

**Attachment B**  
**Details of Example Alternatives**

**Attachment B1**  
**Example Alternatives for Faro Mine Area**

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# 1 Example Alternatives for Faro Mine Area

The major components of the Faro Mine Area include the Faro Pit, various waste rock dumps (including sulphide cells, low-grade ore and oxide fines), the Faro Creek Diversion and the North Fork Rock Drain.

By selecting various combinations of closure methods for each of the components listed above, it is possible to create a closure alternative for the entire area. Table 1.1 summarizes the major components of the four example alternatives for the Faro Mine Area.

Differences between the four alternatives reflect the following considerations:

- The closure method for the Faro Creek Diversion, which can be either:
  - Rerouting of Faro Creek into the Faro Pit, with construction of a Plug Dam and a discharge channel; or
  - Continued diversion of Faro Creek around the Faro Pit.
- The primary approach to long-term water treatment, which can be either:
  - Biological water treatment in the Faro Pit,
  - Chemical water treatment in a treatment plant, or
  - A combination of biological and chemical water treatment.
- The approaches taken for covering and/or moving waste rock.

All of the example alternatives for the Faro Mine Area, and in fact all reasonable alternatives, include requirements for long-term groundwater collection and treatment.

**Table 1.1: Faro Mine Area Example Alternatives**

<b>Component</b>	<b>Alternative 1 Flow-Through Pit</b>	<b>Alternative 2 Upgrade Faro Creek Diversion</b>	<b>Alternative 3 Minimize Construction</b>	<b>Alternative 4 Minimize Water Treatment</b>
<b>Faro Creek</b>	Re-route to pit	Upgrade now	Upgrade in future as needed	Upgrade now
<b>Primary Water Treatment</b>	Biological in Pit with seasonal pump-out	High density sludge	High density sludge	High density sludge with potential to switch to Biological in Pit
<b>Waste Rock</b>	<i>Dependent on waste type (see below)</i>			
<b>Oxide Fines/ Low-Grade Ore</b>	Consolidate with plastic cover	Consolidate with plastic cover	0.5m soil cover	Relocate to Pit with lime
<b>Sulphide Cells</b>	2.0m soil cover	2.0m soil cover	0.5m soil cover	Consolidate with 2.5m soil cover
<b>Faro Valley Dump</b>	0.5m soil cover	0.5m soil cover	0.5m soil cover	Relocated to sulphide cell with 2.5m soil cover
<b>Other Waste Rock</b>	Reslope with 0.5m soil cover	Reslope with 0.5m soil cover	0.5m soil cover – no resloping	Reslope with 2.0 m soil cover
<b>Emergency Tailings Area</b>	Relocate tailings and collect groundwater	Relocate tailings and collect groundwater	Leave as is	Relocate tailings and collect groundwater

## 1.1 Faro Mine Area Alternative 1 – Flow-Through Pit

The “Flow-Through Pit” alternative for the Faro Mine area is illustrated in Figure 1.1. The distinguishing feature of this alternative is that both Faro Creek and all contaminated water will be routed to the Faro Pit. The pit water will be treated each summer using the passive biological treatment system tested in the Grum pit in 2004. Options to allow the Faro Creek water to flow freely out of the pit were assessed, but none allows adequate treatment of the contaminated water during the spring freshet. Therefore, the water will need to be retained each summer until the biological treatment can lower zinc concentrations to a level suitable for discharge. It will then need to be pumped out of the pit to provide adequate room for next year’s inflow.

Other elements of the alternative are described in the following paragraphs. Further details on all the Faro Mine area alternatives can be found in the “Construction Details and Cost Estimates” presented in Attachment E.

### Closure Activities

Faro Creek will be routed into the pit via a lined ditch cut through or around the Faro Valley Dump. Water will cascade over the pit wall into the pit. A berm will be constructed around the pit rim to prevent inadvertent access.

To increase the water storage capacity, a plug dam will be constructed across the mouth of the pit to elevation 1170 m. Phosphate will be added to pit water each spring to promote the biological growth needed to drive the treatment process.

The water pumped out of the pit will run through a pipe system installed in an excavation through the waste rock and mill areas. The base of the excavation will have a maximum elevation of 1168 m so that any excess water will spill before exceeding the Plug Dam freeboard limit. The excavation will connect to the North Wall Interceptor Ditch, which will be upgraded to carry the flow to Rose Creek downstream of the current Cross Valley Dam

The oxide fines and low grade ore stockpiles will be consolidated and covered with very low infiltration covers, to consist of a bedding layer, HDPE geomembrane, and 1.0 m of lightly compacted till. A design variant to covering with similar cost and water quality implications is to add lime to neutralize the acidity in the oxide fines and low grade ore materials, and relocate them to a location below the water level in the Faro Pit. The water quality implications of this variant are still being evaluated.

Waste rock slopes will be regraded to 3H:1V. A low infiltration cover consisting of 0.5 m of compacted till overlain by 1.5 m of lightly compacted till will be placed on the sulphide cell. The remainder of the waste rock piles will be covered with 0.5 m of lightly compacted till. Runoff control ditches will be constructed on the cover. All surfaces will be seeded and fertilized.

The ETA tailings will be relocated to the tailings impoundment or to the Faro Pit if the remainder of the Rose Creek tailings are to be re-located there. A groundwater and surface water collection system will be installed in the ETA area. All collected water will be pumped to the Faro Pit. Additional wells and/or collection trenches will be installed as needed to reduce the escape of contaminated water.

Groundwater collection systems will be installed below the Zone II Pit and in the S-well area. If necessary, a lined diversion channel will be constructed to route the North Fork Rose Creek, to facilitate collection of contaminated groundwater from the base of the valley. The ditch will be continued through a cut in the Haul Road and, if necessary, below the S-wells. Water quality in Rose Creek and groundwater quality down-gradient of the collection systems will be monitored, and additional wells and/or cutoff walls will be constructed as needed to reduce the escape of contaminated groundwater.

Groundwater will also be pumped from the Zone II pit and piped back into the Faro Pit. Outwash material at the toe of the slope below the Zone II pit will be excavated and placed on the Intermediate Dump.

Unnecessary roads will be scarified, seeded and fertilized. All buildings will be demolished and disposed of in a landfill area in the waste rock. Hydrocarbon-contaminated soils will be excavated and bio-remediated. These activities are common to all of the alternatives discussed in this report.

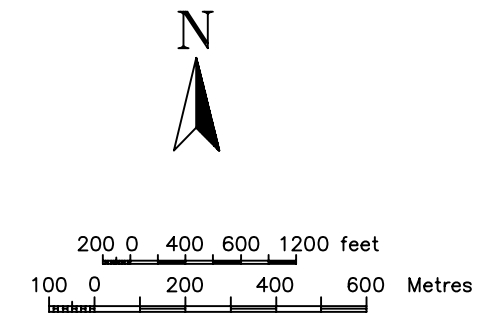
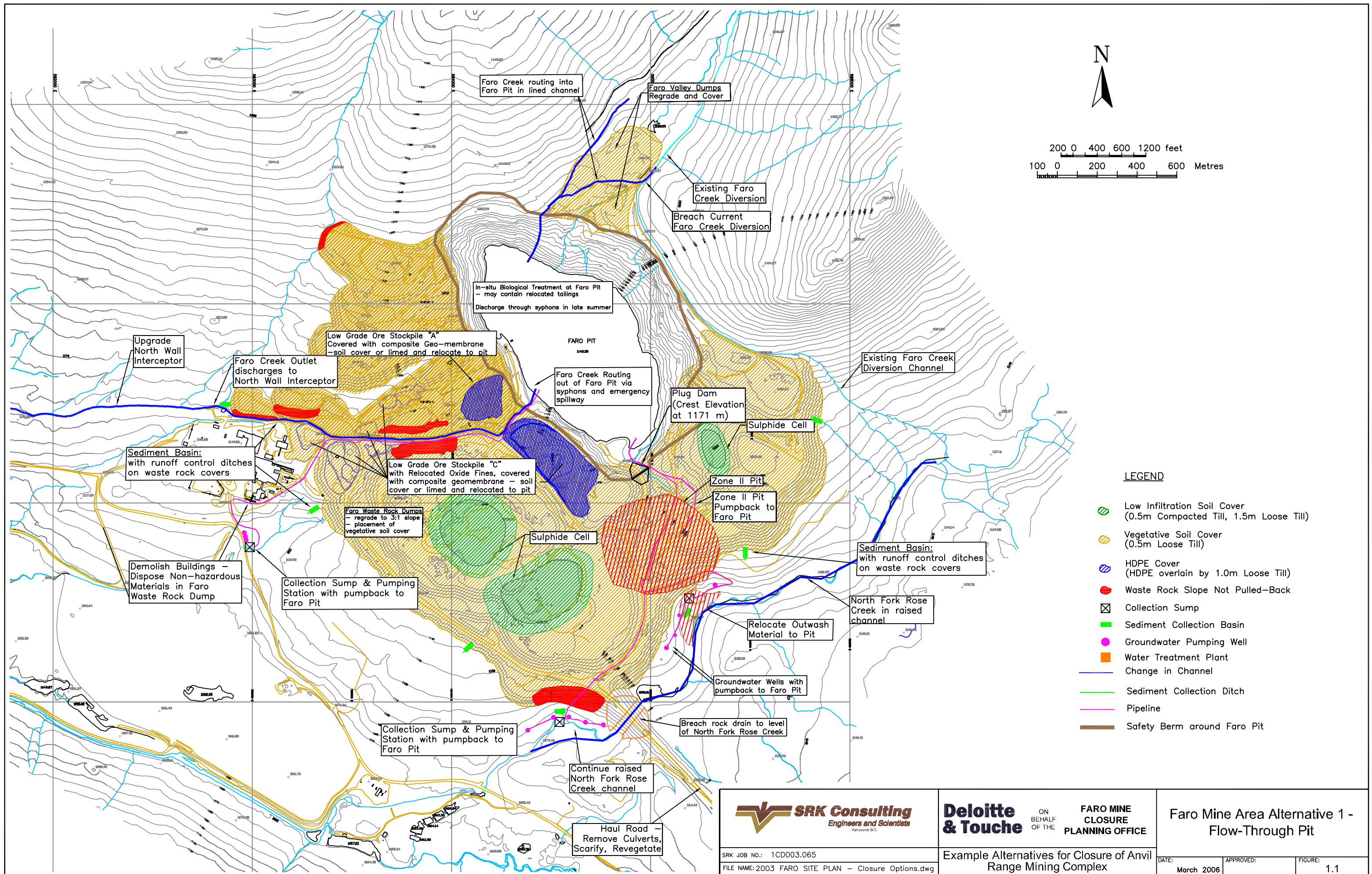
### **Post-Closure Requirements**

Post-closure requirements for the “Flow-Through Pit” alternative include:

- Year-round pumping of contaminated groundwater and seepage to the Faro Pit;
- Seasonal addition of phosphate to the pit water;
- Seasonal discharge of water from the pit;
- Monitoring of water quality in the Faro Pit, in and around each of the groundwater collection systems, and in Rose Creek above and below the site;
- Relocation or installation of additional extraction and monitoring wells;
- Annual inspections of all earthworks, and maintenance or repairs as needed;
- Intensive maintenance of covers and ditches for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

Except for the intensive initial monitoring, all of the above activities are expected to continue to be required for several hundred years.

The current information on the passive water treatment system indicates that the zinc removal capacity could be overwhelmed by future increases in zinc loadings. To cover that risk, and other uncertainties associated with performance of the passive treatment system, a contingency to construct and operate an active water treatment plant is included in the cost estimate. To cover the risk of future deterioration in seepage water quality below the Northwest Dump, a contingency is included for future collection of seepage and its transfer to the Faro pit.



**LEGEND**

- Low Infiltration Soil Cover (0.5m Compacted Till, 1.5m Loose Till)
- Vegetative Soil Cover (0.5m Loose Till)
- HDPE Cover (HDPE overlain by 1.0m Loose Till)
- Waste Rock Slope Not Pulled-Back
- Collection Sump
- Sediment Collection Basin
- Groundwater Pumping Well
- Water Treatment Plant
- Change in Channel
- Sediment Collection Ditch
- Pipeline
- Safety Berm around Faro Pit

<p><b>SRK Consulting</b> Engineers and Scientists Vancouver B.C.</p>	<p><b>Deloitte &amp; Touche</b> ON BEHALF OF THE <b>FARO MINE CLOSURE PLANNING OFFICE</b></p>	<p><b>Faro Mine Area Alternative 1 - Flow-Through Pit</b></p>	
		<p>SRK JOB NO.: 1CD003.065 FILE NAME: 2003 FARO SITE PLAN - Closure Options.dwg</p>	<p>Example Alternatives for Closure of Anvil Range Mining Complex</p>



## 1.2 Faro Mine Area Alternative 2 – Upgrade Faro Creek Diversion

The “Upgrade Faro Creek Diversion” alternative for the Faro Mine area is illustrated in Figure 1.2. The distinguishing feature of this alternative is the storage of all contaminated water in the Faro Pit for seasonal treatment in an active treatment system. To reduce the risk of contaminated water being washed out of the pit, the Faro Creek diversion will be upgraded. Other elements of this alternative are described in the following paragraphs.

### Closure Activities

Faro Creek will be diverted to the east of the pit via a geosynthetic clay lined channel. The east interceptor will be constructed upstream of the present Faro Creek diversion and will discharge into the present diversion north of the Northeast Waste Rock Dump before flowing into North Fork Rose Creek. The channel will include a thermal blanket consisting of granular fill to prevent permafrost degradation on the uphill cut slope. An optional extension of the channel on the west side of the Faro Creek Valley would collect additional runoff.

A water treatment plant will be constructed to treat the water stored in Faro Pit. Water will be continuously pumped out of the pit and treated year-round. The treated water will be discharged into Rose Creek.

Closure measures for the oxide fines, low grade ore and waste rock will be the same as in the previous alternative. Closure measures and groundwater collection in the ETA, Zone II, and S-Well areas will also be the same as in the previous alternative. Closure measure for roads, buildings and soils are the same in all alternatives.

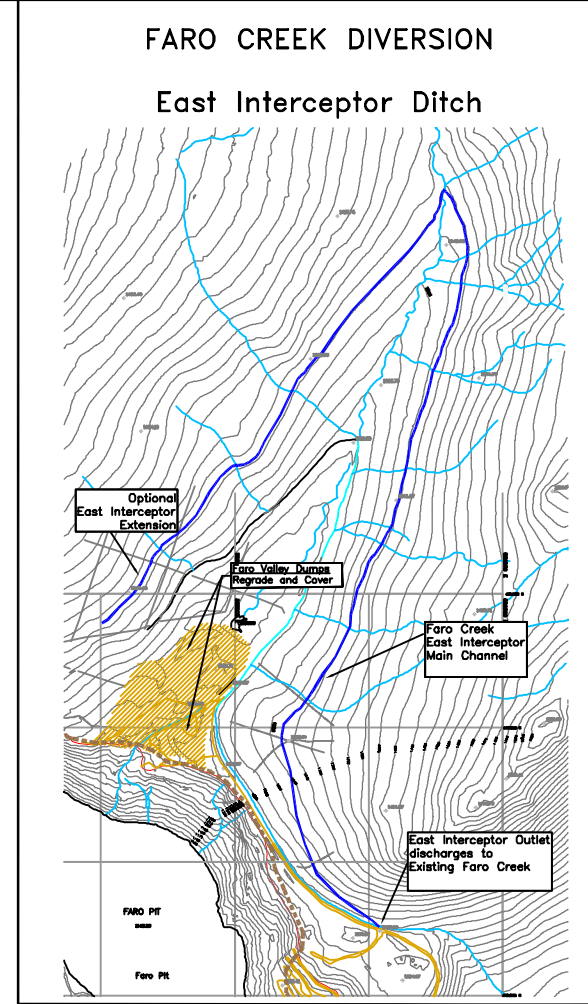
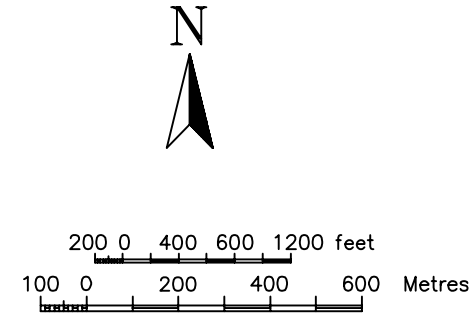
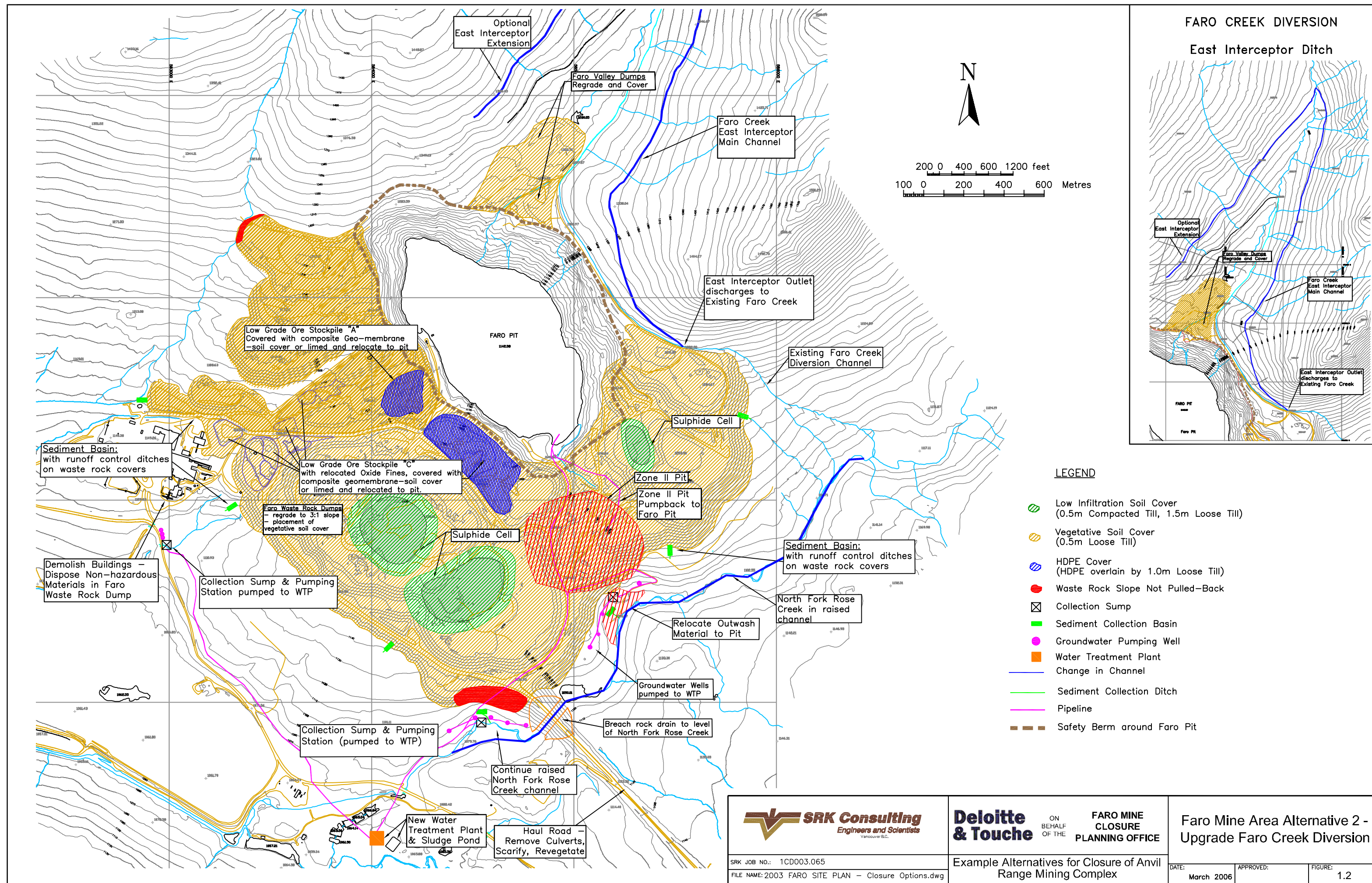
### Post-Closure Requirements

Post-closure requirements for the “Upgrade Faro Creek Diversion” alternative include:

- Year-round pumping of contaminated groundwater and seepage to the water treatment plant with storage of seasonal excess flow in the Faro Pit;
- Annual operation and maintenance of the water treatment plant;
- Periodic disposal of water treatment sludge in constructed cells;
- Monitoring of water quality in the Faro Pit, in and around each of the groundwater collection systems, and in Rose Creek above and below the site;
- Possible installation of additional extraction and monitoring wells;
- Annual inspections of all earthworks;
- Intensive maintenance of covers and ditches for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

With the exception of the initial cover maintenance exception noted above, all of the above activities are expected to continue to be required for several hundred years.

The water treatment system is expected to be capable of dealing with any increases in contaminant loads, so there is no additional treatment contingency in this alternative. There might be an opportunity to reduce treatment costs by using the passive biological method to pre-treat water in the pit. A contingency for future collection of Northwest Dump seepage is included.



**LEGEND**

- Low Infiltration Soil Cover (0.5m Compacted Till, 1.5m Loose Till)
- Vegetative Soil Cover (0.5m Loose Till)
- HDPE Cover (HDPE overlain by 1.0m Loose Till)
- Waste Rock Slope Not Pulled-Back
- Collection Sump
- Sediment Collection Basin
- Groundwater Pumping Well
- Water Treatment Plant
- Change in Channel
- Sediment Collection Ditch
- Pipeline
- Safety Berm around Faro Pit

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FILE NAME: 2003 FARO SITE PLAN - Closure Options.dwg

**Deloitte & Touche**  
ON BEHALF OF THE  
**FARO MINE CLOSURE PLANNING OFFICE**

Example Alternatives for Closure of Anvil Range Mining Complex

**Faro Mine Area Alternative 2 - Upgrade Faro Creek Diversion**

DATE: March 2006    APPROVED:    FIGURE: 1.2



### 1.3 Faro Mine Area Alternative 3 – Minimize Construction

The “Minimize Construction” alternative for the Faro Mine area is illustrated in Figure 1.3. This alternative is intended to represent the case where the up-front expenditure on the site is kept to the minimum which would still provide some level of environmental protection. The focus is then on the long-term collection and treatment of contaminated water.

#### Closure Activities

The Faro Creek diversion will continue to be maintained in its current channel. A contingency is included to re-construct the channel in a new location, either after it fails or when failure is imminent.

Contaminated water will be stored in the Faro Pit. The pit water level will be maintained at a level low enough to store any floods that could breach the Faro Creek diversion channel. No plug dam will be constructed.

A water treatment plant will be constructed to treat contaminated water. Water will be pumped out of the pit and treated each year during the open water season. The treated water will be discharged into Rose Creek.

Rudimentary covers, consisting of 0.5 m of lightly compacted till, will be constructed on the waste rock dumps, sulphide cells, as well as the oxide fines and low grade ore stockpiles. The covers will be seeded and fertilized to promote vegetation growth. The sideslopes of the waste rock dumps will not be re-sloped, and the cover will not be constructed on any slopes steeper than 2H:1V.

The ETA tailings and Zone II Pit outwash material will be left in place. Groundwater collection systems will be constructed below the Zone II Pit and in the S-well area. A contingency is included to upgrade the system as needed. There will be no groundwater or surface collection in the ETA area. Contaminated water will be allowed to drain onto the tailings, as in the current situation, and picked up in the tailings groundwater collection system.

#### Post-Closure Requirements

Post-closure requirements for the “Minimize Construction” alternative are generally the same as in the “Upgrade Faro Creek Diversion” alternative. However, there will be the following differences:

- The rudimentary covers are expected to require additional maintenance and repair.
- The groundwater collection systems will need to operate with a very high efficiency and will therefore need extensive monitoring and possibly upgrading.
- Contaminated water that escapes from the ETA area will need to be collected and treated by the down-gradient tailings groundwater collection system.

- Due to the lack of effective covers on the waste rock, sulphide cells, oxide fines and low grade ore, acid generation is expected to continue and water treatment costs are expected to be higher than in the other Faro Mine alternatives.





## 1.4 Faro Mine Area Alternative 4 – Minimize Water Treatment

The “Minimize Water Treatment” alternative for the Faro Mine area is illustrated in Figure 1.4. This alternative represents the case where additional source control measures are taken in an effort to minimize the generation of contaminated water and the requirements for long-term treatment. Simply put, this alternative represents the opposite of the “Minimize Construction” alternative.

### Closure Activities

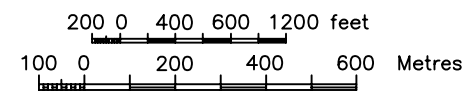
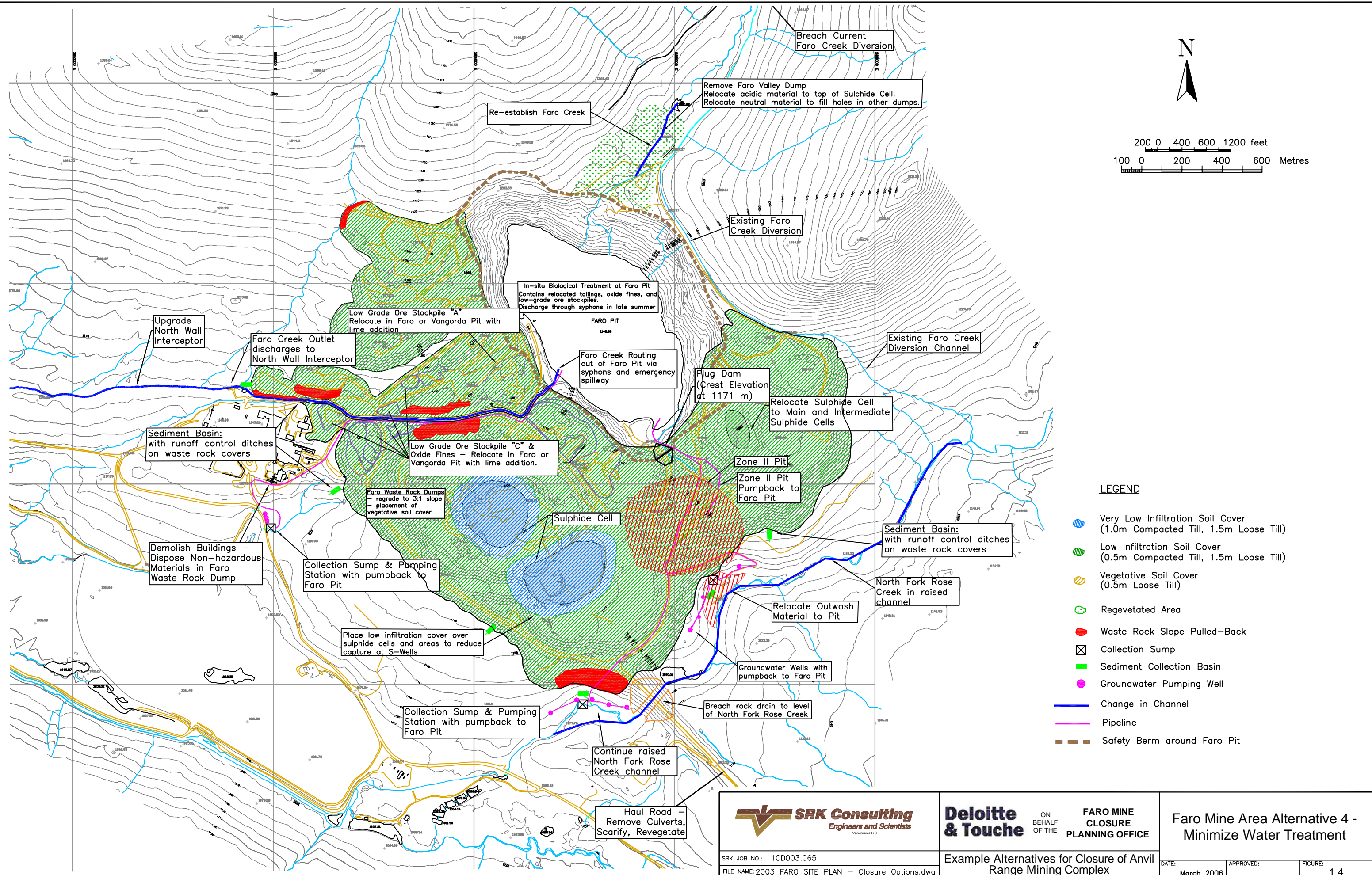
The closure activities under the “Minimize Water Treatment” alternative are similar to those in the “Upgrade Faro Creek Diversion” alternative, with the following differences.

- A plug dam will be built across the mouth of the pit to raise the water level and flood as much pit wall as practical.
- The oxide fines and low grade ore will be excavated, mixed with lime to neutralize their acidity, and deposited below the water level in the Faro Pit.
- The small sulphide cell to the north of the Zone II pit will be excavated, mixed with lime and relocated to the other sulphide cells, where it will be used to contour the surface into a shape that, once covered, will tend to shed water.
- The Faro Valley dumps will be excavated and acidic material will be mixed with lime and placed on the sulphide cells, as above. Neutral material will be used to fill depressions and contour the surface of the other waste rock piles.
- The sulphide cells will be covered with a very low infiltration soil cover, consisting of 1 m of compacted till overlain by 1.5 m of lightly compacted till, seeded and fertilized to promote vegetation growth.
- The remainder of the waste rock piles will be resloped and covered with a low infiltration soil cover, consisting of 0.5 m of compacted till overlain by 1.5 of lightly compacted till, seeded and fertilized to promote vegetation growth.

As in the “Upgrade Faro Creek Diversion” alternative, contaminated groundwater will be collected, stored in the Faro Pit, and treated in an active treatment system each summer. The groundwater collection and water treatment systems specified under that alternative will also be required here.

## **Post-Closure Requirements**

Post-closure requirements for the “Minimize Water Treatment” alternative are the same as in the “Upgrade Faro Creek Diversion” alternative. However, it is expected that, with these additional source control measures, both groundwater collection requirements and treatment costs will be reduced. If the source control measures prove to be sufficiently effective, this option could be converted to a passive treatment system, using only in-pit biological treatment. The additional source control measures will also reduce, but not eliminate, the requirements for long-term inspections, maintenance and repairs.



**LEGEND**

- Very Low Infiltration Soil Cover (1.0m Compacted Till, 1.5m Loose Till)
- Low Infiltration Soil Cover (0.5m Compacted Till, 1.5m Loose Till)
- Vegetative Soil Cover (0.5m Loose Till)
- Revegetated Area
- Waste Rock Slope Pulled-Back
- Collection Sump
- Sediment Collection Basin
- Groundwater Pumping Well
- Change in Channel
- Pipeline
- Safety Berm around Faro Pit

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<small>SRK JOB NO.: 1CD003.065</small> <small>FILE NAME: 2003 FARO SITE PLAN - Closure Options.dwg</small>	<b>Example Alternatives for Closure of Anvil Range Mining Complex</b>	<small>DATE:</small> March 2006 <small>APPROVED:</small> <small>FIGURE:</small> 1.4



**Attachment B2**  
**Example Alternatives for Rose Creek Tailings**



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# 1 Example Alternatives for Rose Creek Tailings

The major components of the Tailings Area include the tailings, a series of dams (Cross-Valley, Intermediate, Secondary and Original) and the Rose Creek Diversion.

The example alternatives for the Tailings Area are developed around the primary closure options for the tailings:

- Relocate all of the tailings to the Faro Pit,
- Leave the tailings in place, or
- Relocate some of the tailings (Intermediate) and leave the remainder in place.

Because the design team considers catastrophic failures of tailings containment structures to be unacceptable, options that leave tailings in the Rose Creek Valley lead to requirements for upgrading critical tailings containment and water conveyance structures to withstand the Maximum Credible Earthquake (MCE) and the Probable Maximum Flood (PMF). Differences in how to deal with the tailings surfaces lead to two “leave in place” alternatives.

Table 1.1 summarizes the closure methods proposed in the four example alternatives for the Tailings Area.

**Table 1.1: Tailings Area Example Alternatives**

<b>Component</b>	<b>Alternative 1 Stabilize in Place</b>	<b>Alternative 2 Complete Relocation</b>	<b>Alternative 3 Partial Relocation</b>	<b>Alternative 4 Minimize Construction</b>
<b>Tailings</b>				
<b>Intermediate</b>	2.0m rock/soil cover	Relocate to Pit	Relocate to Pit	Fence with annual soil tackifier
<b>Original &amp; Secondary</b>			2.0m rock/soil cover	
<b>Rose Creek Diversion</b>	Upgrade to PMF	Re-route to Valley	Upgrade part to PMF and re-route part to Valley	Upgrade to PMF
<b>Dams</b>				
<b>Cross-Valley</b>	Remove (Breach)			
<b>Intermediate</b>	Upgrade to MCE	Remove (Breach)	Remove (Breach)	Upgrade to MCE
<b>Secondary</b>	Upgrade to MCE	Remove (Breach)	Upgrade to MCE	Upgrade to MCE
<b>Original</b>	No Action	Remove (Breach)	No Action	No Action
<b>Water Collection and Treatment</b>	Long-term	Estimated 10 to 20 years	Long-term with additional for estimated 10 to 20 years	Long-term

## 1.1 Tailings Alternative 1 – Stabilize In Place

The “Stabilize In Place” alternative for the Rose Creek Tailings is illustrated in Figure 1.1. The objective of this alternative is to make the tailings physically stable in their current location. Meeting that objective requires upgrading of the Rose Creek Diversion Channel to prevent a flood-induced breaching of the Intermediate Dam, buttressing of the Intermediate and Secondary Dams to prevent earthquake-induced breaching, and covering of the tailings to limit dust releases and direct uptake of tailings contaminants by animals.

The following paragraphs summarize the major activities in each portion of the site. Further details on all the tailings area alternatives can be found in the “Construction Details and Cost Estimate” sheets in Attachment D.

### Closure Activities

The Cross-Valley Dam will be removed. The impounded sludge will be excavated and hauled to a sludge containment cell and contaminated soils will be removed to the mill area. The Intermediate Dam will be stabilized against foundation liquefaction through ground densification with vibro-replacement stone columns and/or the construction of a buttress. The eastern corner of the Secondary Dam will also be stabilized through ground densification with vibro-replacement stone columns.

Tailings in the Intermediate, Secondary and Primary Impoundments will be covered with a low-infiltration cover consisting of 0.5 m of waste rock overlain by 1.5 m of lightly compacted till. Construction of the covers will be sequenced and, if necessary, delayed to allow consolidation and settlement prior to placing a final grading layer. The cover will be seeded and fertilized.

The Rose Creek Diversion Channel will be upgraded to pass the PMF by deepening and widening the channel along its current alignment. The slopes above the diversion will be stabilized where necessary. A concrete spillway will be constructed to route flood flows back to Rose Creek below beyond the intermediate dam. The current channel will be maintained for normal flows and to provide fish passage. Interception and diversion ditches on the north side of the valley will be upgraded to minimize the amount of water flowing onto the tailings surface. The existing spillway for the Intermediate Dam will be upgraded to manage any remaining runoff from the covered tailings and north side of Rose Valley.

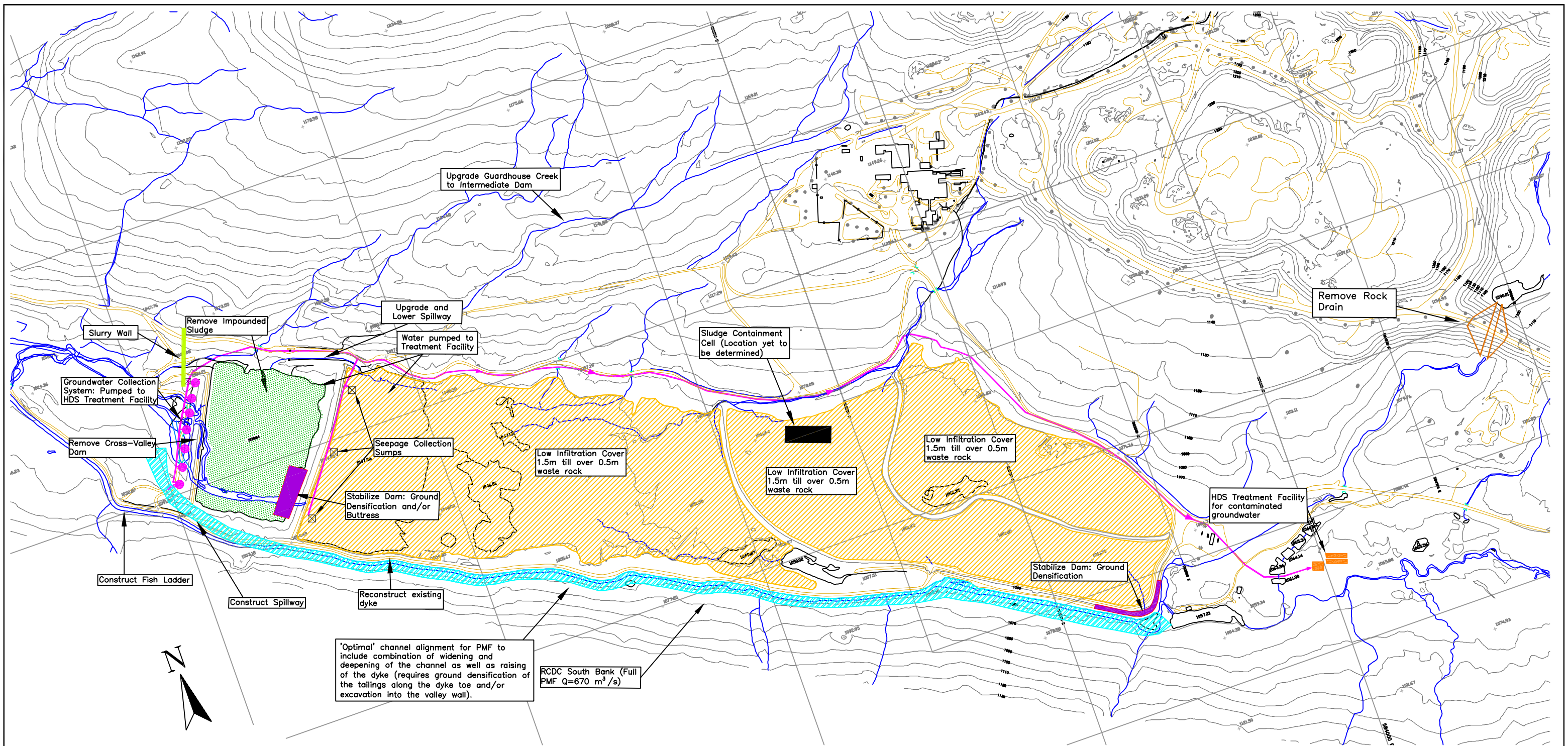
A groundwater collection system will be installed below or along the alignment of the Cross Valley Dam. The collected groundwater will be pumped to a water treatment plant and treated. The groundwater collection system will be extended to the north side of the valley using a cutoff wall where the soil stratigraphy becomes too complex for effective collection by wells only. Spare pumps and a redundant power supply will be put in place for emergency use.

## **Post-Closure Requirements**

Post-closure requirements for the “Stabilize In Place” alternative include:

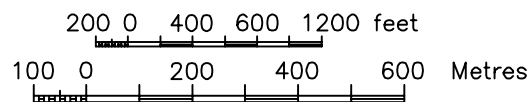
- Year-round pumping of contaminated groundwater and seepage to the water treatment plant;
- Year-round operation and maintenance of the water treatment plant;
- Periodic disposal of water treatment sludge in constructed cells;
- Monitoring of water quality in and around the groundwater collection system, and in Rose Creek above and below the site;
- Relocation or installation of additional extraction and monitoring wells;
- Annual geotechnical inspections of all remaining earthworks and dams;
- Regular inspections and maintenance of the Rose Creek Diversion Channel;
- Intensive maintenance of covers and ditches for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

With the maintenance exception noted above, all of the above activities are expected to continue to be required for several hundred years.




**LEGEND**

-  Revegetated Area
-  Store and Release Cover
-  Dam Stabilization Area
-  Rose Creek Diversion Channel Bed
-  Collection Sump
-  Groundwater Collection Well
-  Water Treatment Plant
-  Groundwater / Seepage Pipeline
-  Slurry Wall



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Contour Interval: 10m  
Survey control derived from existing 1:20000 photography  
Survey control based on: UTM Projection, NAD27  
Compiled by The ORTHOSHOP, Calgary, September 2003  
WO 8856

  
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SRK JOB NO.: 1CD003.065  
FILE NAME: Tailings - Closure Options.dwg

**Deloitte & Touche** ON BEHALF OF THE FARO MINE CLOSURE PLANNING OFFICE

Example Alternatives for Closure of Anvil Range Mining Complex

**Tailings Alternative 1 - Stabilize In Place**

DATE: March 2006	APPROVED:	FIGURE: 4.1
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## 1.2 Tailings Alternative 2 – Complete Relocation

The “Complete Relocation” alternative for the Rose Creek Tailings is illustrated in Figure 1.2. As the name suggests, the objective in this alternative is to move the tailings completely out of the Rose Creek valley, and into the Faro Pit. The following paragraphs summarize the major activities.

### Closure Activities

The Intermediate and Secondary Tailings will be pumped to the Faro Pit. The tailings will be hydraulically monitored along excavated trenches to a collection sump and pumped. Lime will be added to the slurry during pumping. Excess water is to be treated through a HDS system in a new treatment plant and discharged. Any remaining contaminated material in the impoundments will be removed by truck and shovel to the Faro Pit. The re-exposed valley area impoundment will be graded for drainage and all surfaces will be seeded and fertilized. Removal of the tailings is expected to take up to 14 years. The process will be sequenced and monitored to ensure stability is maintained.

To prevent releases of tailings during the relocation, all dams will be kept in place to control water and sediment. The dams will be breached after basin cleanup is completed. The Rose Creek Diversion Channel will be maintained during the period of tailings relocation and groundwater cleanup.

A groundwater collection system consisting of multiple shallow extraction and monitoring wells will be constructed to capture localized groundwater contamination within the footprint of the relocated tailings. The extracted groundwater will be piped to a treatment plant and treated. The locations of the extraction and monitoring wells will be selected after the tailings are relocated. An adaptive management approach will be used, meaning that additional wells will be installed where necessary, until the groundwater is sufficiently clean that it will not contaminate Rose Creek.

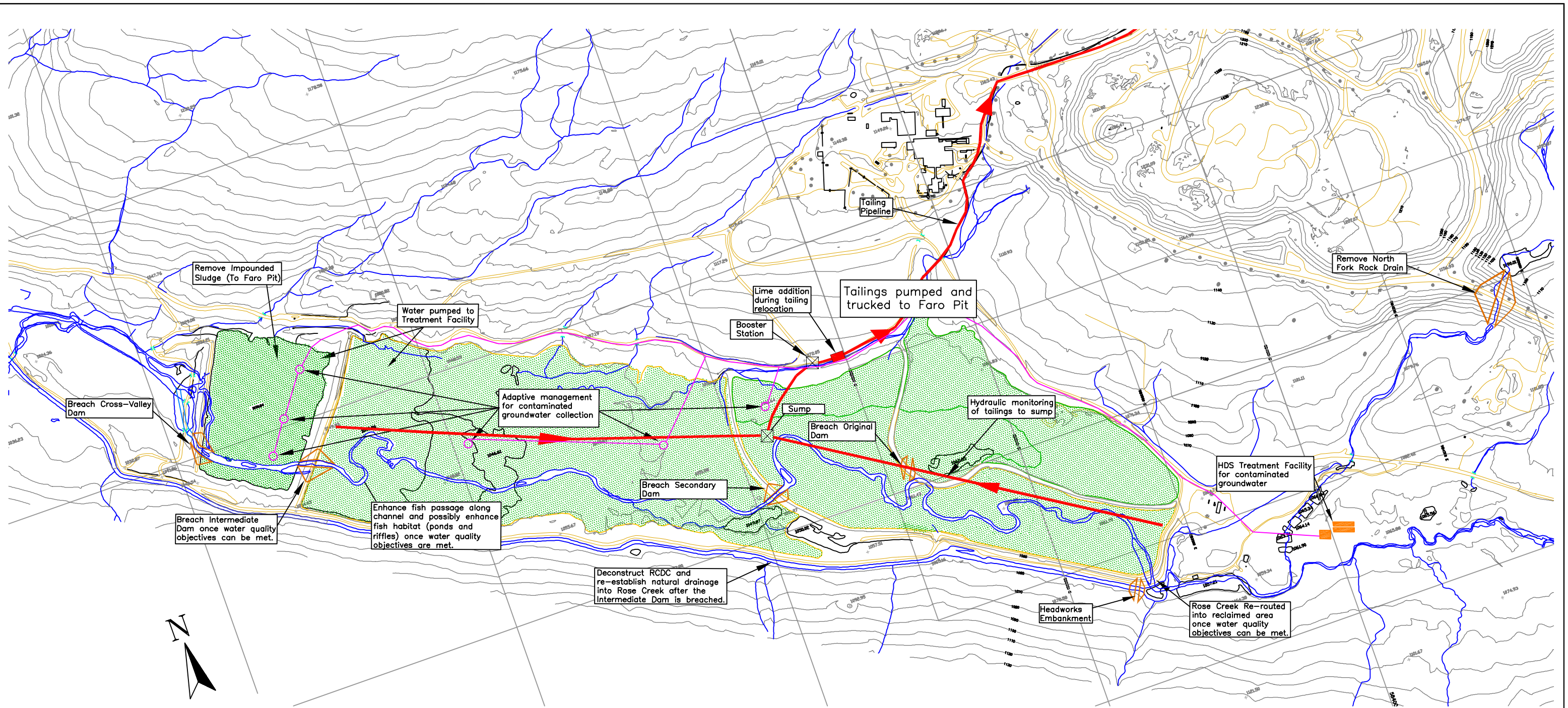
After groundwater cleanup is complete, the Rose Creek Diversion will then be breached to restore flow to approximately the original channel. Fish habitat along the restored channel will be enhanced by installing riffles and excavating pools. Willows will be planted along the restored stream channel and seeded and fertilized. The Rose Creek Diversion channel will then be regraded to create stable slopes and be breached where streams enter the channel from the south. The North Fork Rock Drain will be breached and the material hauled to the Faro Waste Dump.

### Post-Closure Requirements








Post-closure requirements for the “Complete Relocation” alternative include:

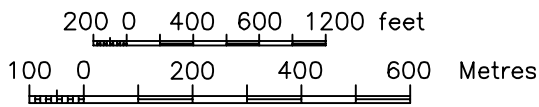
- Year-round pumping of contaminated groundwater and seepage to the water treatment plant for an estimated period of twenty years starting after the completion of tailings removal;
- Year-round operation and maintenance of the water treatment plant for the same period;

- Monitoring of water quality in and around the groundwater collection system for an estimated twenty years, but until no longer required, and in Rose Creek above and below the site for longer;
- Possible relocation or installation of additional extraction and monitoring wells during the twenty year period;
- Annual inspections of all earthworks for an estimated period of twenty years but until no longer necessary.



**LEGEND**

-  Revegetated Area
-  Collection Sump
-  Groundwater Collection Well
-  Water Treatment Plant
-  Groundwater / Seepage Pipeline
-  Tailings Collection Trench
-  Tailings Pipeline



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 Survey control derived from existing 1:20000 photography  
 Survey control based on: UTM Projection, NAD27  
 Compiled by The ORTHOSHOP, Calgary, September 2003  
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**Deloitte & Touche** ON BEHALF OF THE FARO MINE CLOSURE PLANNING OFFICE

Example Alternatives for Closure of Anvil Range Mining Complex

Tailings Alternative 2 - Complete Relocation

DATE: March 2006 APPROVED: FIGURE: 4.2



### 1.3 Tailings Alternative 3 – Partial Relocation

The “Partial Relocation” alternative for the Rose Creek Tailings is illustrated in Figure 1.3. The primary objective of this alternative is to remove the portion of the tailings that presents the greatest risks and the greatest stabilization costs. The tailings in the Intermediate Pond are below the level of the Rose Creek Diversion Channel, and are therefore most at risk from failures of that structure. Relocating those tailings to the Faro Pit will mitigate those risks and significantly reduce the costs of upgrading the channel. The remaining tailings, in the Original and Secondary Ponds, will present much lower risks of physical failure but will continue to need long-term management, including collection and treatment of contaminated groundwater. The following paragraphs summarize the major activities.

#### Closure Activities

The Intermediate Tailings will be pumped to the Faro Pit. The tailings will be hydraulically monitored along excavated trenches to a collection sump and pumped. Lime will be added to the slurry during pumping. Excess water is to be treated through a HDS system in a new treatment plant and discharged. Any remaining contaminated material in the intermediate impoundment area basin will be removed by truck and shovel to the Faro Pit. This area will be then graded for drainage and all surfaces will be seeded and fertilized.

The Cross-Valley Dam will be removed. The impounded sludge and any contaminated soils from below the pond will be excavated and hauled to a sludge containment cell and contaminated soils will be removed to the mill area. The Intermediate Dam will be kept in place to control water and sediment during tailings monitoring will be and breached after basin cleanup is completed. The east and west limbs of the Secondary Dam will be stabilized, either through ground densification with vibro-replacement stone columns or by the construction of buttresses. A compacted berm will also be constructed along the crest of the west limb to increase the freeboard and prevent the release of water that ponds on the tailings surface.

The Secondary and Original tailings will be covered with a low-infiltration cover consisting of 0.5 m of waste rock overlain by 1.5 m of lightly compacted till. Construction of the covers will be sequenced and, if necessary, delayed to allow consolidation and settlement prior to placing a final grading layer. The cover will be seeded and fertilized.

The upper portion of the Rose Creek Diversion Channel will be upgraded to pass the PMF by deepening and widening the channel along its current alignment. Once the basin cleanup is completed, the diversion channel will be breached and re-connected to Rose Creek well downstream of the Secondary Dam. Fish habitat along the thalweg of the Intermediate Impoundment will be enhanced by installing riffles and excavating pools. Willows will be planted along the restored stream channel and the area will be seeded and fertilized. The lower portion of the Rose Creek Diversion channel will then be regraded to create stable slopes and will be breached where streams

enter the channel from the south. The North Fork Rock Drain will be breached and the material hauled to the Faro Waste Dump or used as tailing cover material.

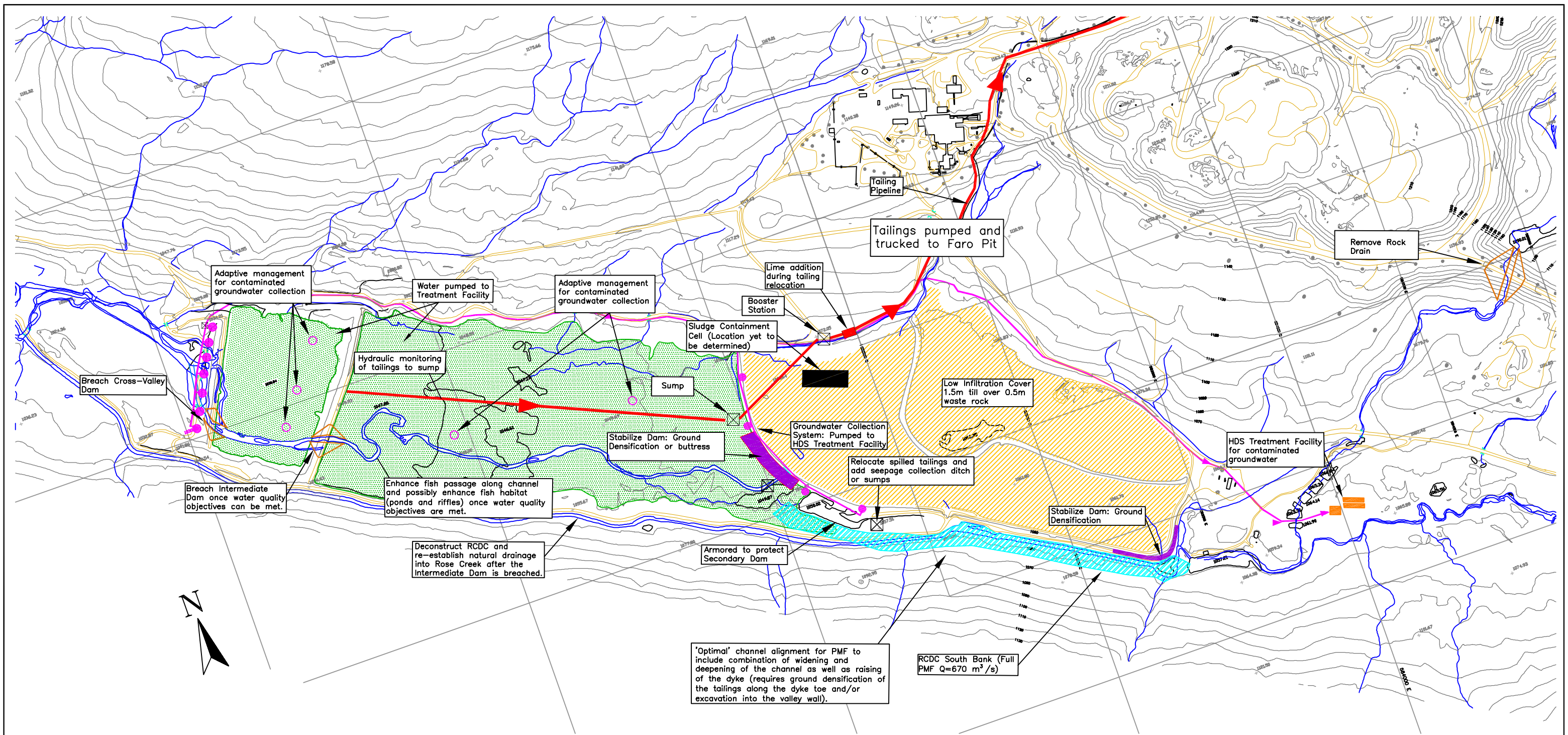
As in the “Complete Relocation” alternative, a groundwater collection system consisting of multiple shallow wells will be constructed to capture localized groundwater contamination from below the footprint of the relocated tailings. An additional long-term groundwater collection system will be constructed below the toe of the Secondary Dam, and will be operated with sufficient drawdown to capture any of the seepage that currently exits from the dam toe. Spare pumps and a redundant power supply will be put in place for emergency use. All extracted groundwater will be piped to a treatment plant and treated.

### **Post-Closure Requirements**


Post-closure requirements for the “Partial Relocation” alternative include:

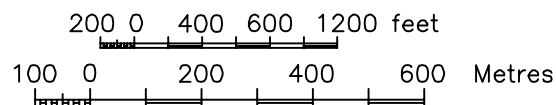
- Year-round pumping of contaminated groundwater and seepage to the water treatment plant;
- Year-round operation and maintenance of the water treatment plant;
- Periodic disposal of water treatment sludge in constructed cells;
- Monitoring of water quality in and around the groundwater collection system, and in Rose Creek above and below the site;
- Relocation or installation of additional extraction and monitoring wells;
- Annual inspections of all earthworks;
- Intensive maintenance of ditches and covers for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

With the maintenance exception noted above, all of the above activities are expected to continue to be required for several hundred years.



**LEGEND**

-  Store and Release Cover
-  Revegetated Area
-  Dam Stabilization Area
-  Rose Creek Diversion Channel Bed
-  Collection Sump
-  Groundwater Collection Well
-  Water Treatment Plant
-  Groundwater / Seepage Pipeline
-  Tailings Collection Trench
-  Tailings Pipeline



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**Deloitte & Touche**  
 ON BEHALF OF THE  
**FARO MINE CLOSURE PLANNING OFFICE**

Example Alternatives for Closure of Anvil Range Mining Complex

**Tailings Alternative 3 - Partial Relocation**

DATE: March 2006 APPROVED: FIGURE: 4.3



## 1.4 Tailings Alternative 4 – Minimize Construction

The “Minimize Construction” alternative for the tailings area is illustrated in Figure 1.4. This alternative represents the case where the up-front expenditure is kept to the minimum that could provide physical stability and environmental protection. The following paragraphs summarize the major activities.

### Closure Activities

Physical stabilization measures are generally the same as those in the “Stabilize in Place” alternative:

- Upgrading of the Rose Creek Diversion Channel to pass a probable maximum flood;
- Buttressing of the Intermediate and Secondary dams; and,
- Removal of the Cross Valley Dam and pond.

The tailings would not be covered. Instead, a soil tackifier would be applied each year to prevent dust release, and a fence would be constructed to prevent direct uptake of tailings by large animals.

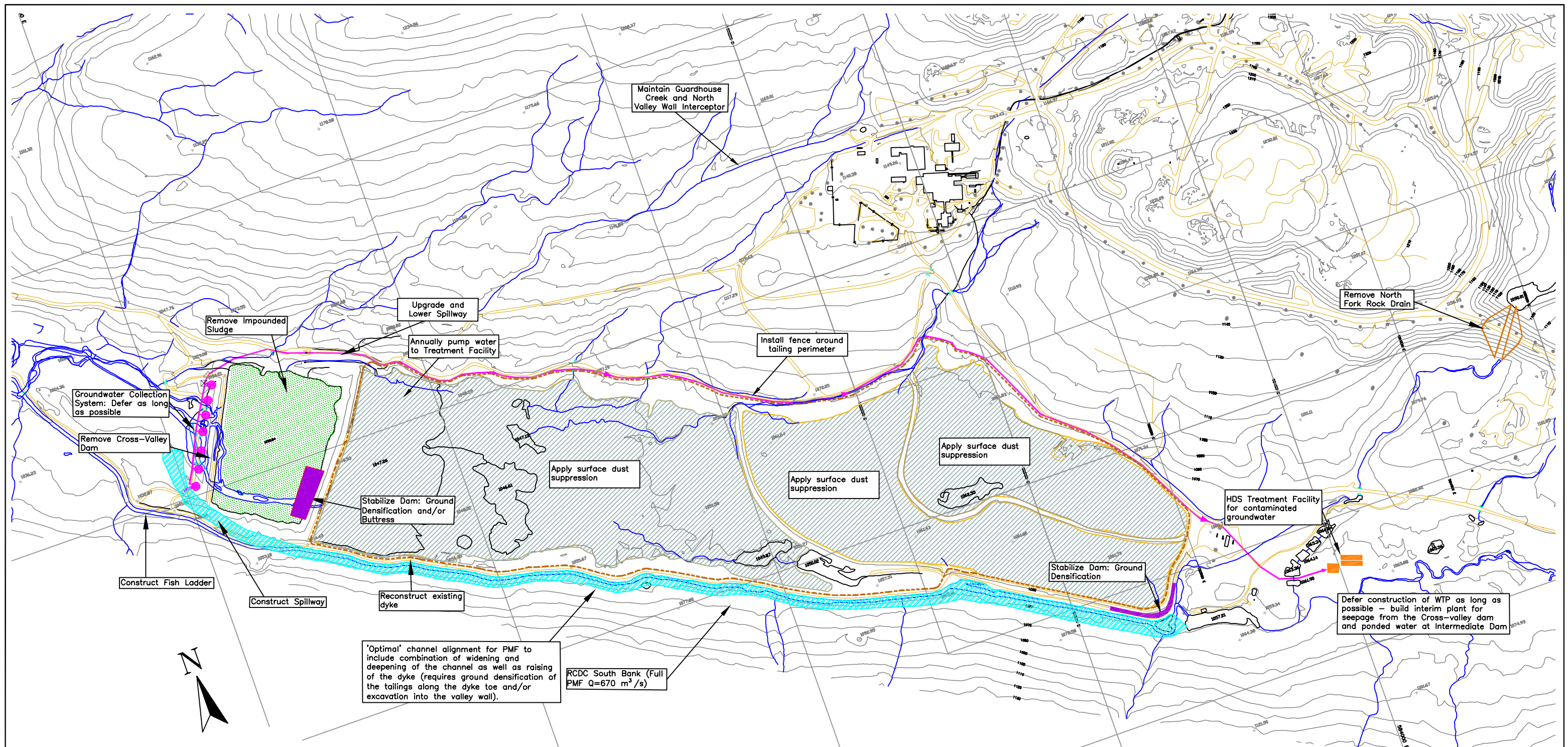
A groundwater collection system similar to that of the “Stabilize in Place” alternative will eventually be needed, but construction will be deferred until monitoring shows that the groundwater contamination is about to reach the surface. An interim water treatment plant will be constructed to treat seepage and tailings runoff.

### Post-Closure Requirements










Post-closure requirements for the “Minimize Construction” alternative include:

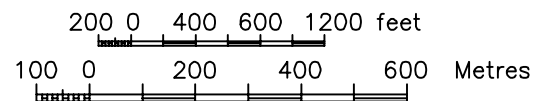
- Annual applications of soil tackifier to the tailings;
- Inspection and regular maintenance of the fence around the tailings;
- Monitoring of water quality in and around the groundwater collection system, and in Rose Creek above and below the site;
- Collection of seepage and eventually contaminated groundwater, and pumping to the water treatment plant;
- Year-round operation and maintenance of the water treatment plant;
- Periodic disposal of water treatment sludge in constructed cells;
- Possible relocation or installation of additional extraction and monitoring wells;
- Annual geotechnical inspections of all remaining earthworks and dams; and,
- Regular inspections and maintenance of the Rose Creek Diversion Channel.

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**LEGEND**

-  Revegetated Area
-  Surface Dust Suppressed Tailings
-  Dam Stabilization Area
-  Rose Creek Diversion Channel Bed
-  Collection Sump
-  Groundwater Collection Well
-  Water Treatment Plant
-  Groundwater / Seepage Pipeline
-  Fence



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Example Alternatives for Closure of Anvil Range Mining Complex

**Tailings Alternative 4 - Minimize Construction**

DATE: March 2006	APPROVED:	FIGURE: 4.4
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**Attachment B3**  
**Tailings Water Cover Alternative:**  
**Additional Assessment**

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## Memo

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<b>To:</b>	Faro Mine Closure Planning Office	<b>Date:</b>	April 4, 2007
<b>cc:</b>	D. Hockley (SRK)	<b>From:</b>	Michael Royle
<b>Subject:</b>	Tailings Water Cover Alternative – Additional Assessment	<b>Project #:</b>	1CD003.065

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This memorandum is a follow-up to the SRK memo by D. Hockley and P. Mikes, December 22, 2006 on the “Tailings Water Cover Alternative” and presents a more detailed assessment of the alternative.

Figure 1 illustrates the conceptual design of the Water Cover option, with relevant elevations indicated. Key points are discussed below.

### Tailings Volumes and Dam Crest Requirements

A more detailed assessment of tailings relocation volumetrics concluded that:

- The tailings from the Original and Secondary Impoundments could be relocated to the Intermediate Impoundment to result in a “struck-level” surface at elevation 1054.5 masl.
- Allowing for 0.5 m of erosion protection (cover) and 2.0 m of water cover, the spillway low flow outlet elevation was revised to elevation 1057.0 masl.
- Allowing an increased 5.0 m of freeboard (was previously 4.0 m, but 5.0 m is needed for PMF), the Intermediate Dam would need to be raised to elevation 1062.0 masl.

### Flow Channel

At elevation 1062.0 masl, the Intermediate Dam would completely block the Rose Creek Diversion Channel (invert at 1050.0 masl at dam centreline). Annual flows would therefore need to be somehow routed over the tailings surface. However, that would lead to a release of contaminated water, at least in the short term. Three options were considered in the original scoping memo:

- A. Treating all of the water passing over the tailings surface until such time as it was suitable for discharge without treatment.
- B. Adding lime to the tailings to minimize the contaminants available for dissolution.
- C. Constructing a service channel to pass “normal flows” through the middle of the pond.

Option A was determined to be too costly, and would not protect against tailings scouring and entrainment during a PMF event. Option B also would not protect against tailings scouring and entrainment during a PMF event. Option C would protect against tailings erosion and transport downstream, and so was assessed further for construction and cost implications.

Option C was carried forward using the following design assumptions:

- Tailings will be relocated and graded to form a relatively flat surface;
- Lime will be mixed into top 0.5m of tailings during relocation;
- Tailings to be covered with 0.5m thick physical barrier of waste rock to allow passage of PMF without scouring/erosion of tailings;
- Water cover will be 2m over rock cover;
- Cross tailings channel (CTC) will be designed to convey 500 year storm event;
- CTC will be lined to avoid contamination from tailings lake water in the short term;
- Lake level will need to be actively controlled initially;
- Once tailings lake chemistry is acceptable, CTC liner will be breached to allow passive control of lake level (CTC spillway invert constructed at design lake level: 1057 masl).

Details of the alternative are discussed below and shown in Figure 1.

### **Tailings Relocation**

Approximately 29,000,000 m<sup>3</sup> of tailings are stored in the Faro tailings facility. An assessment of the total volume of tailings versus the capacity curve for the Original, Secondary, and Intermediate Tailings areas indicates that the tailings could be levelled at an elevation of 1054.5 masl. This would entail relocating approximately 7,500,000 m<sup>3</sup> of tailings (Figure 1). This work would include the requirement to pump out the existing pond upstream of the Intermediate Dam and fill this area. This void has been taken into account when calculating the final elevation of the flattened tailings.

#### *Rock Cover*

The proposed rock cover will be constructed using run of mine waste rock. However, this material may be geochemically unacceptable for use with a water cover. Because of this, the costs for the rock cover have been revised to allow for quarrying of clean material from a new location developed on site and additional closure measures for the quarry.

### **Intermediate Dam Raising**

To accommodate the extra tailings in the Intermediate Impoundment, and the resulting water cover, the dam would need to be raised by 12.0m, based on the following estimates:

- Current Intermediate Dam crest = 1050.0 masl.
- Tailings flattened to 1054.5 masl.
- Erosion cover (waste rock) = 0.5 m thick (1055.0 masl).
- Maintenance of a 2 m water cover on the impoundment = 1057.0 masl.
- 5 m freeboard maintained below the dam crest = 1062.0 masl.

The lateral extent of the dam crest at full height is shown in Figure 1, and can be seen to block the current RCDC.

Construction of the dam raise would require maintaining the current RCDC alignment until such time as the CTC was completed. To do so, the west abutment of the Intermediate Dam can not be completed until after the creek has been rerouted to the CTC. During the intermediate period, several options could be used to manage the construction in this NW corner of the impoundment, consisting of:

1. No tailings relocated to the NW corner, beyond what is required for stable CTC foundation, until after Rose Creek diverted into CTC. At such time, the west abutment would be constructed and

- tailings relocated to NW corner. This would incur a higher cost/m<sup>3</sup> for relocation, in addition to extra costs for ensuring stable foundation of CTC and 2 phase dam raise construction; or
2. Rock fill retaining berm constructed to maximize volume of tailings relocated to NW corner prior to completion of CTC (which will impede truck movement) and realignment of RCDC. The berm could be constructed along the current right bank of the RCDC to allow for maximum relocation to occur.

Both of these options will incur significant extra costs and construction risks compared to relocation without having to accommodate the RCDC at the west abutment. These issues have not been assessed in detail, but are expected to add significant costs and risk to the construction project.

## Site Hydraulics

The topography between the upstream end of the tailings area to the abutments of the Intermediate Dam is quite flat, as shown in Figure 2 (completed alternative channel elevations). This is problematic for the channel design because of the increased potential for glaciation of the flow during winter.

- Original and Secondary Dam at upstream end = ~1064 masl.
- Pump House Pond = 1057.2 masl.
- Intermediate Dam spillway invert = 1057.0 masl.

To create a gradient across the tailings impoundment, a weir would be constructed in the upstream valley floor at an elevation of 1059.0 masl to control flow at the upstream end of the RCDC. This would create a gradient of approximately 2.5 m over the 3275 m from weir to the eastern abutment of the Intermediate Dam. Even this gradient is only 0.0008, and is still likely to be problematic with respect to construction grade control, settlement tolerance, and channel glaciation.

Partial relocation of tailings to the Faro Pit was assessed to increase the gradient at the site. However, even if the tailings were excavated down to 1050.0 masl, the gradient will still only be approximately 0.003 along the diversion. To obtain a lower tailings surface, an additional 525,000 to 580,000 m<sup>3</sup> of tailings would require relocation for each meter of elevation between 150.0 and 1054.0 masl.

## Cross Tailings Channel (CTC) Routing

Routing across the tailings will be via a lined 500 year channel built up above the tailings rock cover. Details of the CTC design will be:

- Flows at or below the 500 year event (145 m<sup>3</sup>/s) will be directed into a lined channel across the tailings;
- The invert of the CTC will be at same elevation as the design pond level (1057.0m) in order to provide passive inflow to the pond at low flow periods;
- The CTC will be lined to prevent contaminated lake water flowing back into the CTC after a high flow event.

## Flood Routing

Flood routing will be separated into 500 year event channels and PMF channels. The planned upgrades are as follows:

- All flow from the North and South Forks of Rose Creek will enter a stilling pond to the south of the impoundment (see Figure 1);
- The weir maintaining pond level will be designed for PMF flow;

- The upstream portion of the Rose Creek Diversion Channel from the stilling pond to the tailings access point will be upgraded to PMF standard;
- A 0.5 m layer of granular material will be constructed over the entire tailings surface to provide a physical barrier during high flow;
- A 500 year event, lined channel will be built across the tailings and tied into the spillway at the east abutment (Figure 2);
- A PMF outlet will be built at the access to tailings to direct PMF overflow onto the tailings (see below);
- PMF flow across the tailings will be collected at a PMF capable inlet at the top of the east abutment spillway; and
- The east abutment spillway will be designed for PMF flow.
- A 0.5 m layer of granular material over the entire tailings surface would be reasonably easy to construct, and was therefore adopted for the cost estimate.

During PMF flow, the tailings lake water would be flushed downstream. Based on expected lake chemistry, this is not expected to cause significant increases in metals concentrations during the high flow events. However, the overflow from the ETA would also be incorporated into this flow and may be significant.

### **Dam Raising**

The Intermediate Dam would be raised to a crest elevation of 1062.0 masl. This would be done as a downstream raise, with the dam core tied into the existing core by means of the cut-off wall. This method of construction is considered to be conservative, and so could be optimized to potentially reduce the required volume of materials.

Prior to commencing the final phase of the dam raise construction at the western abutment, the RCDC will be diverted into the CTC. During this time, the tailings lake to the west of the CTC will need to be kept dry to prevent flow into the construction zone.

Stability of the raised dam has not been assessed formally, but is expected to be achievable within reasonable budgets.

### **Cut-off Wall**

Scoping level costs and construction implications for the cut-off wall were assessed. Cut-off wall technologies used on similar projects in Canada consist of generally two types: 1) Soil mixing where cementitious or polymer grout is mixed into soils using vertical cutting tools, and 2) "Diaphragm" walls, where the soil and soft rock is removed by a vertical cutting tool and completely replaced by a cementitious or polymer grout. Discussions with contractors who have recently worked at the Diavik site estimate that the in-place costs for the two methods are approximately \$300 to 400/m<sup>2</sup> for soil mixing and \$600 to \$800 for a diaphragm wall. Hydraulic performance testing of these wall types show that it is reasonable to expect  $1 \times 10^{-7}$  m/s for soil mixing and  $1 \times 10^{-8}$  to  $1 \times 10^{-9}$  m/s for diaphragm wall.

The deepest soil mixing walls constructed in North America to date are reported to be approximately 40m deep. Diaphragm walls have been constructed to depths of 135m in Quebec, but many technical difficulties (deviation, etc.) occur at these extreme depths. The maximum depth expected for the Intermediate Dam wall would be approximately 85m, ruling out soil mixing, but well within the diaphragm wall limits. Therefore, costs have been based on the diaphragm wall method.

### *Upstream Cut-off Wall*

The IPRP recommended that cut-off walls be constructed at both the upstream and downstream ends of the flooded impoundment to minimize groundwater flow under the tailings, thereby reducing the volume of contaminated groundwater to be treated in the downstream pump and treat system. However, as will be discussed below, a pond will be constructed at the upstream end to increase the gradient along the channel. This pond will be at a higher elevation than the tailings pond level; therefore will form a hydraulic barrier to seepage from the tailings pond. Consequently, the upstream cut-off wall is not required.

### *Intermediate Dam Cut-off Wall*

A downstream cut-off wall constructed through the Intermediate Dam crest is required to reduce seepage from the tailings pond under the dam.

The cross sectional area along the dam centreline of the Intermediate Dam is estimated based on available drilling results; however, information is unavailable along the eastern extent, so could lead to an increase in required wall construction. The wall length was estimated to be 850m, with a median depth of 50m (allowing for a 5m penetration into bedrock). The estimated wall area is shown 42,500 m<sup>2</sup>.

## **Water Treatment**

Under the assumption that the cut-off walls are effective, long-term groundwater treatment costs associated with the Water Cover would be less than that for the “Stabilize in Place” alternative; water treatment costs associated with the “Stabilize in Place” alternative were used for the water cover alternative. An additional water treatment cost of \$500,000 per year was included for the first five years only, to allow for the pond water to be actively neutralized until better water quality develops. As stated in the December memo, we did not model the water quality development, but simply relied on the experience reported by the IPRP that pond water quality improves rapidly in these situations.

Pore water diffusion into the tailings pond is not expected to be significant as the physical driving gradient is expected to impede any upwards movement.

## **Cost Estimates**

The attached tables present the estimated closure and post-closure costs for the water cover option, prepared in the same format as used in Attachment E of the Example Alternatives report.

Tables 1-3 on the following page provide a summary comparison to the other tailings area alternatives. Although the estimates for the Water Cover option have not been reviewed or refined as well as those of the example alternatives, the pattern is clear. The Water Cover option is similar in overall cost to the Stabilize in Place alternative, but with higher closure costs and lower post-closure costs.

It should be noted that the closure costs for the ETA have not been included in any of the alternative costs in Tables 1 to 3.

## **Risks**

A rigorous review of the risk associated with the Water Cover option has not been completed. However, some conclusions are obvious:

### *Construction*

- There is a small risk of dam failure at the west abutment during construction of the dam in this area after the creek has been diverted across the tailings. During this time a PMF flow could break through the cross tailings channel berm and cause significant erosion of tailings through the present Rose Creek channel alignment.
- As the gradient of the CTC is very low, settlement may cause significant maintenance issues unless the channel berms are built to accommodate this, thus requiring additional material and costs.
- May need to buttress the Intermediate dam with a greater volume of material than would be required for just the raise.
- Construction of the cut-off wall will be carried out under current, saturated conditions. The imposed gradient across the wall during construction makes it more likely that defects could occur as compared to the construction at Diavik. The Diavik wall was constructed with lake levels equal on either side; therefore without a gradient across it until completed and the dyked area pumped out.
- Truck and shovel methods may not be possible, therefore more lime would be required to neutralize acidic pore water liberated during hydraulic relocation.
- Lime addition is based on liming the top 0.5 m of tailings only during relocation. This may be inadequate if significant rainfall occurs during relocation, thus liberating acidic porewater.

### *Operation and Maintenance*

- Glaciation of the low gradient channels is likely to be an ongoing operations issue in the channels.
- Ice blockage of the east abutment spillway during spring break-up is considered to present a serious risk in high spring runoff conditions. This risk is especially relevant as the PMF for the site is expected to be a rain on snow event, that is likely to occur when ice is still present in the tailings pond.
- 100 year + flows from the ETA will enter the tailings lake and contaminate the pond.
- ETA overflow into the tailings lake would enter Rose Creek directly in a PMF event as the flow moves through the tailings lake.
- Incomplete capture of seepage from the S-wells and Zone 2 area could contaminate the headwater pond, even if the north fork of rose creek is relocated to a raised channel.
- Groundwater seepage impact is not reduced when compared to the Stabilize in Place alternative, and may be worse.
- Seismic risk is increased by the higher pore pressures in the dam due to the water cover.
- Consequences of a dam failure are significantly higher with the water cover:
  - If dam is breached, lake water (~ 2,000,000 m<sup>3</sup>) would significantly increase breach opening and carry eroded tailings downstream;
  - Failed impoundment would still have Rose Creek flowing across it, but in an uncontrolled state. This would lead to further erosion and transport of tailings downstream;

- Lake water would preferentially infiltrate through the coarser tailings, which have significantly worse pore water chemistry. Infiltration through dry cover would be more uniform.
- There is a small risk of dam failure at the west abutment during construction of the dam in this area after the creek has been diverted across the tailings. During this time a PMF flow could break through the cross tailings channel berm and cause significant erosion of tailings through the present rose creek channel alignment.

## **Recommendations**

The water cover option proposed by the IPRP has been more fully assessed. Although the option is feasible, it has fewer benefits and more risks than the “Stabilize in Place” option.

One attractive element of the water cover option is the routing of large floods over the tailings cover, which reduces the long-term risks associated with reliance on the Rose Creek Diversion for flood routing. That element of the water cover option should be considered further as a potential improvement to the “Stabilize in Place” option.

**Table 1: Estimated Closure Period Costs for Example Alternatives**

Example Alternative	Direct Costs	Indirect Costs	Total Closure Costs
<b>Rose Creek Tailings</b>			
Complete Relocation	\$286,300,000	\$132,200,000	\$418,500,000
Stabilization in place	\$90,200,000	\$42,000,000	\$132,000,000
Partial Relocation	\$173,300,000	\$80,200,000	\$253,500,000
Minimize Up-Front Construction	\$38,700,000	\$18,300,000	\$57,000,000
Water Cover	\$163,300,000	\$75,600,000	\$238,900,000

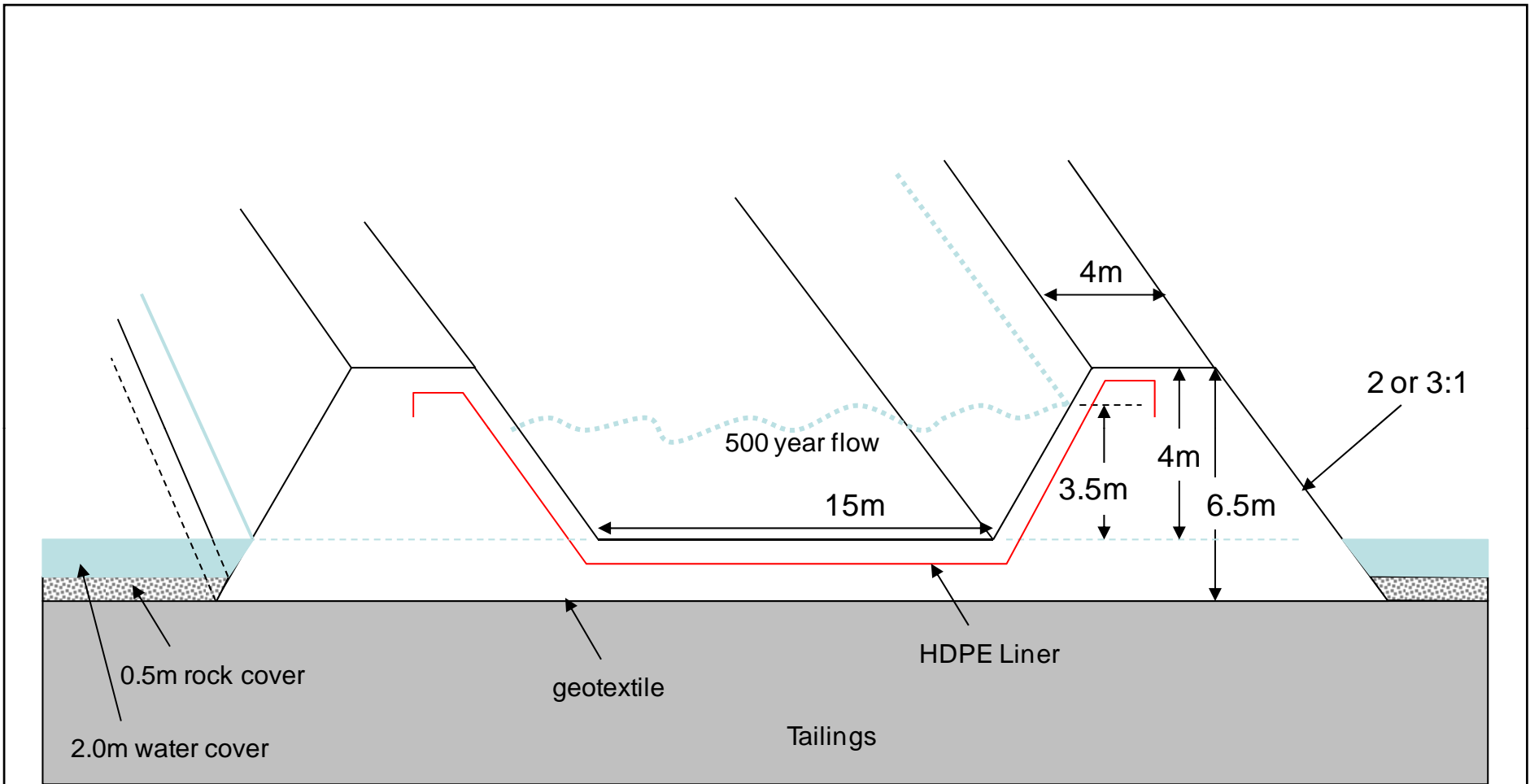
**Table 2: Estimated Post-Closure Costs for Example Alternatives**

Example Alternative	Treatment System Capital Cost	Average Annual Post-Closure Operating & Maintenance Cost	Treatment Capital + Post-Closure (Net Present Value)
<b>Rose Creek Tailings</b>			
Complete Relocation	\$3,400,000	\$640,000	\$24,600,000
Stabilization in place	\$5,200,000	\$1,730,000	\$52,800,000
Partial Relocation	\$3,900,000	\$1,440,000	\$41,800,000
Minimize Up-Front Construction	\$5,300,000	\$1,910,000	\$56,800,000
Water Cover	\$0	\$1,680,000	\$47,900,000

**Table 3: Summary Cost Estimates for Example Alternatives**

Example Alternative	Closure	Post-Closure NPV	Total
<b>Rose Creek Tailings</b>			
Complete Relocation	\$418,500,000	\$24,600,000	\$443,100,000
Stabilization in place	\$132,000,000	\$52,800,000	\$184,800,000
Partial Relocation	\$253,500,000	\$41,800,000	\$295,400,000
Minimize Up-Front Construction	\$57,000,000	\$56,800,000	\$113,800,000
Water Cover	\$238,900,000	\$47,900,000	\$286,700,000

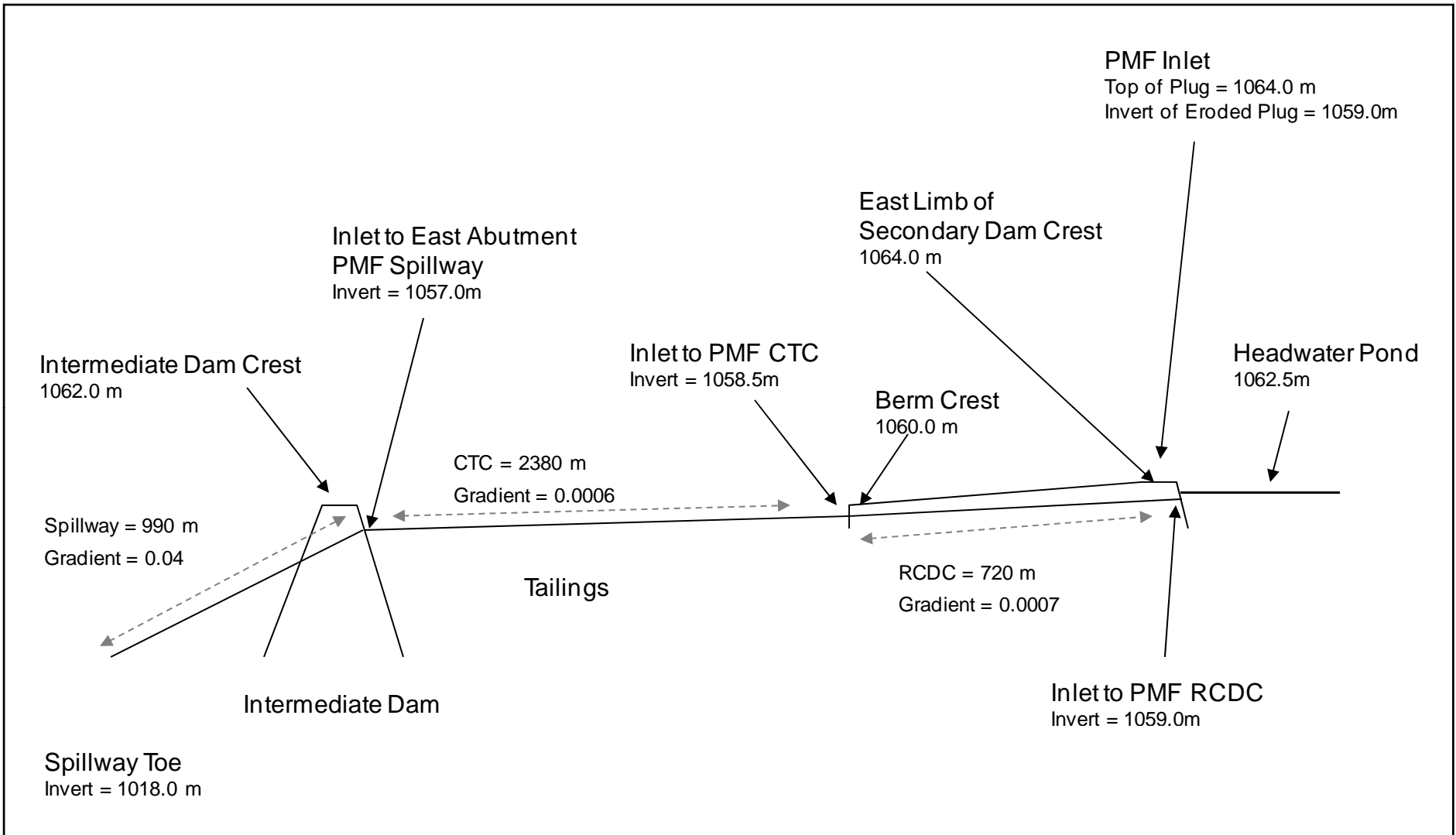
**Figures**






**SRK Consulting**  
 Engineers and Scientists

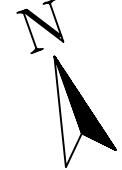
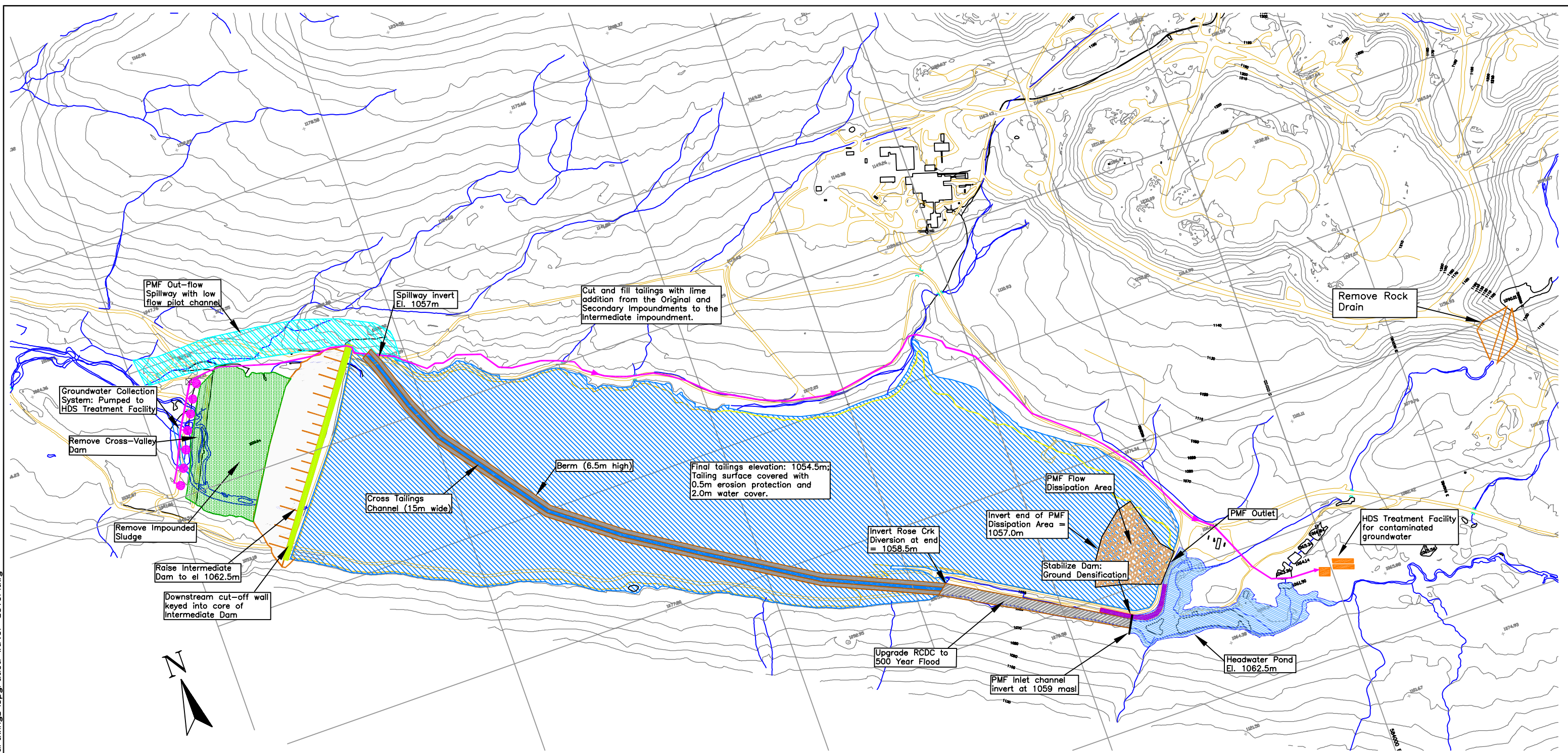

**Deloitte & Touche**

Anvil Range Mining Complex Yukon Territory			
<b>Cross Tailings Channel (500 Year Flood Channel)</b>			
PROJECT: 1CD001.065.100	DATE: April 2007	APPROVED:	FIGURE: <b>1</b>

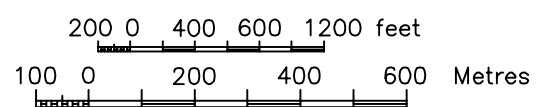


 <p><b>SRK Consulting</b> Engineers and Scientists</p>	Anvil Range Mining Complex Yukon Territory		
	<p align="center"><b>Water Cover Alternative</b> <b>Flow Path Inverts and Gradients</b></p>		
 <p><b>Deloitte &amp; Touche</b></p>	PROJECT: 1CD001.065.100	DATE: April 2007	APPROVED:
			FIGURE: <b>2</b>

Dwg Ref: G:\Deloitte\_touche\Acad-Faro\2006 Acad drawings\Upgraded water cover.dwg



- LEGEND**
- Revegetated Area
  - Final Tailings Surface
  - Water Cover
  - Intermediate Dam Spillway
  - Collection Sump
  - Groundwater Collection Well
  - Water Treatment Plant
  - Groundwater / Seepage Pipeline
  - Cut-off Wall



**SRK CONSULTING**  
 Faro Mine, Yukon

Contour Interval: 10m  
 Survey control derived from existing 1:20000 photography  
 Survey control based on: UTM Projection, NAD27  
 Compiled by The ORTHOSHOP, Calgary, September 2003  
 WO 8856

**SRK Consulting**  
 Engineers and Scientists  
 Vancouver B.C.

SRK JOB NO.: 1CD003.065  
 FILE NAME: Upgraded water cover.dwg

**Deloitte & Touche**  
 ON BEHALF OF THE  
**FARO MINE CLOSURE PLANNING OFFICE**

Example Alternatives for Closure of  
 Anvil Range Mining Complex

**Tailings Alternative 5 - Upgraded Water Cover**

DATE: Feb. 2007	APPROVED:	FIGURE: -
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allings Alternative 5 - Water Cover

Contract Code	Work Area Code	Item	Task	Sub-Task	Estimate Type	Task	Activity	Quantity	Unit	Cost Code	Unit Mhrs	Total Mhrs	Labour Rate	Labour Cost	Unit Mat	Material Cost	Unit Equip.	Equipment Cost	Unit Fuel	Fuel Consumpt (L)	Fuel Cost	Power Rate (\$/Unit)	Power Cost	Unit Cost	Activity Total	Subtotals	Source / Comments		
<b>CLOSURE COSTS - DIRECT CAPITAL</b>																													
<b>Dams</b>																													
<b>Cross Valley Dam</b>																													
1	1	1	600			Remove pond	Pump pond water to discharge	140	days	C.3.11	2,010	337.3	\$ 84.34	\$ 11,807	\$ -	\$ -	\$ -	\$ 130.72	\$ 18,301	\$ 40.72	\$ 4,386	\$ 5,701	\$ -	\$ -	\$ 255.78	\$35,810			
1	1	2	430			Remove impounded sludge	Excavate and create berms for use as sludge cell on top of tailings	1,446	m3	C.2.12	0.024	34.0	\$ 0.86	\$ 29.4	\$ -	\$ -	\$ -	\$ 2.00	\$ 2,865	\$ 0.80	\$ 1,036	\$ 1,347	\$ -	\$ -	\$ 3.79	\$5,477			
1	1	3	430			Place Shell materials	Load, haul and place sludge material	1,600	m3	R.063	0.040	64.0	\$ 1.46	\$ 93.43	\$ -	\$ -	\$ -	\$ 3.91	\$ 6,263	\$ 1.82	\$ 2,957	\$ 3,968	\$ -	\$ -	\$ 7.29	\$11,670			
1	1	3	430			Remove contaminated soil	Excavate, load, haul and place contaminated soils to mill area	322,650	m3	R.096	0.014	4,306.1	\$ 0.49	\$ 159,581	\$ -	\$ -	\$ -	\$ 1.88	\$ 698,195	\$ 1.22	\$ 302,798	\$ 393,622	\$ -	\$ -	\$ 3.60	\$1,161,388			
1	1	4	430			Upgrade roads	Construct new access road where necessary	200	m	C.2.26	0.010	826.5	\$ 0.37	\$ 30,470	\$ -	\$ -	\$ -	\$ 0.14	\$ 2,059	\$ 0.53	\$ 819	\$ 1,065	\$ -	\$ -	\$ 2.27	\$4,660			
1	1	5	430			Remove dam	Excavate, haul and place dam material for the Int. Dam raise.	232,338	m3	R.064	0.020	468,676	\$ 0.72	\$ 167,834	\$ -	\$ -	\$ -	\$ 1.61	\$ 133,919	\$ 1.13	\$ 72,325	\$ 94,023	\$ -	\$ -	\$ 3.85	\$86,153			
1	1	6	430			Revegetate dam footprint and impoundment	Seed/Fertilize, helicopter high application rate	150,700	m2	C.5.01	0.000	18.8	\$ 0.00	\$ 0.77	\$ -	\$ -	\$ -	\$ 0.05	\$ 8,214	\$ 0.77	\$ 100	\$ -	\$ -	\$ 0.15	\$22,692				
<b>Raise Intermediate Dam (1065m)</b>																													
1	2	1	430			Remove Protective cover to expose core	Load, haul, dump, sand and gravel (spot locally)	1,438	m3	C.2.12	0.024	33.8	\$ 0.86	\$ 29.3	\$ -	\$ -	\$ -	\$ 2.00	\$ 2,871	\$ 0.83	\$ 1,031	\$ 1,340	\$ -	\$ -	\$ 3.79	\$5,449			
1	2	2	430			Place Shell materials	Load, haul, dump, compact sand and gravel material	1,303,559	m3	C.2.12	0.024	33,000.1	\$ 1.27	\$ 42,213.3	\$ -	\$ -	\$ -	\$ 2.45	\$ 3,706,000	\$ 1.12	\$ 1,156,458	\$ 1,503,368	\$ -	\$ -	\$ 4.63	\$6,206,398			
1	2	3	430			Place Drainage materials	Produce, screen and stockpile gravel materials	41,250	m3	C.2.02	0.010	412.5	\$ 0.37	\$ 15,098	\$ -	\$ -	\$ -	\$ 1.61	\$ 66,356	\$ 1.13	\$ 35,837	\$ 46,588	\$ -	\$ -	\$ 3.10	\$119,042			
1	2	3	430			Place filter materials	Load, haul, dump, compact drainage materials	41,250	m3	R.099	0.029	120.1	\$ 1.07	\$ 43,960	\$ -	\$ -	\$ -	\$ 2.45	\$ 100,895	\$ 1.12	\$ 35,813	\$ 46,297	\$ -	\$ -	\$ 4.63	\$191,442			
1	2	4	430			Place fiber materials	Produce, screen and stockpile fine and coarse fiber materials	83,250	m3	C.2.02	0.010	832.5	\$ 0.37	\$ 30,470	\$ -	\$ -	\$ -	\$ 1.61	\$ 133,919	\$ 1.13	\$ 72,325	\$ 94,023	\$ -	\$ -	\$ 3.85	\$120,811			
1	2	4	510			Place core material (fill)	Load, haul, dump, compact fiber materials	83,250	m3	R.099	0.029	242.0	\$ 1.07	\$ 88,720	\$ -	\$ -	\$ -	\$ 2.45	\$ 203,604	\$ 1.12	\$ 71,874	\$ 93,436	\$ -	\$ -	\$ 4.63	\$385,780			
1	2	5	430				Load, haul, dump, and compact	102,750	m3	R.105	0.053	542.3	\$ 1.93	\$ 198,076	\$ -	\$ -	\$ -	\$ 4.67	\$ 479,334	\$ 2.28	\$ 180,136	\$ 234,177	\$ -	\$ -	\$ 8.88	\$912,187			
<b>Intermediate Dam Spillway</b>																													
1	3	1	430			Clear and grub	Clear and grub	100,000	m2	C.2.05	0.015	1527.3	\$ 0.53	\$ 55,898	\$ -	\$ -	\$ -	\$ 0.94	\$ 98,181	\$ 0.62	\$ 49,836	\$ 64,787	\$ -	\$ -	\$ 2.08	\$218,888			
1	3	2	430			Excavate Spillway	Soil excavation: Load, haul and dump locally	1,000,000	m3	C.2.12	0.024	20,000.0	\$ 0.86	\$ 17,178	\$ -	\$ -	\$ -	\$ 2.00	\$ 1,996,862	\$ 0.93	\$ 717,285	\$ 932,471	\$ -	\$ -	\$ 3.79	\$3,790,329			
1	3	2	430			Rock excavation: Load, haul and dump locally	Rock excavation: Load, haul and dump locally	500,000	m3	C.2.15	0.017	8666.7	\$ 0.34	\$ 1,720,000	\$ -	\$ -	\$ -	\$ 9.13	\$ 4,563,872	\$ 0.89	\$ 1,418,872	\$ 1,844,533	\$ -	\$ -	\$ 19.16	\$9,580,345			
1	3	3	430			Construct channel - spillway to Rose Cr.	Supply and place geotextile	105,000	m2	C.4.07	0.071	7050.0	\$ 2.52	\$ 264,900	\$ 3.50	\$ 387,500	\$ -	\$ -	\$ 3.07	\$ 165,601	\$ 0.53	\$ 42,658	\$ 55,455	\$ -	\$ -	\$ 7.57	\$773,466		
1	3	3	430			Bedding layer: Screen and stockpile	Bedding layer: Screen and stockpile	31,500	m3	C.2.02	0.010	315.0	\$ 0.37	\$ 11,529	\$ -	\$ -	\$ -	\$ 1.61	\$ 50,672	\$ 1.13	\$ 27,366	\$ 35,576	\$ -	\$ -	\$ 3.10	\$97,777			
1	3	3	430			Bedding layer: Load, haul, dump and place	Bedding layer: Load, haul, dump and place	31,500	m3	R.099	0.029	917.2	\$ 1.07	\$ 33,570	\$ -	\$ -	\$ -	\$ 2.45	\$ 177,059	\$ 1.12	\$ 27,196	\$ 35,354	\$ -	\$ -	\$ 4.63	\$145,960			
1	3	4	430			Rip-rap: Drill, blast and stockpile	Rip-rap: Drill, blast and stockpile	52,500	m3	C.2.24	0.045	2,862.5	\$ 1.62	\$ 85,200	\$ 15.74	\$ 825,300	\$ -	\$ -	\$ 2.64	\$ 138,007	\$ 1.96	\$ 52,077	\$ 71,850	\$ -	\$ -	\$ 21.27	\$120,874		
1	3	5	430			Rip-rap: (angular, high quality): Screen and stockpile	Rip-rap: (angular, high quality): Screen and stockpile	52,500	m3	C.2.26	0.057	3,000.0	\$ 2.09	\$ 109,800	\$ -	\$ -	\$ -	\$ 9.19	\$ 482,562	\$ 0.45	\$ 260,631	\$ 338,820	\$ -	\$ -	\$ 17.74	\$931,212			
1	3	6	430			Rip-rap: Load, haul, dump	Rip-rap: Load, haul, dump	52,500	m3	R.100	0.053	118.3	\$ 0.82	\$ 43,234	\$ -	\$ -	\$ -	\$ 2.00	\$ 104,889	\$ 0.94	\$ 38,163	\$ 49,986	\$ -	\$ -	\$ 3.77	\$197,221			
1	3	7	430			Rip-rap: Place and secure	Rip-rap: Place and secure	52,500	m3	C.2.27	0.013	656.3	\$ 0.46	\$ 24,919	\$ -	\$ -	\$ -	\$ 0.89	\$ 46,693	\$ 0.47	\$ 18,940	\$ 24,823	\$ -	\$ -	\$ 1.82	\$95,334			
<b>Secondary Dam</b>																													
1	4	1	430			Ground densification (East Limb)	Gravel: supply and stockpile locally	2,338	m3	C.2.02	0.010	23.4	\$ 0.37	\$ 856	\$ -	\$ -	\$ -	\$ 1.61	\$ 3,782	\$ 1.13	\$ 2,032	\$ 2,641	\$ -	\$ -	\$ 3.10	\$7,280			
1	4	1	430			Gravel: load, haul, dump	Gravel: load, haul, dump	2,338	m3	R.098	0.023	53.0	\$ 0.83	\$ 19,399	\$ -	\$ -	\$ -	\$ 1.97	\$ 4,806	\$ 0.91	\$ 1,834	\$ 2,124	\$ -	\$ -	\$ 3.71	\$8,668			
1	4	2	430			Drill vibro-replacement stone columns	Drill vibro-replacement stone columns	26,800	m3	C.3.01	0.267	7146.7	\$ 12.56	\$ 326,291	\$ -	\$ -	\$ -	\$ 6.86	\$ 182,362	\$ 4.37	\$ 61,117	\$ 117,152	\$ -	\$ -	\$ 23.72	\$635,754			
1	4	4	600			Verification testing	Verification testing	1	ts	C.9.02	530.839	530.6	\$ 37,845.16	\$ 37,845	\$ -	\$ -	\$ -	\$ 8,410.91	\$ 6,411	\$ 2,743.93	\$ 2,111	\$ 2,744	\$ -	\$ -	\$ 50,000.00	\$50,000			
<b>Subtotal Direct Costs - Dams</b>																													
											<b>194.171</b>	<b>\$7,188,344</b>	<b>\$1,206,592</b>	<b>\$13,234,160</b>	<b>4,806,673</b>	<b>\$6,248,677</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$0</b>	<b>\$27,877,682</b>	
<b>Tailings</b>																													
<b>Level Tailings Surface</b>																													
1	2	1	600			De-water Intermediate Tailings	Pump pond water to Faro Pit or water treatment facility	267,200	m3	C.2.01	0.004	1176.2	\$ 0.15	\$ 41,167	\$ 0.00	\$ 6,208	\$ -	\$ -	\$ 0.01	\$ 1,533	\$ 0.00	\$ 841	\$ 1,000	\$ -	\$ -	\$ 0.19	\$50,000		
2	1	2	600			Upgrade roads	Upgrade roads along tailings areas	4,000	m	C.2.29	0.225	900.0	\$ 8.24	\$ 32,840	\$ -	\$ -	\$ -	\$ 29.67	\$ 118,897	\$ 19.48	\$ 9,845	\$ 77,929	\$ -	\$ -	\$ 57.39	\$229,566			
2	1	3	600			Relocate tailings to grade to 1054.5m at Line addition	Construct new access road where necessary	2,000	m	C.2.23	0.131	262.0	\$ 1.40	\$ 366,808	\$ -	\$ -	\$ -	\$ 10.14	\$ 262.5	\$ 4.80	\$ 3,333	\$ 19,820	\$ -	\$ -	\$ 20.27	\$40,545			
2	1	4	600			Load, haul, dump from Original and Secondary Imp. to Intermediate Imp	Load, haul, dump from Original and Secondary Imp. to Intermediate Imp	7,900,000	m3	R.113	0.008	301608.4	\$ 1.40	\$ 1,039,861	\$ -	\$ -	\$ -	\$ 3.07	\$ 24,252,716	\$ 1.40	\$ 4,840,038	\$ 11,024,800	\$ -	\$ -	\$ 5.86	\$46,937,416			
2	1	5	600			Add lime to top 0.5m of tailings during resection	Add lime to top 0.5m of tailings during resection	16,245	tonnes	C.2.22	0.008	580.2	\$ 1.59	\$ 25,899	\$ 320.00	\$ 5,198.314	\$ -	\$ -	\$ 1.67	\$ 27,102	\$ 0.98	\$ 12,229	\$ 15,988	\$ -	\$ -	\$ 324.24	\$5,267,213		
<b>Lined Channel / Top Tailings</b>																													
2	2	1	430			Excavate Channel	Tailings excavation: spoil locally	-	m	C.2.12	0.024	0.0	\$ 0.86	\$ -	\$ -	\$ -	\$ 2.00	\$ -	\$ 0.93	\$ 0	\$ -	\$ -	\$ -	\$ -	\$ 3.79	\$1,325,925			
2	2	2	430			Supply and place geotextile	Supply and place geotextile	180,000	m2	C.4.07	0.071	12857.1	\$ 2.52	\$ 326,800	\$ 3.50	\$ 630,000	\$ -	\$ -	\$ 3.02	\$ 146,146	\$ 0.53	\$ 78,127	\$ 85,066	\$ -	\$ -	\$ 7.57	\$2,143,900		
2	2	2	430			Excavate Channel	Supply and place HDPE Liner	98,400	m2	C.4.10	1.143	14057.1	\$ 6.33	\$ 62,013	\$ 12.77	\$ 1,256,568	\$ -	\$ -	\$ 1.63	\$ 160,441	\$ 1.13	\$ 79,955	\$ 103,939	\$ -	\$ -	\$ 21.79	\$2,143,900		
2	2	3	430			Bedding layer: Screen and stockpile	Bedding layer: Screen and stockpile	496,320	m3	C.2.02	0.010	4963.2	\$ 0.37	\$ 183,651	\$ -	\$ -	\$ -	\$ 1.61	\$ 798,369	\$ 1.13	\$ 431,188	\$ 560,544	\$ -	\$ -	\$ 3.10	\$1,540,696			
2	2	3	430			Bedding layer: Load, haul, dump and place	Bedding layer: Load, haul, dump and place	496,320	m3	R.101	0.086	17963.1	\$ 1.32	\$ 236,378	\$ -	\$ -	\$ -	\$ 3.04	\$ 1,620,353	\$ 1.96	\$ 1,060,713	\$ 1,387,417	\$ -	\$ -	\$ 21.27	\$2,143,900			
2	2	4	430			Rip-rap: Drill, blast and stockpile	Rip-rap: Drill, blast and stockpile	124,080	m3	C.2.24	0.045	5563.6	\$ 1.62	\$ 201,362	\$ 15.74	\$ 1,950,538	\$ -	\$ -	\$ 2.64	\$ 327,492	\$ 1.96	\$ 132,160	\$ 169,220	\$ -	\$ -	\$ 21.27	\$2,143,900		
2	2	5	430			Rip-rap: (angular, high quality): Screen and stockpile	Rip-rap: (angular, high quality): Screen and stockpile	124,080	m3	C.2.26	0.057	7086.3	\$ 2.09	\$ 285,254	\$ -	\$ -	\$ -	\$ 9.19	\$ 1,163,517	\$ 0.45	\$ 684,777	\$ 904,532	\$ -	\$ -	\$ 17.74	\$2,200,822			
2	2	7	430			Rip-rap: Load, haul, dump	Rip-rap: Load, haul, dump	124,080	m3	R.102	0.032	3970.6	\$ 1.17	\$ 145,322	\$ -	\$ -	\$ -	\$ 2.74	\$ 339,874	\$ 1.24	\$ 118,120	\$ 153,556	\$ -						

Rose Creek Tailings Alternative 5 - Water Cover								
Scenario	Consequence		Likelihood	Risk Rating	Mitigation Measures	NOTES		
	Type	Severity	Probability	Descriptive				
1								
	<b>Construction</b>							
	Soil conditions result in spillway costs significantly greater than present cost estimate	Consec. Costs	Major	Possible	High	detailed geotech investigation	severity overstated	
	Soil and/or permafrost conditions cause additional cost in construction of Rose Creek Diversion	Consec. Costs	Moderate	Unlikely	Moderate	Additional slope measures		
	Tailings consolidation causes additional cost in construction of Cross Tailings Channel	Consec. Costs	Major	Possible	High		20% increase in costs	
	Cost of quarrying clean rock for cover higher than expected	Conseq. Costs	Moderate	Unlikely	Moderate			
	Underestimation of tailings volumes leads to higher elevation of flattened tailings (ie: higher dam raise, etc.) requiring partial relocation	Conseq. Costs	Moderate	Unlikely	Moderate		reasonable data used, but calculations do have assumptions/short-cuts	
	Additional measures required to stabilize the downstream face of the intermediate dam	Consec. Costs	Major	Possible	High		20% increase	
	Inability to tie in cut-off wall to bedrock leading to changes in design/construction	Conseq. Costs	Major	Possible	High			
	Unable to use truck and shovel methods to move tailings leads to higher costs	Conseq. Costs	Major	Possible	High			
	Unable to use truck and shovel methods to move tailings requires hydraulic relocation, leading to release of pore water to environment	Env. Imp.	Moderate	Very Unlikely	Low	install downstream collection system prior to moving tailings		
	Unable to use truck and shovel methods to move tailings requires hydraulic relocation, leading to release of pore water to environment	Legal Obl.	Moderate	Very Unlikely	Low			
	Unable to use truck and shovel methods to move tailings requires hydraulic relocation, leading to high significant pore water loading and high mitigation costs	Conseq. Costs	Major	Unlikely	Moderately High			
	Failure of CTC prior to completion of West Abutment upgrade leads to release of contaminated pond water and/or tailings	Conseq. Costs	Critical	Very Unlikely	Moderately High		Loose control of creek during remediation measures, caused by PMF?	
	Failure of CTC prior to completion of West Abutment upgrade leads to release of contaminated pond water and/or tailings	Env. Imp.	Major	Very Unlikely	Moderate			
	Failure of CTC prior to completion of West Abutment upgrade leads to release of contaminated pond water and/or tailings	Legal Obl.	Major	Very Unlikely	Moderate			
	Failure of CTC prior to completion of West Abutment upgrade leads to release of contaminated pond water and/or tailings	Comm/Media/Rep	Major	Very Unlikely	Moderate			
	<b>Operation</b>							
	East abutment spillway does not pass design flood leading to failure of intermediate dam leading to tailings release	Env. Imp.	Critical	Very Unlikely	Moderately High			
	East abutment spillway does not pass design flood leading to failure of intermediate dam leading to tailings release	Consec. Costs	Critical	Very Unlikely	Moderately High			
	East abutment spillway does not pass design flood leading to failure of intermediate dam leading to tailings release	Legal Obl.	Critical	Very Unlikely	Moderately High			
	East abutment spillway does not pass design flood leading to failure of intermediate dam leading to tailings release	Comm/Media/Rep	Critical	Very Unlikely	Moderately High			
	East abutment spillway does not pass design flood leading to failure of intermediate dam leading to tailings release	Spec. Cons.	Critical	Very Unlikely	Moderately High			
	Greater than 1:100 yr storm causes ETA surface runoff to contaminate tailings pond and release to Rose Creek	Env. Imp.	Minor	Almost Certain	Moderately High	upgrade ETA surface water capture system		
	Greater than 1:100 yr storm causes ETA surface runoff to contaminate tailings pond and release to Rose Creek	Comm/Media/Rep	Moderate	Almost Certain	High			
	Greater than 1:100 yr storm causes ETA surface runoff to contaminate tailings pond and release to Rose Creek	Legal Obl.	Moderate	Almost Certain	High			
	Escape of sig vol of contaminated groundwater (from Tailings) leads to chronic exceedance of site specific criterion (for current design)	Env. Imp.	Major	Unlikely	Moderately High			
	Escape of sig vol of contaminated groundwater (from Tailings) leads to chronic exceedance of site specific criterion (for current design)	Conseq. Costs	Major	Unlikely	Moderately High			
	Shutdown or systematic failure of groundwater collection system for more than 2 weeks leads to periodic exceedance of site specific criterion	Env. Imp.	Moderate	Possible	Moderately High	pumping system redundancy	Rapidly responding - expect discharges to occur within a day when systematic failure occurs; load to increase progressively;	
	Differential hydraulic conductivity in tailings results in preferential flow through coarse tailings leading to higher concentration and increased treatment costs	Consec. Costs	Minor	Possible	Moderate	No mitigation		
	Dam stabilization ineffective leading to a breach of the Intermediate during an earthquake and release of tailings with pond water.	Consec. Costs	Critical	Very Unlikely	Moderately High	No mitigation		
	Dam stabilization ineffective leading to a breach of the Intermediate during an earthquake and release of tailings with pond water.	Env. Imp.	Critical	Very Unlikely	Moderately High	No mitigation		
	Aufeis (Glaciation) leads to partial blockage and overtopping of CTC causing overtopping of Intermediate Dam and release of tailings	Env. Imp.	Critical	Unlikely	Moderately High			
	Aufeis (Glaciation) leads to partial blockage and overtopping of CTC causing overtopping of Intermediate Dam and release of tailings	Comm/Media/Rep	Critical	Unlikely	Moderately High			
	Damming by pond ice leads to blockage of east abutment spillway and overtopping of Intermediate dam, causing erosion and release of tailings	Env. Imp.	Critical	Possible	High	Difficult mitigation	Would need to blast or excavate dam from spillway	
	Damming by pond ice leads to blockage of east abutment spillway and overtopping of Intermediate dam, causing erosion and release of tailings	Comm/Media/Rep	Critical	Possible	High	Difficult mitigation	Would need to blast or excavate dam from spillway	
	Institutional upset leads to a year of groundwater seepage discharge without collection and treatment	Env. Imp.	Major	Possible	High			
	The spillway does not allow fish passage leading to long term impacts	Env. Imp.	Moderate	Very Unlikely	Low	add fisher ladder, \$3M		
	The spillway does not allow fish passage leading to long term impacts	Conseq. Costs	Minor	Very Unlikely	Low	add fisher ladder, \$3M		
	Tailings consolidation under CTC causes break in gradient, leading to overtopping of channel, erosion, and connection to dirty tailings pond and release	Env. Imp.	Moderate	Unlikely	Moderate	mitigated before becomes a problem by site staff		
	Tailings consolidation under CTC causes break in gradient, leading to overtopping of channel, erosion, and connection to dirty tailings pond and release	Consec. Costs	Moderate	Possible	Moderately High	Additional slope measures		
	Rainfall induced upstream slope movement and rainfall event leads to partial blockage of RCDC and overtopping of berm leading to overflow of dirty tailings pond and release	Env. Imp.	Major	Unlikely	Moderately High			
	Rainfall induced upstream slope movement and rainfall event leads to partial blockage of RCDC and overtopping of berm leading to overflow of dirty tailings pond and release	Consec. Costs	Major	Unlikely	Moderately High			
	Leakage through fault/joints under cut-off wall leads to unacceptable seepage flow volumes	Consec. Costs	Major	Unlikely	Moderately High			
	Failure of Headwater Pond berms leads to connection of Rose Creek to dirty pond and release	Consec. Costs	Moderate	Unlikely	Moderate			
	ETA groundwater impacts pond water, leading to continued exceedance of water quality in pond requiring active pond level maintenance	Consec. Costs	Moderate	Unlikely	Moderate			
	Unidentified groundwater source contaminates pond	Consec. Costs	Moderate	Very Unlikely	Low			
	<b>Maintenance</b>							
	Vegetation growth and sedimentation cause decrease in capacity and overtopping of diversion or CTC, leading to overtopping Int Dam	Env. Imp.	Critical	Very Unlikely	Moderately High		chain of events (institutional failure, etc) very unlikely	
	Tailings consolidation cause additional cost in maintenance of Cross Tailings Channel	Consec. Costs	Moderate	Likely	Moderately High	Design for consolidation, or preconsolidate		
	Institutional failure leads to lack of adequate maintenance leading to breach of the Intermediate Dam	Env. Imp.	Critical	Very Unlikely	Moderately High	No mitigation		

**Attachment B4**  
**Example Alternatives for Vangorda/Grum Area**



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# 1 Example Alternatives for Vangorda/Grum Area

The major components of the Vangorda/Grum Mine Area include the Vangorda Pit, Grum Pit, Vangorda waste rock, Grum waste rock (including sulphide cell, till dump, ore transfer pad and other waste) and the Vangorda Creek Diversion.

Table 1.1 summarizes the closure methods proposed in the example alternatives for the Vangorda/Grum Mine Area. In general, the different alternatives for the Vangorda/Grum Mine Area arise from a decision either to place the Vangorda waste rock back in the Vangorda Pit, or to stabilize it in place.

Technical studies indicate that the decision about Vangorda waste rock constrains the other major choice of closure method in the Vangorda/Grum Area, that of water treatment methodology. If the Vangorda waste rock is relocated to the Vangorda Pit, biological treatment in the Grum Pit will be the primary, and possibly the only water treatment method. If the Vangorda waste rock is stabilized in place, long-term chemical water treatment will be necessary.

In addition to the above components, all closure alternatives for the Vangorda/Grum Mine Area will include long-term groundwater collection and covers for the Grum waste rock.

**Table 1.1: Vangorda/Grum Mine Area Example Alternatives**

<b>Component</b>	<b>Alternative 1 Backfill Vangorda Pit</b>	<b>Alternative 2 Stabilize in Place</b>	<b>Alternative 3 Minimize Construction</b>	<b>Alternative 4 Minimize Water Treatment</b>
<b>Vangorda Waste Rock</b>	Relocate to Vangorda Pit	Cover with 2.0m soil cover	Cover with 0.5m soil cover	Relocate to Vangorda Pit
<b>Vangorda Creek Diversion</b>	Re-route over Vangorda Pit	Upgrade now	Upgrade in future as needed	Upgrade now
<b>Grum Waste Rock</b>	<i>Dependent on waste type (see below)</i>			
<b>Sulphide Cell</b>	Cover with 2.0m soil cover	Cover with 2.0m soil cover	Cover with 0.5m soil cover	Cover with 2.5m soil cover
<b>Ore Transfer Pad</b>	Relocate part to Vangorda Pit Cover remainder with 0.5m soil cover	Relocate part to Grum Sulphide Cell Cover remainder with 0.5m soil cover	Cover with 0.5m soil cover	Cover with 2.0m soil cover
<b>Other Waste</b>	Cover with 0.5m soil cover	Cover with 0.5m soil cover	Cover with 0.5m soil cover	Cover with 2.0m soil cover
<b>Water Collection</b>	Below Grum waste rock	Below Grum and Vangorda waste rock	Delay until necessary below Grum and Vangorda waste rock	Below Grum and Vangorda waste rock
<b>Water Treatment</b>	Biological in Grum Pit	High density sludge with biological in Grum Pit	High density sludge with biological in Grum Pit	Biological in Grum Pit

## 1.1 Vangorda/Grum Alternative 1 – Backfill Vangorda Pit

The “Backfill Vangorda Pit” alternative for the Vangorda Mine area is illustrated in Figure 1.1. The distinguishing feature of this alternative is the relocation of the entire Vangorda Dump into the Vangorda Pit. The relocation will accomplish two objectives. It will neutralize the most strongly acid-generating material in the area, thereby reducing the likelihood that long-term water treatment will be required. And it will allow Vangorda Creek to be routed back along its original alignment, thereby minimizing the risk of future failures. The following paragraphs summarize the major activities in each portion of the site. Further detail can be found in the “Construction Details and Cost Estimate” sheets found in Attachment D.

### Closure Activities

Water from the Vangorda Pit will be pumped out and treated at the present water treatment plant. The pit will then be backfilled with material from the Vangorda Dump, the high sulphide parts of the ore transfer pad and the high sulphide area at the southern end of the pit. Lime will be added to the acidic material during the backfill. The backfilled pit will be graded to direct runoff to runoff control ditches. Dust control measures will be taken during the relocation. A low infiltration cover consisting of 0.5m of compacted till overlain by 1.5m of lightly compacted till will be placed over the area. All surfaces will be seeded and fertilized.

Vangorda Creek will be routed over the backfilled pit via a constructed channel. A series of rip rap lined drop sections will be included.

The footprint of the Vangorda Dump, after relocation of all material to the Vangorda Pit will be graded to ensure runoff, seeded and fertilized. Little Creek Dam will be breached.

The Grum Pit will be used for passive treatment by seasonal phosphate addition. The Grum Interceptor Ditch will be routed into the pit. The ditch will include a rip-rapped overflow point from which the water will cascade into the pit lake. A rock berm will be constructed at the mouth of the outlet channel at the slot cut on the south end of the pit to filter algae from discharging water. The outlet channel will be excavated to a elevation of 1230m, at the Grum Pit Lake and will discharge either into Vangorda Creek Tributary B or directly along its previous channel. In this case, waste rock will be excavated as needed to establish a drainage path. A berm will be constructed around the rim of the pit to prevent inadvertent access.

The Grum Dump waste rock slopes will be regraded to 3H:1V. A low infiltration cover consisting of 0.5 m of compacted till overlain by 1.5 m of lightly compacted till will be placed on the sulphide cell. The remainder of the waste rock piles will be covered with 0.5 m of lightly compacted till. Runoff control ditches will be constructed on the cover. All surfaces will be seeded and fertilized.

Material remaining in the Overburden Dump slopes will be regraded to 3H:1V, seeded and fertilized.

The Ore Transfer Pad after relocation of acidic materials to the Vangorda Pit, will be graded to ensure runoff and covered with 0.5 m of lightly compacted till, then seeded and fertilized.

A groundwater collection system will be installed below the Grum Waste Dumps. An adaptive management program will be followed, and additional wells and cutoff walls will be constructed as required. A contingency is provided for groundwater collection at the backfilled Vangorda Pit. All collected groundwater will be pumped to the Grum Pit.

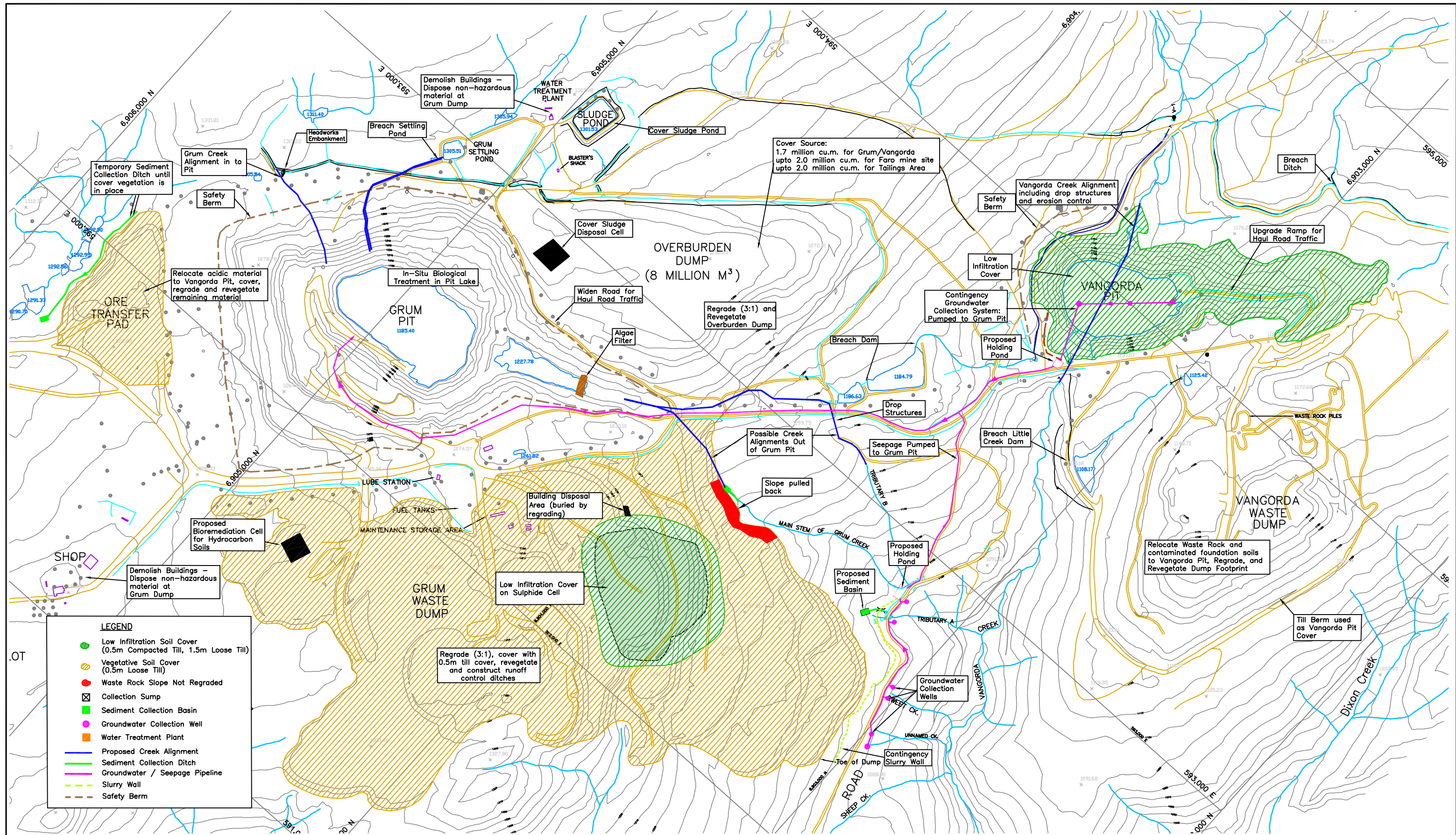
Unnecessary roads will be scarified, seeded and fertilized. All buildings will be demolished and disposed off in an unlined landfill area in the waste rock. Hydrocarbon contaminated soils located around mine maintenance areas will be excavated and remediated in the bioremediation cell. The existing bioremediation cell and sludge pond will be covered. All dams and existing settling ponds will be breached.

### **Post-Closure Requirements**

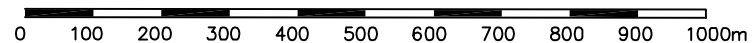
Post-closure requirements for the “Backfill Vangorda Pit” alternative include:

- Year-round pumping of contaminated groundwater and seepage to the Grum Pit;
- Seasonal addition of phosphate to the Grum Pit lake;
- Monitoring of water quality in the Grum Pit, in and around the groundwater collection systems, and in Vangorda Creek above and below the site;
- Annual inspections of all earthworks;
- Intensive maintenance of covers and ditches, including the new Vangorda Creek channel for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

With the maintenance exception noted above, all of the above activities are expected to continue to be required for several hundred years.



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		<b>Vangorda/Grum Alternative 1 - Backfill Vangorda Pit</b>	
		Example Alternatives for Closure of Anvil Range Mining Complex	DATE: March 2006    APPROVED:    FIGURE: 5.1
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## 1.2 Vangorda/Grum Alternative 2 – Stabilize In Place

The “Stabilize In Place” alternative for the Vangorda Mine area is illustrated in Figure 1.2. The objective of this alternative is to physically stabilize the area, collect all contaminated water in the Vangorda Pit, and treat it year-round. The following paragraphs summarize the major activities in each portion of the site.

### Closure Activities

A berm will be constructed around the rim of the pit to prevent inadvertent access. A water treatment plant will be constructed to treat all contaminated water from the area, which will be stored in Vangorda Pit. The treated water will be discharged into Vangorda Creek.

The Vangorda Dump and the waste rock piles located at the southern end of the Vangorda Pit will be regraded to 3H:1V. The dumps will be covered with a low infiltration cover consisting of 0.5 m of compacted till overlain by 1.5 m of lightly compacted till. Runoff control ditches will be constructed on the cover. All surfaces will be seeded and fertilized.

Vangorda Creek will be routed north of the pit along the present Vangorda Creek Diversion. The channel will be slightly re-aligned and also widened and deepened. A plunge pool will be constructed at the bottom of the diversion to disperse energy before discharging into Vangorda Creek. The interceptor ditch above the northeast wall of Vangorda Pit will be upgraded.

Acidic materials from the Ore Transfer Pad will be relocated to the sulphide cell area at the Grum Dump. The pad will be graded to promote runoff, covered with 0.5m of lightly compacted till, seeded and fertilized.

The Grum Dump waste rock slopes will be regraded to 3H:1V. A low infiltration cover consisting of 0.5 m of compacted till overlain by 1.5 m of lightly compacted till will be placed on the sulphide cell. The remainder of the waste rock piles will be covered with 0.5 m of lightly compacted till. Runoff control ditches will be constructed on the cover. All surfaces will be seeded and fertilized.

The Overburden Dump slopes will be regraded to 3H:1V, seeded and fertilized.

A groundwater collection system will be installed below the Grum Waste Dump. The seepage collection system around the Vangorda Dump will be upgraded. All collected groundwater and seepage will be pumped to the water treatment plant.

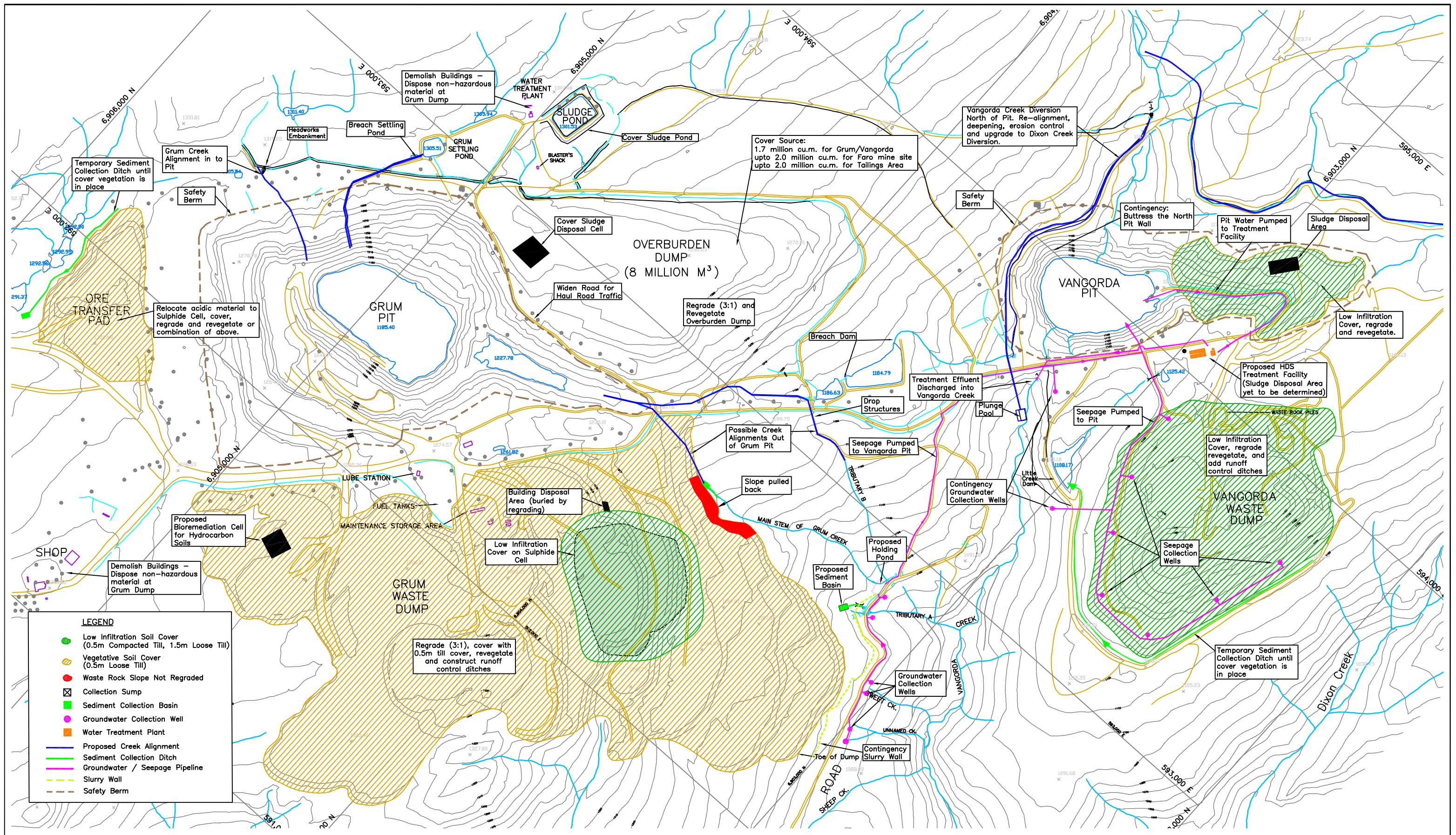
Unnecessary roads will be scarified, seeded and fertilized. All buildings will be demolished and disposed off in an unlined landfill area in the waste rock. Hydrocarbon contaminated soils located around mine maintenance areas will be excavated and remediated in the bioremediation cell. The existing bioremediation cell and sludge pond will be covered. All dams and existing settling ponds except for Little Creek Dam will be breached.

## **Post-Closure Requirements**

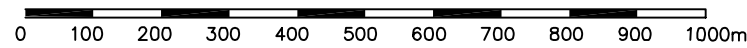
Post-closure requirements for the “Stabilize in Place” alternative include:

- Year-round pumping of contaminated groundwater and seepage to the water treatment plant;
- Year-round operation and maintenance of the water treatment plant;
- Periodic disposal of water treatment sludge in constructed cells;
- Seasonal addition of phosphate to the Grum Pit lake;
- Monitoring of water quality in the Grum Pit, in and around the groundwater collection systems, and in Vangorda Creek above and below the site;
- Annual inspections of all earthworks;
- Intensive maintenance of covers and ditches, including the upgraded Vangorda Creek Diversion, for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

With the maintenance exception noted above, all of the above activities are expected to continue to be required for several hundred years.



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Vangorda/Grum Alternative 2 - Stabilize in Place

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Example Alternatives for Closure of Anvil Range Mining Complex

DATE: March 2006 APPROVED: FIGURE: 5.2



### 1.3 Vangorda/Grum Alternative 3 – Minimize Construction

The “Minimize Construction” alternative for the Vangorda/Grum area is illustrated in Figure 1.3. This alternative represents the case where the up-front expenditure on the site is kept to the minimum while still providing some level of environmental protection.

#### Closure Activities

The Vangorda Creek diversion will be maintained in the current flume, with only minor upgrades. A contingency is included to re-construct the channel after it fails or when failure is imminent.

Contaminated water will be stored in the Vangorda Pit. The pit water level will be maintained at a level low enough to store any floods that may breach the Vangorda Creek diversion channel. A water treatment plant will be constructed to treat contaminated water.

Rudimentary covers, consisting of 0.5 m of lightly compacted till, will be constructed on the waste rock dumps, sulphide cells, as well as the oxide fines and low grade ore stockpiles. The covers will be seeded and fertilized to promote vegetation growth. The sideslopes of the waste rock dumps will not be re-sloped, and the cover will not be constructed on any slopes steeper than 2H:1V.

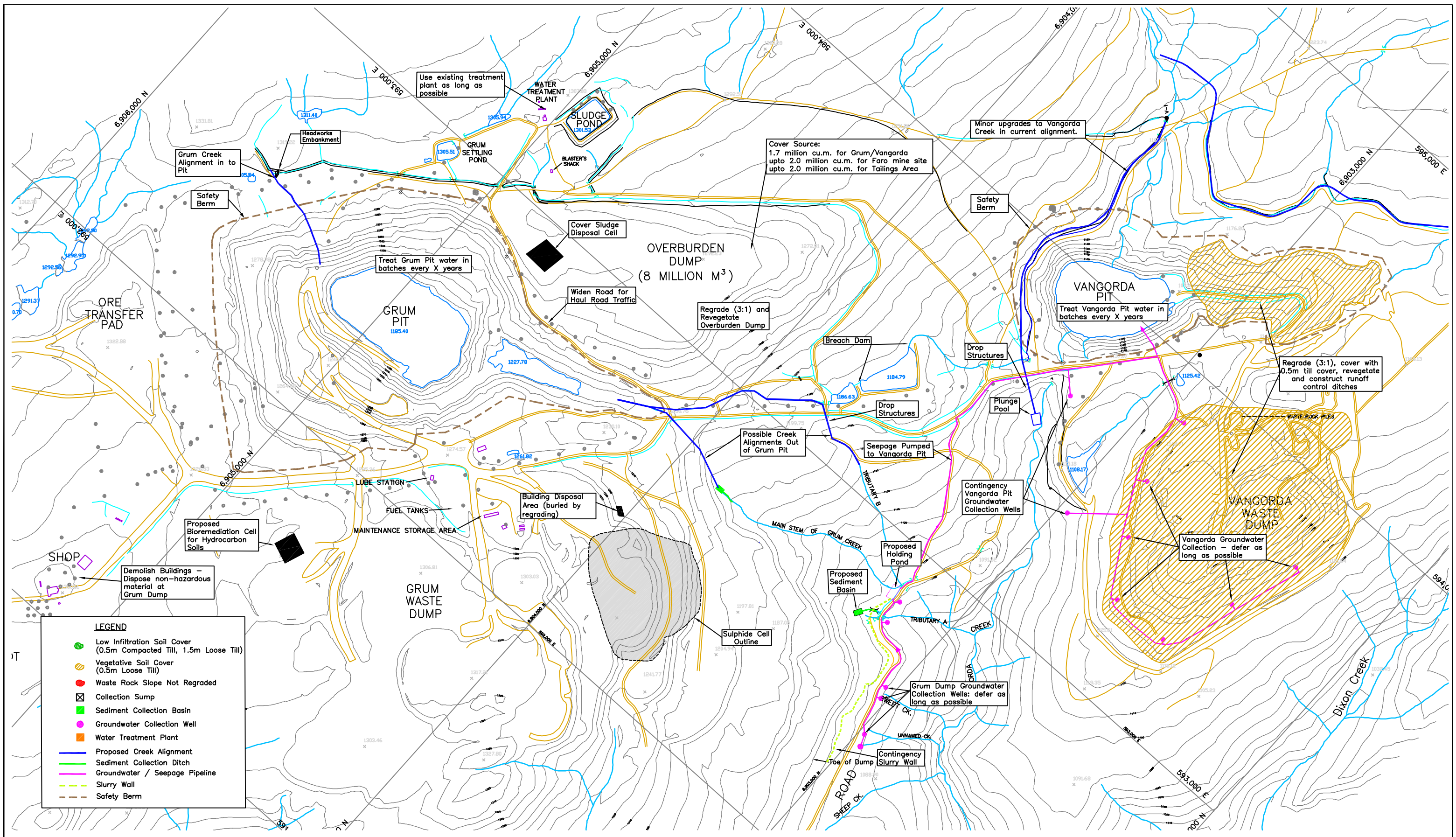
The construction of groundwater collection systems below the Grum and Vangorda Dumps will be deferred until escape of groundwater contamination is determined to be imminent.

#### Post-Closure Requirements

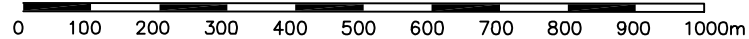
Post-closure requirements for the “Minimize Construction” alternative are generally the same as in the “Stabilize in Place” alternative. However, there will be the following differences:

- The rudimentary covers are expected to require additional maintenance and repair.
- Groundwater will need to be rigorously monitored to determine when it is necessary to construct a groundwater collection system.
- Once groundwater collection begins, the systems will need to operate with a very high efficiency, and will therefore need extensive monitoring and possibly regular upgrading.
- Due to the lack of effective covers on the waste rock, sulphide cells, oxide fines and low grade ore, acid generation is expected to continue and water treatment costs are expected to be higher than in the other Vangorda/Grum alternatives.

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Example Alternatives for Closure of Anvil Range Mining Complex

Vangorda/Grum Alternative 3 - Minimize Construction

DATE: March 2006	APPROVED:	FIGURE: 5.3
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## 1.4 Vangorda/Grum Alternative 4 – Minimize Water Treatment

The “Minimize Water Treatment” alternative for the Vangorda/Grum area is illustrated in Figure 1.4. This alternative represents the case where additional source control measures are taken in an effort to minimize the generation of contaminated water and the requirements for long-term treatment.

### Closure Activities

The closure activities in this alternative are the same as in the “Backfill Vangorda Pit” alternative, with the following exceptions:

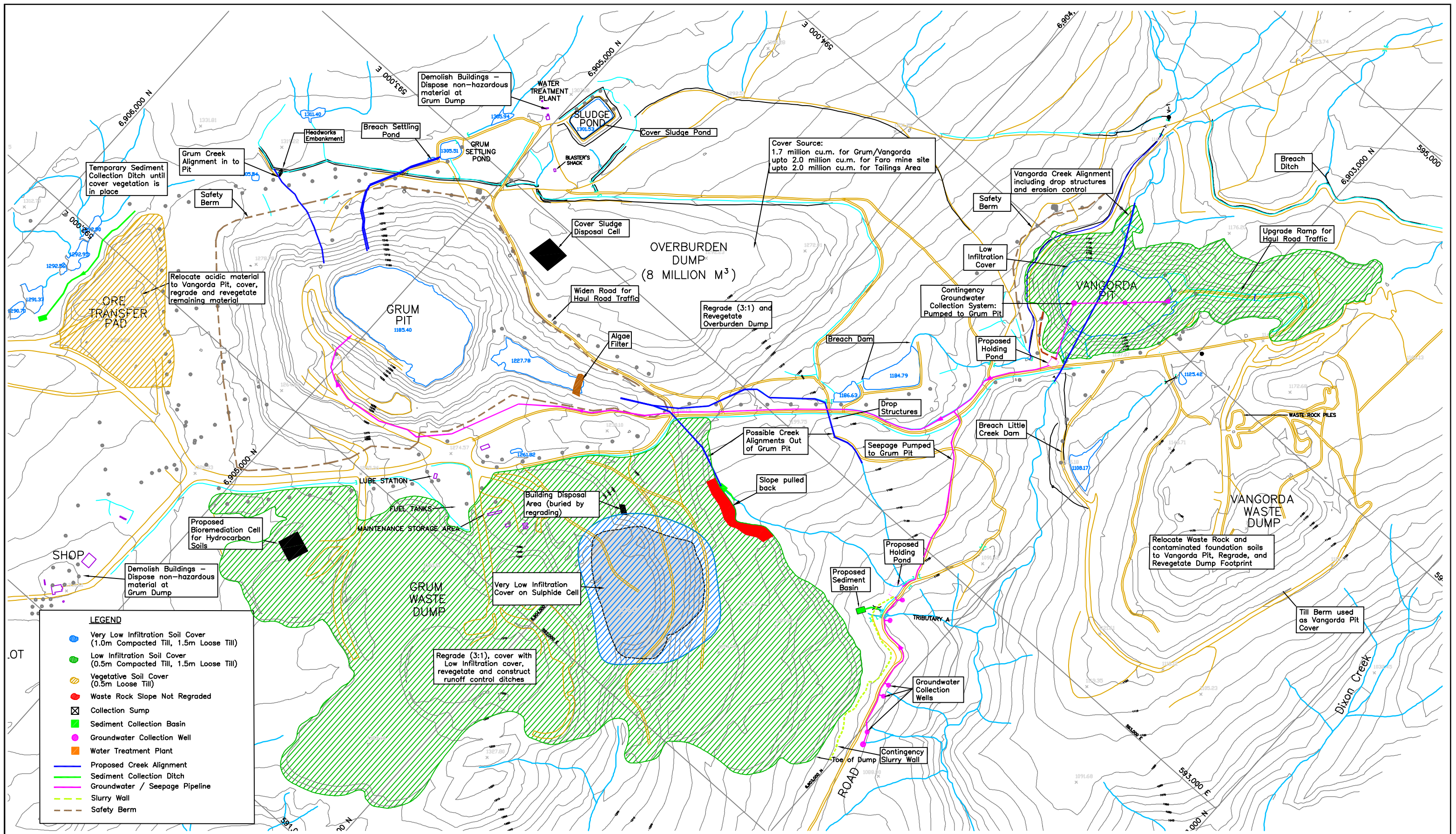
- The Grum sulphide cell will be covered with a very low infiltration soil cover, assumed to consist of 1 m of compacted till overlain by 1.5 m of lightly compacted till, seeded and fertilized to promote vegetation growth.
- The remainder of the Grum Dump and the backfilled Vangorda Pit will be covered with a low infiltration soil cover, assumed to consist of 0.5 m of compacted till overlain by 1.5 of lightly compacted till, seeded and fertilized to promote vegetation growth.

### Post-Closure Requirements

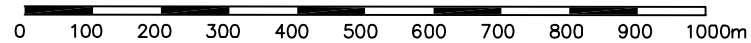
Post-closure requirements for the “Minimize Water Treatment” alternative include:

- Year-round pumping of contaminated groundwater and seepage to the Grum Pit, and seasonal addition of phosphate to the water;
- Monitoring of water quality in the Grum Pit, in and around the groundwater collection systems, and in Vangorda Creek above and below the site;
- Annual inspections of all earthworks;
- Intensive maintenance of covers and ditches for a period of five years after closure, and limited bi-annual maintenance thereafter with additional repairs after extreme events.

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Example Alternatives for Closure of Anvil Range Mining Complex

**Vangorda/Grum Alternative 4 - Minimize Water Treatment**

DATE: March 2006 APPROVED: FIGURE: 5.4

