Cross Valley Dam Seepage Interception System Phase 1 - Design Definition Summary

PREPARED FOR: Government of Yukon

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Background

This Technical Memorandum (TM) documents the results of a groundwater modelling analysis, which evaluated various technical approaches to design a groundwater seepage interception system (SIS) near the Cross Valley Dam (CVD). This TM includes the following components:

1. A brief description of the hydrogeologic system in the Rose Creek Tailing Area (RCTA)
2. A discussion of the overall remedial concept being considered for the CVD area
3. A description of the relationship between the current modelling effort and the overall design process for the SIS in the CVD area
4. A description of the remedial scenarios evaluated, alongside a discussion of the results

Site Conditions

The RCTA consists of a series of tailings impoundments that span the Rose Creek Valley; these retain tailings that were discharged during mill facility operations, as well as water decanted from the tailings. The tailings were deposited over the alluvial valley-fill deposits (the Rose Creek Alluvial Aquifer [RCAA]) to a maximum thickness of about 25 metres (m). Three dams hold the tailings in place, and a fourth dam (Cross Valley Dam [CVD]) holds polishing pond water that was discharged from the Faro Water Treatment Plant (WTP) (Figure 1).

The RCAA system is a fluvial depositional system deposited by Rose Creek and its tributaries (the North Fork of Rose Creek and the South Fork of Rose Creek). The alluvial aquifer comprises a heterogeneous mixture of silt, sand, gravel, and cobbles. The alluvial deposits are thickest near the centre of the valley (approximately 50-m thick), aligned with the ancestral thalweg of Rose Creek. Figures 2 and 3 present geological cross-sections constructed across the Rose Creek Valley, near the Cross Valley and Intermediate dams, respectively. Figure 4 presents a geological cross-section that is parallel to the axis of the Rose Creek Valley, near the two dams. These figures generally represent the observed lithology of the RCAA, as well as its underlying bedrock topography.

Contamination from the tailings deposits, and from the Emergency Tailings Area (ETA) via Faro Creek Canyon, is migrating through the RCAA toward the CVD (Robertson Geoconsultants Inc. [RGC], 2006). Attenuation processes within the alluvial aquifer system are currently limiting how quickly these contaminants can migrate downgradient. Because of uncertainty about the attenuation processes, it is also uncertain how long they will continue to limit contaminant movement. Data indicate that the metals contaminant front is currently more than 400 m upgradient of the CVD. However, the risk of early contaminant breakthrough remains high, because the rate of the contaminant migration is difficult to estimate.

The document contained herein should be considered Final as approved by the Government of Yukon on August 27, 2017 with no changes made since the draft submission.

Remedial Concept

The movement of contamination through the RCAA represents an environmental threat to the downstream aquifer and to Rose Creek. Contaminated groundwater moving beneath the CVD effectively leaves the Faro Mine Complex (FMC) and enters the receiving environment, at which point it is not possible to prevent the contamination from spreading. Therefore, designing and constructing an SIS at the CVD will provide the "last line of defense" for collecting contaminated groundwater that originates from the FMC. This is proposed to capture contaminated groundwater moving beneath the CVD, as part of the FMC remedial actions. The Independent Peer Review Panel recognized how important this structure would be; as a result, the Draft 4A 2010 Closure Plan included a SIS and a cut-off wall (SRK, 2010).

Trend data and the distribution of the RCTA groundwater contamination indicate that over the next 5 to 10 years, it might be necessary to construct an SIS that can intercept a high percentage of the groundwater that flows through the RCAA (RGC, 2012), to protect groundwater and surface water quality downstream from the CVD. It is not known when zinc and other contaminants will break through; however, data indicate that a significant threat to downgradient water quality will persist until an SIS is implemented to intercept contaminated groundwater.

The CVD SIS will be located downgradient of the CVD, and will include nine extraction wells oriented across the Rose Creek Valley, at the downstream toe of the dam. The wells (8-inch diameter, with continuous wire wrap stainless steel well screens) will be spaced approximately 55 m apart, and screened throughout the entire thickness of the glaciofluvial sediments (drilled into the weathered bedrock). A groundwater interception trench is also currently being evaluated; this would be located downstream of the CVD, along with a low-permeability slurry wall system, which would be located further downgradient and oriented across the Rose Creek Valley. A conveyance system will be required to transport the groundwater pumped year-round from the SIS location up into the Faro Pit or the Faro WTP, depending on the time of year. The SIS conveyance system will include high-density polyethylene piping, which will be insulated and heat-taped. Eventually, each of the production wells will be connected to a pipeline header that will convey the extracted groundwater from each well into a single conveyance pipeline. These pumps, controllers, and pipeline header systems will be installed when the SIS begins to operate.

Relationship Between Current Effort and CVD Design

Simulations were performed as part of this initial effort to provide preliminary information that will inform the CVD SIS design effort, and to identify remaining data gaps, related to site characterization. This modelling effort investigated remedial options that span the range of technical approaches that could form part of the overall CVD SIS remedy. These approaches include vertical extraction wells, lateral extraction trenches, and low-permeability slurry wall systems oriented across the Rose Creek Valley and adjacent to the Rose Creek Diversion (RCD). When coupled with appropriate costing information, the results of this analysis will provide a preliminary assessment of which remedy components seem the most cost-effective, and should be retained for further analysis. The analysis will also identify data gaps that are critical to further develop the design effort, and will justify the initiation of field efforts to fill these data gaps. Once these data gaps are filled, the modelling tools will be refined, and will then be used to support the basis of design analysis for the CVD SIS design.

Remedial Scenarios Evaluated

Several remedial scenarios were developed for the CVD SIS, to determine the following factors:

1. The approximate quantity of groundwater that must be extracted to hydraulically capture contaminated groundwater in the CVD area
2. The potential advantages and disadvantages of each conceptual remedial design element

This TM describes the following five remedial scenarios:

- **Scenario A**: Six extraction wells at the north end of the RCAA, without a slurry wall
- **Scenario B1**: Nine extraction wells, with a slurry wall extending across the RCAA

- **Scenario B2**: Nine extraction wells, with a slurry wall extending across the RCAA and a wall extension along the RCD
- **Scenario C1**: A shallow trench, with a slurry wall extending across the RCAA
- **Scenario C2**: A shallow trench, with a slurry wall extending across the RCAA and a wall extension along the RCD

Modelling

The simulated design scenarios described herein were evaluated using the calibrated RCAA model, described in CH2M HILL (2013). The parameters and boundary conditions described in the original model were retained, except that additional boundary conditions were included to represent the SIS components.

Available Information

The SIS design for each scenario and the related model implementation were based on the following existing data and information:

1. Numerous boring logs for borings and wells throughout the RCTA and, specifically, the CVD area
2. Results from an extensive aquifer testing program for both the RCAA and the underlying weathered bedrock aquifer
3. A numerical groundwater flow model of the FMC that was calibrated to site-wide groundwater levels and aquifer test results (CH2M HILL, 2013)
4. Groundwater quality data from wells across the RCTA

For site characterization, the most critical remaining data gap is the spatial distribution and magnitude of seepage from the RCD. Very little information has been collected to accurately quantify these seepage rates. The location and rate of leakage from the RCD has a significant influence on the benefit that could be realized by constructing a slurry wall adjacent to the RCD, near the CVD. If leakage rates from that portion of the channel are relatively low, as the current flow model assumes, there would be little advantage to constructing a slurry wall in that area. However, if the flow rates are significantly higher, as some historical data suggest, constructing a slurry wall segment in this area may be very beneficial to the operation of the SIS.

When interpreting the results of this analysis, it is important to understand the current conceptual model of the interaction of the RCD and the alluvial aquifer. Based on CH2M HILL Canada Limited's (CH2M HILL's) current understanding of the conceptual site model, and based on recent model calibration activities, most of the RCD leakage appears to stem from the area upstream of the Intermediate Dam Pond, and much less appears adjacent to and below the CVD (Figure 5). However, it is not certain how surface water and groundwater react within the RCAA. Additional data collection is recommended to characterize the seepage quantities from the RCD, as well as where they occur.

Approach & Methodology

This section describes the conceptual design of each SIS scenario and how each model was constructed to represent and simulate the scenarios. The scenarios were informed by the results of the RCAA application model run (as described in CH2M HILL, 2013). The general concept was to start with a simple scenario (a minimal number of extraction wells and no associated slurry wall system), and then incorporate additional design elements to obtain more complex remedial designs (addition of trenches and slurry walls). Each scenario is described herein.

Scenario A

This scenario includes six extraction wells, located downstream of the CVD (Figure 6). The purpose of this scenario is to minimize the extraction rate while still achieving hydraulic capture of the portions of the alluvial aquifer that are currently contaminated. The southernmost monitoring well that shows high zinc concentrations is P05-02; therefore, this simulation only included extraction wells near and north of this well. This simulation is intended to provide design flow rates for an initial SIS that could be implemented before mine-affected water fully breaks through across the entire width of the RCAA.

The extraction wells used in this simulation were screened throughout alluvial model layers 2, 3, and 4, and extend to the top of the weathered bedrock.

Scenario B1

This scenario includes the nine extraction wells that were included in the RCAA model application (CH2M HILL, 2013), all of which are screened throughout model layers 2, 3, and 4. A 620-m (2,033.6-foot) long slurry wall was also constructed across the RCAA, about 40 to 80 m (131.2 to 262.4 feet) downgradient of the extraction wells. The wall was assumed to be about 3 m (10 feet) wide, and to be constructed with a material of very low-permeability. The simulated hydraulic conductivity across the wall is 0.000864 metres per day (m/day) (0.0028 feet/day). The wall was assumed to be emplaced throughout model layers 1 through 5 (extending to the top of the competent bedrock) and was simulated as a hydraulic flow barrier. Figure 7 provides the layout of the extraction wells and the slurry wall for Scenario B1.

Scenario B2

This scenario is similar to Scenario B1, but it includes an additional segment of slurry wall that extends about 300 m (984 feet) perpendicular to the first wall and parallel to the RCD, for a total length of 920 m (3,017.6 feet). This wall would be placed along the access road adjacent to the RCD and would divert clean RCD seepage downgradient of the SIS system, to reduce the overall groundwater flow rate to the SIS. Figure 8 shows the layout of the extraction wells and the slurry wall for Scenario B2.

Scenario C1

This scenario includes constructing a broad shallow excavation across the width of Rose Creek Valley (approximately 15 m wide and 5 m deep), along with a permeable subsurface drainage trench in the floor of the excavated area. This drain system would be constructed approximately 130 m (426.4 feet) downstream of the CVD. The subsurface trench would be aligned parallel to the CVD, within the excavated area. The depth of the drain system would vary with location – it would be as shallow as 1 m (3.2 feet) deep at the centre of the Rose Creek Valley near the central sump, and as deep as 6 m (19.7 feet) below grade at the margins of the Valley. The drain would be constructed with a perforated drain pipe, within a trench of high-permeability backfill material. In the model, this feature was simulated by depressing the original ground surface topography by 5 m to represent the larger excavation, and adding a drain (head-dependent flux) boundary condition across the Valley, extending up to an additional 6 m deep, to the bottom of model layer 1 (depending on location). Table 1 summarizes the SIS design parameters for the shallow trench scenarios. The collection drain was designed to include two segments, each sloping from the Valley walls toward a centrally located sump (Figure 9). Intercepted groundwater collected within the drain structure will then be extracted with a shallow sump pump and conveyed to the Faro Pit or WTP.

TABLE 1
Shallow Trench Model Design Parameters
Faro Mine Remediation Project

Parameter	Scenario C1	Scenario C2
Total Length	328 m (1,075.8 feet)	328 m (1,075.8 feet)
North portion length	89 m (291.9 feet)	89 m (291.9 feet)
North portion slope	0.0056 m/m	0.0056 m/m
South portion length	239 m (783.9 feet)	239 m (783.9 feet)
South portion slope	0.0083 m/m	0.0083 m/m
Width	3 m (9.84 feet)	3 m (9.84 feet)
Hydraulic conductivity	200 m/day (656 feet/day)	200 m/day (656 feet/day)

Source: Unpublished data; preliminary design parameters for CVD SIS scenarios developed by CH2M HILL.

Note:

TABLE 1
Shallow Trench Model Design Parameters
Faro Mine Remediation Project

Parameter	Scenario C1	Scenario C2

m = metre

A slurry wall would also be constructed approximately 20 m (65.6 feet) downgradient of the excavated area, to improve the groundwater capture efficiency. The slurry wall was simulated as 620 m (2,033.6 feet) long, 3 m (9.84 feet) thick, with a hydraulic conductivity of 0.000864 m/day (0.0028 feet/day).

Scenario C2

This scenario is similar to Scenario C1, except that it includes a portion of slurry wall perpendicular to the first wall and parallel to the RCD, similar to Scenario B2. This wall would be placed along the access road adjacent to the RCD and would prevent the shallow trench from capturing clean RCD seepage flow. The total length of this slurry wall would be 920 m (3,017.6 feet). The shallow trench has the same layout and design as in Scenario C1. Figure 10 shows the layout of the shallow trench and the slurry wall for Scenario C2; Figure 11 shows sections of the slurry wall and trench.

Summary of Results

Each of the scenarios described herein were implemented within the same original model. Once the new SIS boundary conditions were configured for each scenario, the models were run multiple times to optimize the rate of flows that the SIS would capture. After each model was run, post-processing tools were used to evaluate the performance of the SIS in terms of capture efficiency, and to quantify the rate of groundwater extraction from the extraction wells or interceptor drain. CH2M HILL (2013) fully describes the MODPATH particle capture post-processing package.

For each simulation associated with Scenarios A, B1, and B2, the individual well extraction rates were modified until full capture of groundwater was achieved (as indicated by the results of the particle tracking visualization utility) with the lowest possible total extraction rate. Table 2 presents the simulated extraction well flow rates. Similarly, for Scenarios C1 and C2, the hydraulic grade line assumed to result from operation of the shallow trench system was adjusted to yield varying drain flows until an optimal configuration was achieved. Table 3 presents the final optimized trench extraction rates for these scenarios.

TABLE 2
Simulated Extraction Well Pumping Rates
Faro Mine Remediation Project

Extraction Well Name	Approximate Extraction Well Rate for Scenario A (L/sec) [USgpm]	Approximate Extraction Well Rate for Scenario B1 (L/sec) [USgpm]	Approximate Extraction Well Rate for Scenario B2 (L/sec) [USgpm]
SIS1	5.2 [82]	4.3 [68]	4.3 [68]
SIS2	5.8 [92]	5.8 [92]	5.8 [92]
SIS3	8.1 [128]	8.1 [128]	8.1 [128]
SIS4	11.0 [174]	11.0 [174]	10.9 [172]
SIS5	13.3 [211]	12.5 [198]	12.3 [194]
SIS6	15.6 [247]	14.8 [234]	14.7 [232]
SIS7	N/A	19.1 [302]	19.0 [300]
SIS8	N/A	14.7 [232]	14.6 [231]
SIS9	N/A	9.8 [156]	9.5 [150]
Total	59.0 [934]	100.1 [1,584]	99.1 [1,567]

Source: Unpublished data; preliminary modelling results for the CVD SIS developed by CH2M HILL

TABLE 2
Simulated Extraction Well Pumping Rates
Faro Mine Remediation Project

Extraction Well Name	Approximate Extraction Well Rate for Scenario A (L/sec) [USgpm]	Approximate Extraction Well Rate for Scenario B1 (L/sec) [USgpm]	Approximate Extraction Well Rate for Scenario B2 (L/sec) [USgpm]

Notes:

L/sec = litre per second
N/A = Well not included in this Scenario
USgpm = United States gallon per minute

TABLE 3
Simulated Shallow Trench and Sump Extraction Flow Rates
Faro Mine Remediation Project

	Scenario C1	Scenario C2
Approximate Average Drawdown (m) [feet]	6.0 [19.7]	5.5 [18.0]
Approximate Extraction Rate (L/sec) [USgpm]	110.0 [1,739]	108.2 [1,711]

Source: Unpublished data; preliminary modelling results for the CVD SIS developed by CH2M HILL.

The following paragraphs summarize the simulation results for each modelled scenario.

Scenario A

Scenario A includes six extraction wells, with a total simulated approximate pumping rate of 59 L/sec (934 USgpm). These six wells were selected to contain the portion of the aquifer that is currently contaminated with elevated levels of sulphate and low levels of zinc. Figure 12 presents the modelled extent of hydraulic capture in the RCAA for each of the wells included in Scenario A. Simulation results in model layers 2 through 6 indicate nearly complete hydraulic capture of flows upgradient of the CVD in the northern portion of the aquifer that shows early signs of contamination. Layer 1 is almost completely unsaturated so no particles are shown in that layer.

Scenario B1

Scenario B1 includes nine extraction wells, with a total simulated pumping rate of 100.1 L/sec (1,584 USgpm). This pumping rate is approximately 6.4 L/sec (101 USgpm) less than the initial SIS design described in CH2M HILL, 2003. The lower pumping rate is because a low-permeability slurry wall has been added downgradient of the extraction wells, which reduces the overall groundwater flow rate to the extraction wells. Figure 13 shows the modelled extent of hydraulic capture in the RCAA for each of the extraction wells included in Scenario B1. Simulation results in model layers 2 through 6 show full capture of flows upgradient of the CVD, along the entire width of the aquifer, with no flows crossing the slurry wall. Again, model layer 1 does not show particles, as it is unsaturated in the CVD RCTA.

Scenario B2

Scenario B2 uses the same nine extraction wells as Scenario B1, with a total simulated pumping rate of 99.1 L/sec (1,567 USgpm). Even though this scenario includes an additional slurry wall segment parallel to the RCDC, the reduction in pumping rate compared to Scenario B1 is very small (1 L/sec [17 US gpm]). Figure 14 presents the modelled extent of hydraulic capture in the RCAA for each of the wells included in Scenario B2. Simulation results in model layers 2 through 6 show full hydraulic capture of flows upgradient of the CVD and along the entire width of the aquifer, with no flows crossing the slurry wall.

Scenario C1

Scenario C1 uses a shallow trench, oriented across the Rose Creek Valley, to intercept shallow groundwater located upgradient of a low-permeability slurry wall across the RCAA. The total simulated trench extraction rate is approximately 110 L/sec (1,739 USgpm). Figure 15 presents the modelled extent of hydraulic capture in the RCAA, as a result of operating the trench in Scenario C1. Simulation results in model layers 1 through 6 show full capture of flows upgradient of the CVD and along the entire width of the aquifer, with no flows crossing the slurry wall across the RCAA.

Scenario C2

Scenario C2 includes a shallow trench to intercept groundwater (identical to Scenario C1), along with a low-permeability slurry wall across the RCAA and a wall parallel to the RCDC. The total simulated trench extraction rate is approximately 108.2 L/sec (1,711 USgpm), which is only about 1.8 L/sec (28 USgpm) less than for Scenario C1. Figure 16 presents the modelled extent of hydraulic capture in the RCAA, as a result of operating the trench in Scenario C2. Simulation results in model layers 1 through 6 show full capture of flows upgradient of the CVD, along the entire width of the aquifer, with no flows crossing the slurry wall along the RCAA. Results further suggest that the slurry wall segment that parallels the RCD cannot completely isolate the lateral and vertical inflows from the RCD into the trench collection system.

Summary and Conclusions

The results of this modelling evaluation provide insight into the groundwater extraction rates that are necessary to achieve complete hydraulic capture of mine-impacted water moving through the RCAA near the CVD. These results also provide insight into the benefits (in terms of reduced groundwater extraction rates requiring treatment) that could be realized by adding various low-permeability slurry wall systems to the extraction system design. The accuracy of these model forecasts, related to the potential benefits of including slurry wall systems in the SIS design, are strongly influenced by CH2M HILL's understanding of the location and rate of seepage from the RCD to the RCAA. The current model depicts a relatively high rate of leakage from the RCD to the aquifer upstream of the Intermediate Dam (93 L/s), and a much lower rate near the CVD (4 L/s). Because of how the leakage is distributed, the model results imply that SIS flows will not be reduced significantly by including a slurry wall adjacent to the RCD, near the CVD. However, there is very little information available to quantify the rate and location of leakage from the RCD to the underlying groundwater. Therefore, the conclusions presented herein may be modified as additional field data are collected to quantify these leakage rates.

Table 4 summarizes the primary conclusions of this analysis, which can be summarized as follows:

- In the near term, an SIS with six extraction wells and a total flow rate of 59 L/s (934 US gpm) can hydraulically capture most of the northern portion of the RCAA, which currently shows mine-related impacts to water quality.
- To achieve full hydraulic capture of the entire width of the RCAA using groundwater extraction wells (Scenario B1), a total groundwater extraction rate of 100 L/s (1,584 USgpm) is required if a slurry wall is constructed across the Rose Creek Valley (Note: without a slurry wall, approximately 1,685 USgpm would be required to achieve nearly full capture [CH2M HILL, 2013]).
- The addition of a 300-m slurry wall segment adjacent to the RCD (Scenario B2) reduces the required groundwater extraction rate by approximately 1 L/s, or 15 USgpm.
- To achieve full hydraulic capture of the entire width of the RCAA using a shallow groundwater interception trench system (Scenario C1), including the construction of a slurry wall across the Rose Creek Valley, a total groundwater extraction rate of 110 L/s (1,739 USgpm) is required.
- The addition of a 300-m slurry wall segment adjacent to the RCD (Scenario C2) reduces the required groundwater extraction rate by approximately 2 L/s, or 30 USgpm.

TABLE 4

Comparison of CVD SIS Scenario Simulation Results
Faro Mine Remediation Project

Parameter	Scenario A	Scenario B1	Scenario B2	Scenario C1	Scenario C2
Number of Extraction Wells	6	9	9	0	0
Length of Trench (m) [feet]	N/A	N/A	N/A	328 [1,075.8]	328 [1,075.8]
Length of Slurry Wall (m) [feet]	N/A	620 [2,033.6]	920 [3,017.6]	620 [2,033.6]	920 [3,017.6]
Total Simulated Extracted Flow (L/sec) [USgpm]	59.0 [934]	100.1 [1,584]	99.1 [1,567]	110.0 [1,739]	108.2 [1,711]

Source: Unpublished data; preliminary modelling results for the CVD SIS developed by CH2M HILL

Note:

N/A = means not applicable.

Overall, these results suggest that, because of the lower required groundwater extraction rates and lower potential construction costs, vertical extraction wells are preferred to provide hydraulic capture of groundwater flowing through the RCAA. Furthermore, while the addition of a slurry wall across the RCAA allow for more complete capture of the flows upgradient of the CVD, it would not be cost-effective to install low-permeability cut-off walls either across the Rose Creek Valley or adjacent to the RCDC, because they do not effectively reduce required groundwater extraction rates. However, these conclusions are subject to remaining uncertainly in the rate and location of leakage from the RCD into the RCAA, and additional field investigation is recommended to reduce the level of uncertainty in these estimates.

Recommendations

Based on the results of this modelling analysis, CH2M HILL recommends additional characterization of the rate and location of RCD leakage into the RCAA. To further characterize the leakage rates from the RCD, it will be necessary to construct several new groundwater monitoring well pairs adjacent to the RCD, along with associated stream-stage recorders. These data would provide critical information that, in conjunction with the existing RCAA groundwater model, would provide significant improvements to the accuracy and reliability of the predictions provided herein.

Several geophysical transects near the CVD are also recommended to improve the characterization of the bedrock surface in the area. An improved understanding of the characteristics of the bedrock/alluvial interface is necessary to improve the accuracy of SIS model simulations, as well as to allow more accurate assessments of how viable and cost-effective the construction of a slurry wall in the area would be.

Works Cited

CH2M HILL Canada Limited (CH2M HILL). 2013. *Fiscal Year 2012 Modelling Analysis Report, Faro Mine Remediation Project.* Prepared for the Government of Yukon. March.

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SRK Consulting Engineers and Scientists (SRK), 2010. *Faro Mine Complex Closure and Remediation Plan. Project Description – Draft 4A*. Prepared for: Yukon Government. March.

Figures

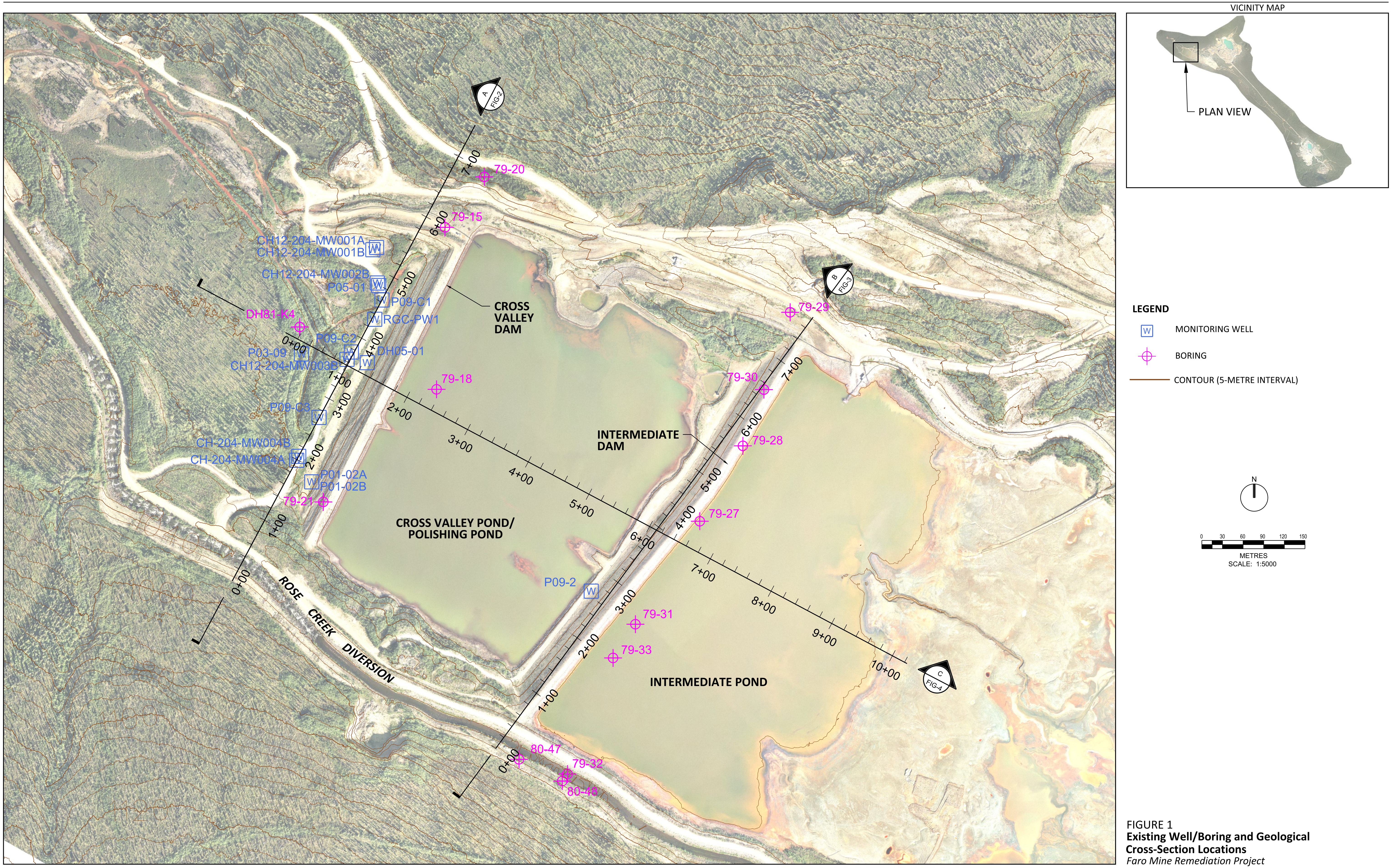
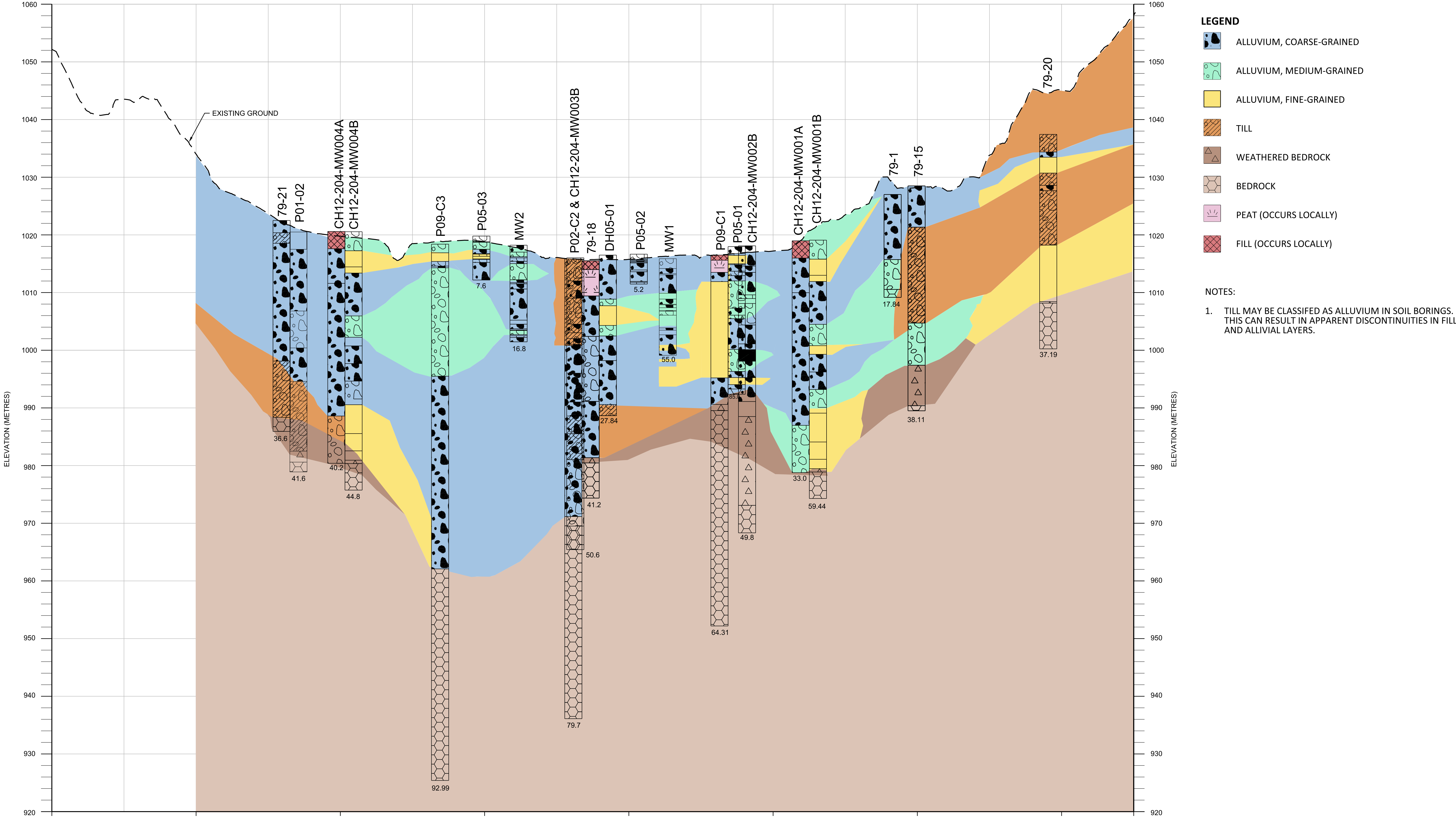


FIGURE 1
Existing Well/Boring and Geological Cross-Section Locations
Faro Mine Remediation Project

CH2MHILL.

200_CVDSIS_FIG01.dgn 2013\03\27 10:27:38 AM



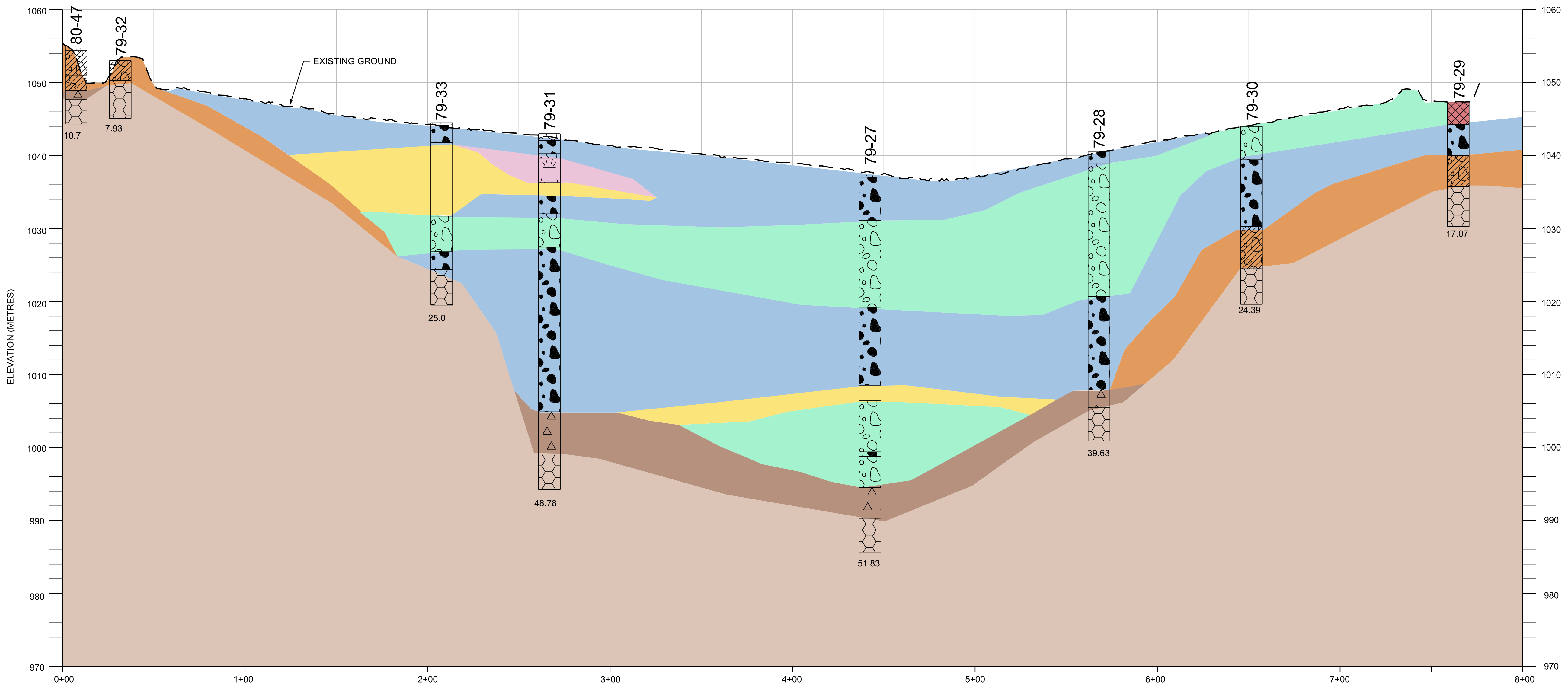
NOTES:

1. TILL MAY BE CLASSIFED AS ALLUVIUM IN SOIL BORINGS. THIS CAN RESULT IN APPARENT DISCONTINUITIES IN FILL AND ALLIVIAL LAYERS.

A SECTION
HORZ SCALE: 1:2500
VERT SCALE: 1:625
FIG 1

FIGURE 2
Geological Cross-Section Along Cross Valley Dam
Faro Mine Remediation Project

CH2MHILL



B
FIG 1
SECTION
HORZ SCALE: 1:2500
VERT SCALE: 1:625

LEGEND

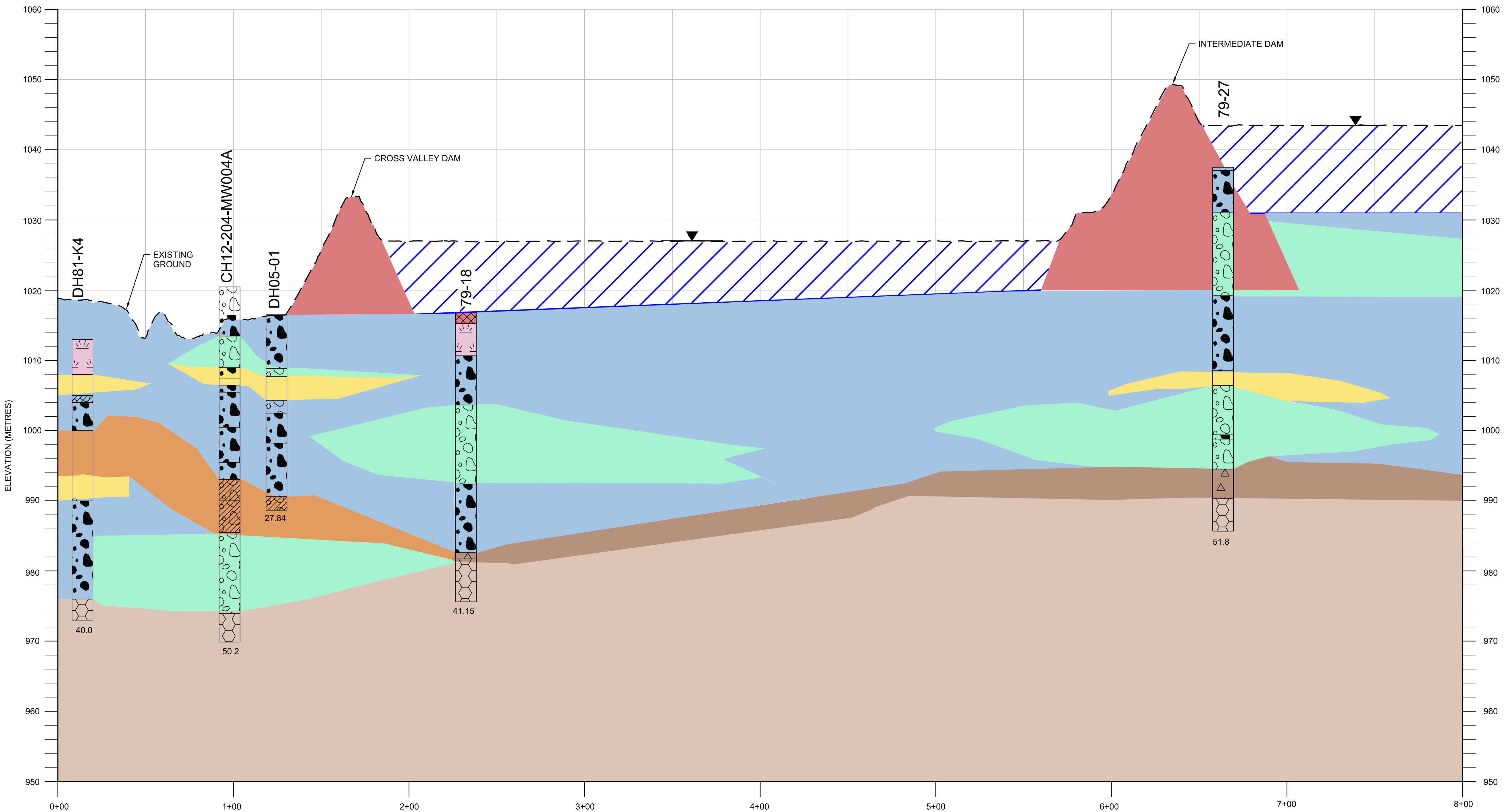
- ALLUVIUM, COARSE-GRAINED
- ALLUVIUM, MEDIUM-GRAINED
- ALLUVIUM, FINE-GRAINED
- TILL
- WEATHERED BEDROCK
- BEDROCK
- PEAT (OCCURS LOCALLY)
- FILL (OCCURS LOCALLY)

NOTES:

1. TILL MAY BE CLASSIFED AS ALLUVIUM IN SOIL BORINGS. THIS CAN RESULT IN APPARENT DISCONTINUITIES IN FILL AND ALLIVIAL LAYERS.

FIGURE 3
Geological Cross-Section Along Intermediate Dam
Faro Mine Remediation Project

CH2MHILL.



LEGEND

- ALLUVIUM, COARSE-GRAINED
- ALLUVIUM, MEDIUM-GRAINED
- ALLUVIUM, FINE-GRAINED
- TILL
- WEATHERED BEDROCK
- BEDROCK
- PEAT (OCCURS LOCALLY)
- FILL/EMBANKMENT (OCCURS LOCALLY)
- WATER (DEPTH APPROXIMATE)

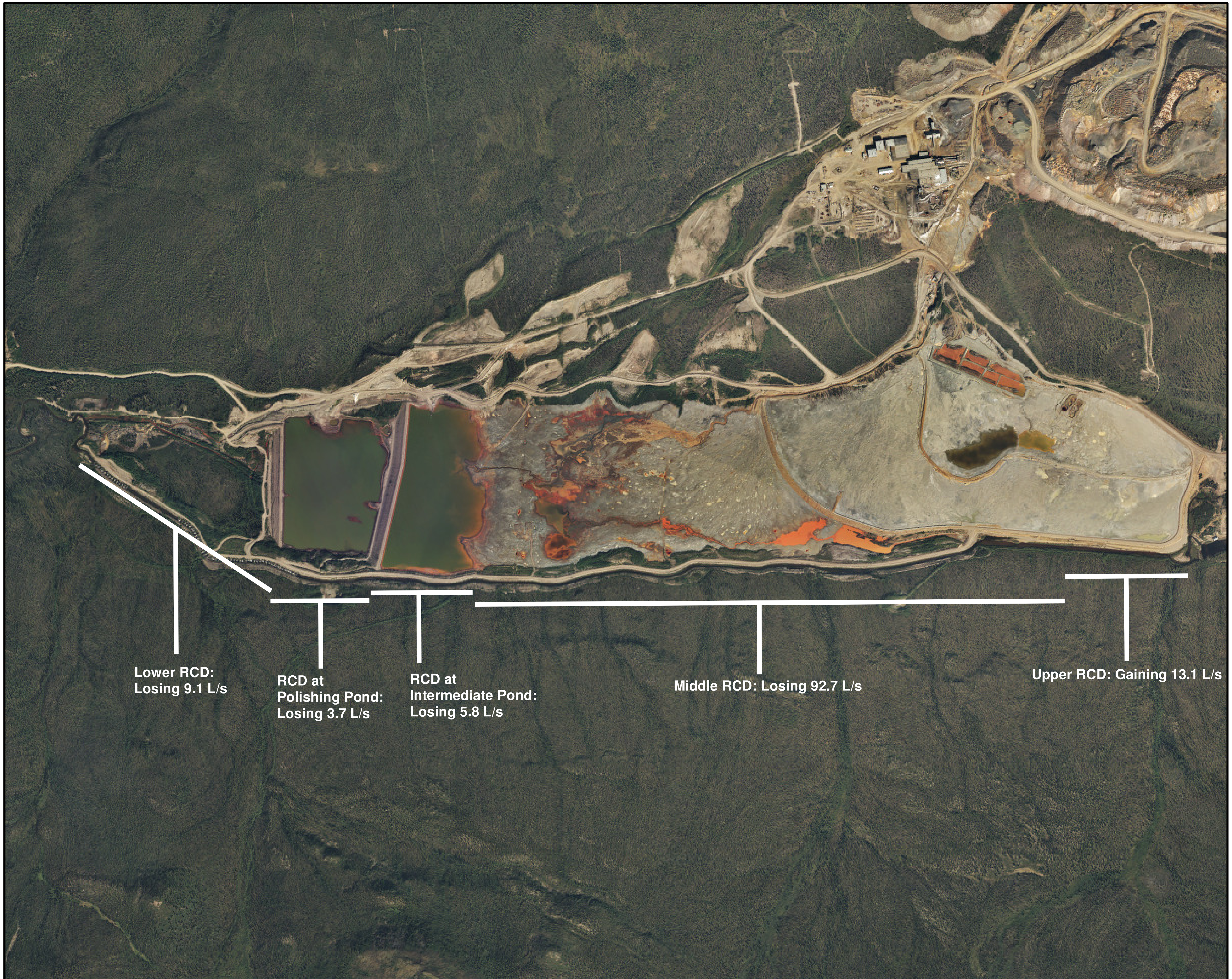
NOTES:

1. TILL MAY BE CLASSIFED AS ALLUVIUM IN SOIL BORINGS. THIS CAN RESULT IN APPARENT DISCONTINUITIES IN FILL AND ALLUVIAL LAYERS.

C SECTION
FIG 1
HORZ SCALE: 1:2500
VERT SCALE: 1:625

FIGURE 4
Geological Cross-Section Perpendicular To Cross Valley Dam and Intermediate Dam
Faro Mine Remediation Project

CH2MHILL.



REGIONAL MAP

Note:
1. Negative mass balance rates indicate gaining conditions (flow is from groundwater to stream). Positive mass balance rates indicate losing conditions (flow is from stream to groundwater).
2. L/s= litre per second
3. RCD= Rose Creek Diversion
4. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
5. Orthophotography prepared by Critigen Canada Corp.

N

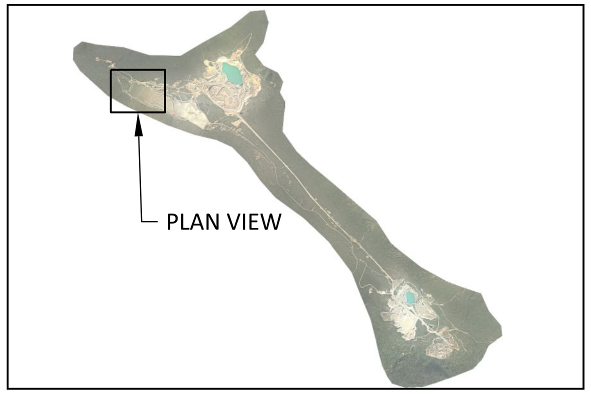
0 160 320 480 640
Metres

Created by:
CRITIGEN

FIGURE 5
Simulated Groundwater-Surface Water Exchanges at River and Drain Boundaries
Faro Mine Remediation Project

CH2MHILL.

VICINITY MAP



LEGEND

W MONITORING WELL

CONTOURS (5-METRE INTERVAL)

NOTES:

1. TOPOGRAPHY PREPARED FROM LIGHT DETECTION AND RANGING (LIDAR) DATED 10-03-11. HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002. VERTICAL DATUM:CGVD28 (HTV2.0) 5-METRE INTERVAL CONTOURS ARE SHOWN.
2. AERIAL PHOTO SHOWN DATED AUGUST 2012.

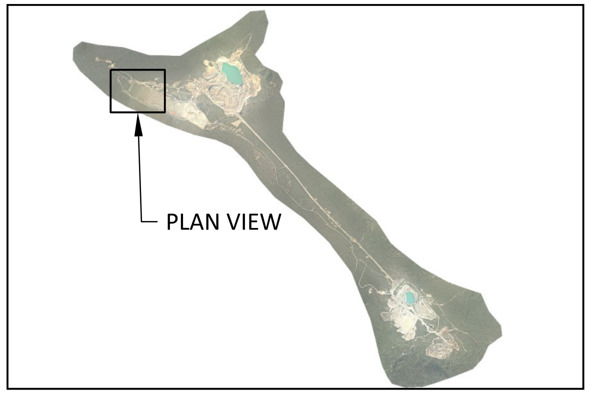
N

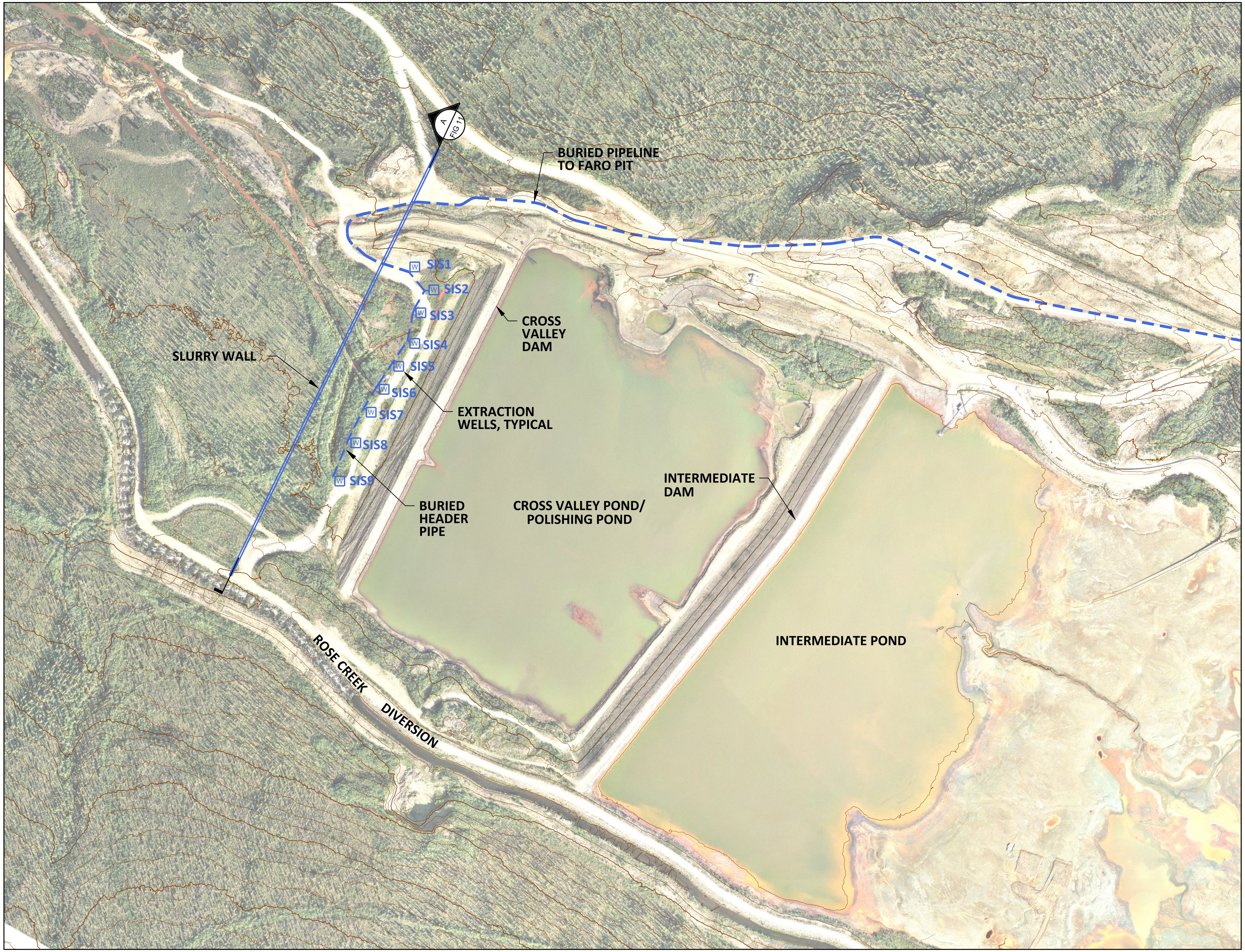
0 30 60 90 120 150
METRES
SCALE: 1:5000

FIGURE 6
Layout of Scenario A SIS Design
Faro Mine Remediation Project

CH2MHILL.

VICINITY MAP





LEGEND

W MONITORING WELL

CONTOURS (5-METRE INTERVAL)

NOTES:

1. TOPOGRAPHY PREPARED FROM LIGHT DETECTION AND RANGING (LIDAR) DATED 10-03-11. HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002. VERTICAL DATUM:CGVD28 (HTV2.0) 5-METRE INTERVAL CONTOURS ARE SHOWN.
2. AERIAL PHOTO SHOWN DATED AUGUST 2012.

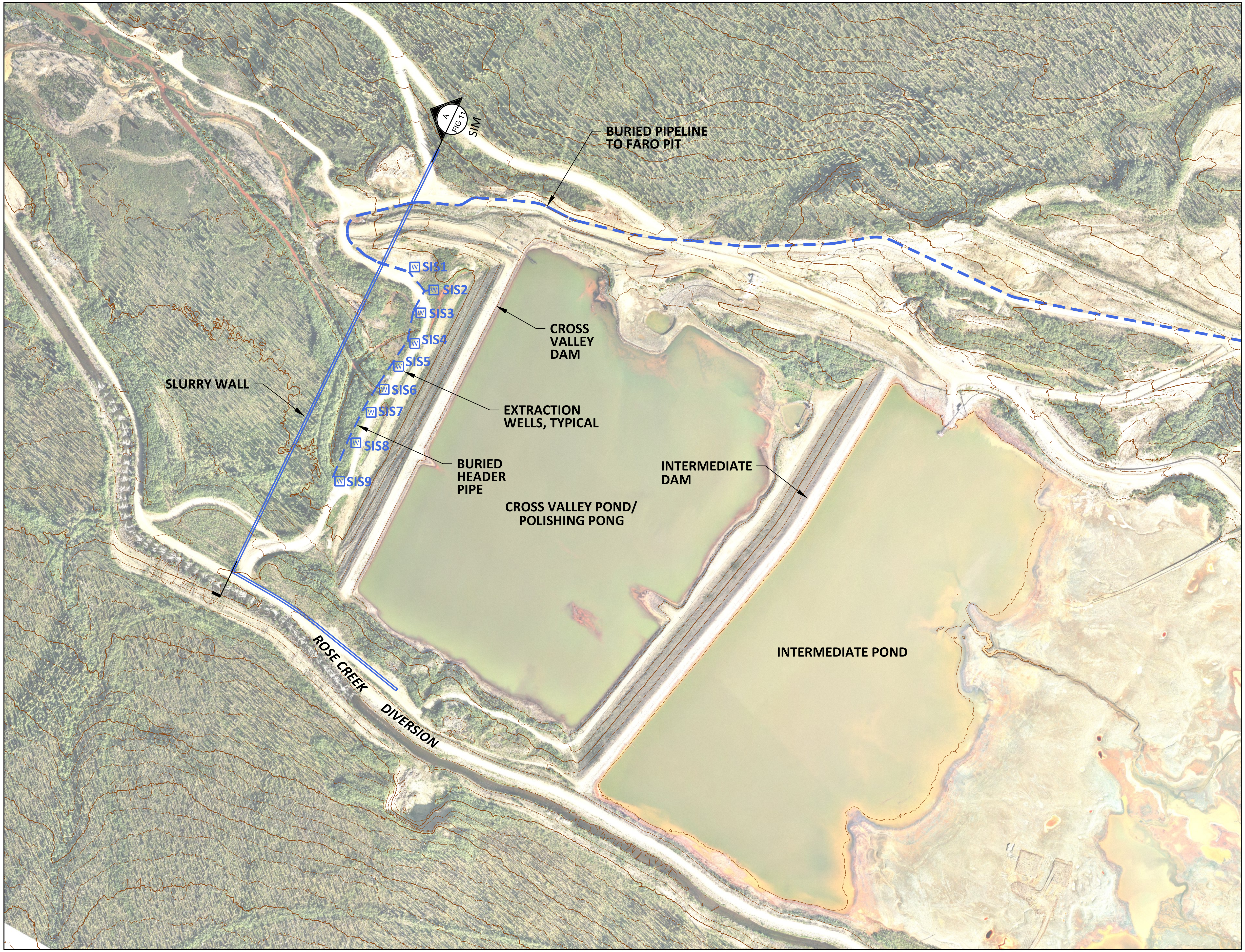
N

0 30 60 90 120 150

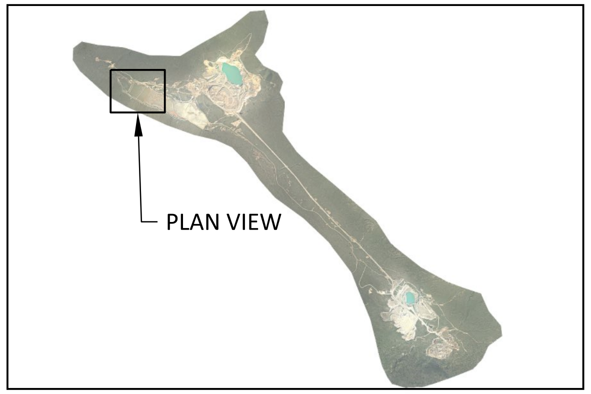
METRES
SCALE: 1:5000

FIGURE 7
Layout of Scenario B1 SIS Design
Faro Mine Remediation Project

CH2MHILL.



VICINITY MAP



LEGEND

W MONITORING WELL

CONTOURS (5-METRE INTERVAL)

NOTES:

1. TOPOGRAPHY PREPARED FROM LIGHT DETECTION AND RANGING (LIDAR) DATED 10-03-11. HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002. VERTICAL DATUM:CGVD28 (HTV2.0) 5-METRE INTERVAL CONTOURS ARE SHOWN.
2. AERIAL PHOTO SHOWN DATED AUGUST 2012.

N

0 30 60 90 120 150

METRES

SCALE: 1:5000

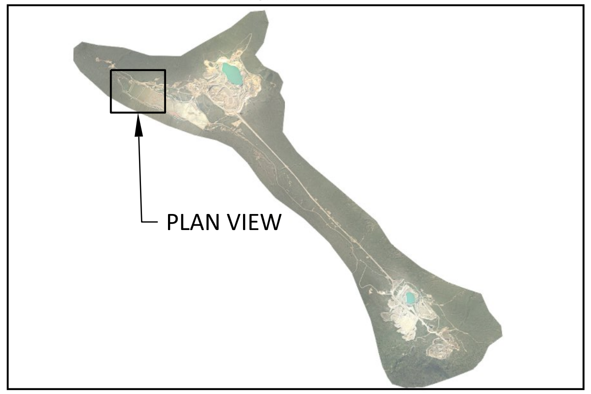
FIGURE 8

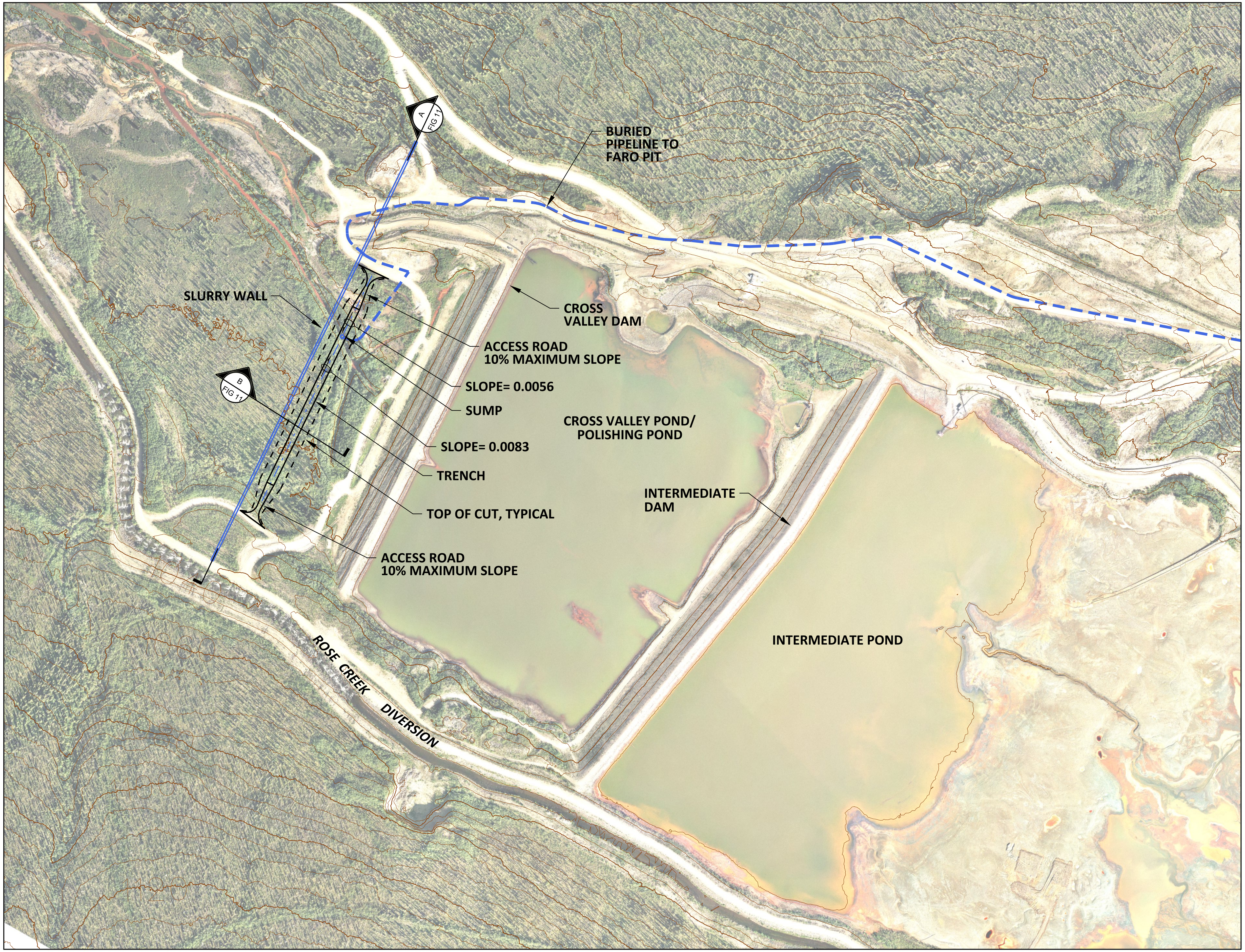
Layout of Scenario B2 SIS Design

Faro Mine Remediation Project

CH2MHILL.

VICINITY MAP





LEGEND

CONTOURS (5-METRE INTERVAL)

NOTES:

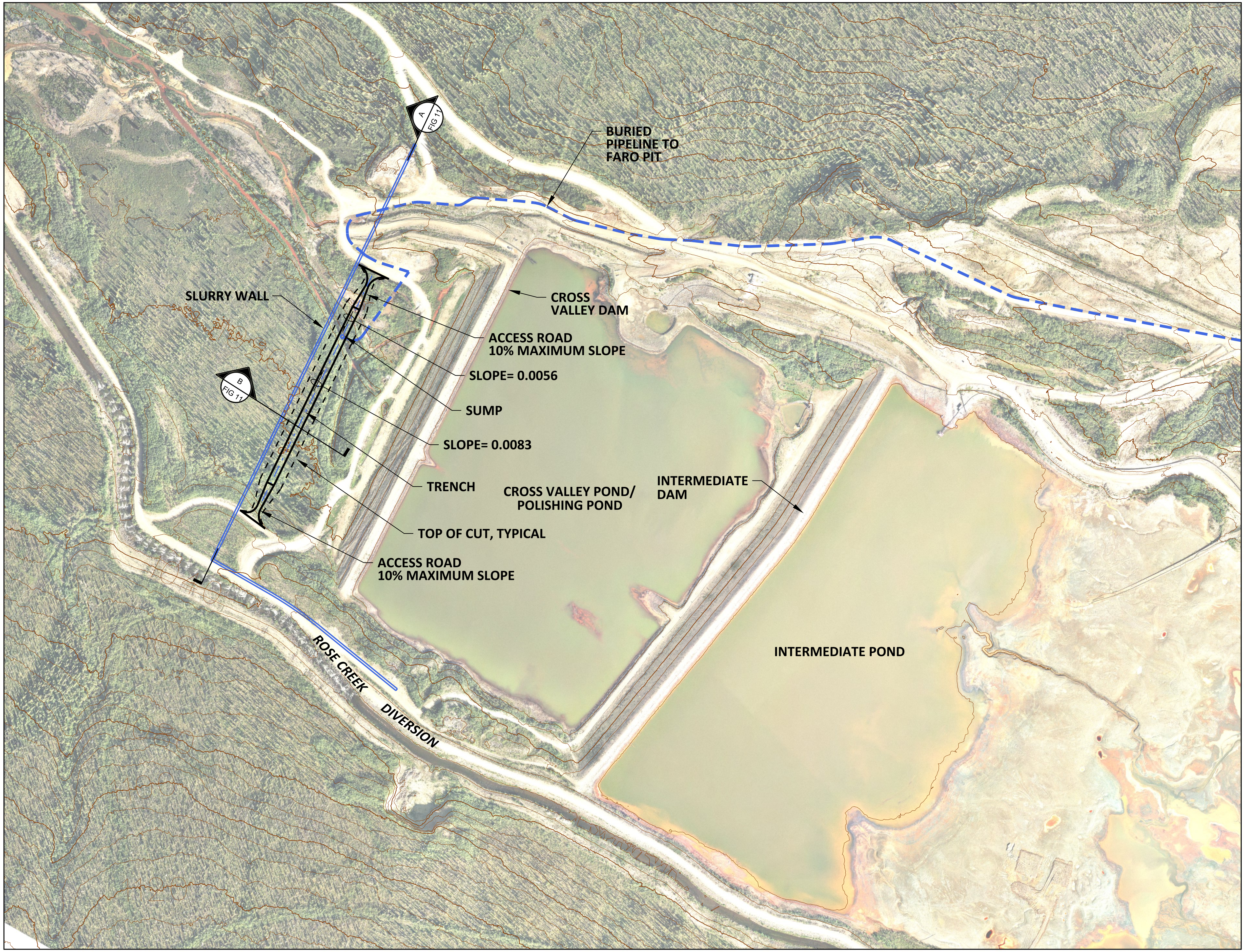
1. TOPOGRAPHY PREPARED FROM LIGHT DETECTION AND RANGING (LIDAR) DATED 10-03-11. HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002. VERTICAL DATUM:CGVD28 (HTV2.0) 5-METRE INTERVAL CONTOURS ARE SHOWN.
2. AERIAL PHOTO SHOWN DATED AUGUST 2012.

N

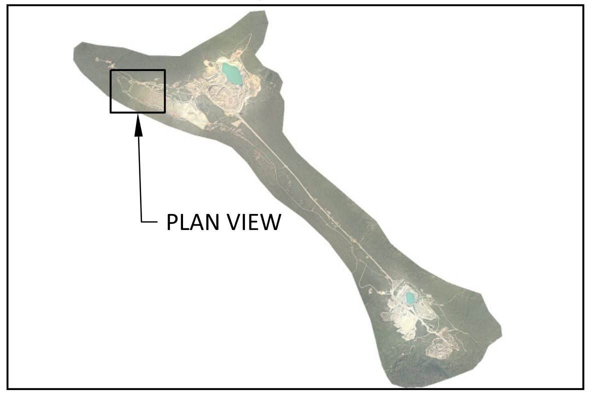
0 30 60 90 120 150
METRES
SCALE: 1:5000

FIGURE 9
Layout of Scenario C1 SIS Design
Faro Mine Remediation Project

CH2MHILL.



VICINITY MAP



LEGEND

CONTOURS (5-METRE INTERVAL)

NOTES:

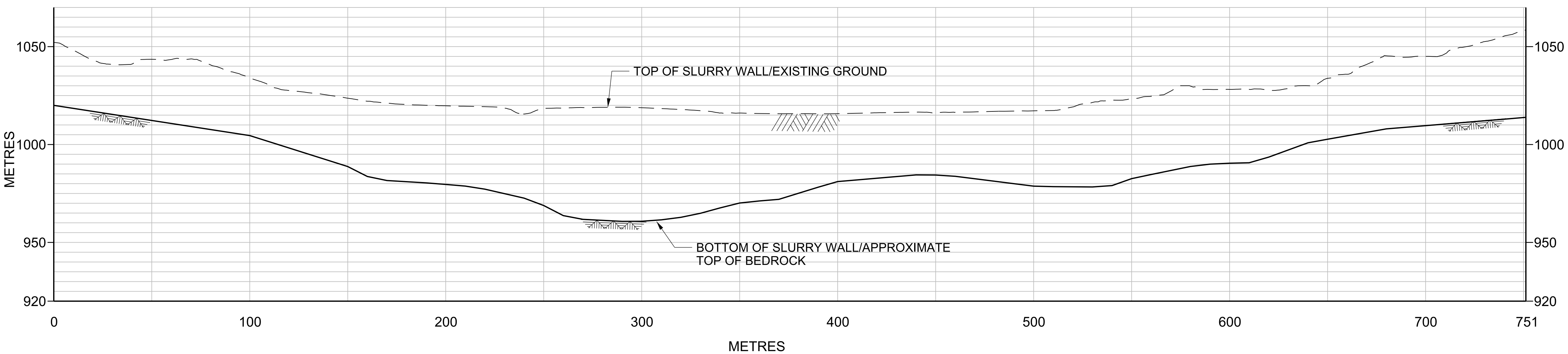
1. TOPOGRAPHY PREPARED FROM LIGHT DETECTION AND RANGING (LIDAR) DATED 10-03-11. HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002. VERTICAL DATUM:CGVD28 (HTV2.0) 5-METRE INTERVAL CONTOURS ARE SHOWN.
2. AERIAL PHOTO SHOWN DATED AUGUST 2012.

N

0 30 60 90 120 150
METRES
SCALE: 1:5000

FIGURE 10
Layout of Scenario C2 SIS Design
Faro Mine Remediation Project

CH2MHILL.



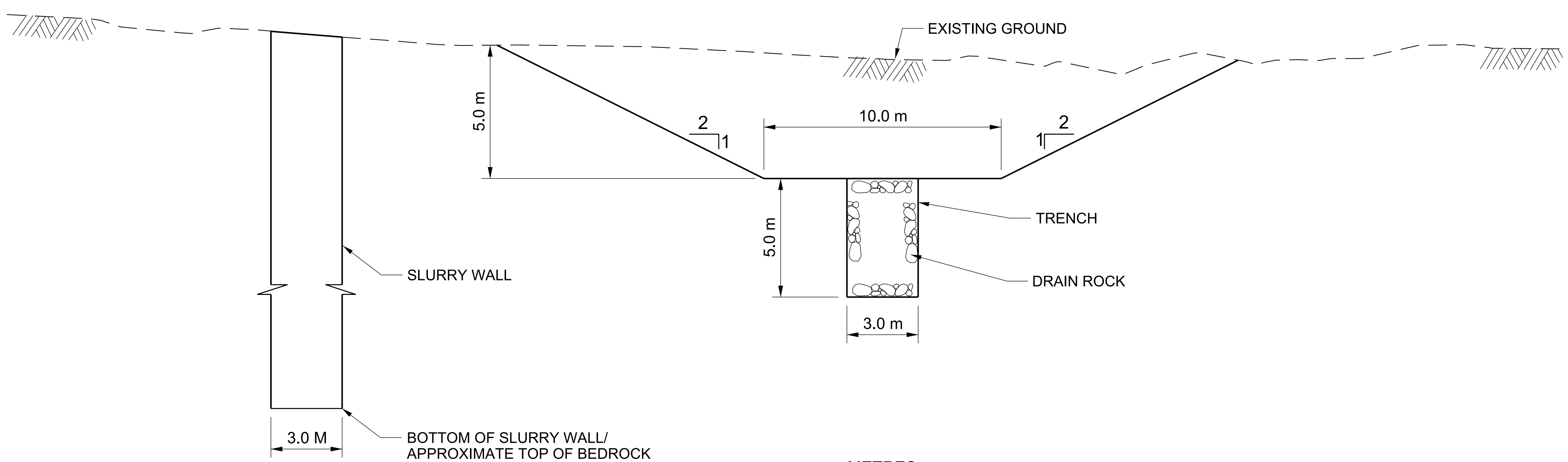
NOTES:

1. LENGTH OF SLURRY WALL VARIES. SEE PLAN.

A SECTION - ALONG SLURRY WALL

SCALE: 1:2500

FIG 7
FIG 8
FIG 9
FIG 10



m=METRES

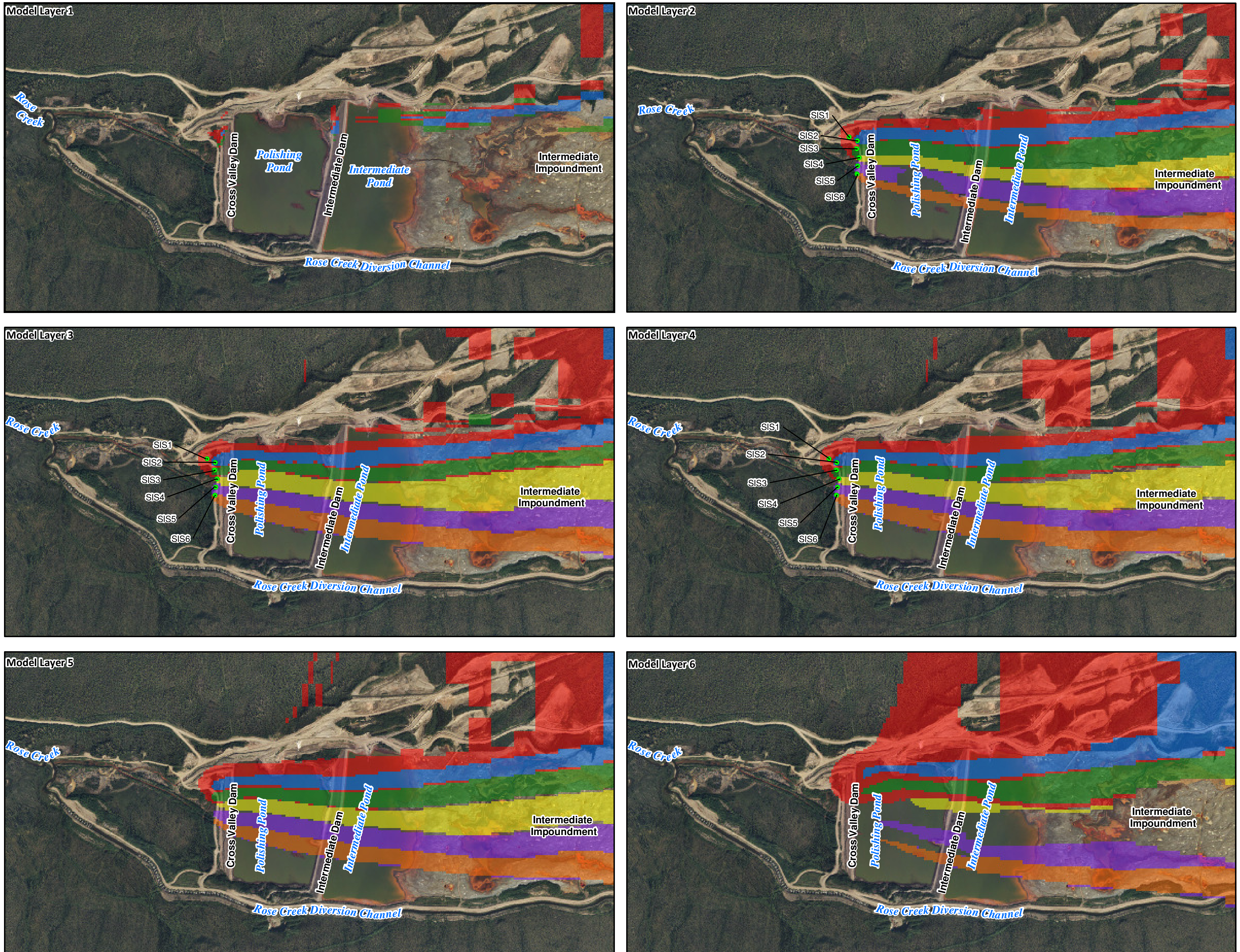
B SECTION - SLURRY WALL AND TRENCH

SCALE: 1:250

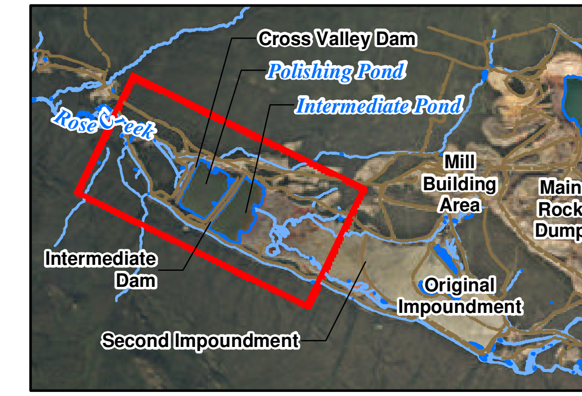
FIG 9
FIG 10

FIGURE 11
Slurry Wall and Trench Sections
Faro Mine Remediation Project

CH2MHILL.



VICINITY MAP



LEGEND

- Modelled Extraction Well

Destination of Modelled Particle

- SIS1
- SIS2
- SIS3
- SIS4
- SIS5
- SIS6

Notes
1. Particle starting cells are symbolized by a colour representing the destination at which the particle leaves the model.
2. Particles were started at the vertical midpoints of each cell and tracked forward (downgradient) until reaching the feature indicated in the legend.
3. Extraction wells are screened in model layers 2 - 4.
4. Aerial Photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
5. Orthophotography prepared by Critigen Canada Corp.

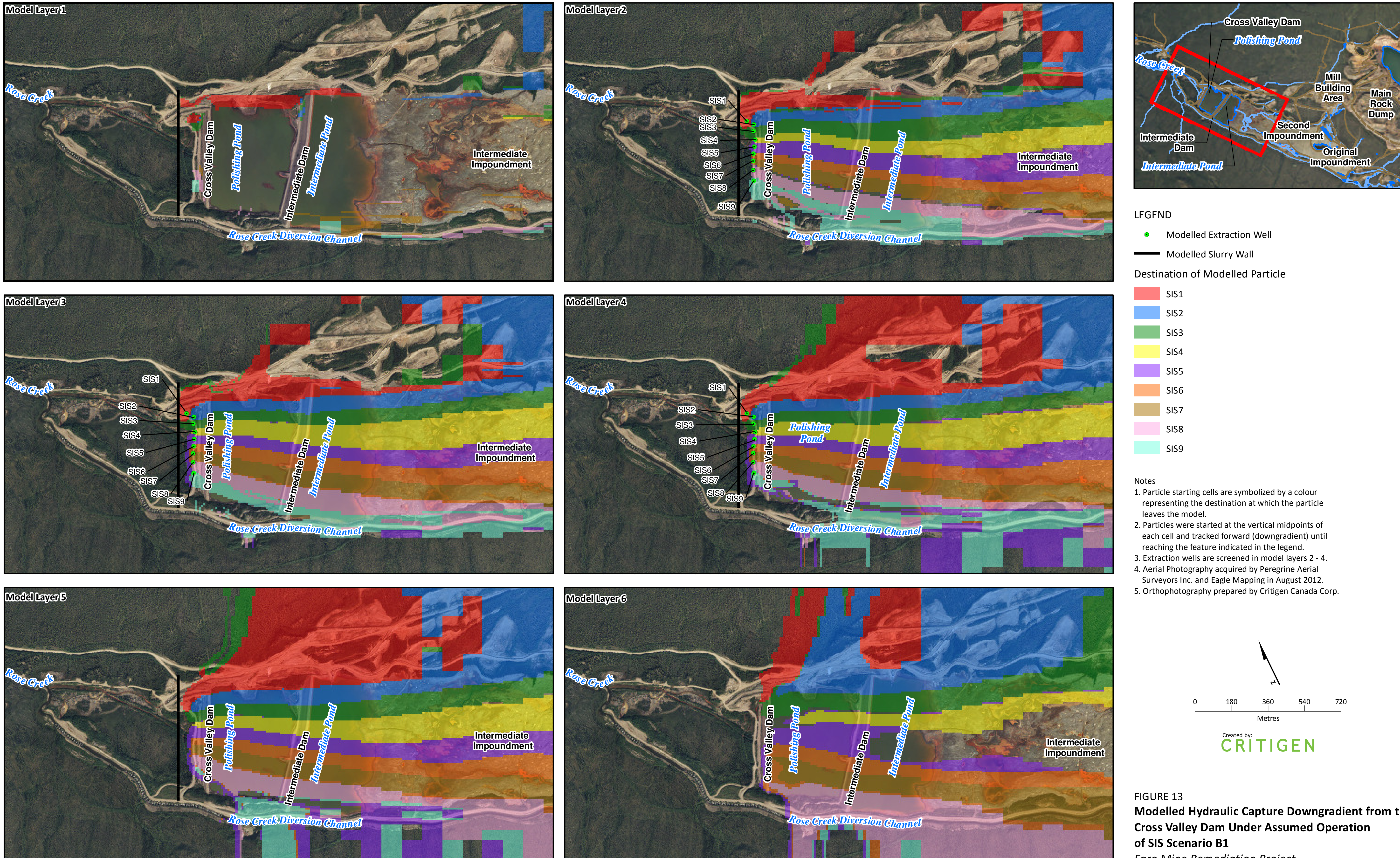
N

0 180 360 540 720
Metres

Created by: CRITIGEN

FIGURE 12
Modelled Hydraulic Capture Downgradient from the Cross Valley Dam Under Assumed Operation of SIS Scenario A
Faro Mine Remediation Project

CH2MHILL.



LEGEND

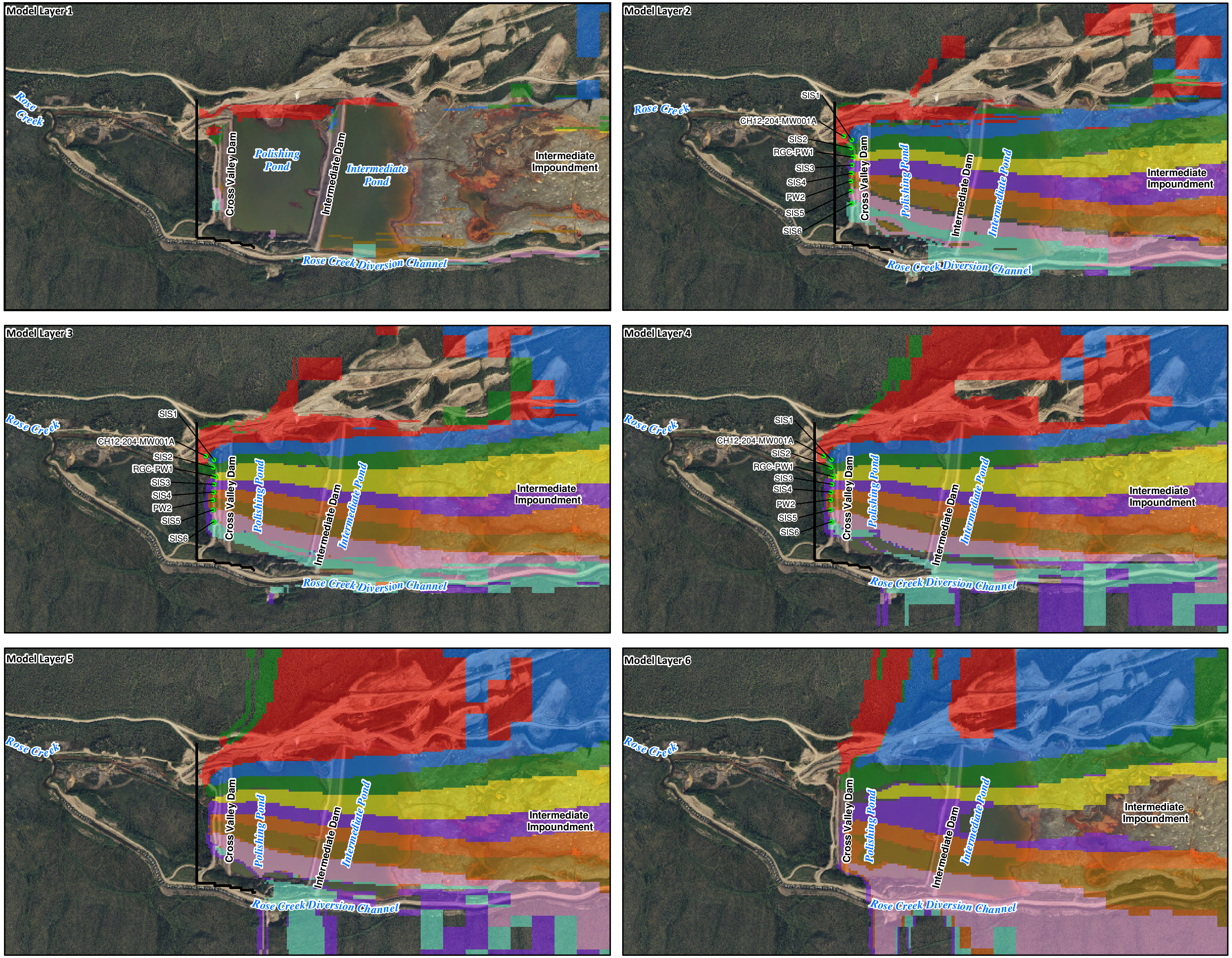
- Modelled Extraction Well
- Modelled Slurry Wall

Destination of Modelled Particle

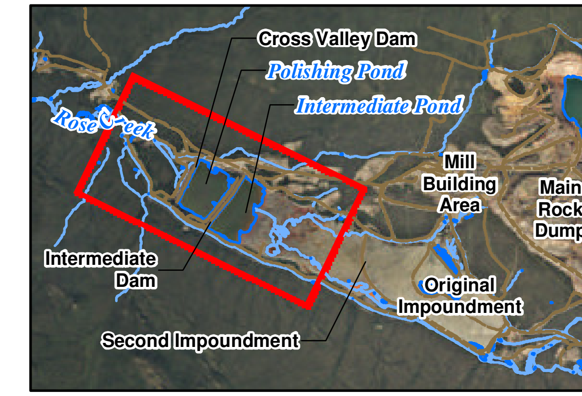
- SIS1
- SIS2
- SIS3
- SIS4
- SIS5
- SIS6
- SIS7
- SIS8
- SIS9

Notes
1. Particle starting cells are symbolized by a colour representing the destination at which the particle leaves the model.
2. Particles were started at the vertical midpoints of each cell and tracked forward (downgradient) until reaching the feature indicated in the legend.
3. Extraction wells are screened in model layers 2 - 4.
4. Aerial Photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
5. Orthophotography prepared by Critigen Canada Corp.

FIGURE 13
Modelled Hydraulic Capture Downgradient from the Cross Valley Dam Under Assumed Operation of SIS Scenario B1
Faro Mine Remediation Project



VICINITY MAP



LEGEND

- Modelled Extraction Well
- Modelled Slurry Wall

Destination of Modelled Particle

- SIS1
- SIS2
- SIS3
- SIS4
- SIS5
- SIS6
- SIS7
- SIS8
- SIS9

Notes
1. Particle starting cells are symbolized by a colour representing the destination at which the particle leaves the model.
2. Particles were started at the vertical midpoints of each cell and tracked forward (downgradient) until reaching the feature indicated in the legend.
3. Extraction wells are screened in model layers 2 - 4.
4. Aerial Photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
5. Orthophotography prepared by Critigen Canada Corp.

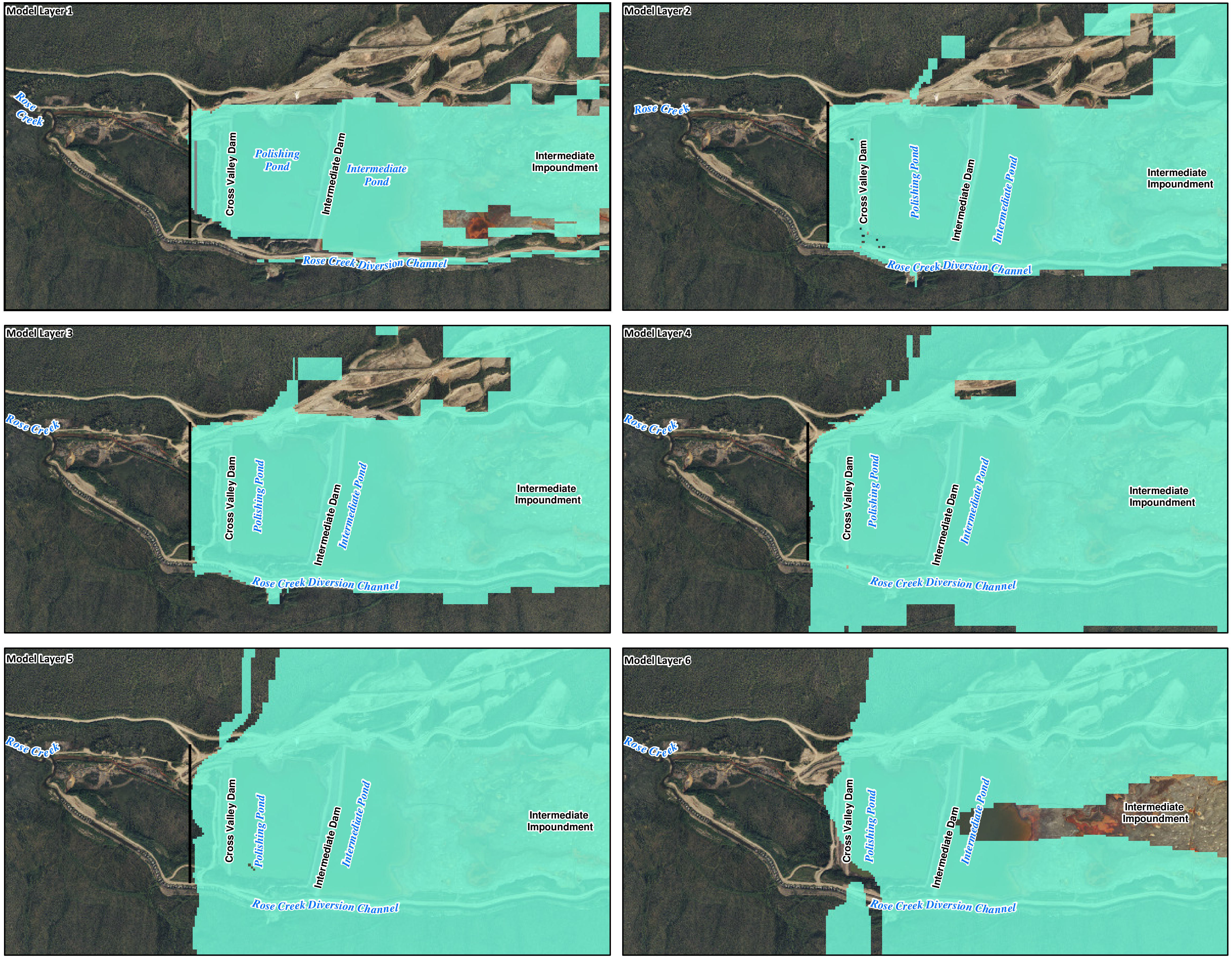
N

0 180 360 540 720
Metres

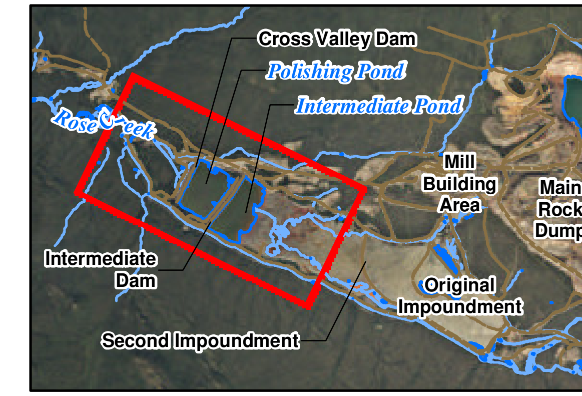
Created by:
CRITIGEN

FIGURE 14
Modelled Hydraulic Capture Downgradient from the Cross Valley Dam Under Assumed Operation of SIS Scenario B2
Faro Mine Remediation Project

CH2MHILL.



VICINITY MAP



LEGEND

- Modelled Shallow Interception Trench
- Modelled Slurry Wall
- Modelled Trench Capture Zone

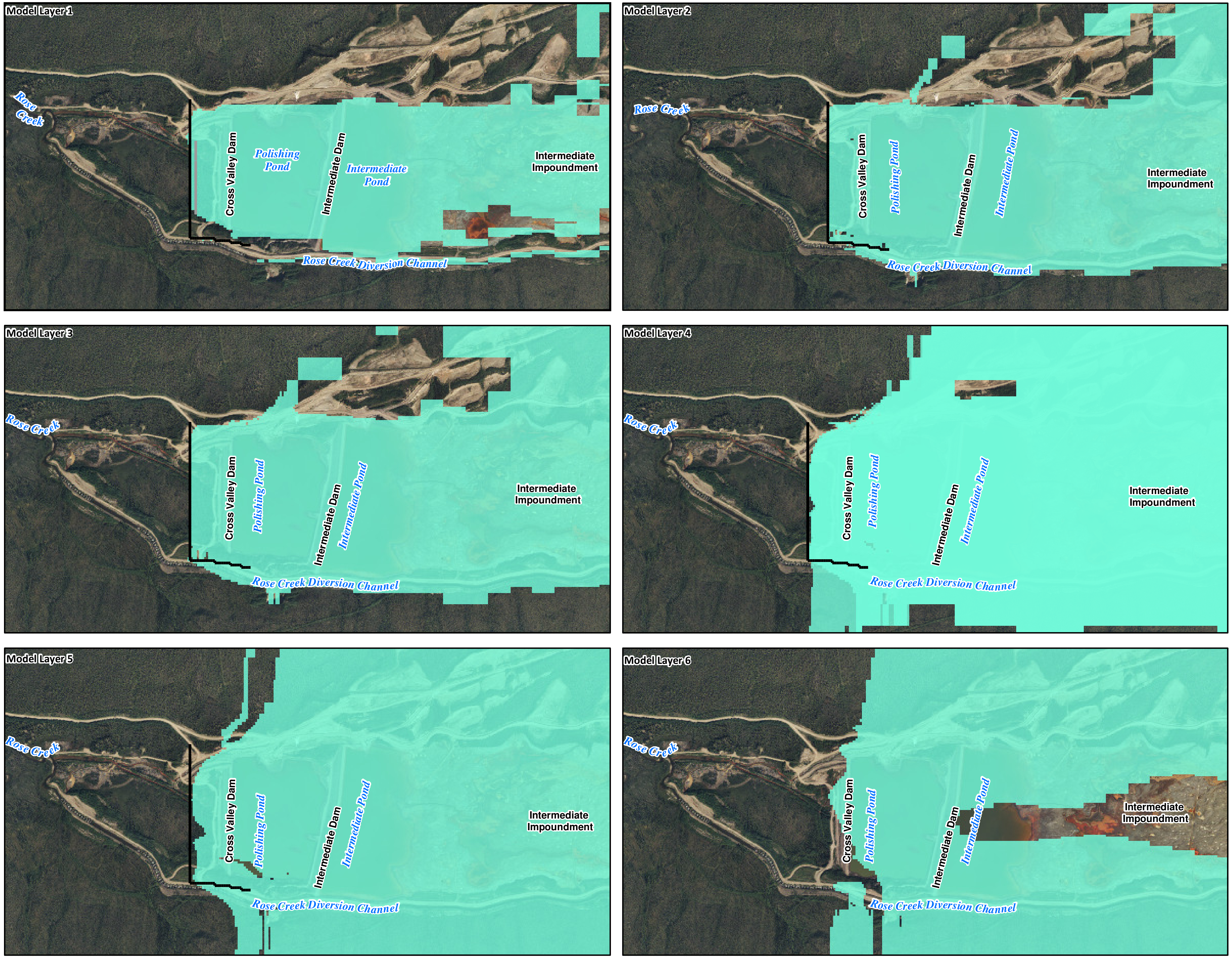
Notes
1. Particle starting cells are symbolized by a colour representing the destination at which the particle leaves the model.
2. Particles were started at the vertical midpoints of each cell and tracked forward (downgradient) until reaching the feature indicated in the legend.
3. Aerial Photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

N

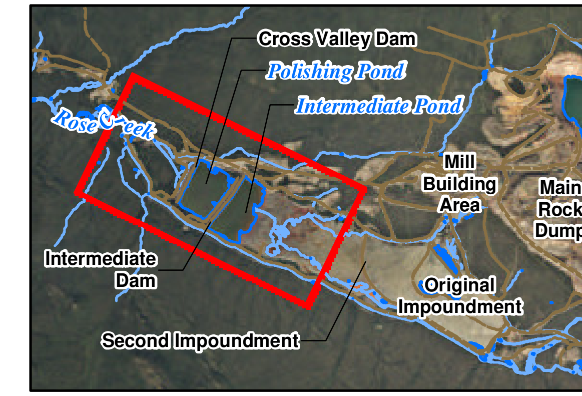
0 180 360 540 720
Metres

Created by: CRITIGEN

FIGURE 15
Modelled Hydraulic Capture Downgradient from the Cross Valley Dam Under Assumed Operation of SIS Scenario C1
Faro Mine Remediation Project



VICINITY MAP



LEGEND

- Modelled Extraction Well
- Modelled Slurry Wall
- Modelled Shallow Interception Trench
- Modelled Trench Capture Zone

Notes
1. Particle starting cells are symbolized by a colour representing the destination at which the particle leaves the model.
2. Particles were started at the vertical midpoints of each cell and tracked forward (downgradient) until reaching the feature indicated in the legend.
3. Aerial Photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

0 180 360 540 720
Metres

Created by: CRITIGEN

FIGURE 16
Modelled Hydraulic Capture Downgradient from the Cross Valley Dam Under Assumed Operation of SIS Scenario C2
Faro Mine Remediation Project