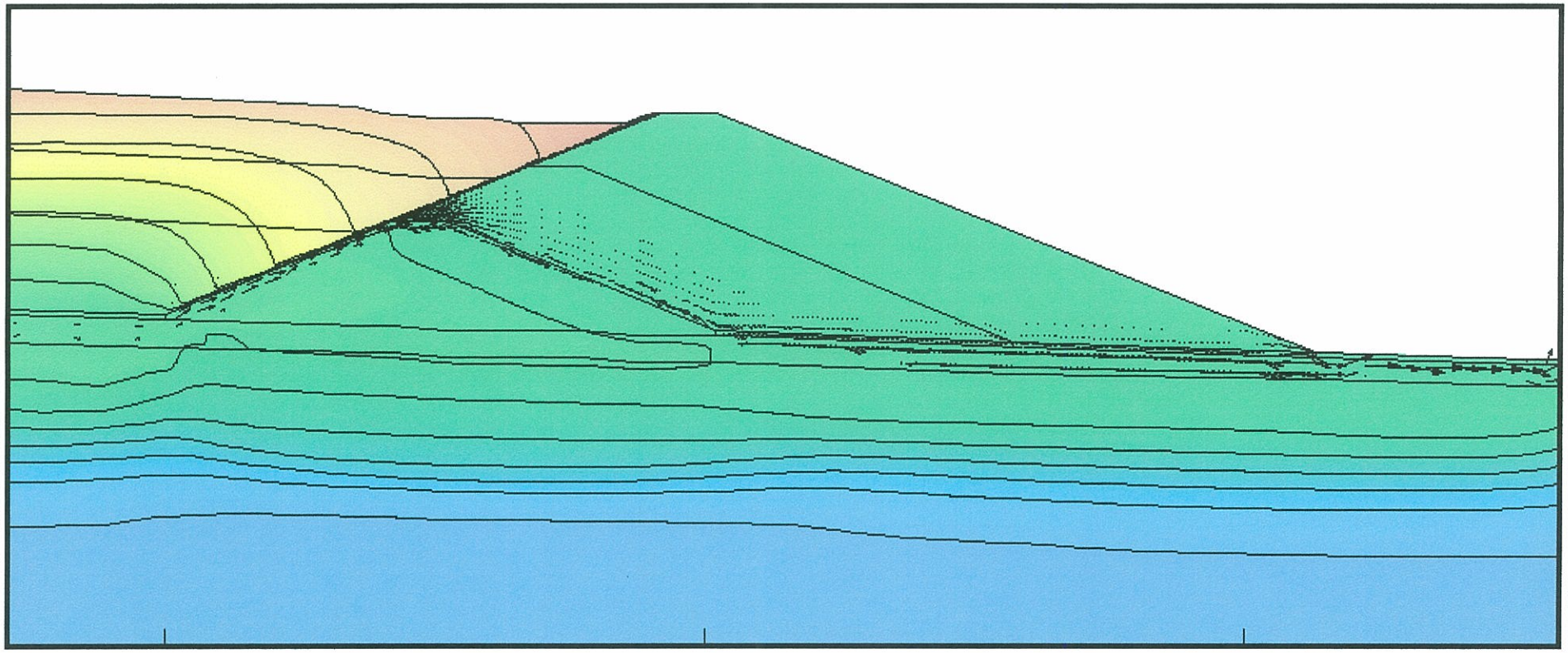
0 20 40

Meters

Thermal Contour Map
Scenario 4 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-4t



Scale 1:1

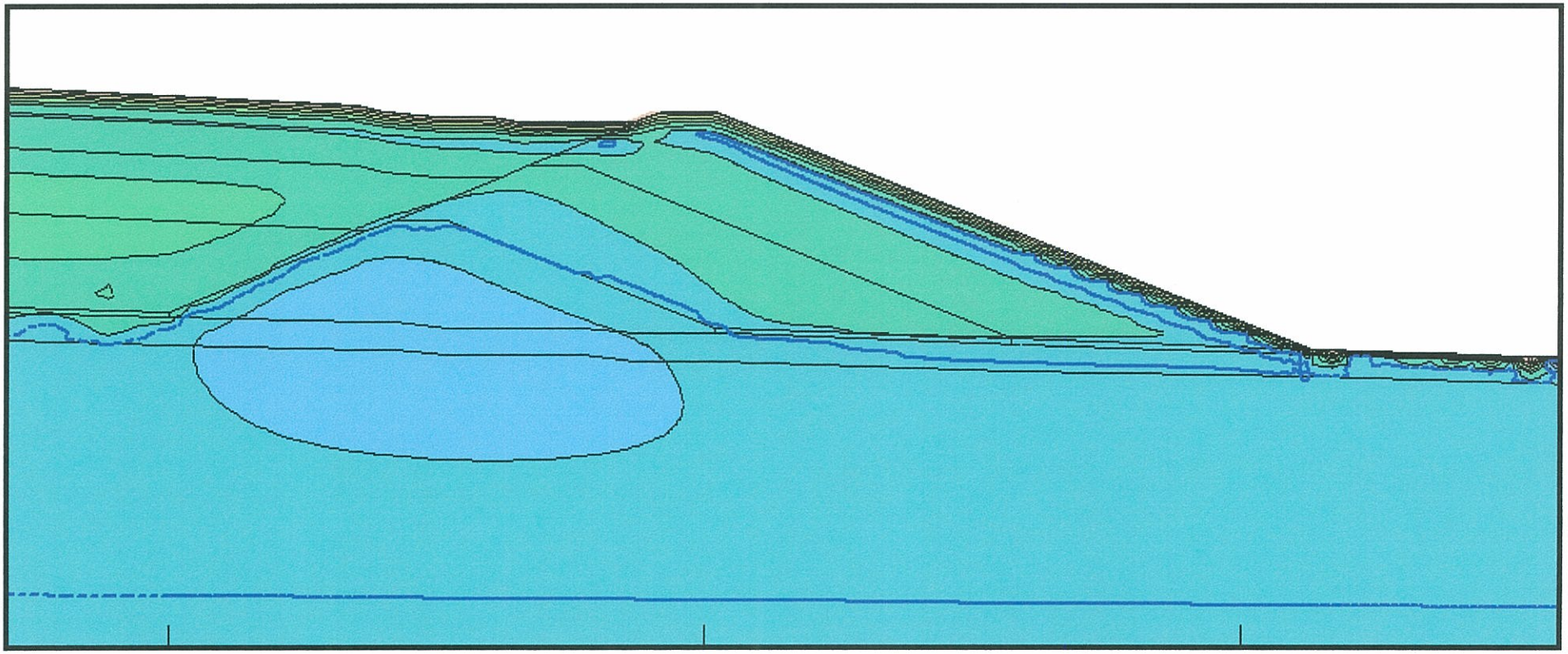
0 20 40

Meters

Hydraulic head Contour Map
Scenario 5 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-5h



Scale 1:1

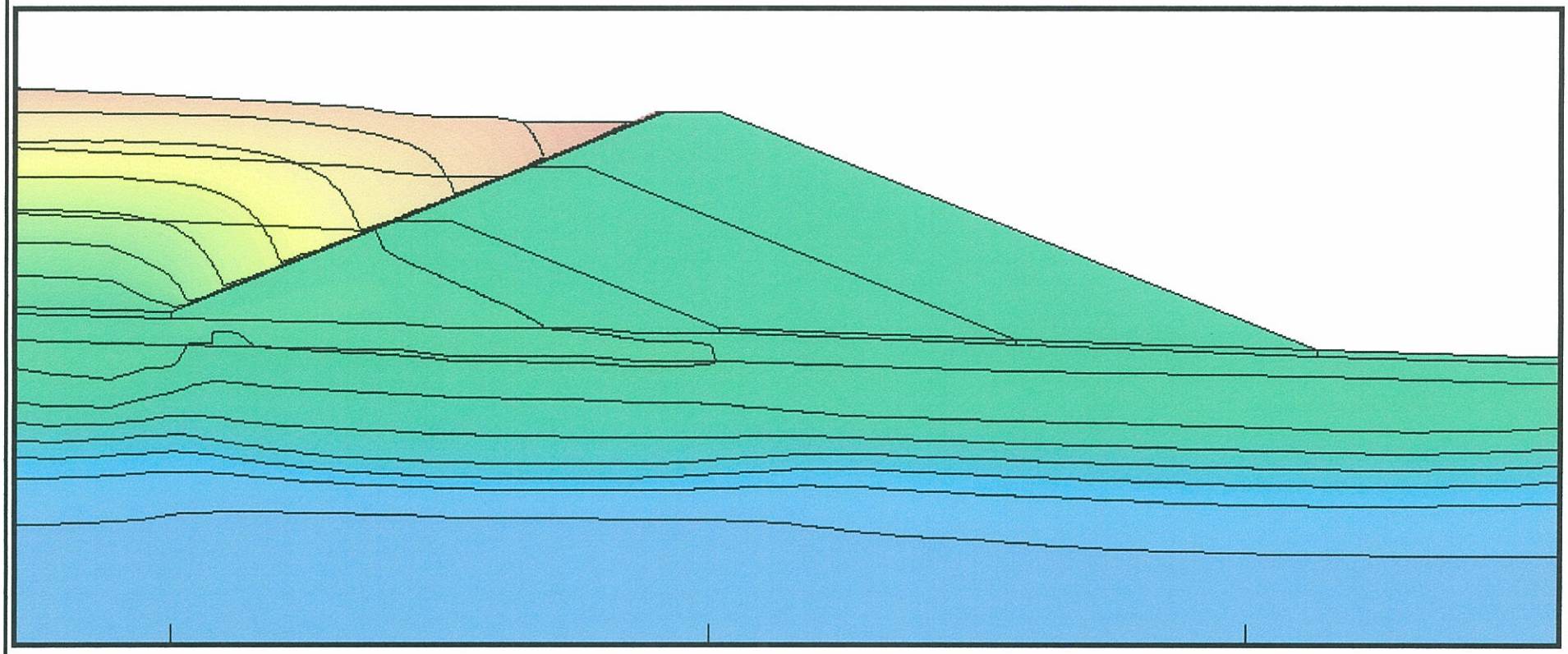
0 20 40

Meters

Thermal Contour Map
Scenario 5 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-5t



Scale 1:1

0 20 40

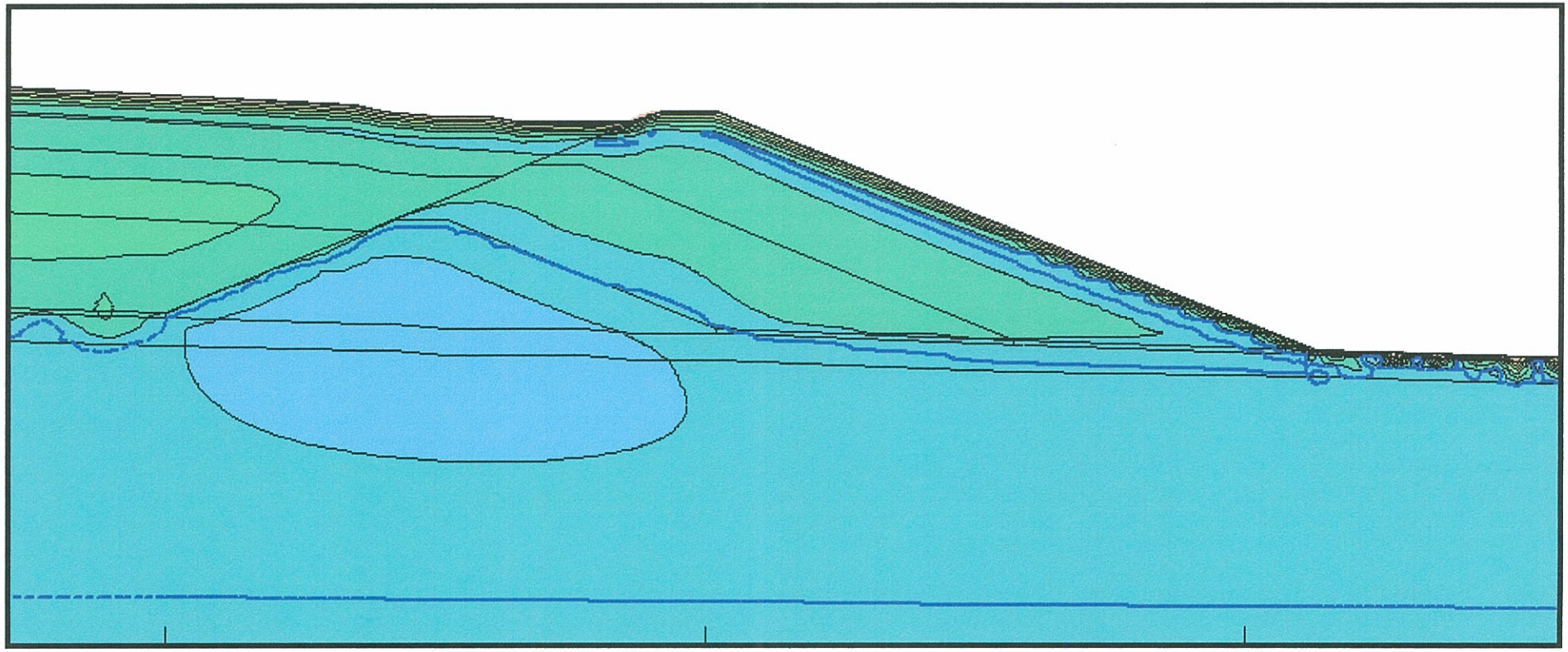
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 6 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-6h



Scale 1:1

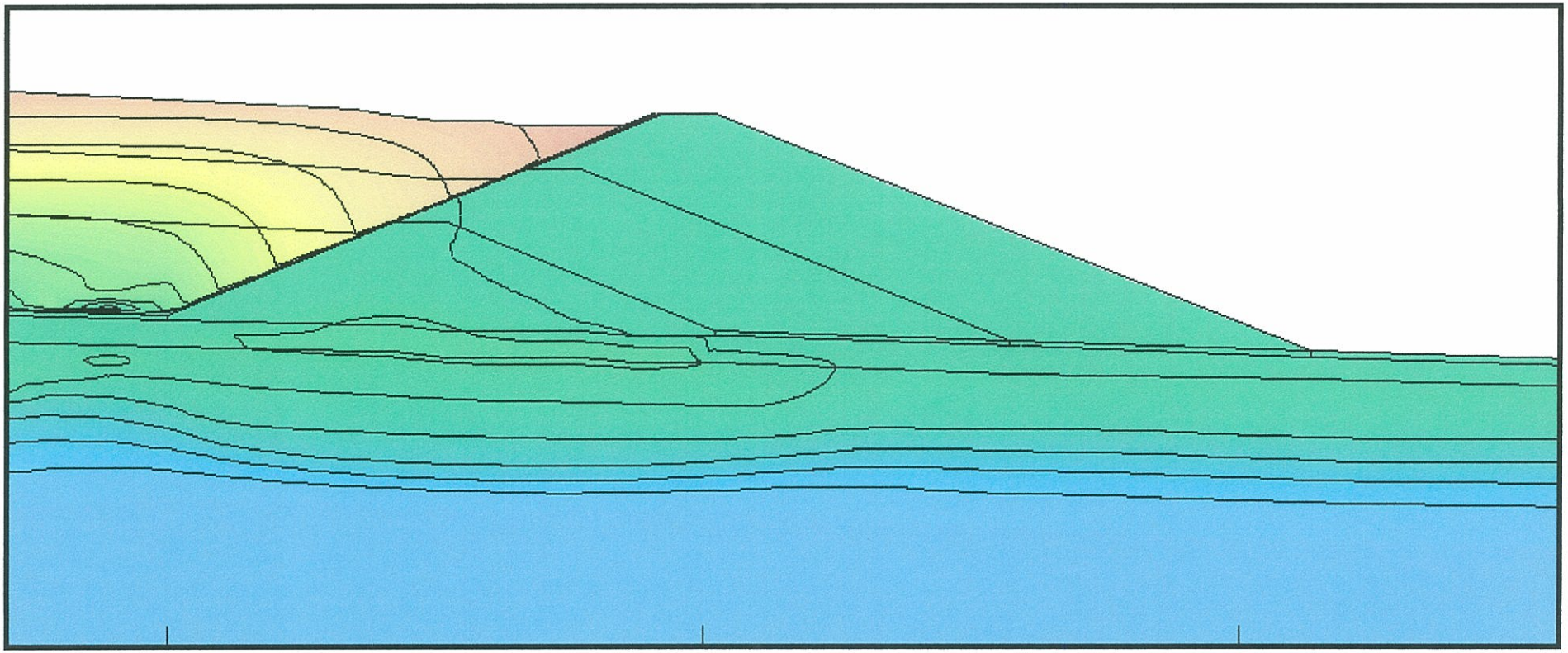
0 20 40

Meters

Thermal Contour Map
Scenario 6 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-6t



Scale 1:1

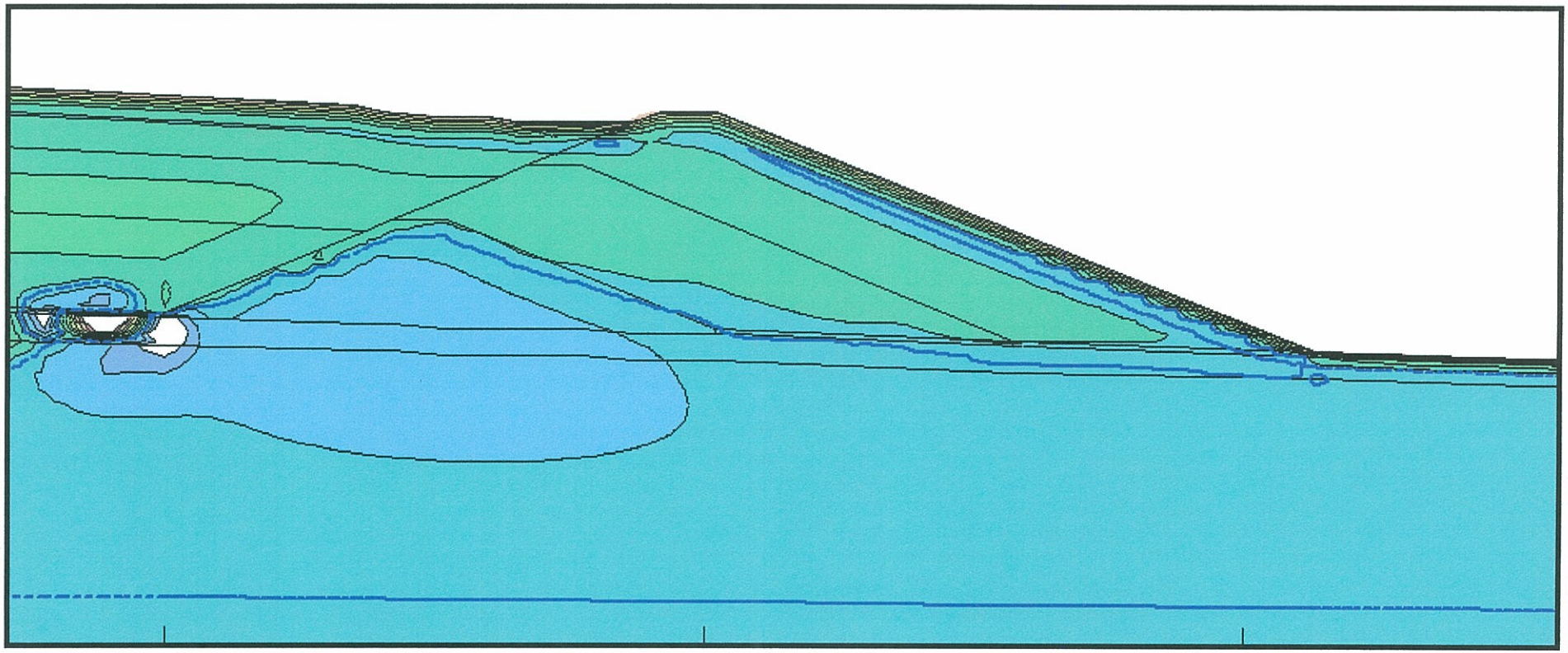
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 7 – Phase 3 – AUG 05

Rock Creek Dam,
Nome, Alaska

H-7h



Scale 1:1

0 20 40

Meters

Thermal Contour Map
Scenario 7 – Phase 3 – AUG 05

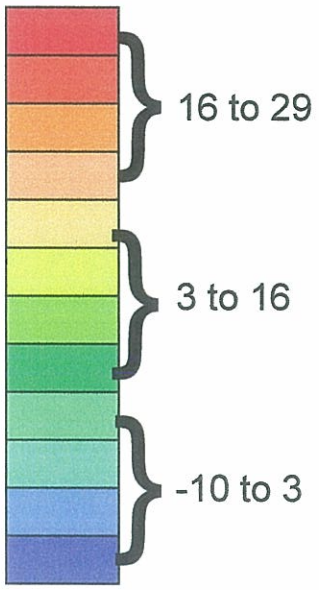
Rock Creek Dam,
Nome, Alaska

H-7t

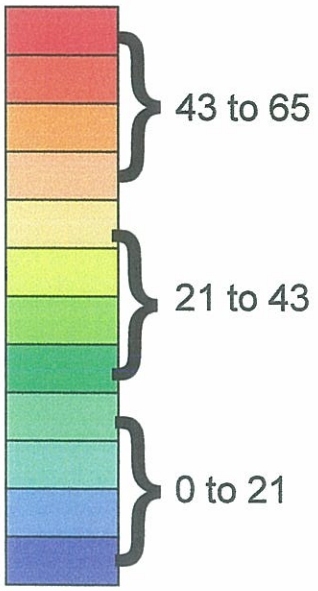
APPENDIX I

SCENARIO 2
PHASE III TIME STEP
RESULTS

Thermal Contour Gradient (Degrees Celsius)



Hydraulic Contour Gradient (Meters above MSL)



= Freeze/thaw Interface

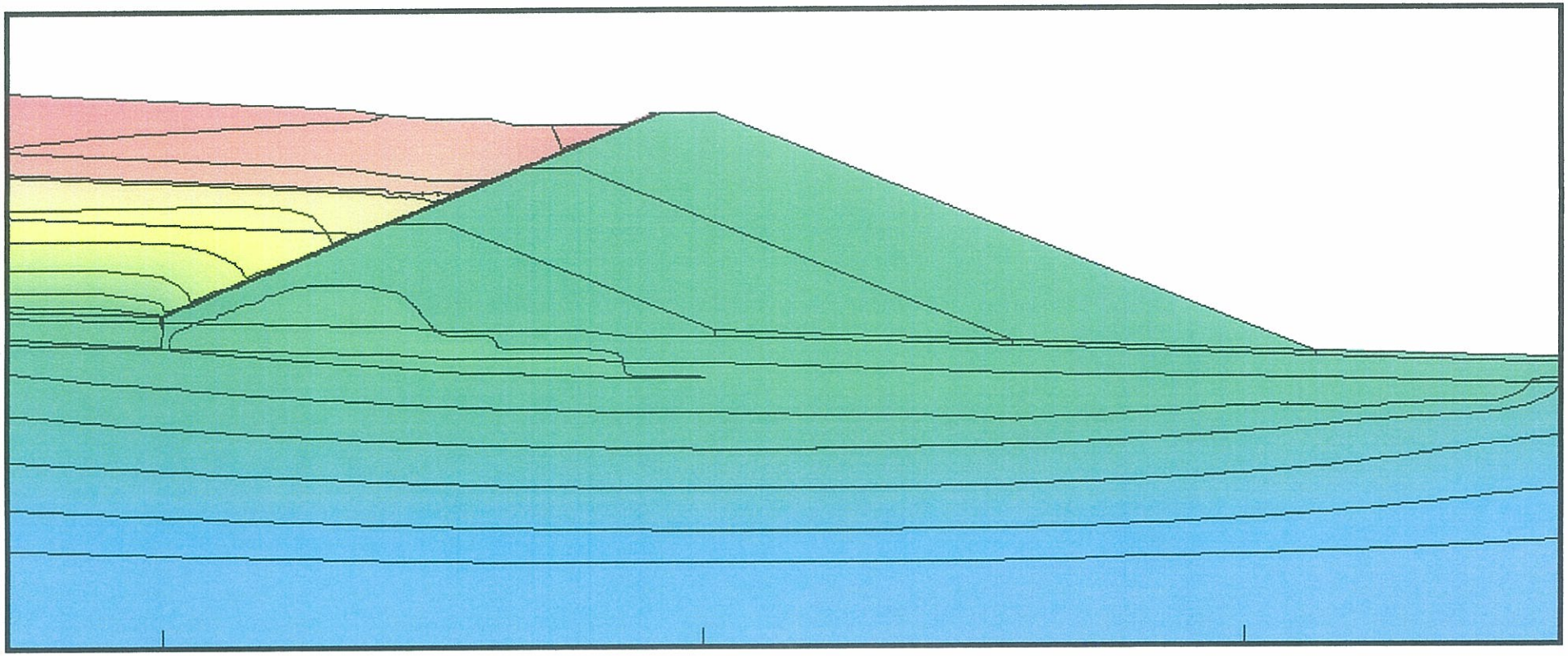
= Contour Interval Line

Scenario 2 = Current site conditions w/ liner material extended into weathered bedrock unit and w/ no thermosyphons

APPENDIX I KEY

Rock Creek Dam,
Nome, Alaska

I - 0



Scale 1:1

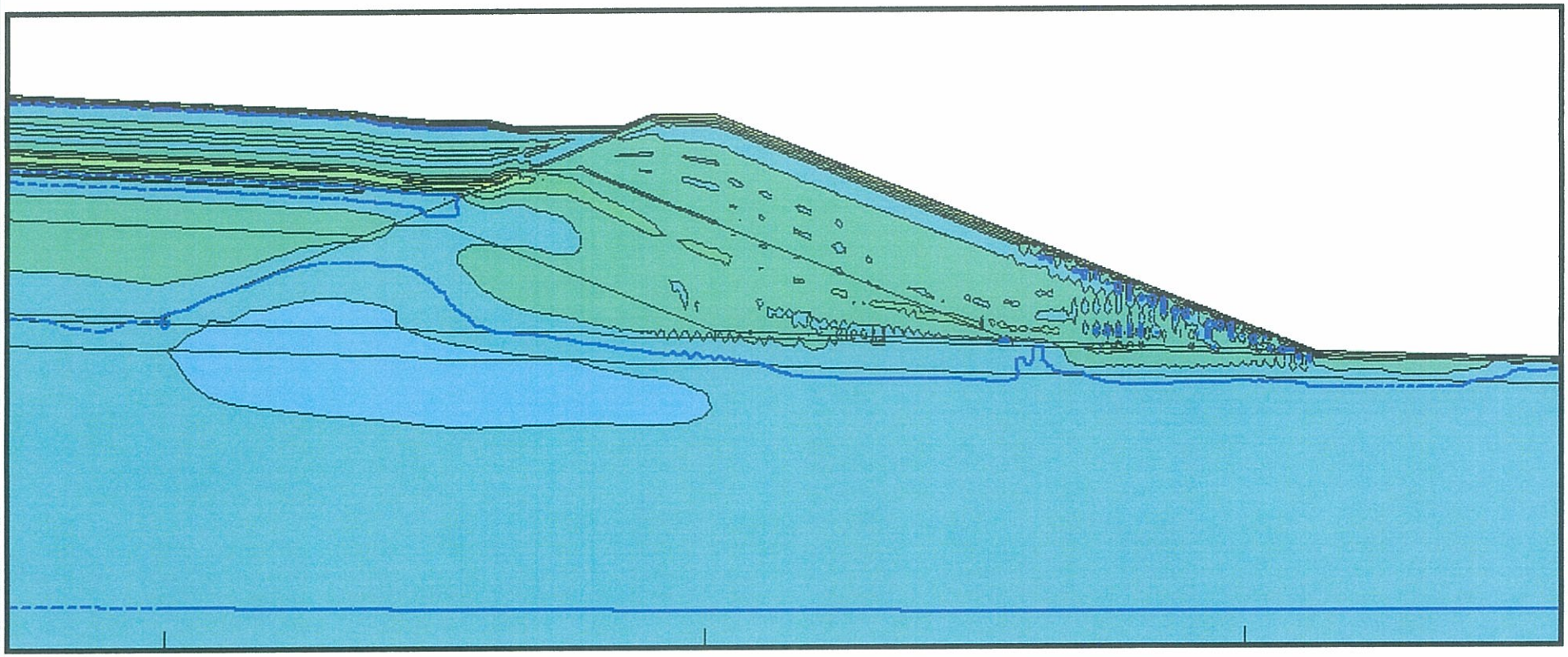
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 20
Aug 5 / 04

Rock Creek Dam,
Nome, Alaska

I-1h



Scale 1:1

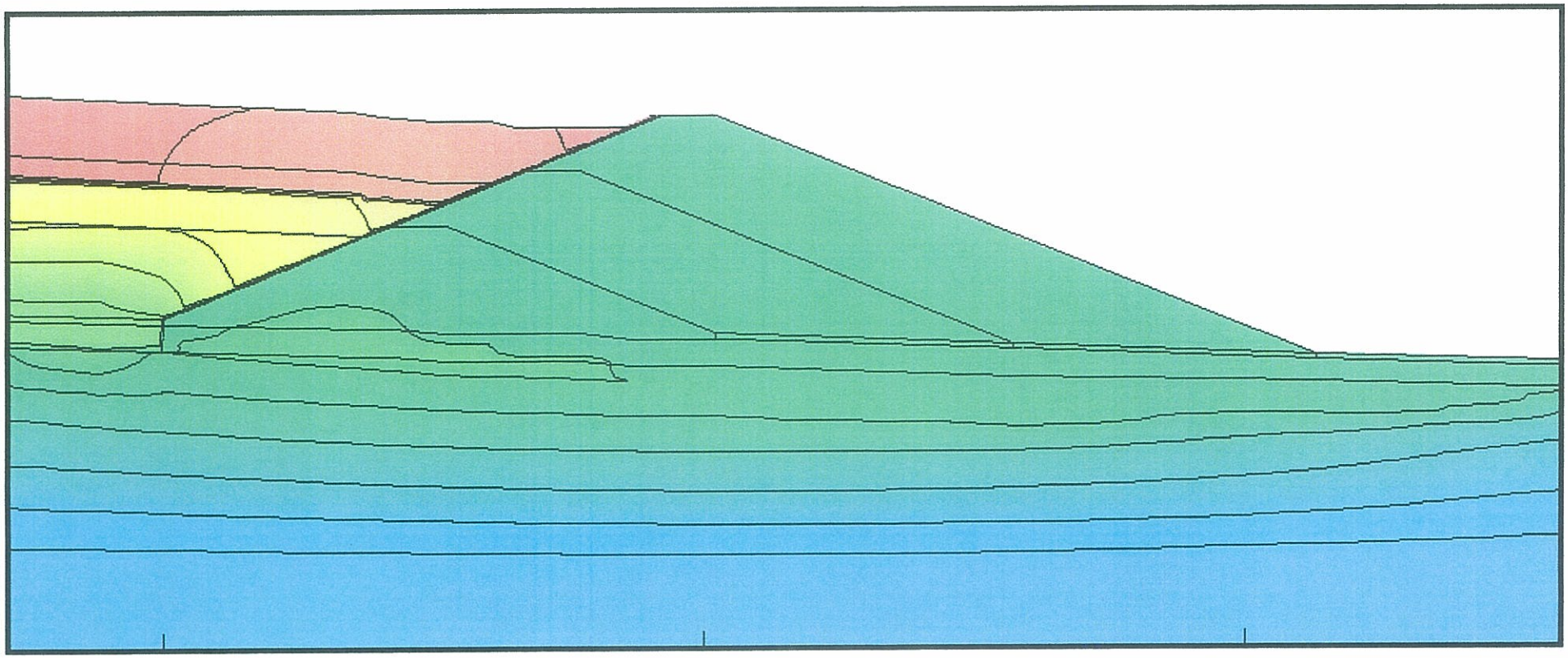
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 20
Aug 5 / 04

Rock Creek Dam,
Nome, Alaska

I-1t



Scale 1:1

0 20 40

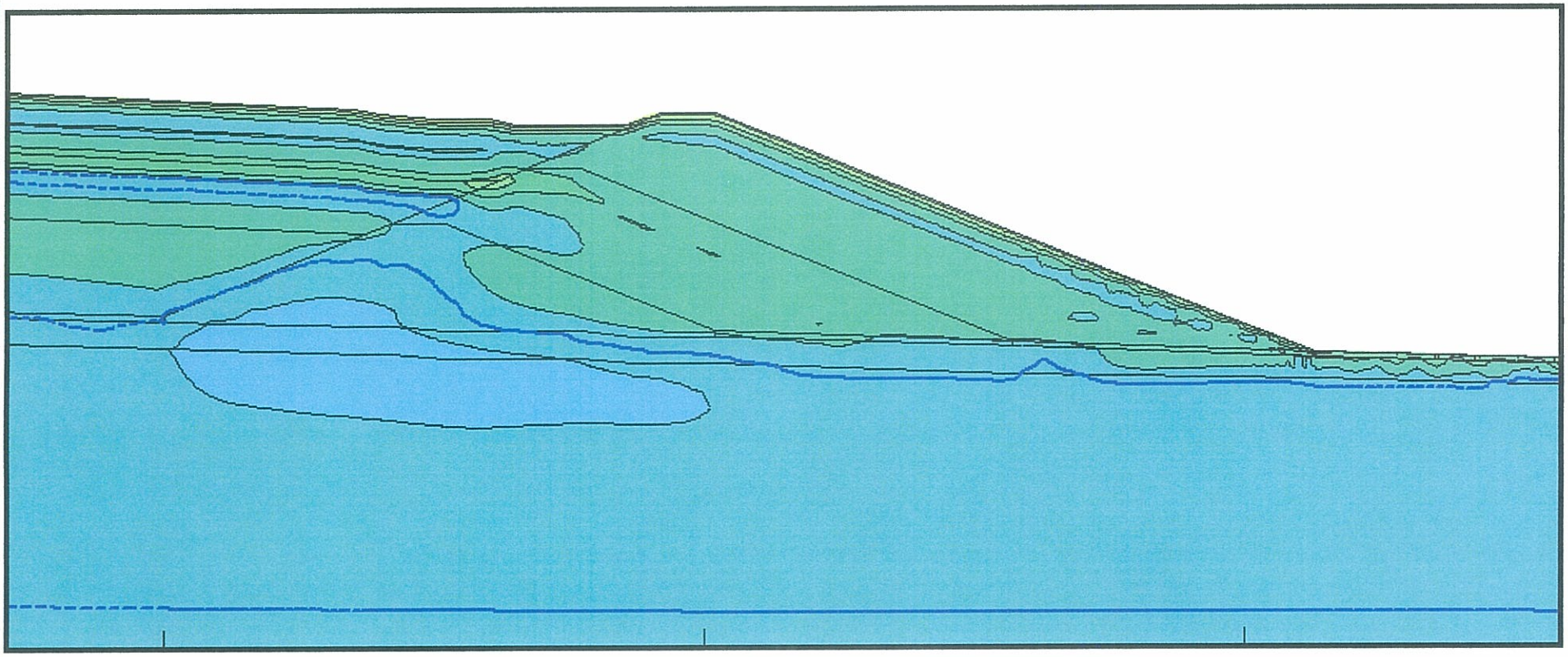
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 100
Aug 25 / 04

Rock Creek Dam,
Nome, Alaska

I-2h



Scale 1:1

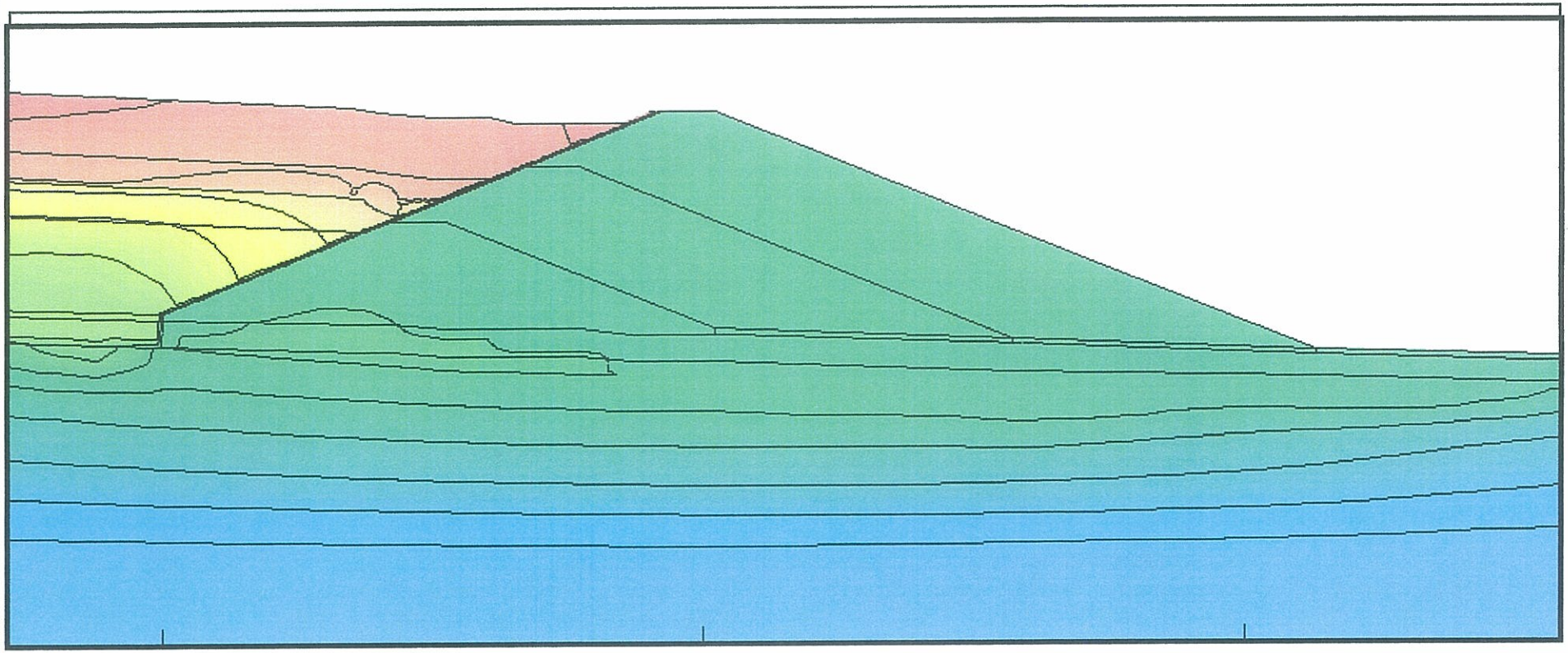
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 100
Aug 25 / 04

Rock Creek Dam,
Nome, Alaska

I-2t



Scale 1:1

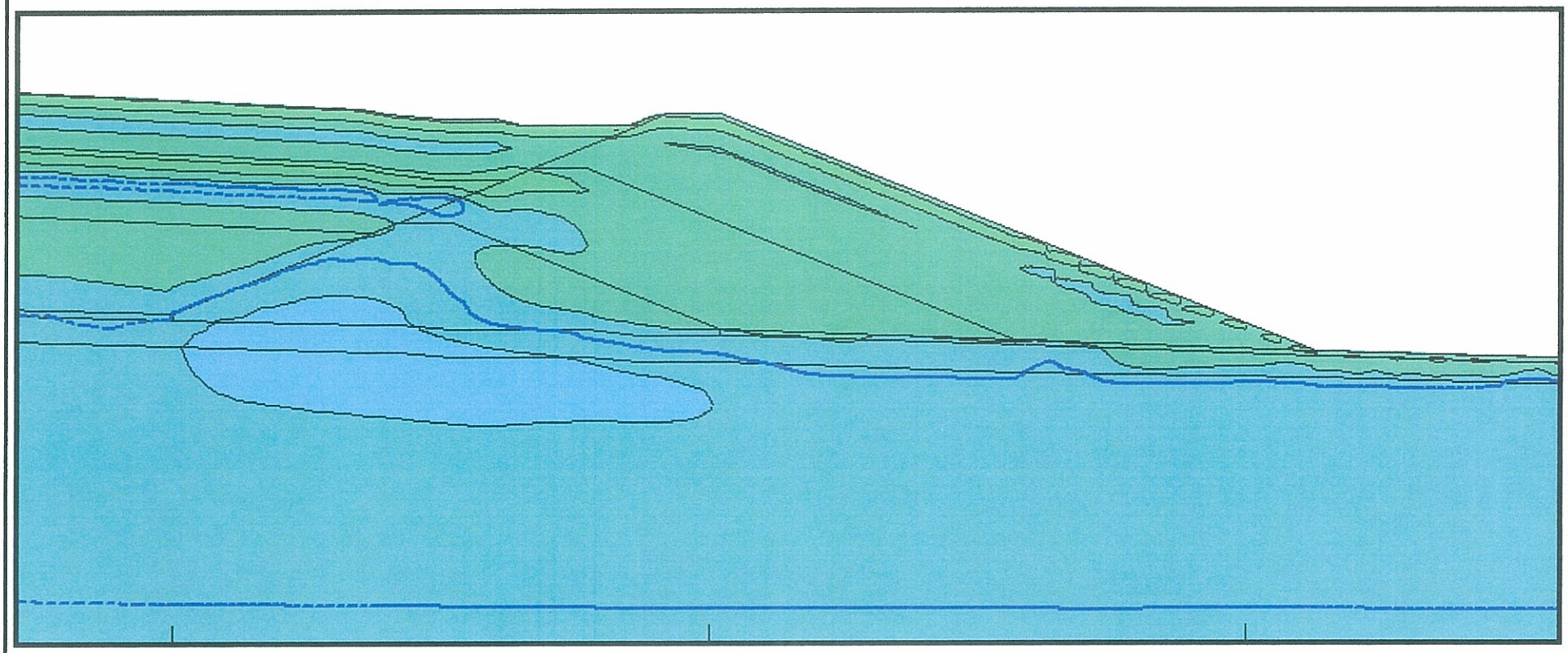
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 180
Sept 15 / 04

Rock Creek Dam,
Nome, Alaska

I-3h



Scale 1:1

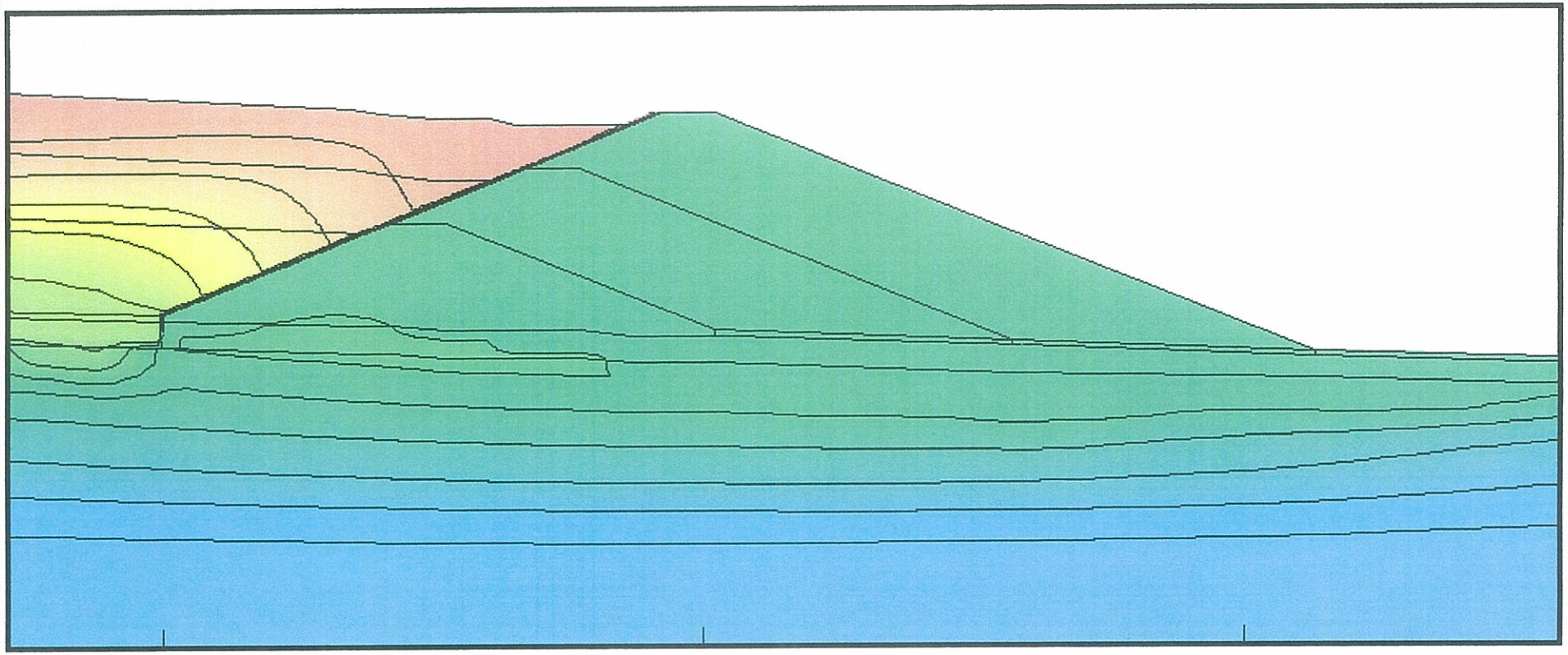
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 180
Sept 15 / 04

Rock Creek Dam,
Nome, Alaska

I-3t



Scale 1:1

0 20 40

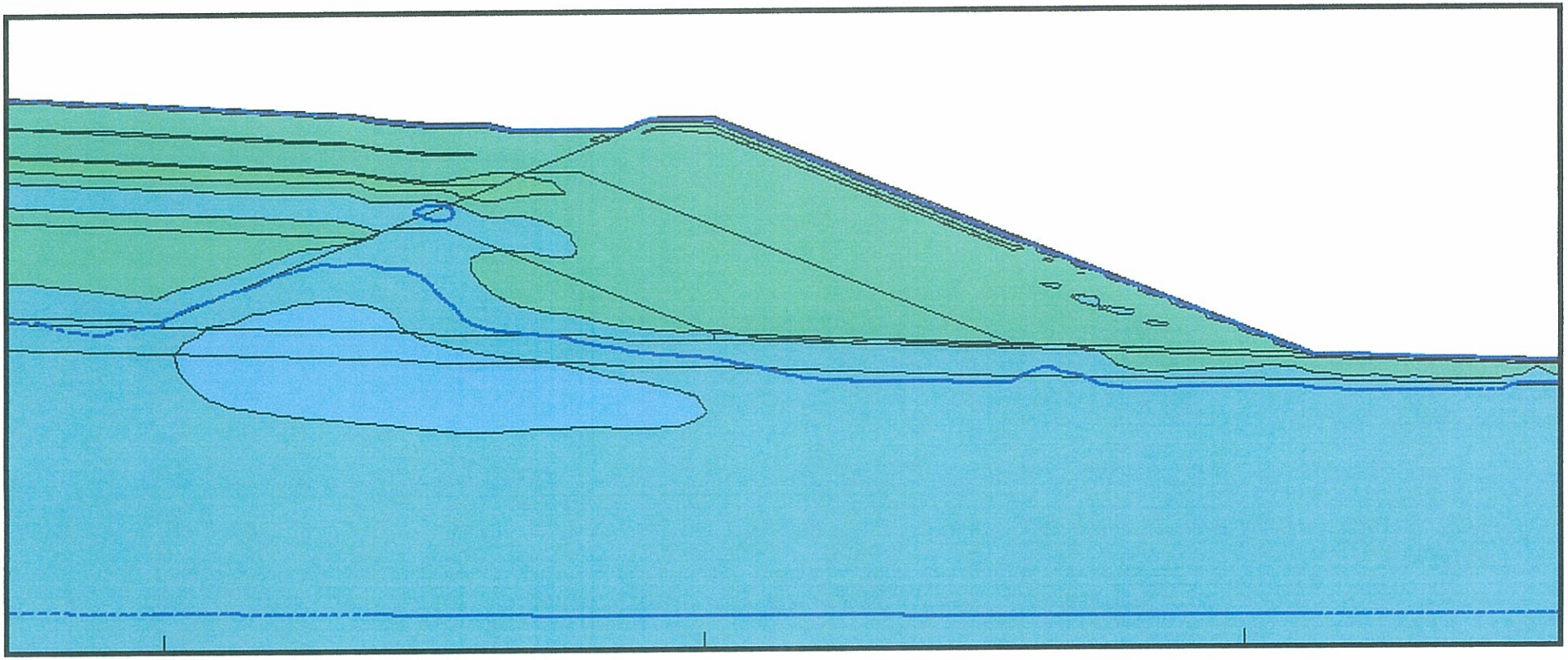
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 260
Oct 5 / 04

Rock Creek Dam,
Nome, Alaska

I-4h



Scale 1:1

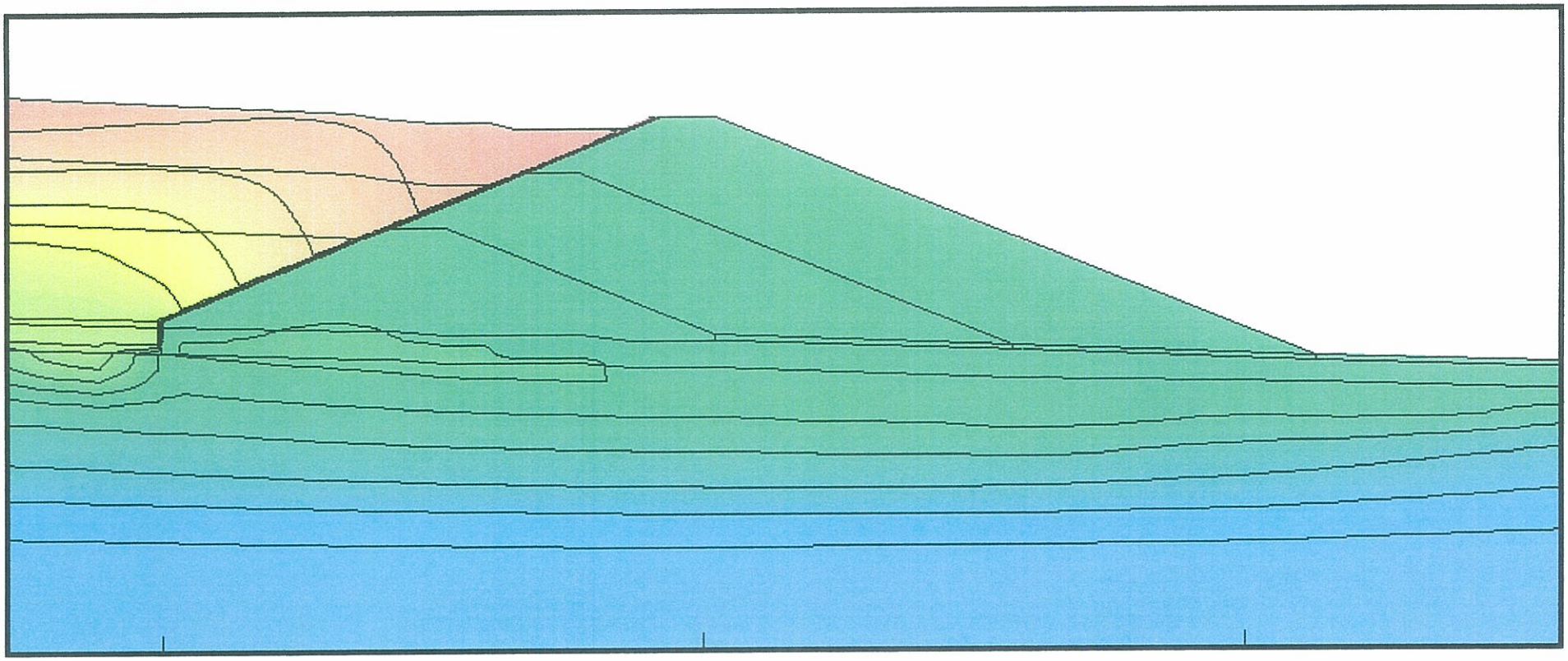
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 260
Oct 5 / 04

Rock Creek Dam,
Nome, Alaska

I-4t



Scale 1:1

0 20 40

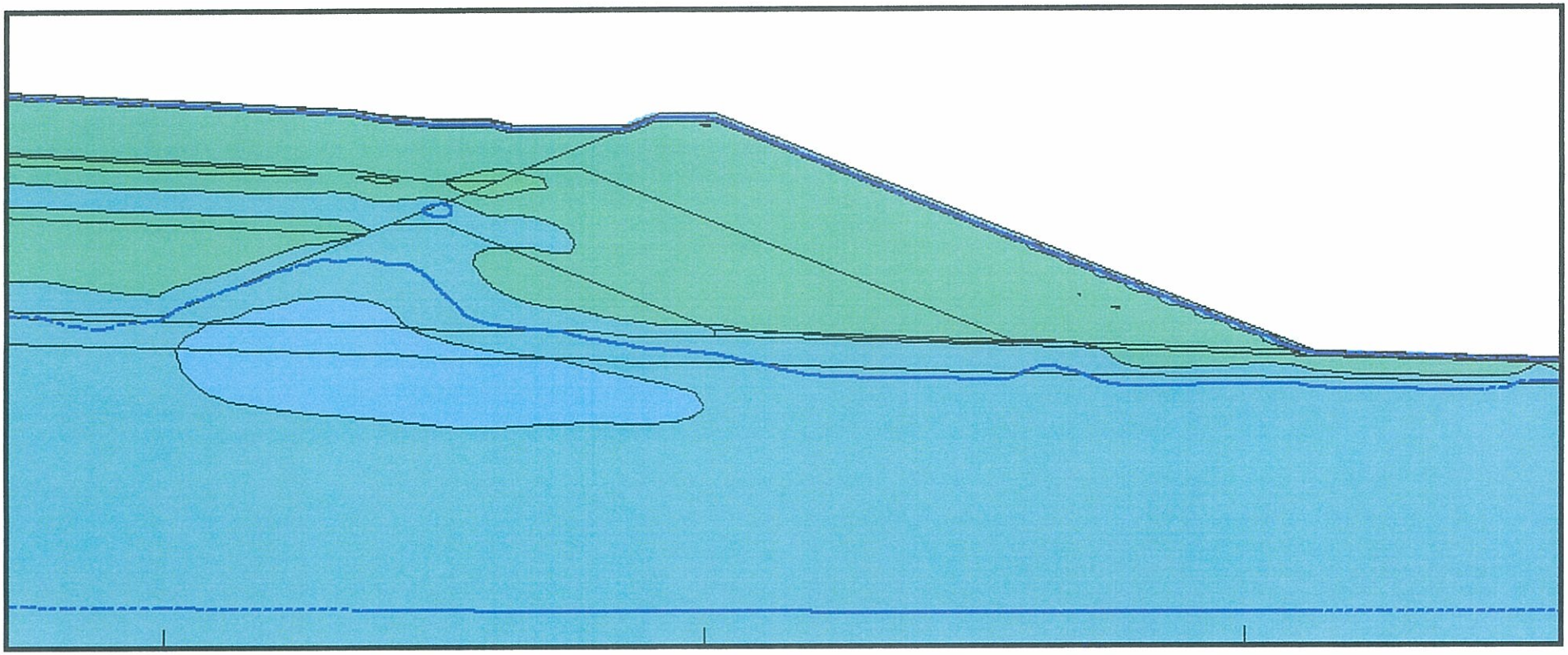
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 340
Oct 25 / 04

Rock Creek Dam,
Nome, Alaska

I-5h



Scale 1:1

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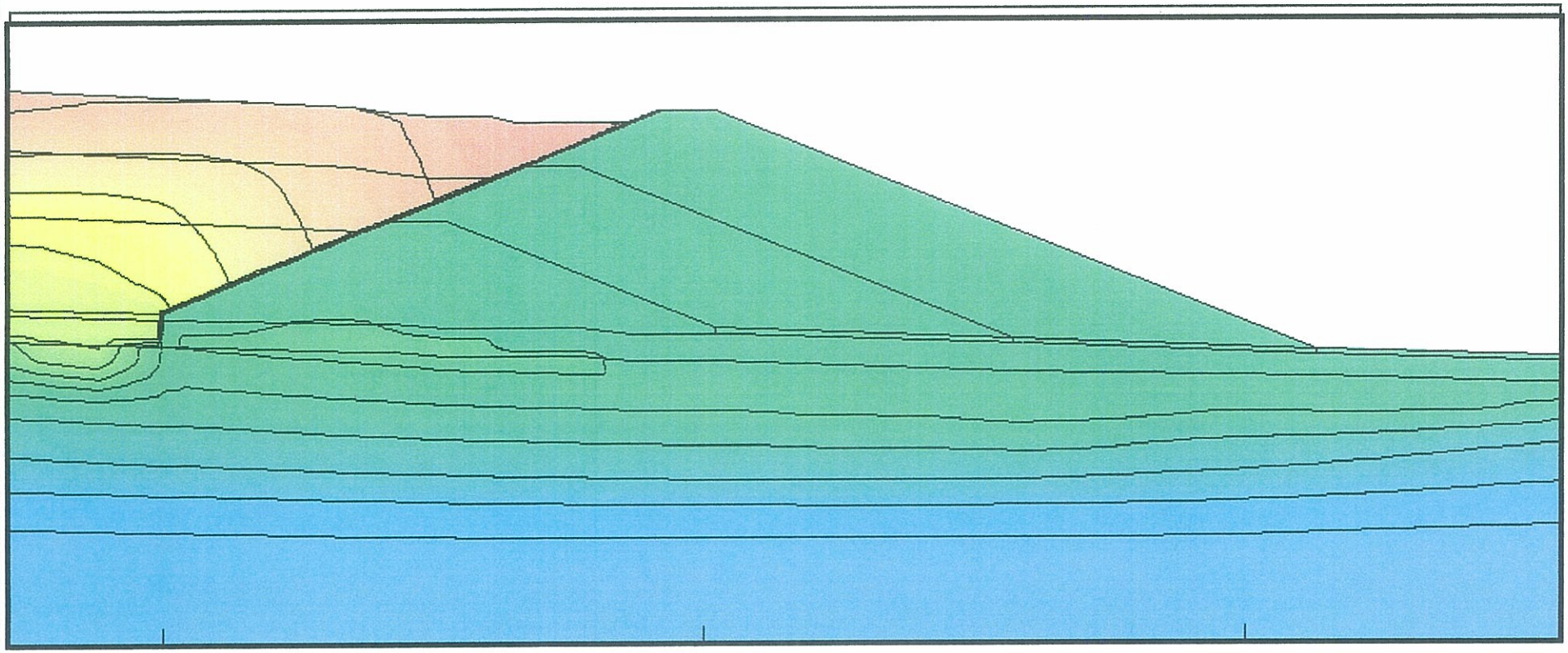
Meters

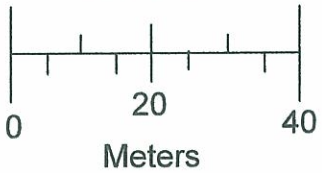
Thermal Contour Map
Scenario 2 – Phase 3 – Time step 340
Oct 25 / 04

Rock Creek Dam,
Nome, Alaska

I-5t



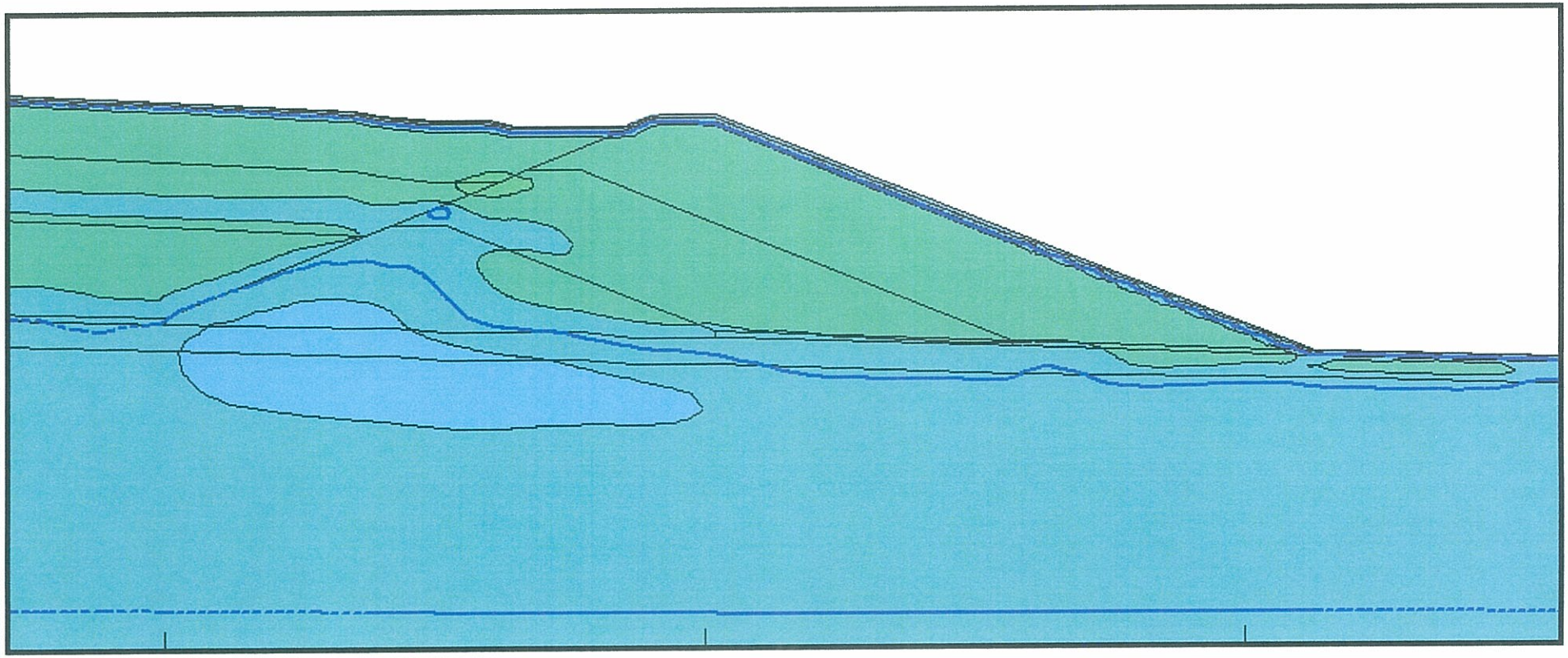
Scale 1:1



Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 420
Nov 15 / 04

Rock Creek Dam,
Nome, Alaska

I-6h



Scale 1:1

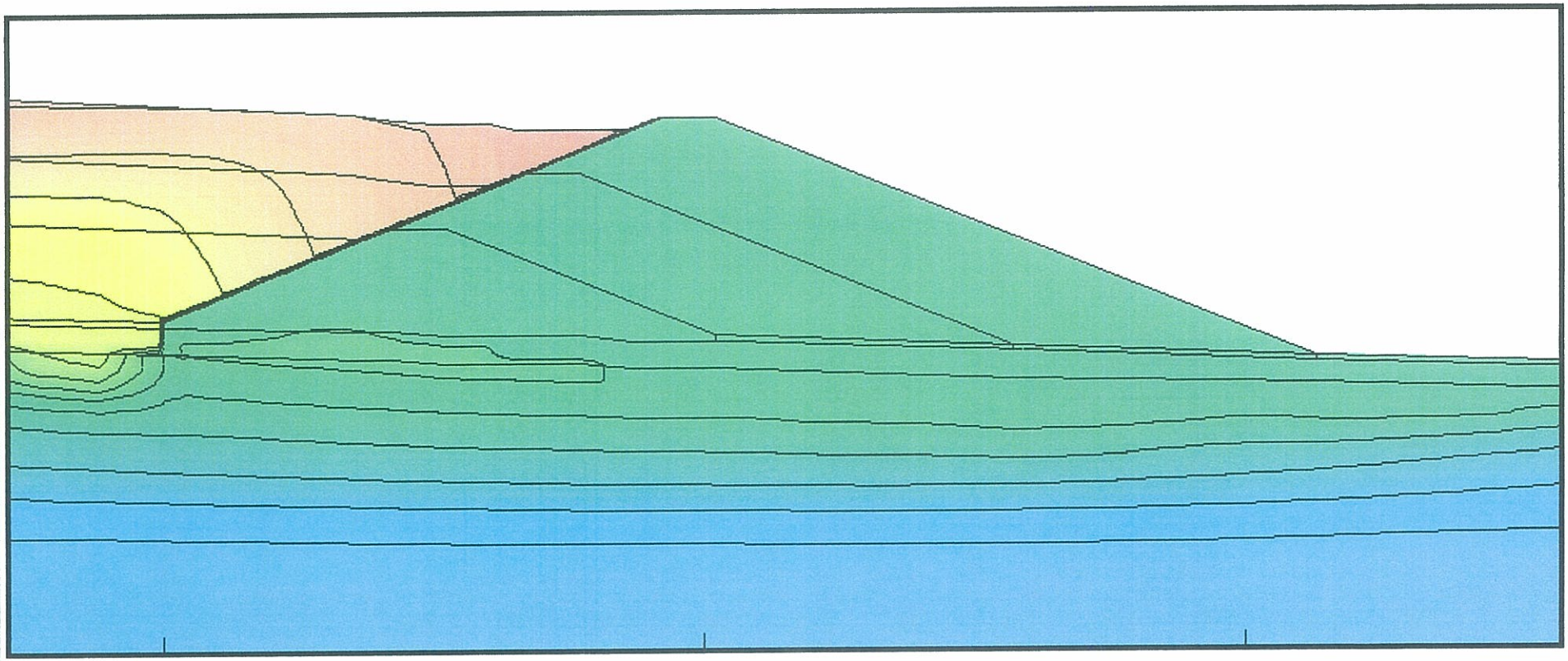
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 420
Nov 15 / 04

Rock Creek Dam,
Nome, Alaska

I-6t



Scale 1:1

0 20 40

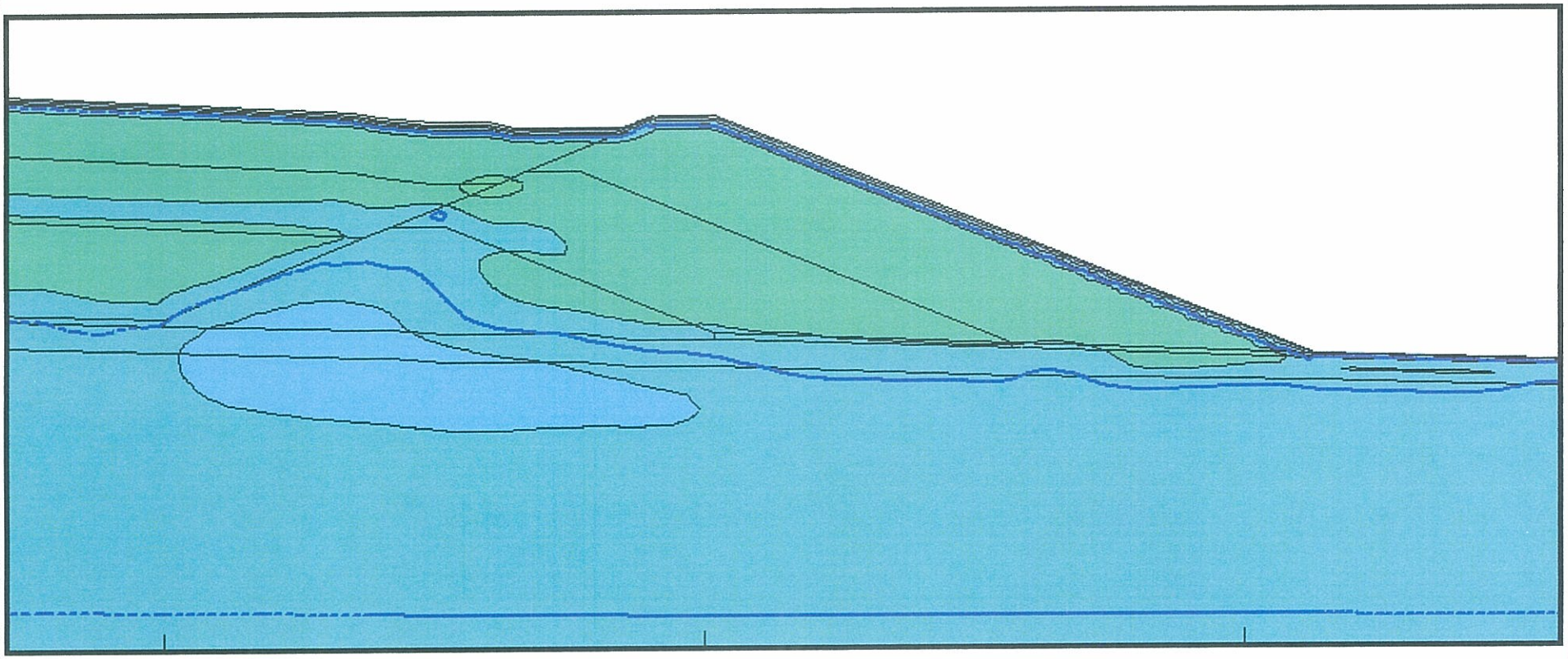
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 500
Dec 5 / 04

Rock Creek Dam,
Nome, Alaska

I-7h



Scale 1:1

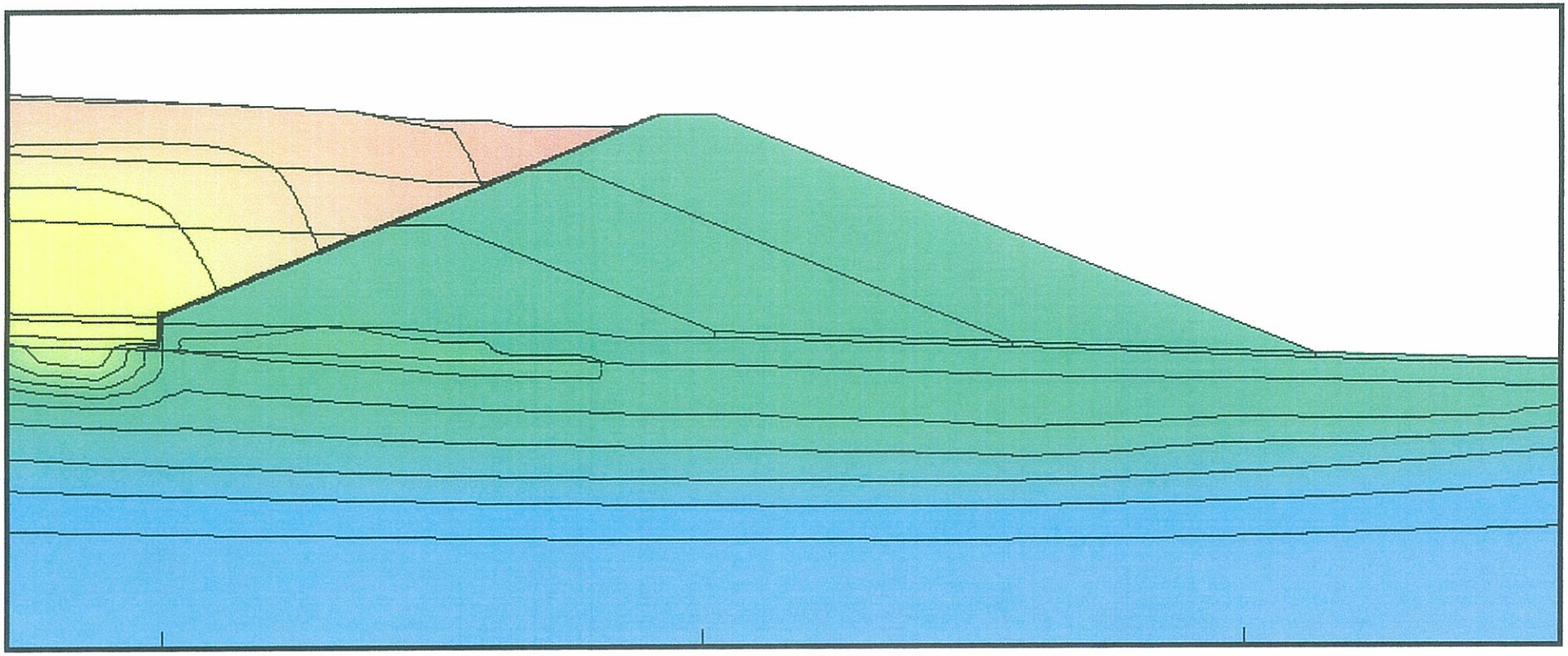
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 500
Dec 5 / 04

Rock Creek Dam,
Nome, Alaska

I-7t



Scale 1:1

0 20 40

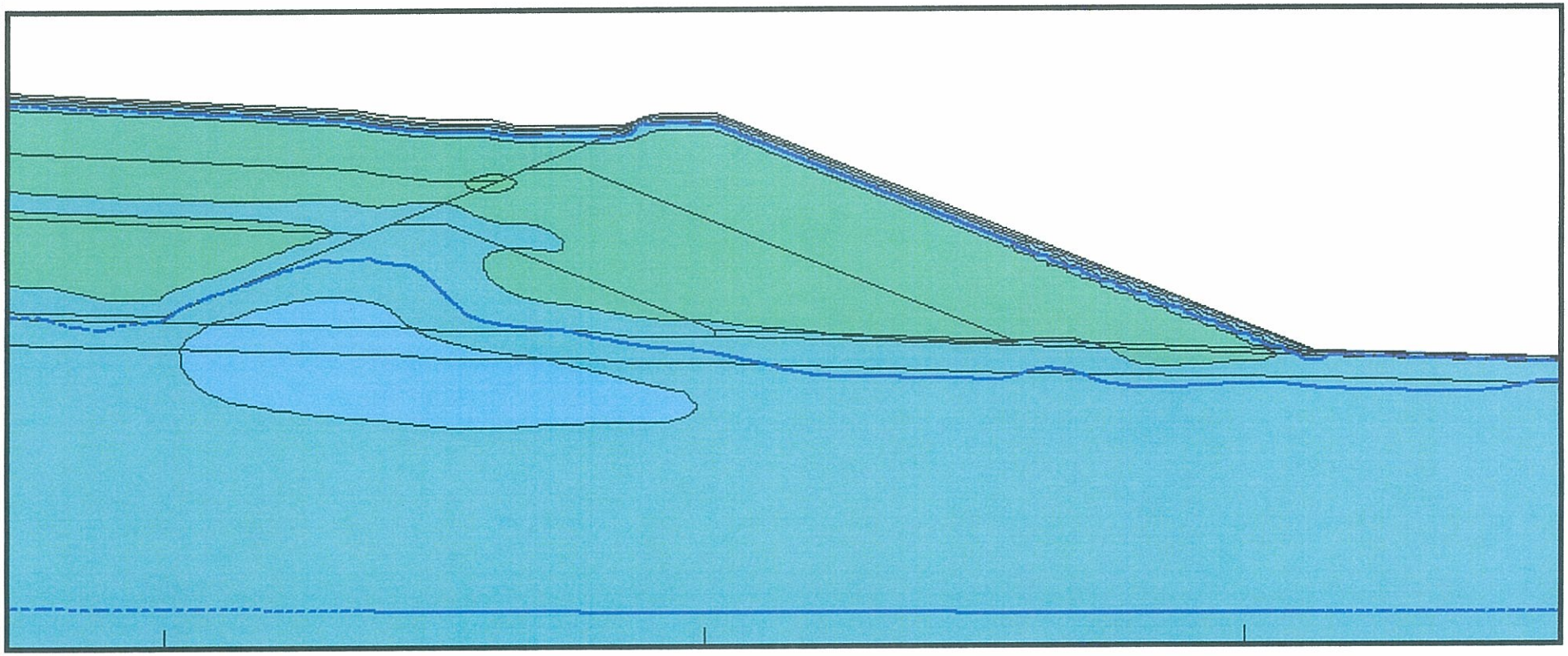
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 580
Dec 25 / 04

Rock Creek Dam,
Nome, Alaska

I-8h



Scale 1:1

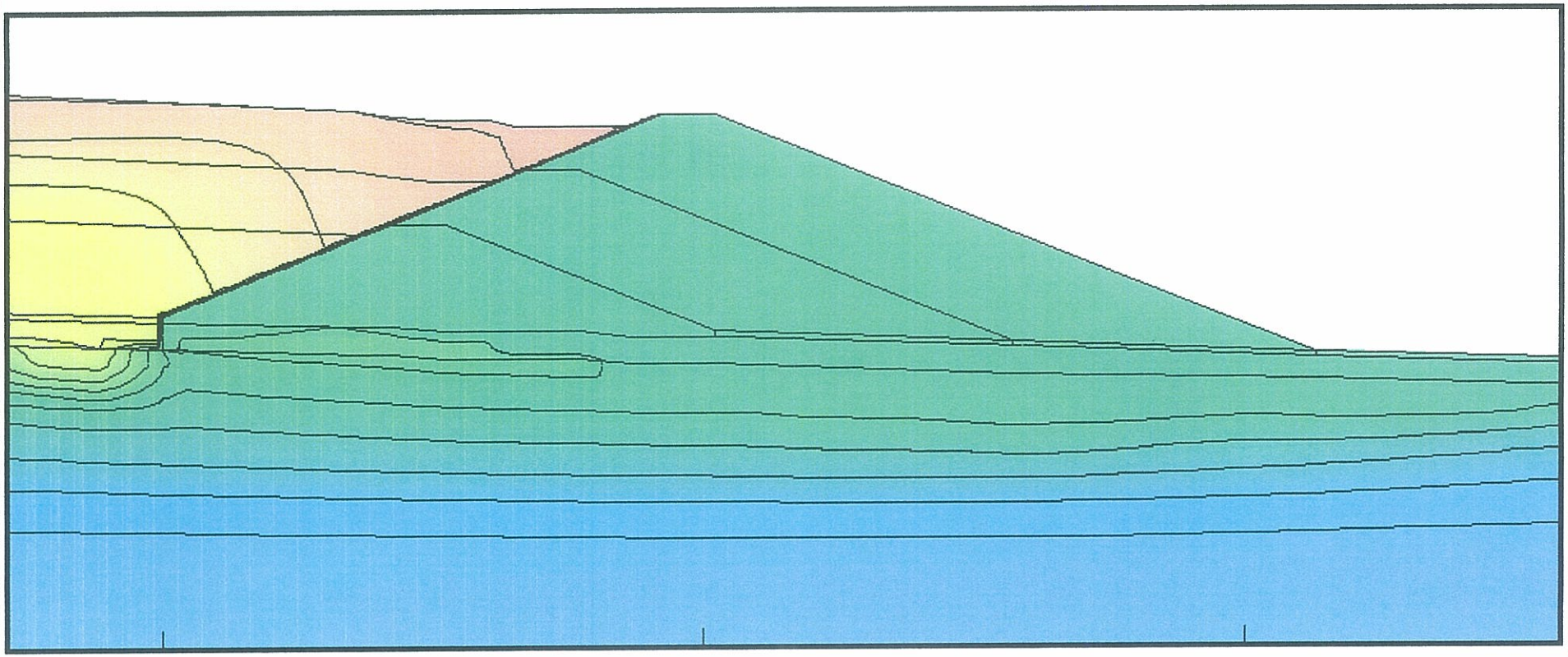
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 580
Dec 25 / 04

Rock Creek Dam,
Nome, Alaska

I-8t



Scale 1:1

0 20 40

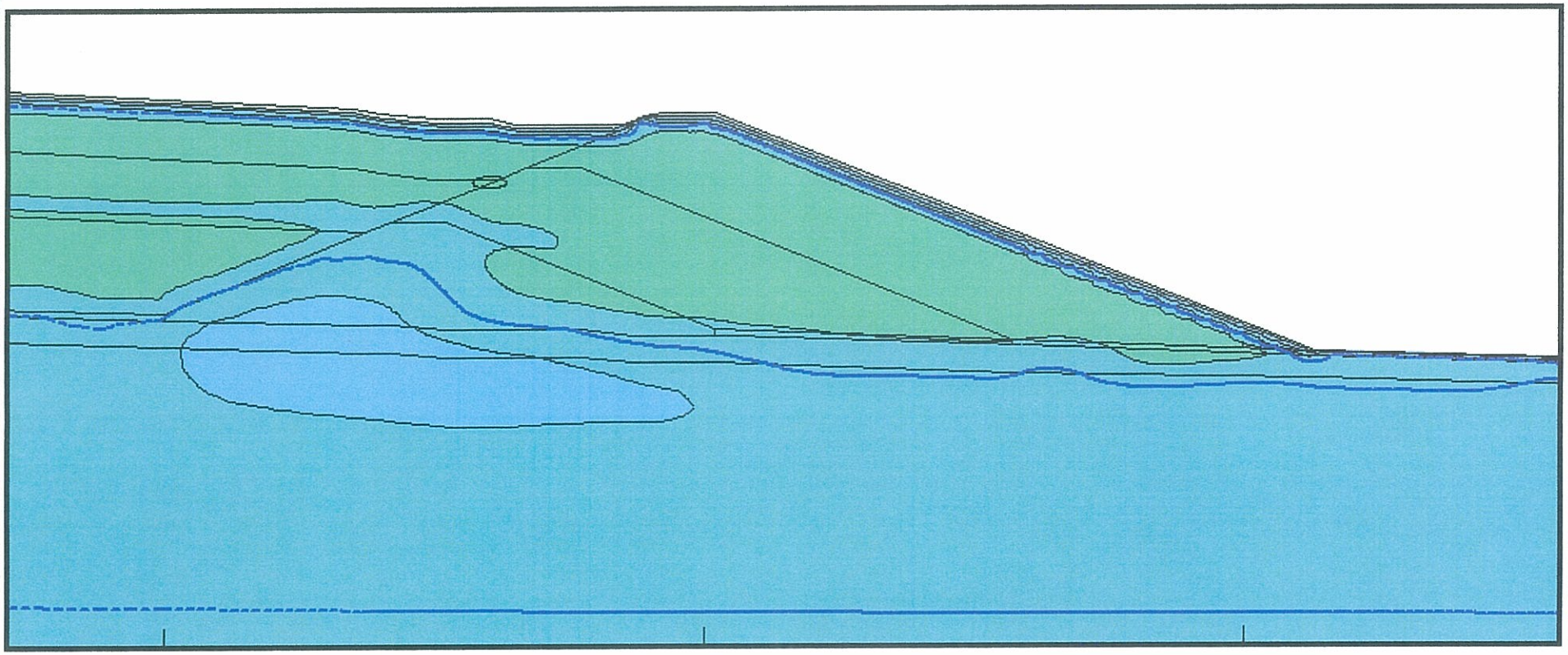
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 660
Jan 15 / 05

Rock Creek Dam,
Nome, Alaska

I-9h



Scale 1:1

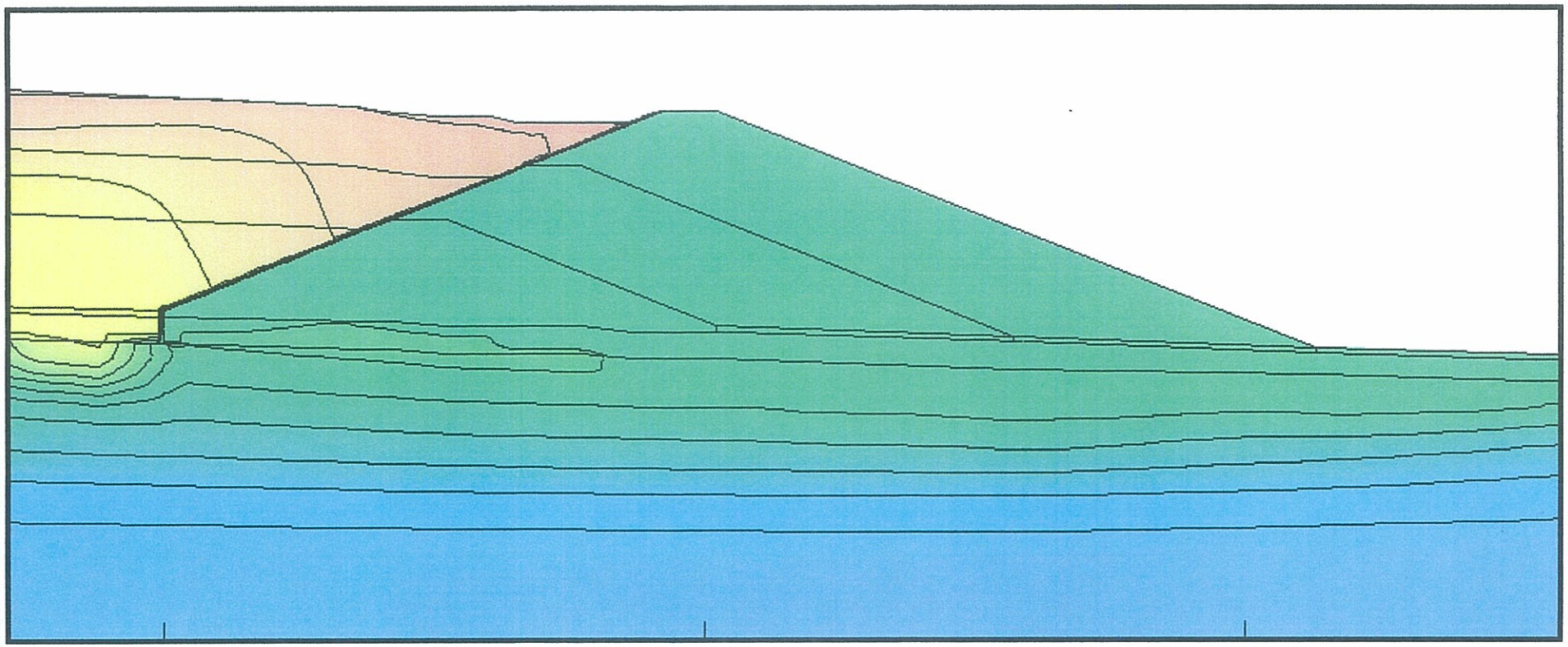
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 660
Jan 15 / 05

Rock Creek Dam,
Nome, Alaska

I-9t



Scale 1:1

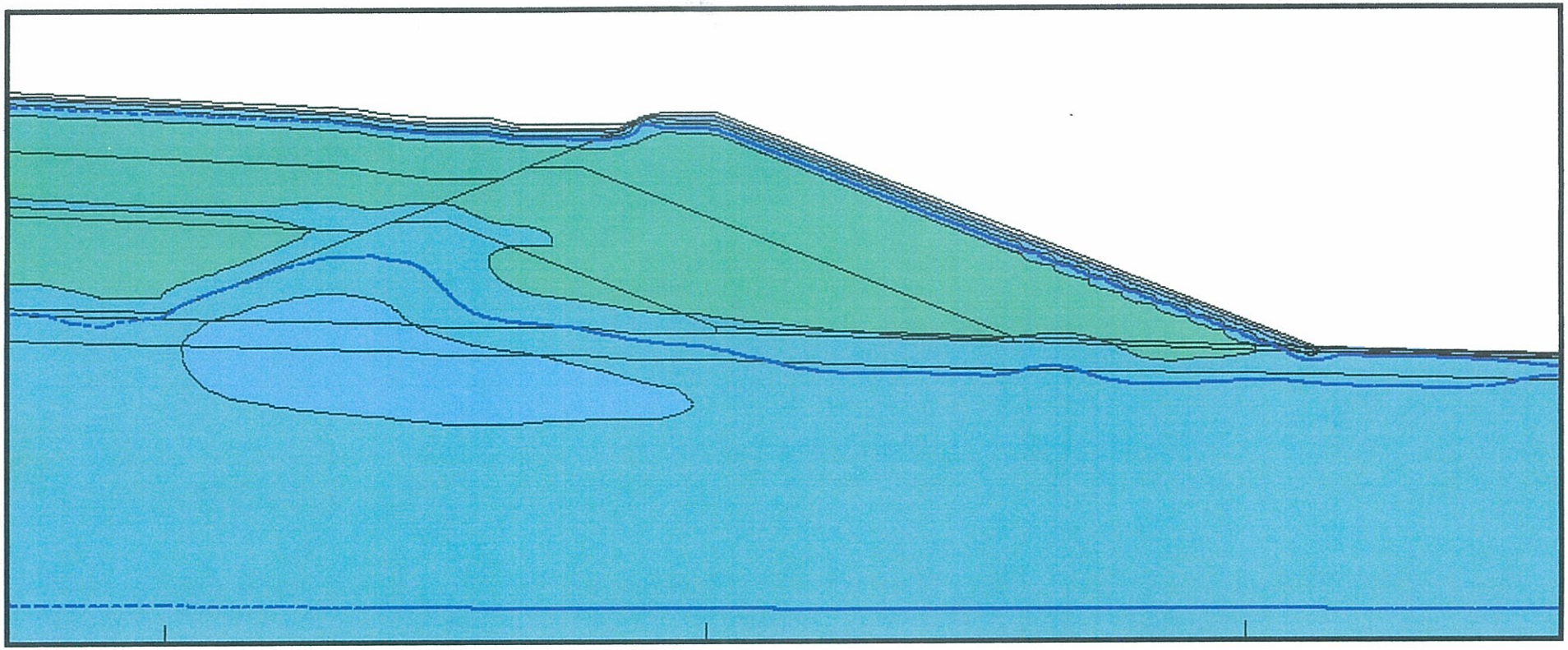
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 740
Feb 5 / 05

Rock Creek Dam,
Nome, Alaska

I-10h



Scale 1:1

0 20 40

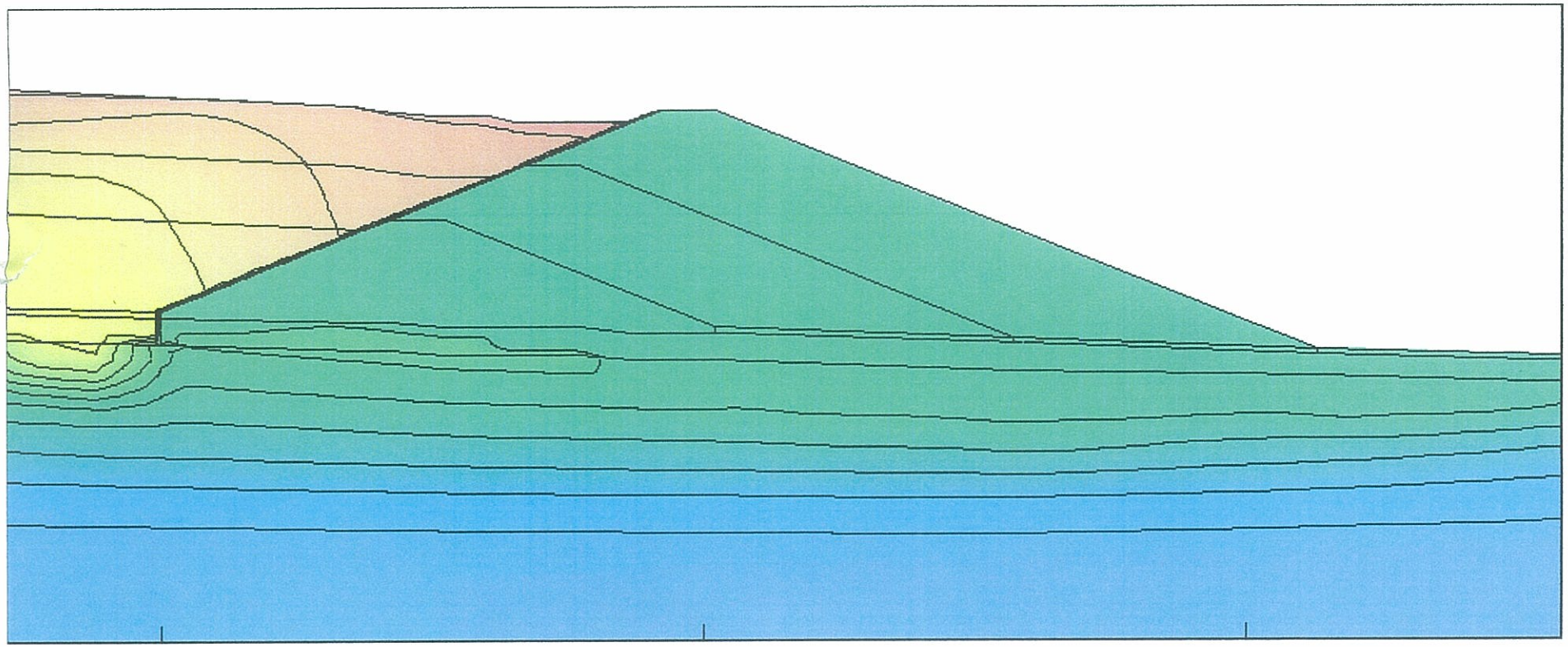
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 740
Feb 5 / 05

Rock Creek Dam,
Nome, Alaska

I-10t



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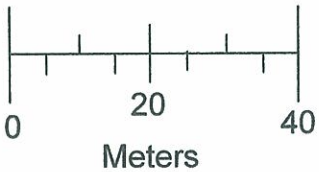
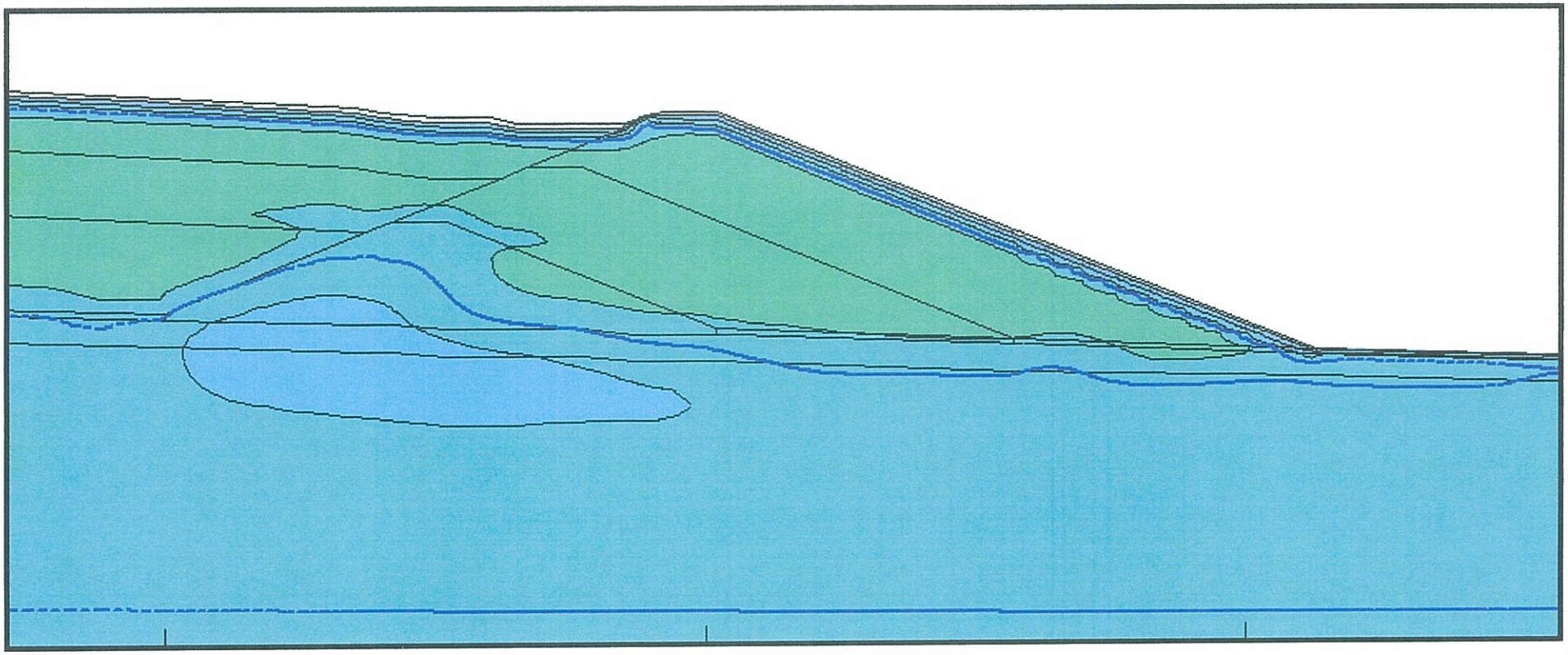


Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 820
Feb 25 / 05

Rock Creek Dam,
Nome, Alaska

I-11h



Scale 1:1

0 20 40

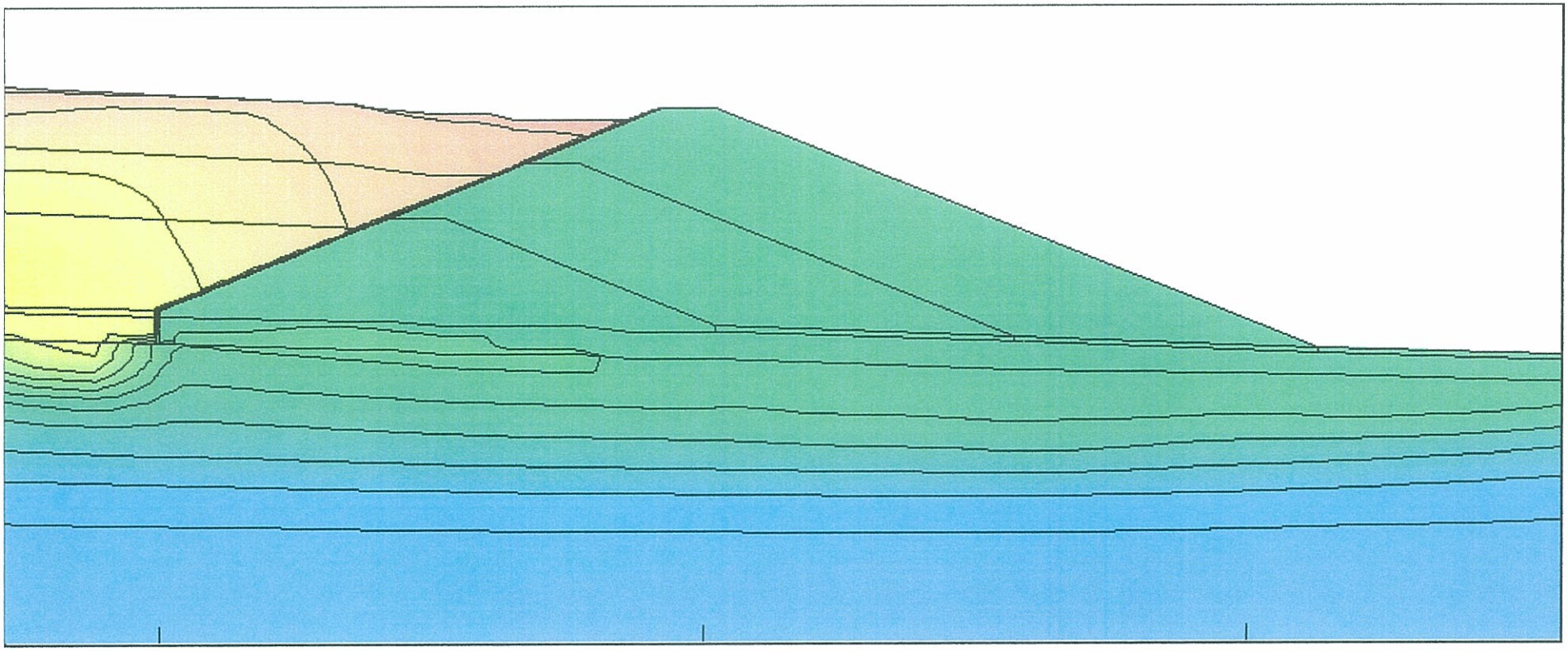
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 820
Feb 25 / 05

Rock Creek Dam,
Nome, Alaska

I-11t



Scale 1:1

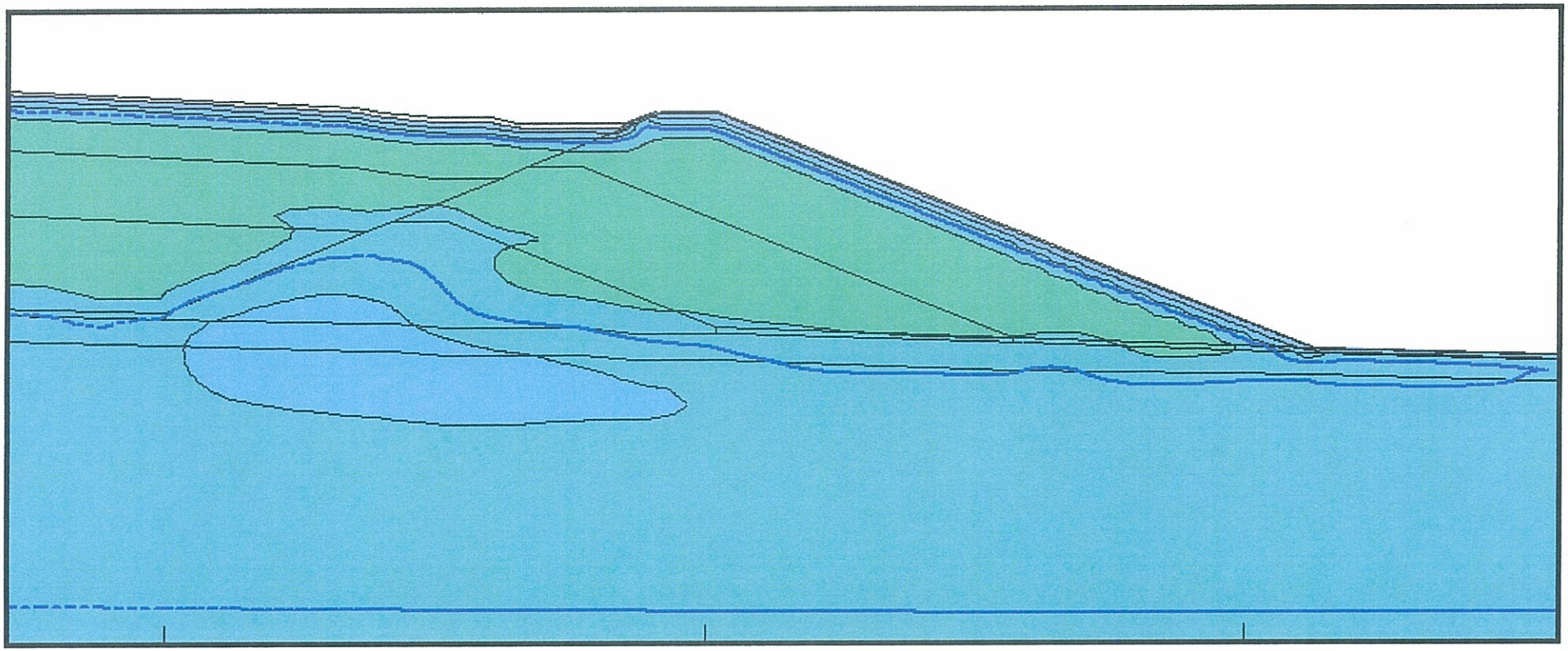
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 900
Mar 15 / 05

Rock Creek Dam,
Nome, Alaska

I-12h



Scale 1:1

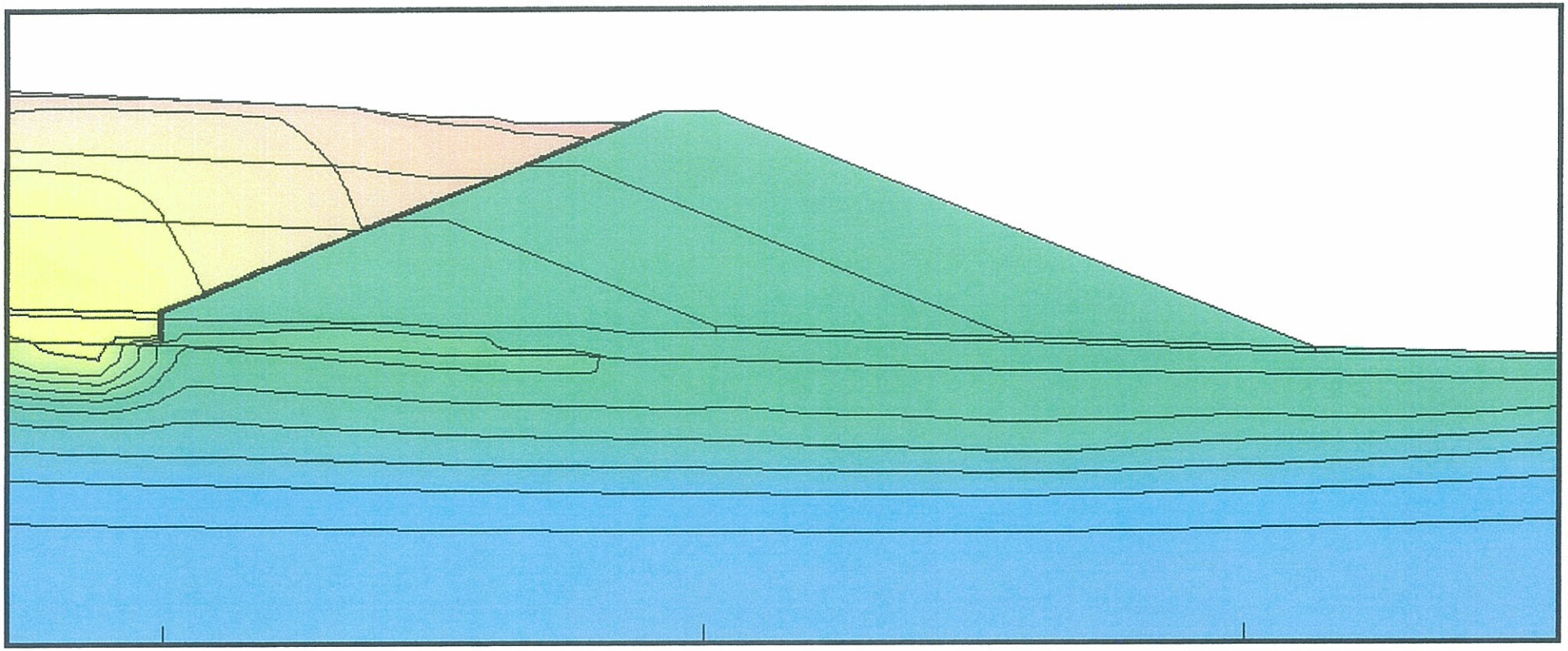
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 900
Mar 15 / 05

Rock Creek Dam,
Nome, Alaska

I-12t



Scale 1:1

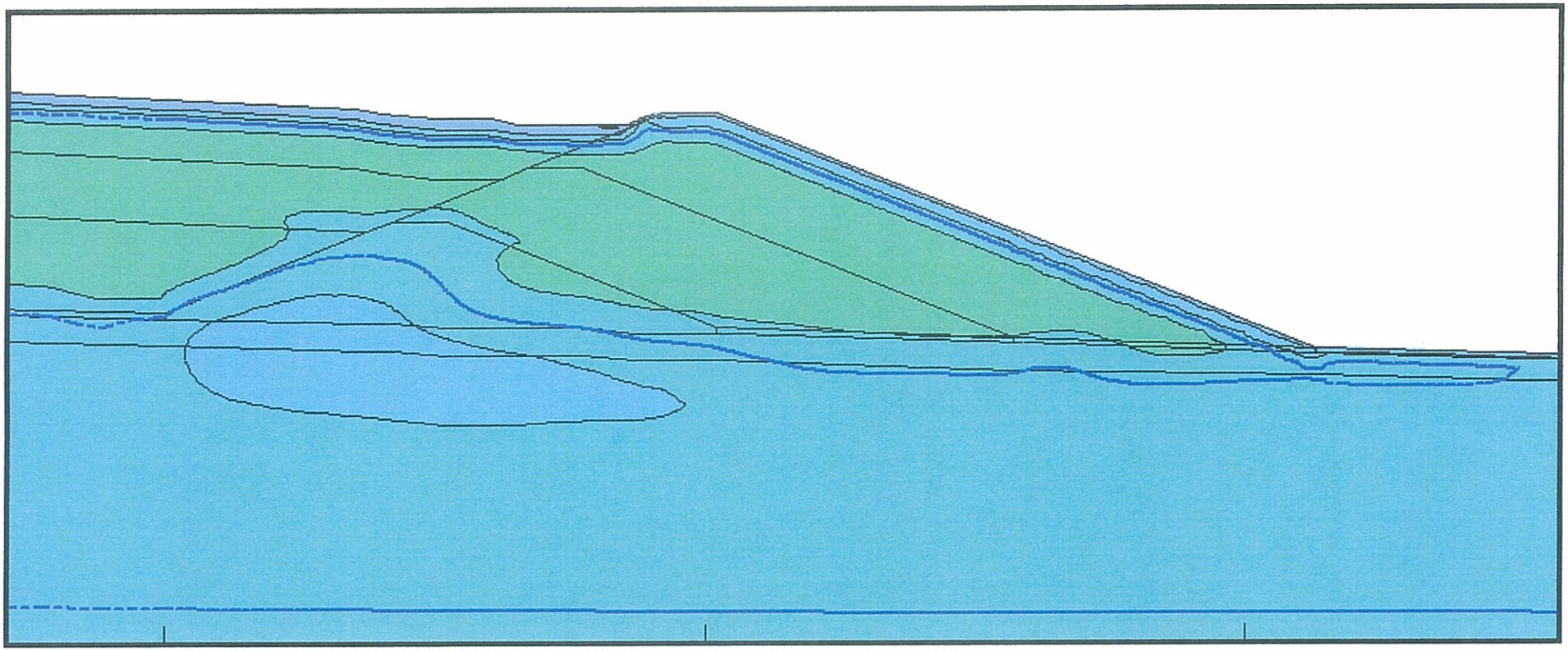
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 980
Apr 5 / 05

Rock Creek Dam,
Nome, Alaska

I-13h



Scale 1:1

0 20 40

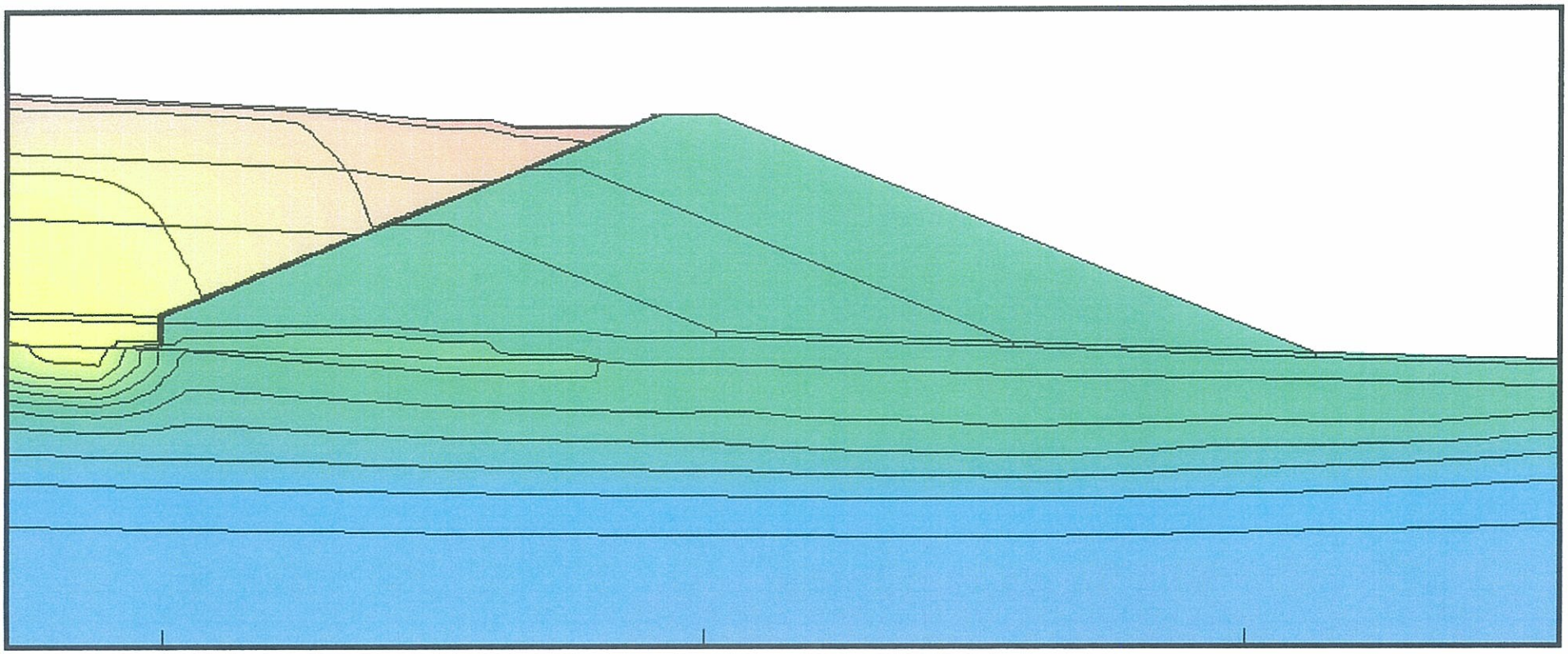
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 980
Apr 5 / 05

Rock Creek Dam,
Nome, Alaska

I-13t



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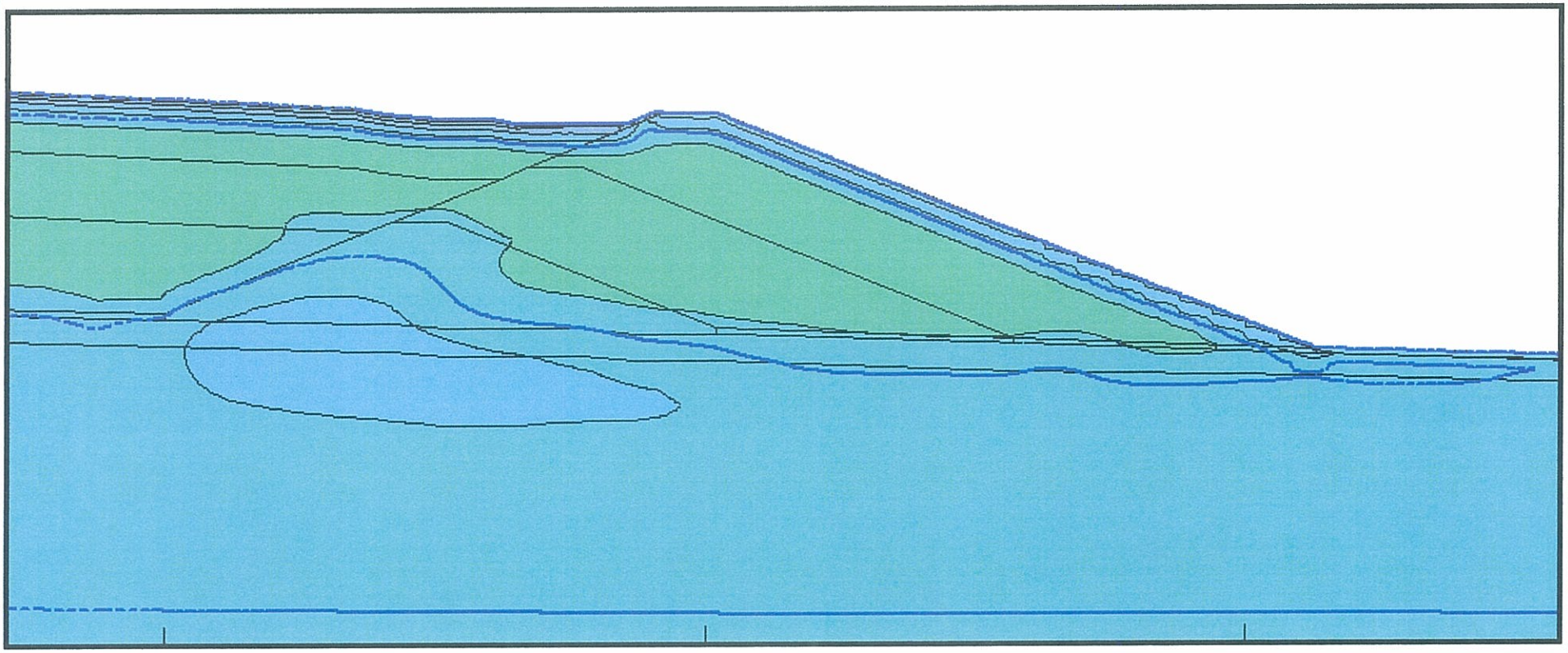
Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1060
Apr 25 / 05

Rock Creek Dam,
Nome, Alaska

I-14h



Scale 1:1

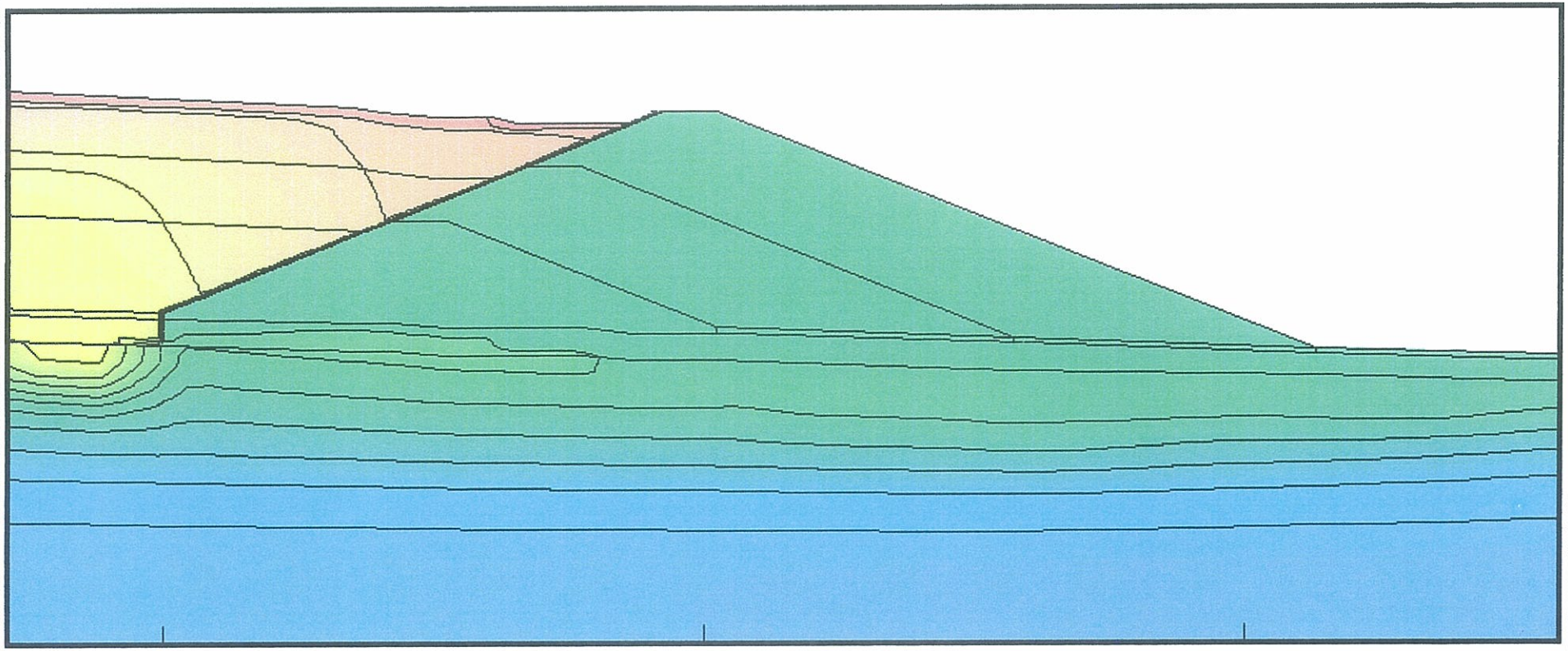
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1060
Apr 25 / 05

Rock Creek Dam,
Nome, Alaska

I-14t



Scale 1:1

0 20 40

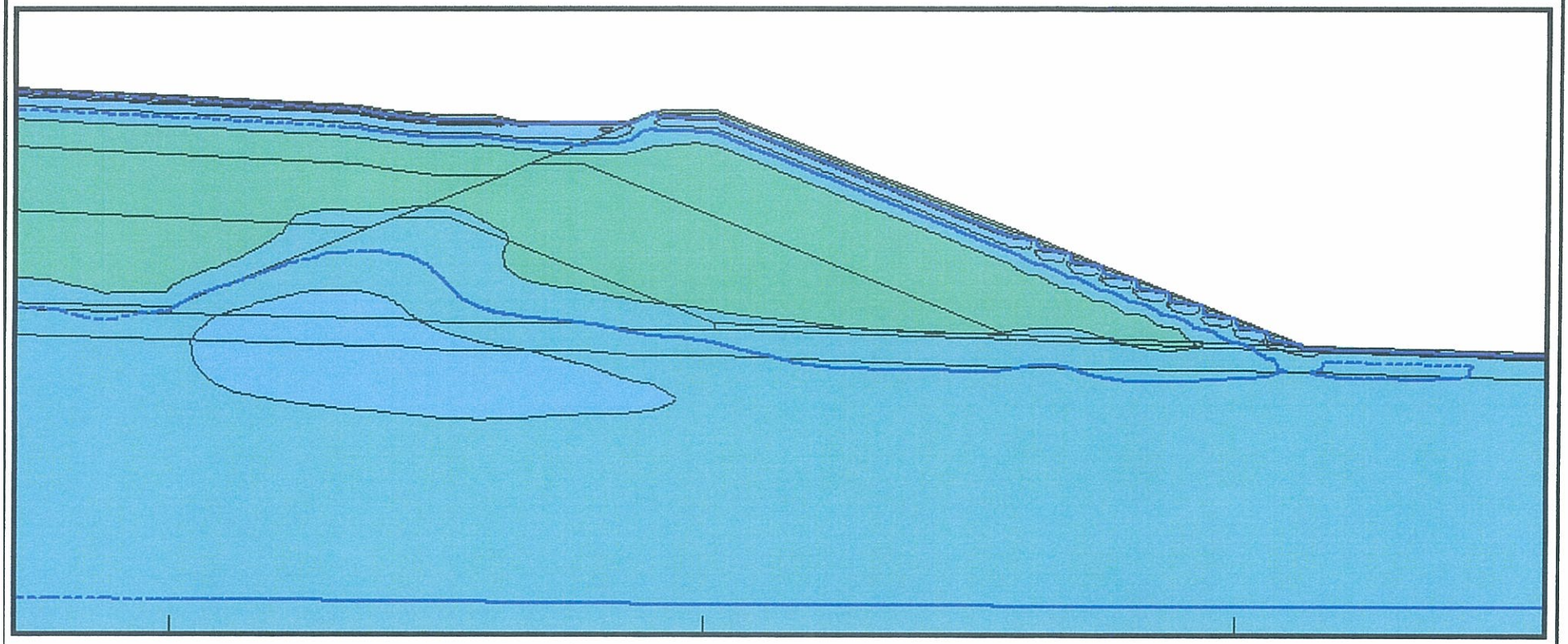
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1140
May 15 / 05

Rock Creek Dam,
Nome, Alaska

I-15h



Scale 1:1

0 20 40

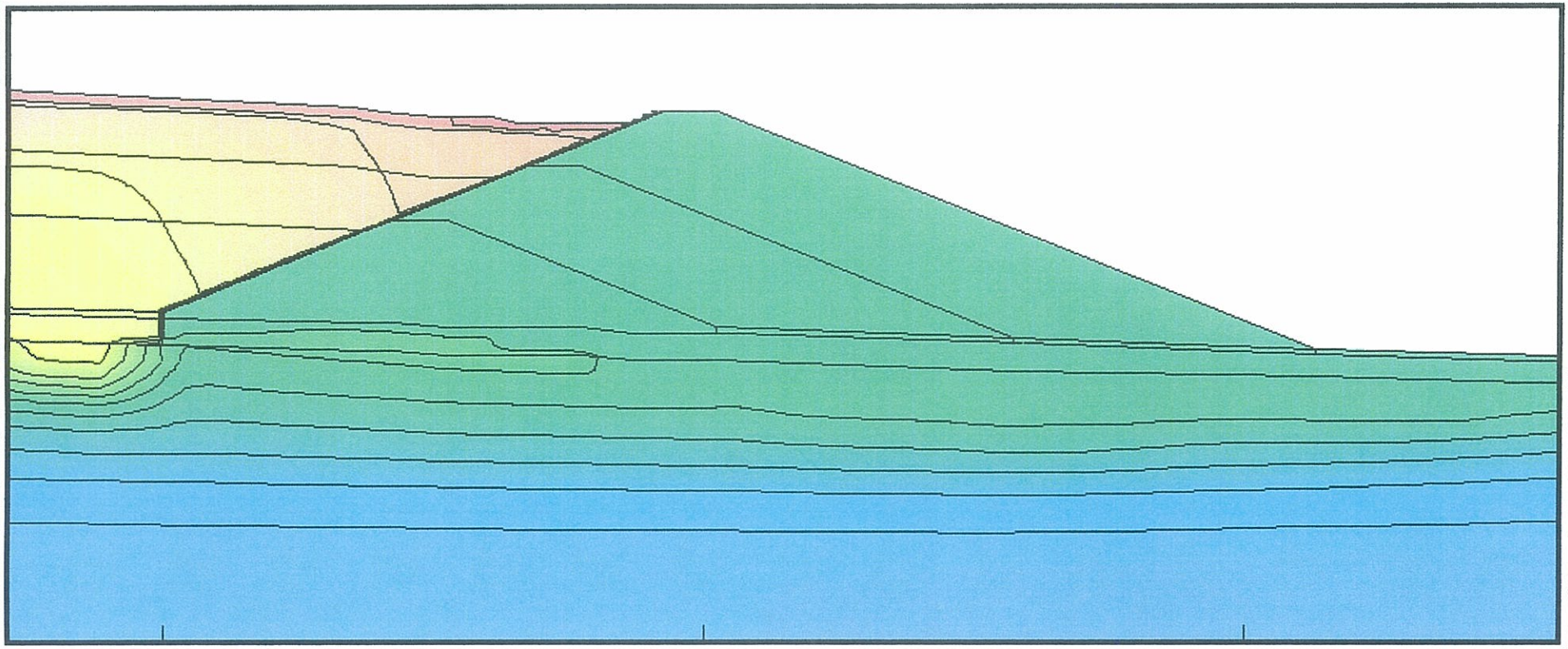
Meters

NORTHERN GEOTECHNICAL ENGINEERING INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1140
May 15 / 05

Rock Creek Dam,
Nome, Alaska

I-15t



Scale 1:1

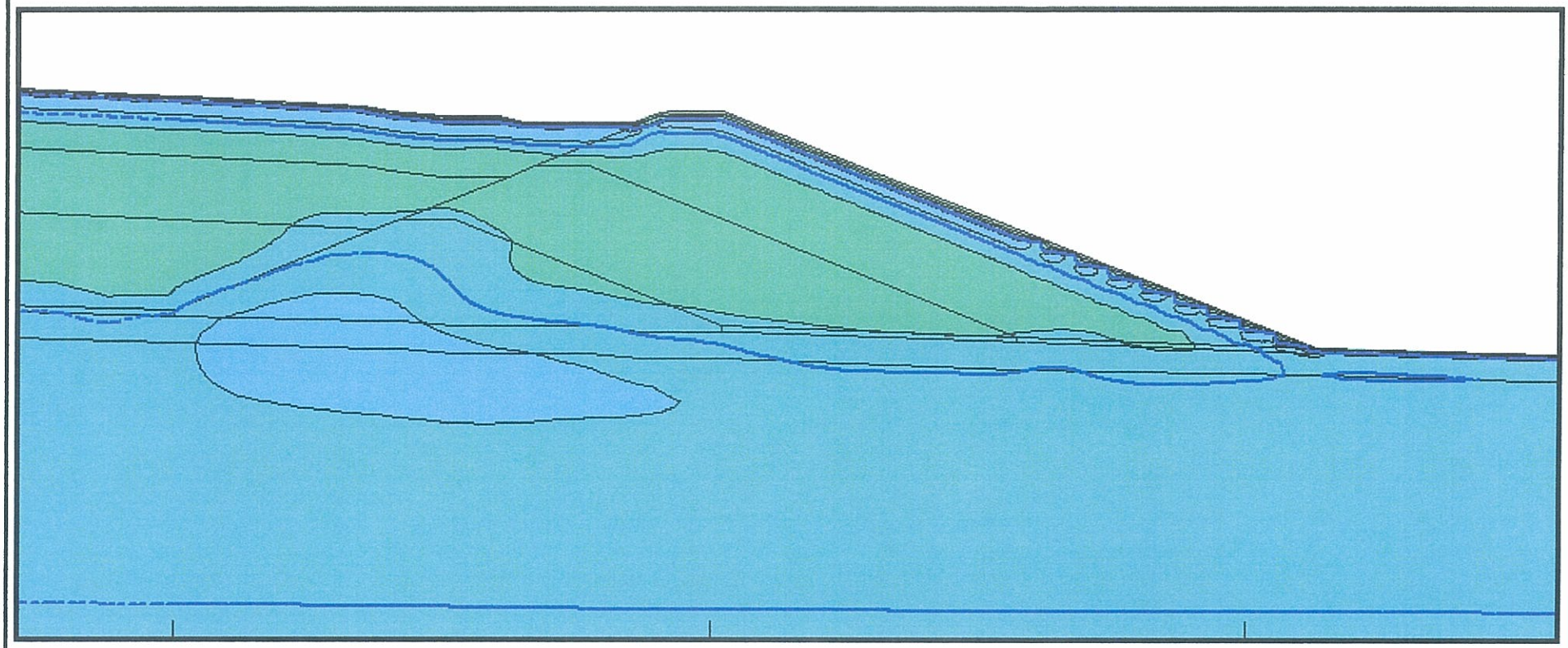
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1220
Jun 5 / 05

Rock Creek Dam,
Nome, Alaska

I-16h



Scale 1:1

0 20 40

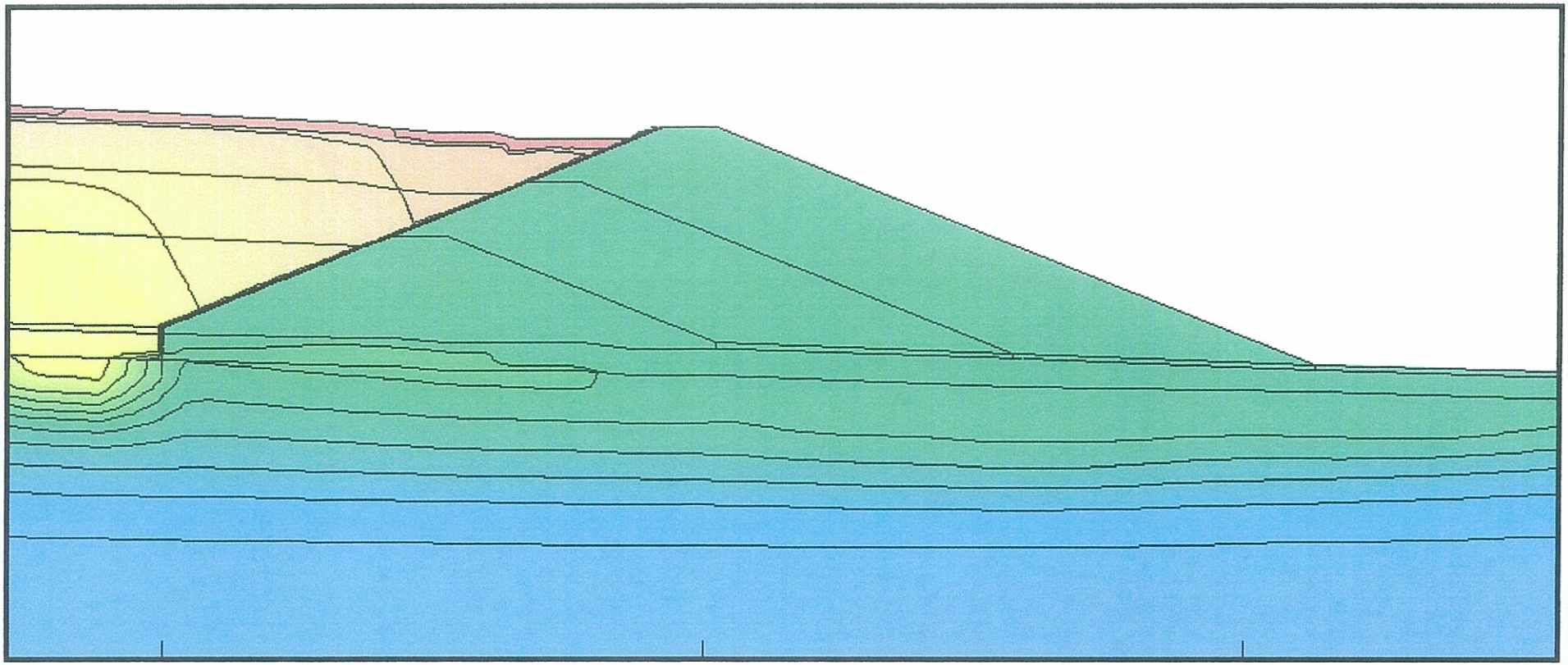
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1220
Jun 5 / 05

Rock Creek Dam,
Nome, Alaska

I-16t



Scale 1:1

0 20 40

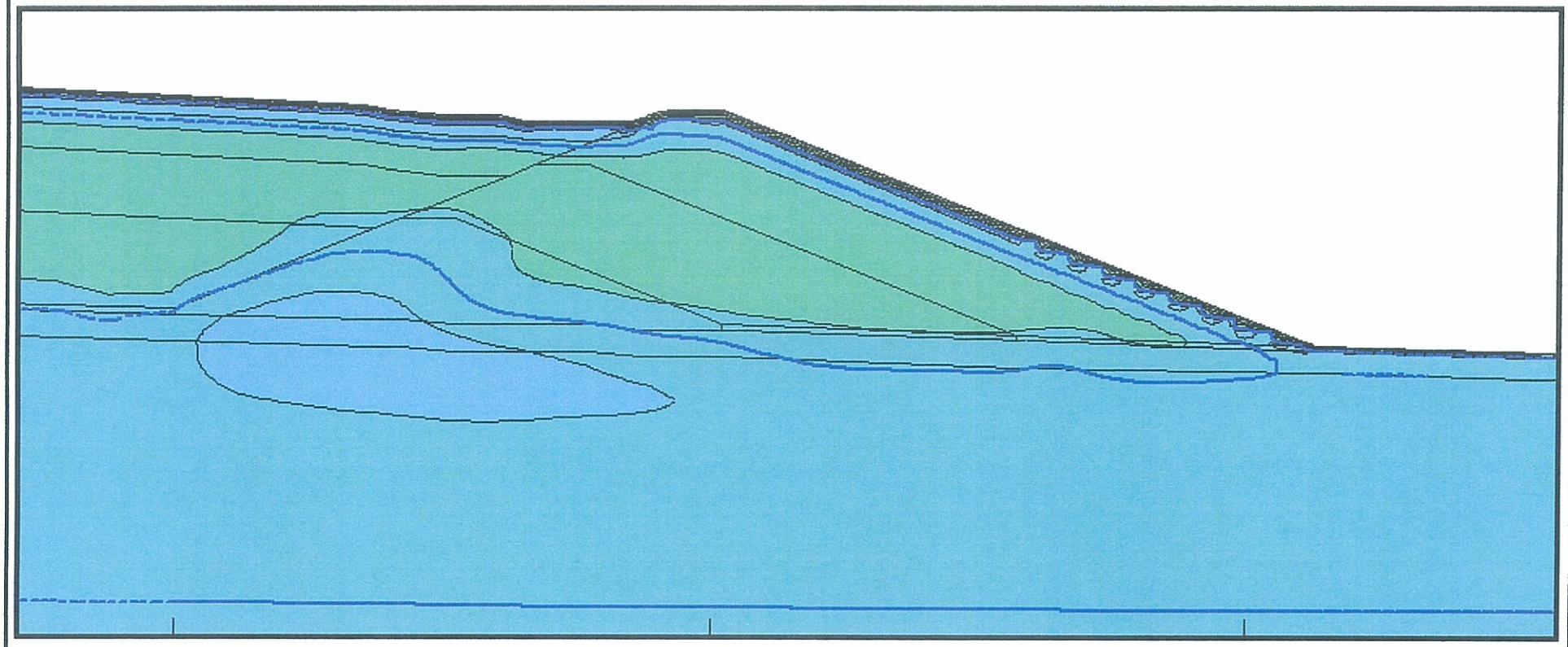
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1300
Jun 25 / 05

Rock Creek Dam,
Nome, Alaska

I-17h



Scale 1:1

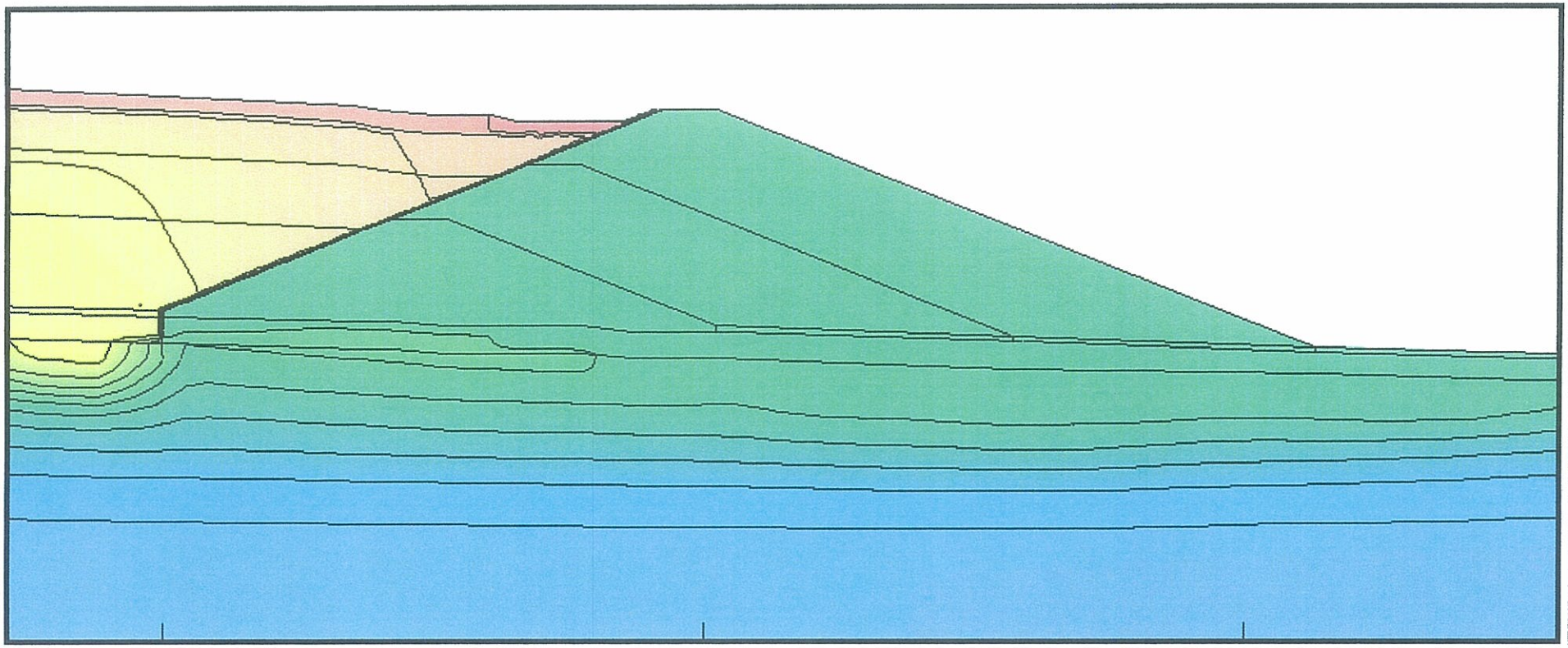
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1300
Jun 25 / 05

Rock Creek Dam,
Nome, Alaska

I-17t



Scale 1:1

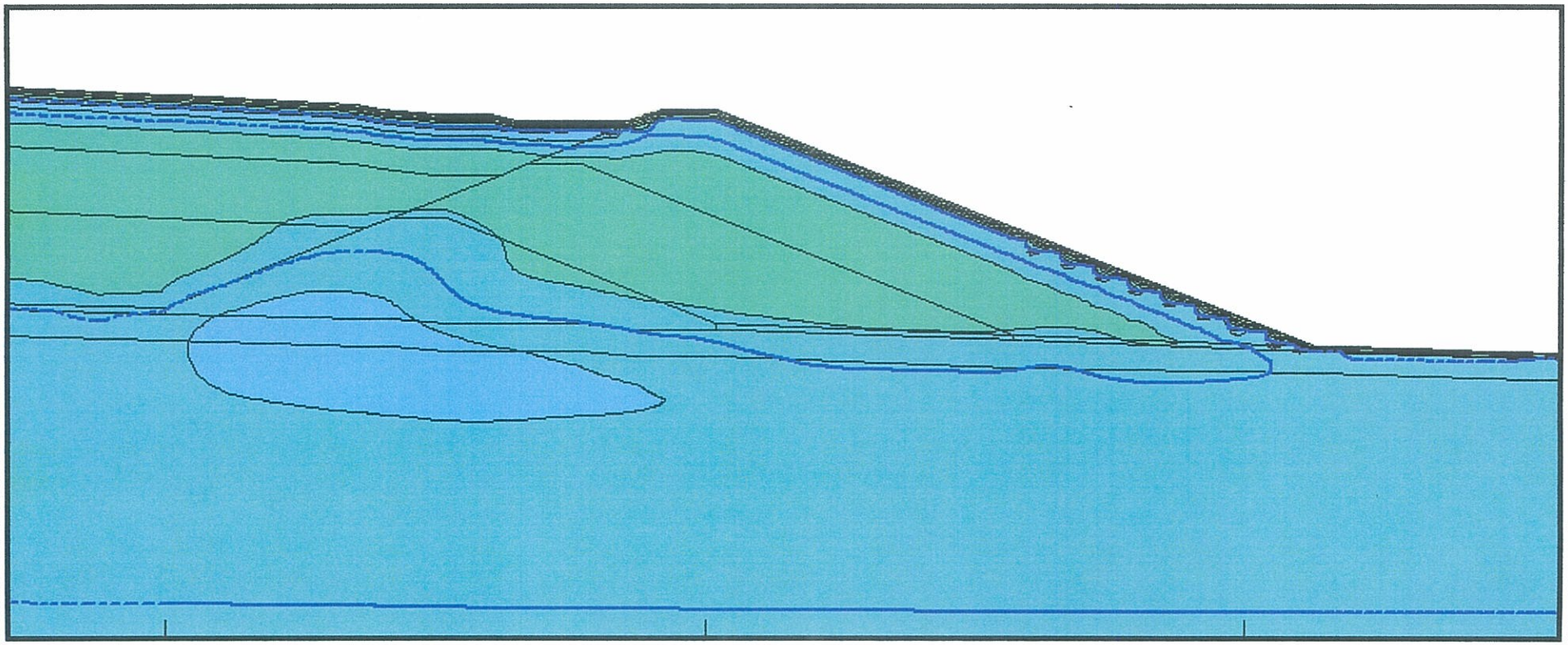
0 20 40

Meters

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1380
Jul 15 / 05

Rock Creek Dam,
Nome, Alaska

I-18h



Scale 1:1

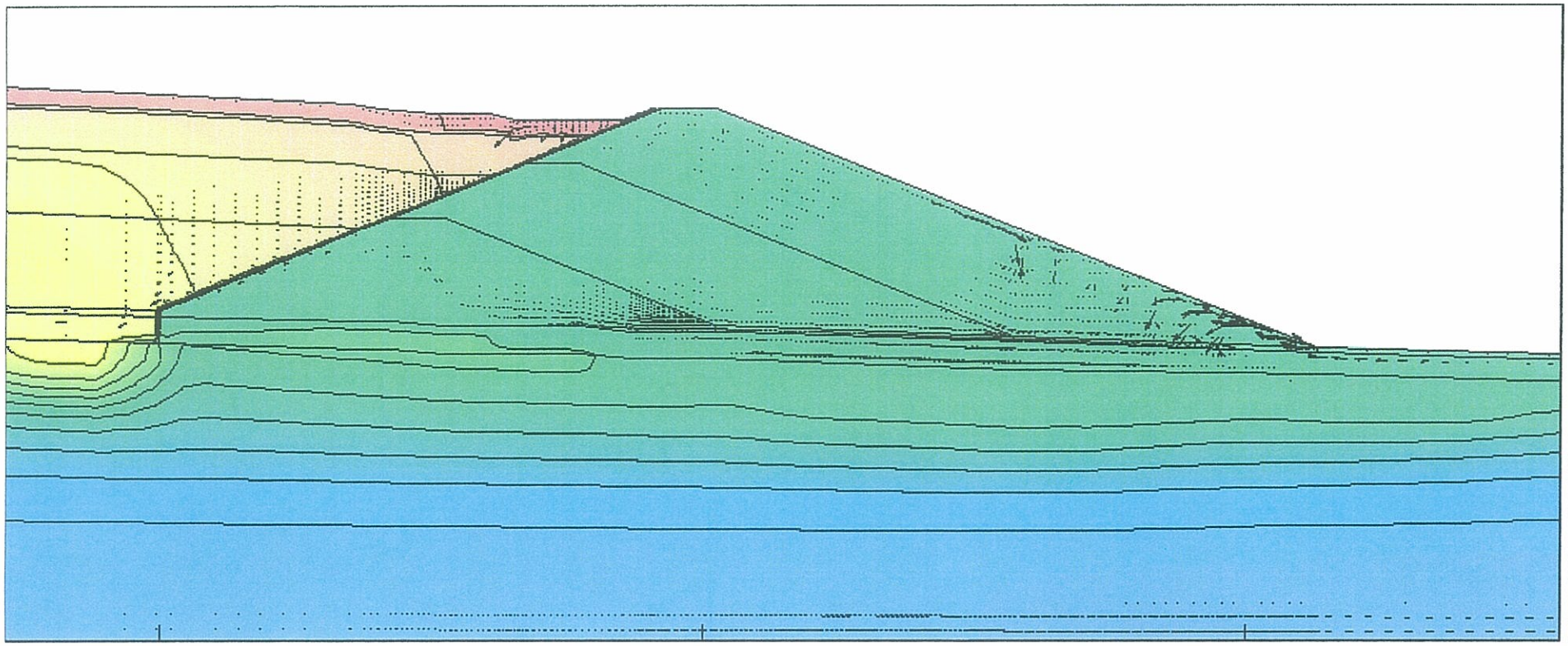
0 20 40

Meters

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1380
Jul 15 / 05

Rock Creek Dam,
Nome, Alaska

I-18t



Scale 1:1

0 20 40

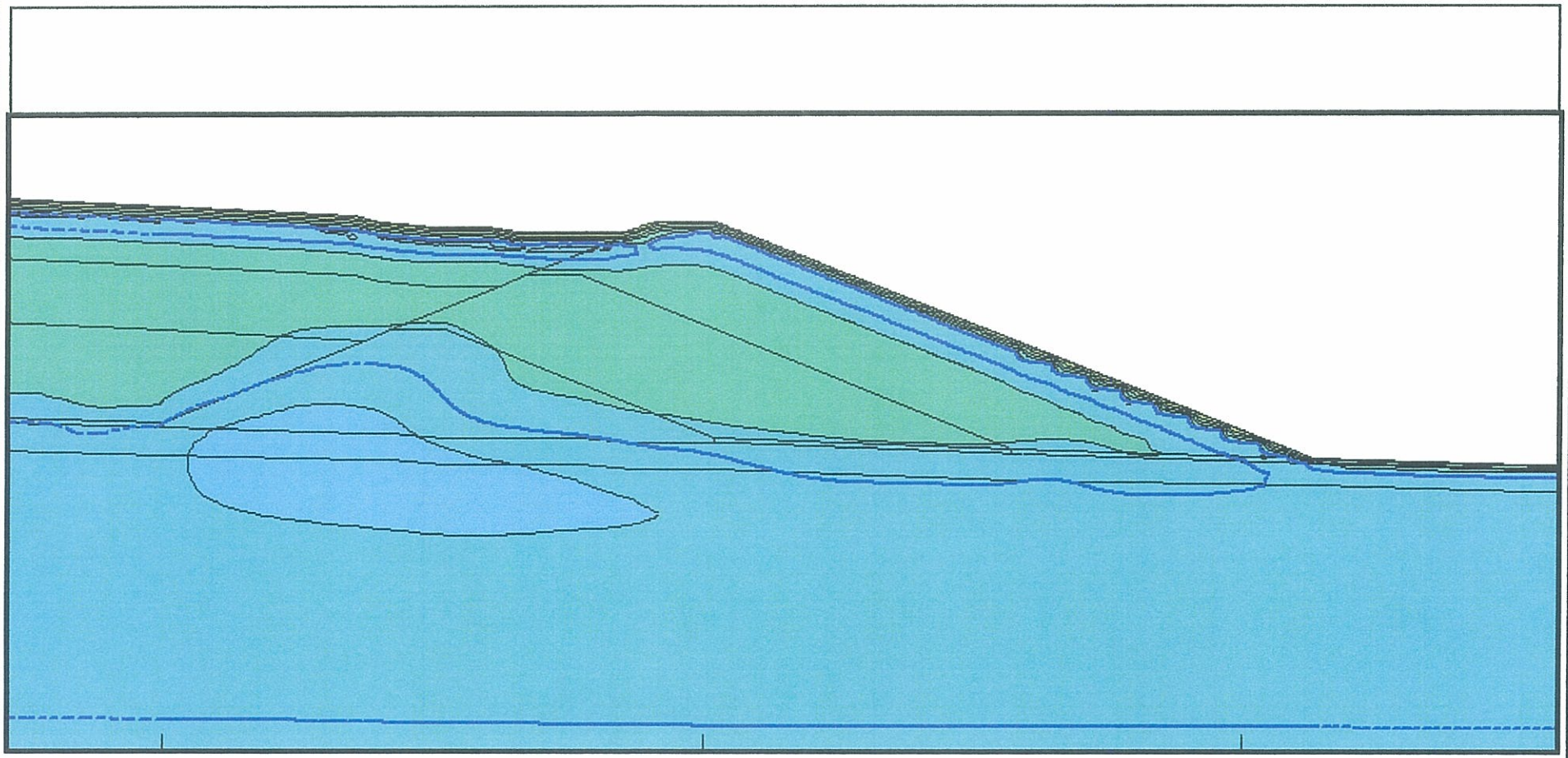
Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Hydraulic Head Contour Map
Scenario 2 – Phase 3 – Time step 1460
Aug 5 / 05

Rock Creek Dam,
Nome, Alaska

I-19h



Scale 1:1

0 20 40

Meters

NORTHERN GEOTECHNICAL ENGINEERING, INC. TERRA FIRMA TESTING

Thermal Contour Map
Scenario 2 – Phase 3 – Time step 1460
Aug 5 / 05

Rock Creek Dam,
Nome, Alaska

I-19t