September 17, 2010

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REPORT ON

Sä Dena Hes Mine 2009 Dam Safety Review

REPORT

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Executive Summary

This report summarizes a dam safety review for the Sä Dena Hes Mine. The work was supported by a review of all project documents listed in this report and a site visit conducted by John Hull, senior geotechnical engineer, on June 23 and 24, 2009. This report provides the results of the dam safety review, which was conducted in accordance with the current Dam Safety Guidelines published by the Canadian Dam Association (CDA 2007).

Description of the Mine Development

This mine development is a zinc mine located in the Yukon approximately 70 km by road from the Town of Watson Lake. The mine was put into production in August 1991, and operations ceased in December 1992 due to a sharp downturn in metal prices. The mine is now owned by the Sä Dena Hes Joint Venture, which is comprised of Teck Metals Ltd. (50% ownership), and Pan Pacific Metal Mining Corp., a wholly owned subsidiary of Korea Zinc, (50% ownership). Teck Metal Ltd. is the operator under the Joint Venture Agreement.

The mine site is currently under active care and maintenance by Teck. A caretaker is present at the mine site to perform routine surveillance and maintenance work. Steffen Robertson & Kirsten Consulting Engineers (SRK) have been identified as the consultant for the dam infrastructure of the mine. Since 1992, SRK has carried out annual review site visits and other design and construction monitoring activities related to the maintenance of the key dams and dykes.

The Sä Dena Hes Mine received a water licence for the mine (licence number QZ99-045, YTWB 2002), which requires that a dam safety review be conducted at regular intervals. A first review was conducted in 2003 (KC 2003).

The dam safety review is intended to assess the tailings dams and associated water management infrastructure built for the tailings management facility and for supporting mill activities. The structures included in the dam safety are

- The North Dam;
- The South Dam;
- The Cofferdam;
- The Reclaim Dam;
- The Camp Creek Diversion;
- The North Creek Dyke; and
- The East and West Interceptor Ditches.

The Camp Creek Diversion, Cofferdam, and North, South and Reclaim Dams are parts of the Tailings Management Facility (TMF) at the Sä Dena Hes Mine, while the North Creek Dyke is a part of the mill water

supply system. The mine also has water pumping facilities at the Reclaim Dam and the North Creek Dyke that have not been used since the shut-down of mining operation and are not included in this review.

The North and South Dams retain the Tailings Impoundment. Between these two dams is the Cofferdam, which has a gated culvert to control the flow of water and tailings from the northern half of the impoundment to the southern half. All three dams are earthfill structures. The South Dam has a concrete decant tower structure to decant supernatant water from the Tailings Pond to the Reclaim Pond through a decant pipe. The decant tower has been temporarily sealed off to prevent discharge while the mine is not in operation. An emergency culvert spillway is located on the west abutment of the South Dam.

The Reclaim Dam is an earthfill structure that retains the supernatant water decanted from the Tailings Pond. This structure also collects seepage water from the Tailings Pond as well as the surface runoff between the South and Reclaim Dams. The Reclaim pond has an open channel emergency spillway which discharges into the Camp Creek Diversion Channel, upstream of the culverts across the west abutment of the Reclaim Dam.

The Camp Creek Diversion Channel diverts Camp Creek flows along the west side of the Reclaim pond. The diversion channel directs run off downstream of the Reclaim Dam, into the original Camp Creek channel.

The North Creek Dyke is located on North Creek approximately 1 km north of the Tailings Pond. The dyke forms a head pond for the mill water supply pipeline pump station. Several culverts carry the overflow through the dyke and discharge into North Creek downstream. Immediately below the dyke is a second culvert road crossing of the creek.

Conclusions and Recommendations of the Dam Safety Review

Key conclusions from the dam safety review are as follow:

- In general, the dams and associated water management infrastructure are considered to be maintained in good condition.
- Based on the CDA (2007) dam classification, the North, South and Reclaim Dams are in the Significant class. Consequently, these dams and their associated water management infrastructure *(i.e.,* the South Dam Emergency Spillway, the Reclaim Dam emergency spillway channel and Camp Creek Diversion) must be able to sustain flood events of 200 years (Reclaim Dam) or 1000 years (South and North Dams).
- The North Creek Dyke and the Cofferdam are in the low dam class, and their associated water management infrastructure (*i.e.,* the North Creek Dyke Culvert and the Cofferdam gated culvert) must be able to sustain a flood event of 100 years.
- It was estimated that the water management infrastructure has the capacity to manage extreme flow events corresponding to the dam class (*i.e.,* Significant or Low) of each dam, while providing adequate freeboard to prevent overtopping of any dam.
- All dams (North, South and Reclaim Dams, Cofferdam and North Creek Dyke) would satisfy the seismic requirement corresponding to their respective dam class.

- Since the previous dam safety review (KC 2003), an operating, maintenance and surveillance manual (SRK 2004) was developed to describe the operation and maintenance of these dams and related water management infrastructure as well as to provide guidelines for the monitoring of these structures. The manual also include an emergency and preparedness response plan that address actions to be taken for several possible incidents.

Recommendations provided as a result of this dam safety review are as follow:

- An inspection of the seal of the pipe inlet at the decant structure (South Dam) would be recommended to determine if repairs or a replacement are required. Detail design of a permanent seal will be needed if the decant tower is expected to remain in place following permanent closure of the mine.
- Repair to the weir at water quality monitoring station MH-07 should be made when possible to ensure that all water pass through the V-notch and the seepage flow from the Reclaim Dam are not underestimated.
- The conditions of the steel plate armour in the Camp Creek Diversion should be monitored on a regular basis and repairs undertaken as soon as possible when needed. Alternate and more stable armouring options must be considered in plans for permanent closure of the mine site.
- The siphon systems at both the Reclaim Dam and the South Dam should be maintained in a working condition so that the water levels in the Reclaim and Tailings Ponds can be positively controlled.
- Sand bags are used as erosion control measure on the upstream face of the North Creek Dyke. Any damage sand bags should be replaced as early as practical.
- It is important that the capacity of the conveyance structures be maintained to their full potential. Any material accumulating in culvert entrance should be removed (e.g. gated culvert). Shrubs and trees should also be removed from channels (*e.g.,* Reclaim Dam emergency spillway channel and Camp Creek Diversion).
- Flood routing analysis should be undertaken to verify the capacity of the Cofferdam gated culvert to pass the 200 flood event. The result of this analysis will determine if the capacity of that conveyance structure needs to be increased (*i.e.,* add culverts or develop low point on cofferdam to allow overflow or controlled breach of the Cofferdam).
- Flood routing analysis should be undertaken to verify water levels in the Reclaim Dam emergency spillway channel during 200 year flood event. This analysis is intended to verify if the banks of this channel can be overtopped and eroded during this event. The channel bank height should be increased if overtopping is predicted to occur.
- Flow velocities in the Camp Creek Diversion channel should be estimated for average and extreme flow conditions to assess the ability of unlined bank and bed material to resist erosion. The result of this estimation will determine the need and size of any riprap lining.
- Confirm that surveillance activities in the log sheets match activities listed in the OMS manual. For example, the daily log sheets list 16 and 5 surveillance items, respectively during mine operations and shutdown, while the text in the OMS manual refer to 15 and 9 items. Other similar discrepancies exist in

the daily activities. Checking for seepages on a weekly basis is not identified on the weekly log sheets, although this activity is mentioned in the surveillance summary table in the manual.

- The log sheets should details the extent of the monitoring for the Camp Creek Diversion channel. Monitoring near the Camp Creek Diversion culverts and spillway chute on a daily and monthly basis is considered sufficient. Monitoring the entire length of the diversion channel is recommended on a monthly or at least on an annual basis.
- The monthly and annual log sheet should include inspection of the east and west interceptor ditches.
- The surveillance section of the OMS manual provides specific details on: 1) rates of rise of tailings; 2) water balance; 3) freeboard; 4) seepage flows; 5) piezometers and pond water levels; 6) precipitation; 7) diversion structures; and 8) settlement gauges. It is recommended that a clear distinction be made in the text as to which of these components are addressed in the log sheets (likely components 3, 4, 5, 7, and 8) and which are not (likely components 1, 2 and 6). Additional details should be given in the text on the components not addressed in log sheets, notably about who is responsible for collecting the information, and how the information must be processed and filed.
- Details on surveillance activities following storm or seismic events should also include assessment of incident level as part of the emergency preparedness and response plan.
- The emergency preparedness and response plan describe the typical characteristics of several possible incidents as well as detailing response plans based on the incident level. The treatment of each incident is consistent and sufficient, except for the following:
  - The description of the characteristics of Channel Slope instability is not provided; and
  - The response plan for Puncture/Burst Tailings Distribution Pipeline is not provided.
- Internal and external notifications based on incident level are part of the response plan and presumably summarized in a figure in the OMS manual. This figure was absent in the copy of the manual provided for the DSR. Care should be given to ensure all available copies of the OMS manual are complete.

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1.0 INTRODUCTION

1.1 Scope of Work

Teck Metals Ltd. (Teck) mandated Golder Associates Ltd. (Golder) with the completion of a Dam Safety Review (DSR) of the Tailings Management Facilities (TMF) at the Sä Dena Hes Mine. The work was supported by a review of all project documents listed in this report and a site visit conducted by John Hull, senior geotechnical engineer, from June 23 to 24, 2009. This report provides the results of the dam safety review, which was conducted in accordance with the current Dam Safety Guidelines published by the Canadian Dam Association (CDA 2007).

1.2 Description of the Mine Development

The Sä Dena Hes Mine is located in the Yukon approximately 70 km by road from the town of Watson Lake (Figure 1). The access road to the mine site connects with the Robert Campbell Highway, at approximately 47 km north of Watson Lake. From the highway, the access road stretches for 25 km to reach the mine property.

The original discovery was made by prospectors working for the Francis River Syndicate in 1962, and was followed in the next few years by geochemical and geophysical surveys and some diamond drilling. Further diamond drilling programs were undertaken by Cima Resources Ltd. from 1979 to 1982. Canamax purchased the property in 1984 and began geological and geochemical prospecting and geophysical surveys. The Mount Hundere Joint Venture (Curragh Resources Ltd. at 80% and Hillsborough Resources Ltd. at 20%) purchased the property from Canamax in 1989 and undertook a drilling program to upgrade reserve estimates in the Jewelbox Hill and North Hill areas. The program results in an assessment of proven plus probable mineable reserves of 3.9 million tonnes at 11.5% Zn, 3.8% Pb and 53 grams/tonne Ag.

Financing was secured from the Bank of Nova Scotia in 1990, and the property was put into production in August 1991. The first zinc and lead concentrate shipment to the port of Skagway (Alaska) occurred in September 1991. The design capacity for mine production and mill processing was 1,500 tonnes per day. Operations ceased in December 1992 due to due to a sharp downturn in metal prices.

The mine is now owned by the Sä Dena Hes Joint Venture, which is comprised of Teck (50% ownership), and Pan Pacific Metal Mining Corp., a wholly owned subsidiary of Korea Zinc, (50% ownership). Teck is the operator under the Joint Venture Agreement. The Joint Venture purchased the Sä Dena Hes property in March, 1994 from the Mt. Hundere Joint Venture.

The mine site is currently under active care and maintenance by Teck. A caretaker is present at the mine site to perform routine surveillance and maintenance work. The mine has been visited by Teck management on a regular basis to provide guidance on the routine and special maintenance works. Mr. Bruce Donald is currently the Reclamation Manager in charge of the care and maintenance of the mine.

Steffen Robertson & Kirsten Consulting Engineers (SRK) have been identified as the consultant for the dam infrastructure of the mine. Since 1992, SRK has carried out annual review site visits and other design and construction monitoring activities related to the maintenance of the key dams and dykes.

The Sä Dena Hes Mine received a water licence for the mine (licence number QZ99-045, YTWB 2002), which required that a DSR be conducted no later than 2003 for all water retention structures, including but not limited to dams, dykes, weirs and appurtenances. This DSR was conducted in 2003 by Klohn Crippen Consultants Ltd, and this review herein answers the water licence requirement that such a work be undertaken at regular intervals.

1.3 Data Sources

This DSR was supported by the following information and data sources related to the mine:

- The 2003 DSR of the mine (KC 2003);
- Water licence number QZ99-045 for the mine (YTWB 2002), and its amendment (YTWB 2005);
- The operation, maintenance and surveillance (OMS) manual of the tailings management facility (TMF) of the mine (SRK 2004a);
- Geotechnical inspections of the TMF from 2000 to 2008 (AECOM 2009, SRK 2000, 2001, 2003, 2004b, 2005a, 2006 to 2009);
- Initial environmental evaluation for the mine area (SRK 1990a) and geotechnical investigations and final design for the mill and TMF (SRK 1990b);
- As-built construction report for the North, South and Reclaim Dams (SRK 1992a);
- Design reports for the Reclaim Dam toe buttress (SRK 1992b), the South Dam expansion (SRK 1992c and 1998), and the South Dam toe buttress (SRK 1997a);
- Construction reports for remedial work (SRK 1994), the North Creek Dyke (SRK 1995), and the South Dam extension and toe buttress (SRK 1997b and 1999); and
- The detailed decommissioning and reclamation plan for the mine (SRK and AMC 2000), and its update for climate and hydrology (SRK 2005b).

Furthermore, a site visit was completed from June 23 to 24, 2009, to complement the existing information and data. Photographs taken during the visit are provided in Appendix A.

1.4 Structure of the Report

The report addressed the requirements outlined in CDA (2007) for a DSR. The document contains the following:

- Review of site information and data (Section 2): A description of the mine site and its dam and water management infrastructure from the information and data sources listed in Section 1.3;

- Dam safety analysis (Section 3): include an assessment of the dam class of the dams at the mine, a summary of observations made on the mine site during the site visit of June 23 to 24, 2009, and an assessment of the dam and water management infrastructure;
- Review of operational components (Section 4): include operation, maintenance, surveillance, emergency preparedness, public safety and security, and dam safety management system; and
- Conclusions and recommendations (Section 5).

2.0 REVIEW OF SITE INFORMATION AND DATA

2.1 Mine Site Description

2.1.1 Physical Setting

The physical setting of the Sä Dena Hes mine were characterized in SRK (1990a). The mine is located in Mount Hundere, in the Yukon, near Watson Lake. The terrain around this mountain is dominated by moderately steep forested slopes. Mount Hundere reaches an elevation of about 1,600 m, with the surrounding peaks of North Hill and Jewelbox Hill reaching elevations of 1,494 m and 1,433 m, respectively (Figure 2). The valley bases range from narrow to very broad and are generally marshy with alluvial foundations. All mine facilities are within the drainage basin of False Canyon Creek (Figure 1), which drains into the Frances River, a tributary of the Liard River. Access to the mine is from the south across the drainage basin of Tom Creek, which flows directly into the Liard River.

The tailings impoundment is in a saddle lying along the drainage divide between Tributary E and the Camp Creek, both streams being tributaries of False Canyon Creek (Figure 2). These two streams drain away from the saddle at approximately 30H:1V slope. The hillsides on the east side of the valley slope towards the impoundment at approximately 4.5H:1V, while the west side of the impoundment is bounded by a small hill at the base of a 2H:1V slope. All drainage from the Jewelbox mine development and the mill site is directed to Camp Creek (Figure 2). The Burnick development (Figure 2) is within the drainage basin of Tributary D, which conveys its water to False Canyon Creek. The total drainage area of False Canyon Creek at its confluence with Frances River is 492 km^2.

The mine site is considered to be in a moderate seismic zone. The site horizontal peak ground acceleration (PGA) value of 0.055 g corresponding to an annual probability of exceedance of 0.021 (*i.e.,* 10% chance of exceedance in 50 years) was obtained from the Pacific Geoscience Centre. This value was amplified to 0.069 g by SRK, and used as the seismic coefficient in their pseudo-static stability analyses for the dams (SRK, 1990b). Similarly, SRK and AMC (2000) used the PGA value of 0.089 g corresponding to an annual probability of exceedance of 0.001 for their decommissioning study.

2.1.2 Infrastructure Component Setting

The components of the mine infrastructure included in the DSR are (Figures 2 and 3):

- The North Dam;
- The South Dam;
- The Cofferdam;
- The Reclaim Dam;
- The North Creek Dyke;
- The East and West Interceptor Ditches; and
- The Camp Creek Diversion.

These components are collectively part of the Tailings Management Facility (TMF), and include associated discharge outlets, namely: the South Dam Emergency Spillway, the Camp Creek Diversion Culverts and the North Creek Dyke Culverts. The North Dam (Figures 4 and 5) and the South Dam (Figures 6 and 7) enclose the tailings impoundment area, including the Tailings Pond. The Cofferdam is located between these two dams, and has a gated culvert to control the flow of water and tailings between the northern and southern halves of the impoundment. The North and South Dams and the Cofferdam are earthfill structures. The South Dam has a decant tower intended to direct water from the Tailings Pond to the Reclaim Pond through a pipe during mining operation. This tower has however been temporarily sealed to prevent discharge while the mine is not in operation. The South Dam Emergency Spillway is located on the west abutment of the South Dam, and this structure consists of two 900 mm diameter CSP culverts, which direct water to the Reclaim Pond. Unseasonably high rainfall contributed to elevated water levels within the Tailings Pond in 2002, and Teck installed an HDPE pipeline through one of the spillway culverts. This pipe acted as a siphon to facilitate the transfer of water from the Tailings to the Reclaim Ponds, and was installed as an alternative to re-opening the decant tower.

The Reclaim Dam (Figures 8 and 9) is an earthfill structure that impounds the Reclaim Pond. The pond receives water released from the Tailings Pond and also captures seepage water from the Tailings Pond and surface runoff between the South Dam and Reclaim Dam. During mine operation, water from the Reclaim Pond was recycled to the mill by pumping, and/or discharged into the Camp Creek Diversion Channel from April to October each year. In recent years the pumping system has not been operated.

The Reclaim Pond has an open channel emergency spillway with a riprap sill control located on the west abutment of the Reclaim Dam. The spillway may release water into the Camp Creek Diversion Channel (Figure 10), which diverts Camp Creek flows along the west side of the Reclaim Pond. Just south of the spillway, the diversion channel directs water to the Camp Creek Diversion Culverts, consisting of two 1,200 mm diameter CSP pipes, and into a riprap-lined exit chute downstream of the Reclaim Dam. From the exit chute, the flow returns to the original Camp Creek downstream of the Reclaim Dam. During the summer of 2002, Teck installed a siphon system over the dam and through one of the culverts to transfer water from the Reclaim Pond to Camp Creek Diversion Channel.

As shown in Figure 3, a total of three interceptor ditches are associated with the tailings impoundment. Two of these channels are located on the east side of the Tailings Pond (*i.e.,* the East Interceptor Ditches), while the third one is found on the west side (*i.e.,* the West Interceptor Ditch). The East Interceptor Ditches intercept surface runoff from upslope of the tailings impoundment and the Reclaim Pond, and convey the flow south beyond the Reclaim Dam and north beyond the North Dam. The West Interceptor Ditch captures surface runoff from upslope of the tailings impoundment and directs the flow south into Camp Creek.

The North Creek Dyke (Figures 11 to 14) is located on North Creek, approximately 1 km north of the tailings impoundment. The dyke was constructed to provide a reservoir from which water could be pumped to the northern end of the tailings impoundment in preparation for the start-up of the mill. The pump station is located on the north bank of the creek, upstream of the dyke. The North Creek Dyke Culverts carry the overflow across the dyke and into North Creek downstream. Immediately downstream the dyke is a second culvert road crossing of the creek (Figure 2).

The mine also has water pumping facilities at the Reclaim Dam and the North Creek Dyke. These pumping facilities were not within the scope of this DSR.

2.1.3 Climate and Hydrology

The characterization of the site climate was initially undertaken in 1990 (SRK 1990a), then was updated in 1999 with data available up to 1997 (SRK and AMC 2000). Both studies were based solely on regional data (*i.e.*, no local data collected at the site). The climate station at Watson Lake airport, which is the closest to the mine, recorded a total mean annual precipitation of 425 mm of which about 239 mm was rainfall. Total annual snowfall was 229 cm. The mean monthly temperatures at Watson Lake ranged from lows of about -30 °C up to highs of about 15 °C.

A further review with local and regional data from 1998 to 2005 (SRK 2005) confirmed the long term precipitation characteristics estimated in the 1999 assessment. This review also indicated that mean annual precipitation could be overestimated, although no adjustment was proposed due to the short record of local data available. Mean annual precipitation at the mine site was estimated at about 690 mm of which 300 mm was rainfall and 390 was snowfall as water equivalent.

The mean annual temperature at the mine site was estimated at -6.6 °C, compared to -3.1 °C at Watson Lake airport climate station (SRK 2004). Extreme minimum and maximum temperatures recorded at Watson Lake airport station were respectively -59 and 34 °C. The annual evaporation rate at the mine site is estimated at 430 mm (SRK 2004).

Mean annual runoff for the site was estimated to be between 266 and 330 mm. Flood predictions at the locations of the TMF discharge outlets were provided in the initial environmental evaluation (SRK 990a), then updated in the decommissioning plan (SRK and AMC 2000) and the OMS manual (SRK 2004). The results of these predictions are given in Table 1. The 200-year instantaneous peak flow for the North Creek Dike Culverts was estimated at 4.2 m^3/s (SRK 1995).

Table 1: Predicted Floods for the TMF Discharge Outlets (SRK 2004)

Flood Event	South Dam Emergency Spillway (1.33 km^2)			Camp Creek Diversion Culverts (4.47 km^2)		
	SRK (1990)	SRK and AMC (2000) and SRK (2004)		SRK (1990)	SRK and AMC (2000) and SRK (2004)	
		Conservative Estimate	Best Estimate		Conservative Estimate	Best Estimate
Mean annual flood (m^3/s)	NA	0.77	0.40	NA	2.1	1.1
200-year instantaneous peak flow (m^3/s)	0.46 [(a)]	2.4 [(b)]	0.95	4.0	6.6	2.6
1000-year instantaneous peak flow (m^3/s)	NA	3.2	1.1	NA	8.9	3.1

(a) Based on a smaller drainage area of 0.99 km2.
(b) Estimates do not allow for attenuation of the reservoir.

2.1.4 Geotechnical Investigation

The geotechnical investigation of the tailings impoundment site was described in SRK (1990b). The investigation consisted of 7 boreholes (DH S2-1 through S2-7) and 22 test pits (TP S2-1 through S2-4, TP S2-G1 and S2-G2, and TP S2-6 through S2-21). The boreholes were completed in the valley, with three of the boreholes in the vicinity of the North Dam, three in the vicinity of the South Dam, and one in the centre of the tailings impoundment. The boreholes were extended to depths from 3.7 m to 11.6 m, and Standard Penetration Tests (SPTs) were performed at about 1.5 to 2 m intervals.

The observed site stratigraphy typically consisted of less than 0.3 m of black, organic cover underlain by 3 to 5 m of gravelly-sandy-silt till deposits. The soils are underlain by phyllite bedrock, which was observed to be layered and fractured within the top 3 m. At the south end of the site, the observed thickness of the till deposits increased to about 10 m. The till material was typically grey to brown in colour, with a moisture content of about 9%. The till was well graded and consisted of approximately 15 to 35% gravel, 36 to 55% sand and 28 to 37% fines. The recorded SPT blow counts through the till deposits ranged from 9 to 46. The higher blow count values could potentially have been the result of the influence of gravelly content.

2.1.5 Construction

From the review of available documents, the following main construction activities related to dams are inferred:

- Phase 1 – 1990-1991: Construction of the tailings dams commenced in July 1990 with the North Dam, and was completed in October 1991 with the South Dam. Construction was shut down over the winter period from November 1990 to June 1991 (SRK 1992a).
- Phase 2 – 1992: A downstream rockfill toe buttress berm at the Reclaim Dam was constructed in March, 1992 (SRK 1992b), and the South Dam was partially raised from elevation 1095 m to elevations 1096.4 and 1097 m from September to October 1992 (SRK 1992c and 1997b).
- Phase 3 – 1994: Remedial works from September to October 1994 were undertaken and included (SRK 1994 and 1995):
  - Retrofitting and work on the toe buttress berm at the east end of South Dam;
  - Extending a 1.6 m thick and about 6 m wide toe rockfill buttress berm at the east end of Reclaim Dam;
  - Constructing berms and drainage ditches to control surface runoff at the abutments of the South and Reclaim Dams;
  - Retrofitting outlet culverts through North Creek Dyke; and
  - Placing additional riprap along Camp Creek exit channel.
- Phase 4 – 1997: A 100 m long, 10.5 to 12 m wide and 3 m thick drainage zone to add to the toe buttress was added over the existing rockfill toe buttress berm along the South Dam toe in the valley segment from August to October 1997 (SRK 1997a and b). About 90% of this work was completed before construction shut down due to freezing weather.

- Phase 5 – 1998: The drainage zone addition on the South Dam was completed and three finger drains were constructed, respectively, at Sta. 0+420 m, Sta. 0+445 m, and Sta. 0+447 m (SRK 1999).

During and after dam construction, additional sub-soil information was gained through 1) the installation and monitoring of instrumentation and 2) the foundation preparation work for the dams.

2.1.6 Seepages

Details of seepages from the TMF are provided in SRK and AMC (2000). Direct seepages were identified at the toe of the North and South Dams. These flows have not been consistently measured; however visual estimates have been recorded since 1993.

Visual observations at the South Dam identified a seepage area along a 115 m zone at the low point of the structure, with a flow rate estimated at approximately 60 L/min.

Visual observation at the North Dam identified a seepage area along an 80 m zone of the downstream toe of the structure. Flows measured at the toe of the dam (station MH-02, Figure 3) are comprised of water from surrounding hills to the east and west of the valley and seepage water from the North Dam. The fraction of the flows considered as seepages was estimated to be 20 to 25 L/min.

2.2 Infrastructure Component Details

Key Characteristics and design criteria of the dams and the dyke are summarized in Tables 2 and 3, respectively. The design event considered for the emergency spillway structure was the 200-year instantaneous peak flow (Table 1). Additional details on these retention structures as well as on the interceptor ditches and Camp Creek diversion are presented below.

Table 2: Key Characteristics of Dams and Dyke

Dam / Dyke [(a)]	North Dam	South Dam	Cofferdam	Reclaim Dam	North Creek Dyke
Type	Zoned earthfill dam	Zoned earthfill dam	Earthfilled dyke	Zoned earthfill dam	Earth filled dyke
Purpose	Tailings impoundment	Tailings impoundment	Tailings impoundment	Water impoundment	Water impoundment
Year Constructed	1990	1990 to 1991	1991	1990 to 1991	1991
Location	Northern end of TMF	Southern end of TMF	Between North and South Dams	South of South Dam	800 m north of North Dam
Access	Access road from west abutment	Access road from east and west abutments	Access road from west side of impoundment	Access road from west abutment	Access road from the south
Emergency Spillways	None	Two 900 mm CSP culverts on west abutment (South Dam Emergency Spillway)	None	Rock-lined open channel to Camp Creek Diversion	Three CSP culverts, 600, 900 and 1000 mm diameters (North Creek Dyke Culverts)
Appurtenances	None	Decant tower (currently sealed)	Gated culvert (450 mm diameter)	Recycle pump (currently not operational)	Pump house (currently not operational)
Crest Width	10 m	12 to 13 m	2 to 3 m	10 m	8 m
Maximum Crest Height at Centerline	15 m	17 m	2 m	16 m	5 m
Crest Elevation	1098 m	1096.4 to 1097 m	1098 m	1082 m	99.25 (relative to slab in pump house at elevation 100 m)
Crest Length	280 m	400 m	100 m	250 m	50 m
Upstream Slope	2H:1V	2H:1V	2H:1V	2.5H:1V	2H:1V
Downstream Slope	2H:1V	2.5H:1V	2H:1V	2.5H:1V	2.5H:1V
Construction Material	Silty till (upstream zone, sandy till filter (central zone), sand and gravel (downstream zone)	Upstream silty till zone, silty sand and gravel outer shell on downstream face, sand and gravel drainage blanket	Silty till	Sandy till on upstream face, silty till core, sandy till downstream outer shell, sand and gravel drainage blanket	Silty sandy till
Construction Method	Centreline (SRK 1992), plus downstream (SRK and AMC 2000)	Centreline to complete raise to 1098 m, downstream to complete raise to 1100 m	Centreline	Centerline	Unknown

(a) Data in the table collected from SRK (2004), unless noted otherwise.

Table 3: Design Criteria of Dams and Dyke

Dam / Dyke [a]	North Dam	South Dam	Cofferdam	Reclaim Dam	North Creek Dyke
Ultimate design crest elevation	1102 m	1100 m	Presumed at 1098 m (current elevation)	1082 (current elevation)	99.25 (current elevation) [b]
Ultimate top of till core elevation	1102 m	1100 m	Not applicable	1082 m	99.25 m [b]
Ultimate maximum operating tailings level	1101 m	1099 m	Not applicable	Not applicable	Not applicable
Ultimate maximum operating pond level	1099 m	Assumed same as North Dam	Not applicable	1079 m (SRK 2005a)	97.10 m [b]
Spillway invert elevation	No spillway	1094 m	1096 m (approximate) for gated culvert	1080 m	97.43 m [b]
Design freeboard	1 m	2m for normal operating conditions, and 1 m under flood event	Unknown	2.5 m for normal operating conditions, and 1.5 m under flood event	2.15 m for normal operating conditions, and 0.45 m under flood event
Design return period for spillway	Not applicable	200 years (0.46 m^3/s, SRK 1992)	Unknown for gated culvert	200 years (4 m^3/s, SRK 1992)	200 years (4.2 m^3/s, SRK 1995)
Design seepage	35 to 50 L/min	35 to 50 L/min	Unknown	Unknown	Unknown
Design seismic event	1:1000 years	1:1000 years	Unknown	1:1000 years	1:475 years
Peak acceleration (1:1000 year)	0.089 g	0.089 g	Unknown	0.089 g	0.069 g
Factor of safety (shallow failure)	1.63 (static), 1.28 (pseudo-static)	1.59 (static), 1.24 (pseudo-static)	Unknown	1.65 (static), 1.26 (pseudo-static)	2.53 (static), 2.08 (pseudo-static)
Factor of safety (deep seated)	1.83 (static), 1.43 (pseudo-static)	1.83 (static), 1.39 (pseudo-static)	Unknown	1.59 (static, deep failure surface)	2.42 (static), 1.86 (pseudo-static)
Reference for seismic design	SRK and AMC (2000)	SRK and AMC (2000)	Unknown	SRK (1992 and 2006)	SRK (1995)

(a) Data in the table collected from SRK (2004), unless noted otherwise.
(b) Elevation relative to slab in pump house at elevation 100 m

2.2.1 North Dam

The subsoil profile under the dam consists of a grey to brown gravelly silt till unit underlain by fractured and weathered phyllite bedrock. The thickness of the till unit is in a range of 1 to 2.5 m, increasing towards the east abutment.

The North Dam was constructed essentially according to the original design (SRK, 1990b). The entire footprint of the dam was stripped of organic and soft topsoil, and proof rolled prior to placement of fill materials. All fill materials were compacted to 95% Modified Proctor optimum dry densities. The dam was constructed up to its present crest at elevation 1098 m from September to November 1990.

Tailings to the west end are almost level with the crest of the dam. Wind erosion of tailings materials from the upstream beach on the west end has been controlled by the placement of a 50 mm to 75 mm thick sand and gravel covering layer in September, 2000 (SRK and AMC 2000, see Figure 3). Tailings to the east end are 1.5 m below the crest of the dam.

Most of the tailings lie within the northern half of the impoundment above the Cofferdam. Water was observed to pond over 40% of the northern tailings surface following spring melt, extending up to the Cofferdam. Excess water to the northern tailings may be released to the southern end through the gated culvert of the Cofferdam.

The current crest elevation of the dam is 1098 m, with an ultimate elevation considered at 1102 m. The northern half of the tailings impoundment currently holds an estimated 700,000 tonnes of tailings. Further details on retention capacity of the North Dam are provided in Table 4.

Periodical surveys of three crest settlement monuments indicate negligible dam settlement. Ongoing monitoring of piezometric levels and downstream seepage flow indicates similar seasonal variations since dam completion. Instrumentation installed at the North Dam includes three standpipe piezometer clusters: NDW-1A and 1B, NDW-2A and 2B, NDW-3A and 3B. Furthermore, one single piezometer (NDW-4A) and one monitoring well (TH-14-91) are installed at the North Dam (Figure 4). Surface flow monitoring downstream the toe of the dam is undertaken at station MH-02 (Figure 3).

Table 4: Retention Characteristics of TMF and North Creek Dyke

Dam/Dyke [(a)]	North Dam	South Dam	Reclaim Dam	North Creek Dyke
Historical pond elevation	Water seasonally pools in the low lying area of the northern impoundment up to elevation 1096.5 m.	Pond levels have fluctuated between 1087 to 1094 m.	Pond levels have fluctuated between 1076 to 1080 m.	No record available
Design storage capacity	The northern impoundment currently stores 700,000 tonnes of tailings, which is almost the maximum capacity for the crest at elevation 1098 m. An additional 450,000 tonnes of tailings may be added if the dam crest reach its ultimate elevation of 1102 m.	The southern impoundment presently stores 300,000 tonnes of tailings. The remaining capacity of the southern half of the tailings impoundment is 400,000 tonnes for the current elevation of the South dam at 1096 to 1097 m. At ultimate elevations (1102 for North Dam and 1100 m for South Dam), the total remaining capacity of the tailings impoundment (northern and southern halves combined, excluding current stored tailings) is presumed to be 1.8 million tonnes of tailings (or 1.2 million m^3 for a tailings specific density of 1.5, see Figure 15).	The Reclaim Pond has a capacity of 270,000 m^3.	Unknown
Water conveyance	Water in the northern half of the tailings impoundment may be released to the south through the gated culvert of the Cofferdam.	Water may be released through the South Dam Emergency Spillway, or the decant tower once reactivated.	Water may be released through an open channel emergency spillway into Camp Creek, then Camp Creek Diversion Culverts. The recycle pump, if reactivated, may also draw water from the Reclaim Pond	Water may be released through the North Creek Dyke Culverts. The recycle pump, if reactivated, may also draw water from the pond behind North Creek Dyke.

(a) Data in the table collected from SRK (2004), unless noted otherwise.

2.2.2 South Dam

The subsoil overburden profile under the dam, in general, consists of a brown gravelly, sandy silt till unit underlain by a layer of brown sandy silt till with varying thickness. The fractured and weathered phyllite bedrock is covered by this overburden with varying thickness ranging from 2 m at the two abutments to about 11 m in the valley.

All fill materials placed from 1990 to 1991 were compacted to 95% Modified Proctor of the optimum dry densities. Following this initial construction phase, other activities at the South Dam included the following:

- Construction of a downstream rockfill toe buttress berm to manage toe seepage (March, 1992);
- Raising of the dam from elevation 1095 m to elevations between 1096.4 and 1097 m (September and October 1992);
- Retrofitting of the downstream toe buttress berm at the east end, and construction of drainage ditches at the abutments to control surface runoff (September to October 1994); and
- Addition of a drainage zone over the existing rockfill toe buttress berm, and construction of three finger drains in localized toe areas to improve internal drainage (1997 and 1998).

The total amount of tailings stored in the impoundment is estimated at 1 million tonnes, based on the comparison of the initial storage capacity established by SRK (1990b) and the remaining storage capacity provided in SRK (2004) and illustrated in Figure 15. The southern half of the tailings impoundment therefore assumed to store 300,000 tonnes of tailings, and the remaining capacity would be 400,000 tonnes considering the current South Dam crest elevation. The available data suggests that the total remaining capacity of the tailings impoundment, if the crest of the North and South Dams are extended to their ultimate elevations (*i.e.,* 1102 and 1100 m, respectively) is 1.8 million tonnes, or 1.2 million m^3 for a tailings specific density of 1.5.

The dam was initially designed to retain tailings; however the water quality at the Reclaim Pond deteriorated to levels that required additional water retention behind the South Dam prior to discharge downstream.

Ongoing monitoring of piezometric levels in the dam indicates relatively reduced piezometric level increases in response to the pond level rise, since the improvements of the downstream drainage zones in 1997 and 1998. Instrumentation installed at the South Dam includes five standpipe piezometer clusters, namely SDW-1A and 1B, SDW-2A and 2B, SDW-3A and 3B, SDW-4A, 4B and 4C, and SDW-5A and 5B.

2.2.3 Reclaim Dam

The subsoil overburden profile under the dam consists of a brown silty to gravelly surficial till unit with a thickness of about 2 m on the east abutment slope and increasing westwards to a maximum of 14 m. On the west abutment slope, the surficial till unit is underlain by a succession of the following flat-lying overburden units:

- A 1 m to 2 m thick, brown, silty sand and gravel layer;
- A 1.5 m thick brown sandy to blue-grey silty till; and
- A 1 m to 3 m thick grey sandy gravel.

The grey friable phyllite bedrock is therefore covered by overburden with thickness varying from 1 m to 2 m at the east abutment to a maximum of 20 m at the west abutment.

The available records indicate that the Reclaim Dam was constructed essentially according to the original design (SRK, 1990b) with the exception of the addition of an inverted gravel filter along the downstream toe. The entire footprint of the dam was stripped of organic and soft topsoil. A cut-off trench was excavated through the two gravelly layers and backfilled with compacted silty till fill to reduce foundation seepage. A downstream drainage blanket was constructed at the dam base, and a finger drain was constructed at the east abutment to control seepage. All fill materials were compacted to 95% Modified Proctor optimum dry densities. The dam was constructed up to its present crest at elevation 1082 m from May to June, 1991. The water storage capacity of the Reclaim Pond is estimated at 270,000 m^3.

In July, 1991 seepage and sand boils were observed along the downstream toe between stations 0+270 m and 0+330 m. To control this toe seepage, a 7 m to 14 m wide ditch was excavated along the toe for a depth of about 1 m and backfilled with sand and gravel filter material, which was then covered by a 1 m thick limestone riprap layer from Sta. 0+220 m to 0+360 m. (SRK, 1992).

In 1994, the toe rockfill buttress berm was extended to the east end of the Reclaim Dam. Berms and drainage ditches were constructed at the abutments to control surface runoff. Additional riprap materials were placed along the exit chute of the Camp Creek Diversion Channel downstream of the Reclaim Dam.

During mine operation, the water from the Reclaim Pond was recycled to the mill by pumping. During the summer of 2002, the valve on the decant pipe at the pond failed when Teck attempted to release water from the pond into Camp Creek. The valve gearbox is no longer functional and Teck installed a siphon system over the spillway sill and through one of the Camp Creek Diversion Channel outlet culverts to remove water from the Reclaim Pond to Camp Creek Diversion Channel.

Instrumentation installed at the Reclaim Dam includes five standpipe piezometer clusters: RDW-1A, 1B and 1C, RDW-2A, 2B and 2C, RDW-3A and 3B, RDW-4A and 4B, and GW-1A and 1B. Two monitoring wells (TH-18-91 and TH-21-91) are also used to monitor the dam.

2.2.4 Cofferdam

No documentation detailing the design and construction of the Cofferdam appear to be available. The dam was constructed by Curragh Resources during mining operation from 1991 to 1992 (SRK 2004). The presumed purpose of this structure is to provide a temporary barrier to tailings while allowing surface water to drain to the southern half of the tailings impoundment. The gate of the culvert through the Cofferdam is normally left 90 percent open (SRK 2004). No issue related to the performance of the Cofferdam appear to have been recorded over the years.

2.2.5 North Creek Dyke

This dyke was built to provide a reservoir of water that could be pumped for the start-up of the mill. The pump is located to the north of the dyke; however pumping from the reservoir has been stopped since the mine shutdown in 1992.

No documentation detailing the design and construction of the North Creek Dyke appear to be available. It is assumed that the dyke was constructed by the Mt. Hundere Joint Venture during mining operation from 1991 to 1992. Approximately 200 m^3 of silty sandy till was estimated to have been used to construct this structure.

Remedial works carried out in 1994 on the outlet culverts and the review of dyke stability was reported by SRK (1994 and 1995). One open, 600 mm diameter culvert (invert relative elevation of 96.48, Figure 14) allows water releases from the impoundment upstream of the dyke. Three other culverts at higher elevations serve as emergency spillways for the discharge of excess water (one 600, one 900 and one 1000 mm diameter pipes with inverts at relative elevations higher than 97 m, Figure 14). Riprap has been installed on the downstream face of the dyke at the locations of the culvert discharge outlets. No issue related to the performance of the North Creek Dam appear to have been recorded over the years.

2.2.6 Camp Creek Diversion

Key characteristics and design criteria for Camp Creek Diversion and the East and West Interceptor Ditches are provided in Table 5. The design event considered for these conveyance structures was the 200-year instantaneous peak flow.

The Camp Creek Diversion re-directs flow from Camp Creek along the west side the Reclaim Pond (Figure 10). The diversion conveys water to the Camp Creek Diversion culverts, which consist of two 1200 mm diameter CSP pipes. These culverts discharge downstream of the Reclaim Dam into a riprap lined channel (*i.e.,* the spillway chute), which directs flow to the original Camp Creek channel.

Lining for erosion protection was installed at the Reclaim Dam spillway and two sections within the diversion channel (1/4 round CMP armouring, Figure 10). The channel of Camp Creek Diversion is otherwise unlined.

Table 5: Key Characteristics and Design Criteria of Camp Creek Diversion and Interceptor Ditches

Structure [(a)]	Camp Creek Diversion	East and West Interceptor Ditches
Type	Trapezoidal earth and riprap-lined open channel	In-ground, unlined open channels
Purpose	Diverting Camp Creek away from the Reclaim Pond	Diverting surface runoff away from the tailings impoundment and Reclaim Pond
Year Constructed	1991	1991
Location	West of the Reclaim Pond	East and west of the TMF
Access	Access road to the west	East interceptor ditches (EID) by foot, access road for west interceptor ditch (WID)
Culverts	Two 1200 mm diameter CSP pipes (Camp Creek Diversion Culverts)	300 mm diameter culverts at the south outlet of EID and WID
Culvert invert elevation	1078.5 m (approximate)	Unknown
Design return period	200 years (4 m^3/s)	200 years
Design channel width	2 m	1 to 2 m for WID and 0.5 to 1 m for EID
Depth of channel	1.5 m	0.5 to 2 m for WID and 0.8 m for EID
Side slopes	1.5H:1V	1.5H:1V
Longitudinal gradient	Unknown	2 percent
Erosion protection	Riprap	None
Design reference	SRK (1990)	SRK (1990)

(a) Data in the table collected from SRK (2004), unless noted otherwise.

2.2.7 East and West Interceptor Ditches

The interceptor (see Figure 3) ditches capture surface runoff from the hillsides above the tailings impoundment and direct this water contribution to Camp Creek (West Interceptor Ditch) or downstream the Reclaim and North Dams (East Interceptor Ditches). Water directed to the south passes through 300 mm culverts, at the downstream ends of both on the East and West Interceptor Ditches. Key characteristics and design criteria of these structures are provided in Table 5.

3.0 DAM SAFETY ANALYSIS

3.1 Consequence Categories

3.1.1 General

All of the water released from the tailings impoundment, Reclaim Pond and North Creek Dyke would ultimately flow into False Canyon Creek, which conveys flows into the Frances River, a tributary of the Liard River. Environment Canada hydrometric station 10AB001 (EC 2009) monitors flows on Frances River near Watson Lake, and is located about 15 km southwest of the mine, where the river crosses the Robert Campbell Highway. The maximum, minimum and mean annual discharges derived from the observations at this station from 1967 to 2008 are respectively 1190, 14 and 159 m^3/s. Environment Canada hydrometric station 10AA001 (EC 2009) is installed on Liard River at Upper Crossing, which is approximately 10 km west of Watson Lake where the river crosses the Alaska Highway. This station is among those on the Liard River that is closest to the mine, and its records from 1961 to 2008 indicate maximum, minimum and mean annual discharges of 3060, 32 and 377 m^3/s, respectively.

The communities of Upper Liard and Watson Lake are located downstream of the mine facilities, in an area that is otherwise relatively undeveloped. Upper Liard is located on the west bank of the Liard River where the Alaska Highway crosses the river. The town of Watson Lake is located about 4 km north of the Liard River; however this community takes its water supply from that river. The upper reaches of Frances River upstream of station 10AB001 follow a relatively straight course. The Frances and Liard Rivers exhibit a meandering pattern from station 10AB001 to the general vicinity of the town of Watson Lake. The distances along the watercourse from the North Dam and North Creek Dyke to the Upper Liard and Watson Lake communities are approximately 140 km and 150 km, respectively. The distance from the South and Reclaim Dams to these two communities is slightly longer.

The downstream consequences classification for the South Dam has been assessed for the detailed decommissioning and reclamation plan for the mine (SRK and AMC 2000) in accordance with the guidelines by INAC (1992). Only the failure of the South Dam spillway was considered in this assessment. The failure of the South Dam or the Reclaim Dam was not considered, since they would be breached upon closure. The decommissioning and reclamation plan classified the size of the tailings impoundment embankment as large (>7.5 m height). However the potential impact or hazard associated with the failure of the spillway was considered to be moderate. Tailings and embankment soil would be released and transported downstream into False Canyon Creek in the event of a spillway failure, although the volume of released material was expected to be less than that of a dam breach. The tailings are not acid generating; however moderate increase in metal concentrations such as zinc may potentially occur in the stream due to oxidation of sphalerite in the exposed tailings, once the flood levels have subsided. The decommissioning and reclamation plan further indicated that no loss of life, damage to buildings or agricultural land, and loss of roads would be expected. This assessment of the South Dam spillway is understood to be the only consequences classification completed for the individual tailings and water management facilities at the Mine, and that no other dam breach or inundation studies have been carried out.

A screening level assessment of the classification of these dam facilities was therefore undertaken for this DSR, so that the appropriate design criteria could be adopted for the dam safety review. The level of effort of the assessment should be commensurate with the dam safety decision to be made (CDA 2007), and a more detailed assessment could have been needed as a confirmation if a high to extreme classification level had been determined. A dam is classified from low to extreme based on the assessment of incremental losses listed in Table 6.

Table 6: Dam Classification (CDA 2007)

Dam Class	Population at Risk [(a)]	Incremental Losses		
		Loss of Life [(b)]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	▪ Minimal short term loss ▪ No long term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	▪ No significant loss or deterioration of fish or wildlife habitat ▪ Loss of marginal habitat only ▪ Restoration or compensation in kind highly possible	Loss to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	▪ Significant loss or deterioration of *important* fish or wildlife habitat ▪ Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
Very high	Permanent	100 or fewer	▪ Significant loss or deterioration of *critical* fish or wildlife habitat ▪ Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (*e.g.,* highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100	▪ Major loss of critical fish or wildlife habitat ▪ Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure (*e.g.,* hospital, major industrial complex, major storage facilities for dangerous substances)

(a) Definition for population at risk:

- None: There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.
- Temporary: People are only temporarily in the dam-breach inundation zone (*e.g.,* seasonal cottage use, passing through on transportation routes, participating in recreational activities).
- Permanent: the population at risk is ordinarily located in the dam-breach inundation zone (*e.g.,* as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

(b) Implication for loss of life:

- Unspecified: The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

3.1.2 North, South and Reclaim Dams

Overtopping and internal erosion have been identified as the two most common causes of recorded dam failures (ICOLD 1995), and both causes would likely develop a breach from the crest of the dam. Overtopping would erode the dam material from the crest downward. Piping involves internal erosion of the dam and loss of material resulting in a caving of the crest and overtopping.

Peak flows from a dam breach were therefore estimated for the following scenarios:

- A breach of the North Dam;
- A breach of the Reclaim Dam; and
- Breaches in succession of the South and Reclaim Dams.

The breach width and height and the time of breach are the factors that affect the magnitude of the flow for dam breach scenarios. Conservative assumptions for the breach width and height are based on the following:

- Breach height was considered equal to the total height of the dams (Table 2);
- The largest breach width calculated from the empirical formulations proposed by the U.S. Dam Safety Office (DSO 1998) was assumed (48 m for all dams, from U.S. Bureau of Reclamation 1988); and
- The shortest estimated time of breach was considered, that is, 860 sec from Von Thun and Gillette (1990) for the North and South Dams, and 570 sec from Froelhich (1995) for the Reclaim Dam.

Flows from a breach scenario would vary with time based on the evolution of the breach. Flow routing according to the Puls method (Watt et al. 1989), modified to account for a varying breach size over time, was used to develop the hydrographs for the three breach scenarios. A storage curve is also required for flow routing, and that of the tailings impoundment (SRK 2004) was used for the North and South Dam breaches (see Figure 15). It was assumed for the North Dam breach scenario that the full storage volume is made of water, even though the current condition is for full tailings storage with a relatively flat slope on the tailings to levels near the dam crest which would provide limited water storage. The storage curve of the tailings impoundment was also used to characterize the Reclaim Pond for the Reclaim Dam breach. The curve was however scaled to reflect the capacity of the Reclaim Pond (Table 4).

The estimated peak flows at the dam are presented in Table 7. The peak flows are of the same order of magnitude as those given in the previous DSR (KC 2003) single dam breach scenario (*i.e.*, North and Reclaim Dam). The breach of the South and Reclaim Dam in succession results in flood peak of similar magnitude as that of the North Dam Breach scenario. The water volume discharged from the South and Reclaim Dam breach would be the sum of the tailings and Reclaim Pond storage (*i.e.*, 1.47 million m^3), while discharged volume from the North Dam breach would be only 1.2 million m^3. High flows are therefore sustained for a longer period for the South and Reclaim Dam breach scenario than for the North Dam breach scenario.

The expected flood peak attenuation in Frances and Liard Rivers were estimated using the data presented by Petrascheck and Sydler (1984). Attenuation was predicted to be approximately 30 to 50% by the time the flood peak reaches Environment Canada hydrometric station 10AB001 on the Frances River, and 50 to 60% at station 10AA001 on the Liard River. Table 7 present the resulting peak flow at these stations, using the lowest attenuation percentage at both locations. The prediction was based considering a 45 m high dam, since the attenuation charts do not cover lower heights. The North, South and Reclaim Dams are in the 15 to 20 m height range, and therefore attenuation based on a 45 m height for these structures is considered to be conservative and adequate for a screening level analysis. The attenuated flows were added to those of the Frances and Liard River, and it is normal practice in dam breach inundation studies to assume concurrent flows in the downstream reaches equal to the mean annual flow.

Table 7: Peak Flows and Incremental Losses Associated to the North, South and Reclaim Dams

Breach Scenario	Breach Height (m)	Breach Width (m)	Time of Breach (sec)	Peak Flow (m^3/s) at		
				The Dam	Station 10AB001 [(a)]	Station 10AA001 [(a)]
North Dam	15	48	860	3200	2400	2000
Reclaim Dam	16	48	570	1200	1000	1000
South and Reclaim Dams	17 (South Dam) and 16 (Reclaim Dam)	48 (both dams)	860 (South Dam) and 570 (Reclaim Dam)	3100	2330	1930

(a) Peak flows at stations 10AB001 and 10AA001 are equal to peak flows at the dam attenuated by 30 and 50%, respectively, plus annual average flow recorded at the stations (159 and 377 m^3/s, respectively).

The North Dam breach and the successive South and Reclaim Dam breaches are the scenario that are predicted to generate the highest flow, both at roughly 2400 and 2000 m3/s at the locations of stations 10AB001 (Frances River) and 10AA001 (Liard River), respectively. The predicted flows in the Frances River from these two breach scenarios would be approximately twice as high as the highest daily flow recorded at station 10AB001. Loss of life along False Creek and the France River is not expected. Loss of habitats is anticipated; however restoration would be highly possible. Loss of infrastructure outside the mine property would likely be limited to the Robert Campbell Highway Bridge crossing the France River. Incremental losses to the False Creek and Frances River following a dam breach are considered in the significant class (Table 6).

Predicted flows from North Dam breach and the successive South and Reclaim Dam breach scenarios in the Liard River would be approximately 65% of the highest daily flow recorded at station 10AA001. A frequency analysis on the annual maximum daily flow at station 10AA001 indicates that the flow from the dam breach would correspond to a 5-year event in the Liard River at the location of the station. Loss of life along the Liard River is not expected. Short term loss of habitats may occur, although no long term loss would be anticipated. Low economic loss should result, with no damage anticipated at the Alaska Highway Bridge crossing the Liard River. Incremental losses to the Liard River following a dam breach are considered in the low class.

Predicted flow from the Reclaim Dam breach in the France River would lower than the maximum daily flow at Station 10AB001. A frequency analysis on the annual maximum daily flow at this station indicates that the flow from the breach correspond to a 20-year event at the location of the station. Predicted flow from the Reclaim Dam breach in the Liard River would be lower than the average annual maximum daily flow observed at station 10AA001 (*i.e.,* 1900 m^3/s). Incremental losses from this Dam Breach may be significant in False Creek, and would likely be low in the Frances and Liard Rivers.

Overall, the North, South and Reclaim Dams are placed in the significant dam class due to the potentially significant incremental losses on the False Creek and Frances River.

3.1.3 Cofferdam

A failure of the Cofferdam is not expected to have any downstream consequences, since this dam is contained between the two main retention structures of the tailings impoundment: the North and the South Dams. The Cofferdam is placed in the Low dam class.

3.1.4 North Creek Dyke

The North Creek Dyke is a small structure with relatively small water storage capacity. Failure of the dyke is not expected to cause any fatalities. Furthermore low to negligible environmental, cultural, infrastructure and economic losses beyond the mine property would be expected. The North Creek Dyke is placed in the Low dam class.

3.2 Site Review of Dam and Water Management Infrastructure

A site inspection was conducted by John Hull, senior geotechnical engineer, on June 23 and 24, 2009. He was accompanied by Peter Healey, project manager of SRK for the mine, and by Bruce Donald, the mine site reclamation manager for Teck. Mr. Hull conducted the inspection for the purpose of the DSR, while Mr. Healey conducted the inspection for the purpose of the annual inspection of the TMF, which SRK has been conducting for a number of years. Weather conditions on both days were overcast sky, with an air temperature of approximately 10^0C, and cool light winds. The inspection was undertaken from 8:30 am to 4:00 pm on both days.

All the civil works reviewed have been regularly maintained by Teck. Special maintenance works have also been carried out based on annual geotechnical reviews and recommendations by SRK (SRK 2000, 2001, 2003, 2004b, 2005a, 2006 to 2009). In general, all civil works appear to be maintained in good condition. Presented in the following sections are observations made during the June 23 and 24 site inspections, and which tend to focus on localized areas or specific items that should be incorporated in future maintenance work.

Observations are provided for:

- The North Dam;
- The South Dam and its spillway;
- The Cofferdam and its outlet;
- The Reclaim Dam and its spillway;
- The Camp Creek Diversion Channel and exit chute;
- The North Creek Dyke and its outlet facilities; and
- The East and West Interceptor Ditches.

All photos of the mine site infrastructure cited in the sections below are found in Appendix A. Photo 1 present an overview of the TMF, including, from left to right, the North Dam, the Cofferdam, the South Dam and the Reclaim Dam.

3.2.1 North Dam

The dam was considered to be in a stable condition at the time of the visit, with a wide crest, uniform and stable slopes, and no visual indication of erosion or slope movement. Most of the tailings had been deposited in the northern half of the impoundment, between the North Dam and the Cofferdam. The tailings are gently sloped to allow surface runoff to drain from the North Dam to the Cofferdam (Photos 2 and 3). The tailings surface is relatively smooth, although a small gully has formed between the dam upstream face and the tailings (Photo 3).

Water was observed to accumulate near the Cofferdam, as observed in Photos 2 and 3. Excess water accumulated in the northern half of the Tailings Pond was being released through a gated culvert in the Cofferdam to reach the Tailings Pond in the southern half.

A sand and gravel cover was placed on the tailing beach on the west side of the northern half of the tailings impoundment to control fugitive dust. Photos 2 and 3 show that this cover is still relatively uniform and therefore appears to still reduce the potential of fine tailings mobilization due to wind. The cover does not extend to the east side of the northern half of the tailings impoundment. However the exposed tailings in this area do not appear to have been affected by wind erosion. As indicated in KC (2003), the relatively lower elevation of the tailings beach and its possibly higher moisture content (water accumulation extended to the east side during the visit, as seen in Photo 1) may prevent the mobilization of fine particles on the east side by winds.

No seepage was present on the downstream end of the dam, on the east side. Seepages were observed on the west side of the dam, along the abutment (Photo 4) and at the dam toe (Photo 5). It is not certain that the seepage along the abutment originated from the tailings impoundment. The seepage long the toe is however considered as water from the tailings impoundment. Total seepage was roughly estimated at 1 L/min, which is below the estimate provided in SRK and AMC (2000). The seepage water was clear, and consequently no loss of material from the dam is suspected. All seepage from the North Dam is directed to a collection pond (Photo 6), and the water flows toward water quality monitoring station MH-02 (Figure 3).

3.2.2 South Dam

The dam is considered in stable condition at the time of the visit, with uniform and stable slopes, and no visual indication of erosion or slope movement. The dam crest is wide and consists of two benches (Photos 7 and 8); as a result of the construction sequencing. The upstream bench is lower than that downstream, and would be raised if mine operations restart. Water elevation in the Tailings Pond was estimated to be at a level that would have provided the minimum 2 m freeboard under normal operation. To facilitate site operation and inspection, markers should be permanently added or marked on the decant wall to indicate important water elevations, such as the maximum operating water level and inflow flood design water level.

The buttress at the toe of South Dam appears in stable condition (Photo 9). Seepage was observed at the toe of the dam, on the west side of the buttress, and was estimated to be flowing at a rate of 0.25 L/min. Seepage water was clear and therefore no loss of material from the dam is suspected. No other seepage was observed along the abutment and toe of the dam (*e.g*. Photo 10); however several wet areas were identified near the dam toe. Regular visits to observe drainage conditions at the toe should therefore be made.

A siphon is used to release water from the Tailings Pond to the Reclaim Pond and is located on the dam crest near the decant tower. This equipment was shut down at the time of the site visit, and an effort was being made to activate the system. It is understood that personnel at the site have the proper instruction on how to operate the siphon.

The South Dam has a decant that consists of a concrete decant tower (Photo 11) and a CSP outlet pipe (Photo 12) which releases water to the Reclaim Pond. The tower inlet was underwater and was not inspected; however it is understood that its entrance is closed with wooden stop logs. The upstream end of the decant pipe is also sealed. It is understood the seal consists of a plywood section and caulking, as indicated in KC (2003). This seal is likely not entirely tight, since a water discharge was observed in the outlet pipe (Photo 12) at a rate estimated at 2 L/min. Recommendations are consistently given in annual geotechnical inspections (SRK 2005a, 2006 to 2009) about the maintenance of the decant structure, including replacing any damaged stop logs and resealing the decant pipe inlet. An inspection of this seal at the decant structure would be recommended to determine if repairs or a replacement are required. Detail design of a permanent seal will be needed is the decant tower is expected to remain in place following permanent closure of the mine.

The South dam spillway channel and culverts appear in relatively good conditions (Photos 13 and 14). Maintenance activities for the channel and spillway should include the removal of in-stream vegetation and debris. Obstruction from sedimentation and channel bank failures should be removed from the spillway channel to maintain the capacity of this conveyance structure. All soil material or debris within or at the entrance to the spillways culverts should also be removed.

3.2.3 Cofferdam

The Cofferdam is an earthfill structure that appeared to be in stable conditions at the time of the visit (Photo 15). This dam constitutes the division between the northern and southern halves of the tailings impoundment. A gated culvert through the dam allows surface runoff in the northern half to drain to the southern half of the impoundment and the Tailings Pond. The gate mechanism was not tested during the site visit, but is presumed to be working based on its visually good conditions.

Soil was observed to fill the bottom third of the culvert inlet (Photo 15) and work was completed during the site visit to remove this deposition and restore the capacity of the culvert. The culvert should be free of soil material and debris to the extent possible, and therefore maintenance by site personnel should include visits monthly during open water and following major rainfall to check the condition of the culvert and remove deposition if needed.

The dam slope at the culvert inlet is relatively steep (Photo 15) and may be subject to erosion. Flattening the slope or riprap armouring on this slope would be recommended (Photos 15 16) Slopes should be developed with a maximum slopes of 2H:1V. Material should be removed from the inlet channel bottom if its elevation is higher than the culvert invert. Low lying vegetation such as grass would be acceptable in the inlet channel bottom and side slopes. However, larger vegetation species such as shrubs and trees should be removed from that inlet channel. The riparian vegetation upstream the inlet channel (Photo 16) is acceptable if a preferential channel remain present to allow drainage of water in the northern half of the tailings impoundment to the culvert.

The slopes of the culvert outlet channel appear stable near the Cofferdam, and therefore erosion is not anticipated (Photo 17). Vegetation is apparent on the southern half of the tailings impoundment, near the Cofferdam (Photo 1); however a preferential channel is present for draining water from the culvert to the Tailings Pond. Low lying vegetation such as grass is acceptable in the culvert outlet channel. Shrubs and tree must be removed from the channel bottom and slopes.

3.2.4 Reclaim Dam

The dam was considered to be in stable conditions at the time of the site visit. The crest was relatively wide and uniform, with no cracks noticed, and no sign of erosion or slope movement were observed on the upstream and downstream faces of the dam (Photos 18 to 20). Shrubs and small trees are present on both faces of the dam.

Monitoring of seepages has been a consistent recommendation in annual geotechnical inspections (SRK 2000, 2001, 2003, 2004b, 2005a, 2006 to 2009), and SRK must indeed be informed, as recommended, of any change in flow rate and form observed by site personnel. The abutment and toe of the dam, including the access road to the dam toe and the buttress were inspected for the presence of seepages. These flows were observed to be minor on the east abutment (Photo 20) and moderate to high at the toe on the east side. The toe of the access road (Photo 21) was also found to be wet in some areas. However, all observed water was clear and there was no indication of loss of material from the dam. Holes were found on the access road to the dam toe, although all were on the downstream edge of the road / berm and were considered a concern.

The seepage flow rate from the dam is monitored by a V-notch weir installed at water quality monitoring station MH-07 (Figure 3, and Photo 22). A close inspection of the station revealed that water escapes on the side of the weir, and flow measurement at the V-notch therefore underestimate flow / seepage. Repair to the weir should be made when possible to ensure that all water pass through the V-notch.

Water level in the Reclaim Pond was estimated to be approximately 3 m below the elevation of the Camp Creek Diversion Culverts invert (1080 m, Table 3). This water level is well below the recommended operating water level of 1079 m. The siphon, which allows the lowering of the water level in the Reclaim Pond, was found to be in working order.

The spillway channel between the Reclaim Pond and the Camp Creek Diversion Channel has a riprap lining with rocks which appear to be of an appreciable size on the side slope. The material on the channel bottom has a wide range of diameters (Photo 23). It is presumed that this riprap was added to the channel as part of the recommendation for such an erosion protection measure as noted in the previous DSR (KC 2003). Significant vegetation (thick shrubs and small trees) was observed across the entire width of the channel entrance and this should be removed at the earliest opportunity. Low lying vegetation such as grass is acceptable within the channel; however shrubs and trees can significantly limited the capacity of the conveyance structure.

3.2.5 Camp Creek Diversion Channel

The inspection of this channel was particularly focused along the first 300 m upstream the Camp Creek Spillway Culverts and then the spillway exit channel downstream of the Reclaim Dam. Riprap lining is present on the spillway exit channel and on the channel base between the Camp Creek Spillway Culverts inlet and the Reclaim Pond spillway channel. In addition, armouring, consisting of ¼ round corrugated metal culvert sections or plates, is on the right bank of the channel at 2 locations upstream of the Reclaim Pond spillway channel. Other sections of the diversion channel were unlined. Some signs of erosion were noted in unlined portions of the channel (*e.g.,* gradient change in the channel side slope to the right of Photo 24). No major failure of the channel side slopes was however observed along the section of channel inspected.

The major concern raised in the previous DSR (KC 2003) with regards to the Camp Creek Diversion Channel was related to the culvert plate armouring. Erosion of the channel side slope below the metal plates was suspected, and was observed to still be occurring at the time of the site visit. The metal plates were also found to have loose or missing panel bolts, and bent or uplifted panels in several locations. The base of the metal plates was weighted down at several locations with large boulders (Photo 24). The intent of these boulders is understood to be to prevent steel plates from becoming loose and potentially blocking the Camp Creek Spillway Culverts. These metal plates should be considered only as a temporary armouring option for this channel. The conditions of these plates should be monitored on a regular basis and repairs undertaken as soon as possible when needed. Alternate and more stable armouring options must be considered in plans for permanent closure of the mine site.

The diversion channel between the Camp Creek Spillway Culverts inlet and the Reclaim Pond spillway channel was observed to be in relatively good conditions (Photo 25). Shrubs and trees within the diversion should however be removed, since this vegetation may limit the capacity of this conveyance structure. Debris and soil material should also be removed from the spillway if observed to be present.

The spillway exit channel was considered to be in good conditions (Photo 26). As indicated in KC (2003), the banks of Camp Creek upstream of the diversion are vegetated and the channel is stable.

3.2.6 North Creek Dyke

The dyke was considered stable, with no indication of slope movement or significant erosion. Sand bags are used on the upstream face of the dyke, particularly around the culverts to reduce erosion (Photo 27). This erosion protection measure remains acceptable as long as visits are made regularly to verify the condition of the bags. Damaged sand bags should be replaced as early as practical.

The conveyance infrastructure through the dyke consists of four culverts, which were all relatively free of debris of soil material (Photo 27). Water was conveyed through the lowest culvert, while the other three where all above the water level. The minimum freeboard of 2.15 m was considered met, since the water level was estimated approximately at relative elevation 97 m and the crest elevation of the dyke is at relative elevation 99.25m (Table 2). Water released from the culverts is directed to a well defined channel downstream of the dyke (Photo 28).

3.2.7 East and West Interceptor Ditches

The East Interceptor Ditch in the vicinity of the Reclaim Dam was inspected. The West Interceptor Ditch and the upstream sections of the East Interceptor Ditch were not inspected due to difficulty of access through dense vegetation and limited time.

The East Interceptor Ditch was dry near the Reclaim Dam at the time of the visit. The ditch was also covered with small trees. This settled vegetation may be indicative that this channel has carried little significant flow in the past, except possibly at the downstream end of the ditch, as water was observed at the culvert through the road downstream the Reclaim Dam. As recommended in KC (2003), interceptor ditches should be inspected during the fall or spring, when there is less vegetation, to ascertain their general condition and effectiveness. The need for maintenance work, such as removal of vegetation or blockages from the channels, should be assessed after those inspections.

3.2.8 Pumping Stations

Two water pumping stations were installed at the mine, and are respectively located at the Reclaim Dam and North Creek Dyke. These stations were not within the scope of the DSR and therefore were not inspected. The pumping station at the North Creek Dyke is inoperable, since no power supply is currently available at this site. It is understood that the pumping station at the Reclaim Dam is operable, but requires large generators for power supply. The operation of this pumping station was not tested during the site inspection.

3.3 Assessment of Dam and Water Management Infrastructure

3.3.1 Design Criteria

The water licence issued for the mine (YTWB 2002) requires all instream works, earthworks, diversions, ditches, spillways and any other water-related structures to be designed and constructed to accommodate the peak instantaneous 200-year return period flood. The South Dam Emergency Spillway, the Camp Creek Diversion Culverts, the North Creek Dyke Culverts and the conveyance structures (*i.e.,* Camp Creek Diversion and East and West Interceptor Ditches) were designed based on this 200-year event (Tables 3 and 5).

Guidelines from CDA (2007) recommend that dams be designed to safely pass the Inflow Design Flood (IDF), which is listed in Table 8 as a function of the dam class.

Table 8: Suggested Design Flood and Earthquake Levels (CDA 2007)

Dam Class [(a)]	Annual exceedance probability (AEP)	
	Inflow Design Flood (IDF) [(b)]	Earthquake Design Ground Motion (EDGM) [(c)]
Low	1/100	1/500
Significant	Between 1/100 and 1/1,000 [(d)]	1/1,000
High	1/3 between 1/1,000 and probable maximum flood [(e)]	1/2,500 [(f)]
Very high	2/3 between 1/1,000 and probable maximum flood [(e)]	1/5,000 [(f)]
Extreme	Probable maximum flood [(e)]	1/10,000 [(f)]

(a) As defined in Table 2.
(b) Extrapolation of flood statistics beyond 1/1,000 year flood (10^{-3} AEP) is discouraged.
(c) AEP levels for EDGM are to be used for mean rather than median estimates of the hazard.
(d) Selected on the basis of incremental flood analysis, exposure and consequences of failure.
(e) PMF has no associated AEP. The flood defined as "1/3 between 1/1,000 year and PMF" or "2/3 between 1/1,000 year and PMF" has no defined AEP.
(f) The EDGM value must be justified to demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contributed to failure initiated by a seismic event. If the justification cannot be provided, the EDGM should be 1/10,000.

The screening level assessment presented in Section 3.1 indicates that the North Creek Dyke and the Cofferdam are in the Low dam class, requiring in inflow design flood (IDF) corresponding to the 100 year flood event. The North, South and Reclaim Dams are in the Significant dam class, and the recommended IDF is between the 100 and 1000 year flood event. Selection of an exact IDF would be based on the expected environmental and cultural values and infrastructure and economics losses. This selection is discussed for the North, South and Reclaim Dams in Sections 3.3.2 and 3.3.3.

The CDA (2007) guidelines require that a dam be evaluated for its ability to withstand the earthquake design ground motion (EDGM) listed in Table 4 as a function of the dam class. The recommended EDGM for the North, South and Reclaim Dams would be 1/1,000 (Significant dam class), while it would be 1/500 for the Cofferdam and North Creek Dyke (Low dam class). It is understood that a 1/1,000 EDGM was used to evaluate the dam stability in the decommissioning study of the mine (SRK and AMC 2000).

3.3.2 Tailings Impoundment

Flood Discharge

A design event of 200 years (Table 1), as used for the design of the South Dam Emergency Spillway, would be within the range of IDF for dams in the Significant class *(i.e.*, the North and South Dam). A summary calculation of the capacity of the South Dam Emergency Spillway was undertaken, considering two 900 mm culverts with the invert elevation at 1094 m. The calculation was based on the methodology provided in AISI (1984), using a conservative assumption of a constant flow of the magnitude of the design event and no storage capacity in the Tailings Pond for flood routing. The result indicated that this conveyance structure can release the most conservative design flow event of 200 years given in Table 1, while meeting the recommended freeboard of 1 m.

The previous DSR (KC 2003) however recommended that the IDF considered for the North and South Dam be the 1000 year event, which is the highest for the Significant class, due to the potential importance of environmental consequences if tailings are released from a dam breach. This recommendation is reasonable.

Flood routing analysis through the Tailings Pond was therefore undertaken by SRK (2005b) to determine if the Tailings Pond and South Dam Emergency Spillway could manage the flood event of 1000 years. The analysis employed the HEC-HMS model, which is a commonly used tool for hydrologic and flood routing analysis, on the assumption that the initial water level in the Tailings Pond is at the elevation of the culvert invert (1094 m) and that the interceptor ditches fail. The prediction from the model indicated that water level in the Tailings Pond would rise to a maximum elevation of 1094.9 m (SRK 2005b) during a flow event of 1000 years, as the water is gradually evacuated through the spillway, and consequently the freeboard would still be more than 1 m.

Due to its location between the South and North Dam, a breach of the Cofferdam would not have an impact on the environment. This location justifies the classification of this structure as a Low dam class. However, this dam limits drainage from the northern half to the southern half of the tailings impoundment, since water can only be conveyed through the gated culvert. A summary calculation of the culvert capacity based on the methodology provided in AISI (1984) indicate that a flow of 0.22 m^3/s can pass through the structure when water elevation in the northern half of the tailings impoundment is at 1097 m (*i.e.,* meeting a 1 m freeboard for the North Dam). Assuming that half of the drainage basin of the tailings impoundment directs water to the northern half, the capacity of this culvert would be less than half of the peak flows provided in Table 1, including the flood event of 200 years.

The northern half of the tailings impoundment however has capacity to store water during flood event. Based on Photo 1 and the presumed water elevation at the gated culvert in Photo 15, about 50 percent of the northern half of the tailings impoundment can store water starting approximately from elevation 1096.2. From Figure 3, the surface area of the northern half of the tailings impoundment was estimated at roughly 80,000 m^2. An estimate of the storage capacity was undertaken given that the precipitation event for the 1000 year flood is considered as 101 mm (SRK 20005b) and that there no capacity to store water on 50 percent of the northern half of the tailings impoundment. This capacity estimate indicated that the precipitation event for the 1000 year flood could be stored in the northern half of the tailings impoundment, with however little freeboard left for the North Dam.

The Cofferdam and its gated culvert have been in operation for nearly 20 years without indication of difficulty. The possibly limited capacity of the gated culvert is not a major issue considering the storage capacity of the northern half of the tailings impoundment. The gate of the culvert should always be in the fully open position. Nevertheless, a flooding routing analysis should be conducted to assess water levels in the northern half of the tailings impoundment subjected to a flood event of 200 and 1000 years. This analysis would assist in determining if the current gated culvert has sufficient capacity or if additional water conveyance should be considered (*i.e.,* more culverts or breaching of the Cofferdam).

Dam Stability

The North and South Dam stability analysis during a seismic event was assessed by SRK and AMC (2000). The design seismic event used for this assessment was the 1/1000 earthquake design ground motion (EDGM), which is the adequate design criterion for dams in the Significant class, as is the case for the North and South Dams. Assuming no seismic pore pressure build-up, the assessment for both dams indicates a static safety factor higher than 1.59 and a pseudo-static safety factor higher than 1.24 (Table 3). The dams are under active care and maintenance, and regular annual geotechnical inspections are conducted to verify the stability of these structures. The performance of both dams to date appears satisfactory.

The Cofferdam seems to have served its function without any incident to date, although this structure appears to be constructed by Mt. Hundere Joint Venture during the mining operation without engineering design. This structure is expected to continue its function adequately with ongoing maintenance. Because of its Low dam class, its existing condition is deemed adequate.

3.3.3 Reclaim Pond

Flood Discharge

Water may be released from the Reclaim Pond through an open channel emergency spillway with a riprap sill that controls the water level. The channel then discharges water into the Camp Creek Diversion. A design event of 200 years (Table 1), as used for the design of that channel, would be within the range of IDF for dams in the Significant class (*i.e.,* the North and South Dam). As indicated in the previous DSR (KC 2003), using the 200 year event as the IDF for the Reclaim Dam is reasonable, since the breach of this structure would involve the release of water, with no tailings.

The emergency spillway channel width is approximately 5 m and the side slopes are 1.5H:1V (SRK 1992a), with a longitudinal slope that appears relatively mild (Photo 23). A summary calculation of the channel capacity was made using Manning's equation (Henderson 1966) on the assumption of a uniform flow, a Manning's coefficient of 0.03, a channel slope of 0.1%, and a channel invert at elevation 1080 m. The resulting water elevation for a flow of 4 m^3/s (*i.e.,* the 200 year event used for design of the dam, see Table 1) is 1080.5 m, which meets the minimum freeboard for the Reclaim Dam (Table 3). Water elevations on the pond were predicted for flows of 6.6 and 8.9 m^3/s (*i.e.,* 200 and 1000 year events calculated in 2000, see Table 1) and these would be 1080.9 and 1081.2 m, which are below the Reclaim Dam crest. These estimations of water elevations would be conservative, since they do not account for flood routing in the Reclaim Pond. However, based on Photo 23, the emergency spillway channel appears rather shallow. This channel may overflow during extreme flood event, likely leading to erosion of its banks. There is then the possibility that the eroded material could partially block the Camp Creek Diversion Culverts.

A flood routing analysis, similar to that done for the South Dam Emergency Spillway, should be undertaken to verify the capacity of the Reclaim Dam emergency spillway channel. Inspection of the channel should also be made at regular interval (*e.g.,* during the freshet and before winter) to verify its condition and initiate maintenance as required (*e.g.,* removal of shrubs and trees across the channel).

Dam Stability

The Reclaim Dam stability analysis during a seismic event was assessed by SRK (2006). The design seismic event used for this assessment was the 1/1000 earthquake design ground motion (EDGM), which is the adequate design criterion for a dam in the Significant class. The assessment for the Reclaim Dam indicates a static safety factor of 1.65 and a pseudo-static safety factor of 1.26 (Table 3). The dam is under active care and maintenance, and regular annual geotechnical inspections are conducted to verify the stability of this structure. The performance of the Reclaim Dam to date appears satisfactory.

3.3.4 Camp Creek Diversion

Since the Camp Creek Diversion Channel downstream of the Reclaim Dam spillway also serves as the outlet for the flood discharges from the South Dam, the design criterion for the channel should be the same as that of the dam, which is the 1000 year flood event. The channel was initially designed based on the 200 year flood event, and a flood routing analysis was subsequently undertaken (SRK 2005b) to verify whether this conveyance structure could pass the 1000 year flood event. The analysis accounts for the storage of water in the Tailings and Reclaim Ponds during the flood events, and assumes the failure of the East Interceptor Ditch near the Reclaim Pond. The Tailings and Reclaim Pond spillways were also both considered as flowing prior to the arrival of the storm, so that storage below the crests of these spillways would not be available to store a portion of the new incoming flood waters. The peak outflow at the Camp Creek Diversion Culverts was predicted to be some 6 m^3/s. The resulting water elevation would be 1081.1 m, which is 0.9 m below the Reclaim Dam Crest.

Unlined section of the diversion channel may be subject to erosion during high flow events. The mobilized material included the steel culvert plates armouring two segments of the channel, may possibly limit the capacity of the Camp Creek Diversion Culverts and ultimately the overtopping of the Reclaim Dam during an extreme flood event. Flow velocities in the channel should be estimated for average and extreme flow conditions to assess the suitability of unlined bank and bed material to resist erosion, and consequently determine the need of riprap lining. Inspection of the Camp Creek Diversion should also be made at regular interval (*e.g.,* during the freshet and before winter) to verify its condition and initiate maintenance as required.

3.3.5 North Creek Dyke

Flood Discharge

The design criteria of the North Creek Dyke and its Culvert satisfy the requirement of the CDA for a dam of this class. A summary calculation of the capacity of the North Creek Dyke Culverts based on the methodology provided in AISI (1984) indicate that this conveyance structure can pass a flow of 5 m^3/s while meeting the recommended freeboard of 0.45 m. This flow is higher than the estimated 200 year flood event for this dyke (Table 3).

Dyke Stability

SRK (1995) carried out static and pseudo-static stability analyses for the North Creek Dyke, and concluded that the dyke has a static safety factor higher than 2.4 and a seismic safety factor higher than 1.8. The dam was considered to be in good conditions at the time of the site visit of June 2009. This dyke is expected to continue its function adequately with ongoing maintenance. Due to the Low dam class of the dyke, the existing conditions of this structure are deemed adequate.

4.0 REVIEW OF OPERATIONAL COMPONENTS

4.1 Operation, Maintenance and Surveillance

An Operation, Maintenance and Surveillance (OMS) manual (SRK 2004a) has been developed since the previous DSR (KC 2003). The manual was prepared as part of Requirement 74 of the current water license of the site (YTWB 2003), and the framework was structured in accordance with the guidelines from CDA (2007) and the Mining Association of Canada's publication titled Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities (MAC 2005). This section discusses the content of this manual.

4.1.1 Operation

Mine production is stopped, and the mine site is under active care and maintenance, with currently performed activities being related largely to water management and preservation of the asset. The OMS manual nevertheless provides operation directives for the tailings impoundment in the case production may resume. The tailings deposition strategy would involve a tailings slurry discharge from:

- The upstream face of the North Dam into the northern half of the impoundment to complete the effort in this area; and
- The south face of the Cofferdam into the southern half of the overall impoundment.

This strategy would be managed such that the elevations of the deposited tailings against the North Dam are higher than those deposited at the cofferdam, and therefore direct surface runoff to the southern half of the impoundment and conveyance structures (*i.e.,* decant tower and South Dam Emergency Spillway). The tailings deposition would control the positioning of the Tailings Pond, which is to be adjacent to the upstream face of the South Dam.

Using the full remaining capacity of the tailings impoundments would require raising the North and South Dams to their ultimate crest elevations or 1102 and 1100 m, respectively. A downstream construction method would be employed to raise both dams, using compacted engineered fill. Raising the South Dam would needed prior to re-initiating production, and a crest raise to elevation 1098 m would provide approximately 6 months of tailings deposition at previous mining rates. No changes would be made to the Reclaim Dam, Cofferdam and North Creek Dyke.

Water management of the Tailings and Reclaim Ponds are based on a water balance between inflows (*i.e*., slurry water, surface runoff and groundwater recharge) and outflows (*i.e*., evaporation, seepages, water entrained within the tailings, releases to the Camp Creek Diversion, and recycle water to the mill). The water balance for the mine site was established by SRK (1990b), and would need to be updated prior to resuming production in order to incorporate recent climate and hydrologic updates (SRK 2005).

During both the production and care and maintenance periods, the Tailings and Reclaim Pond water levels should be maintained below the elevation required to meet the minimum freeboard requirements (Table 3). The maximum elevations listed in SRK (2004a) are 1094 and 1079 m for the Tailings and Reclaim Ponds, respectively. Levels in both ponds would be controlled by using the siphon systems at the South Dam and into Camp Creek Diversion Channel. Water in the Reclaim Pond must be released to Camp Creek channel in accordance with the Water Licence requirements, which limits discharges to during the period from April 15 to October 15. The maximum allowable total volume of water that can be released during this period is 228 m^3/hr or up to 490, 000 m^3/year.

4.1.2 Maintenance

Routine and preventive maintenance was outlined for the following components: 1) dam crest and outer slopes; 2) spillways and diversion structures; 3) decant system; 4) tailings and recycle water pipelines and siphons; 5) valves; and 6) monitoring instrumentation. Table 9, which is extracted from SRK (2004a), lists the maintenance activities and the frequencies for these components. The list appears reasonable in terms of the scope of activities for the maintenance of the TMF; except with regards to the Cofferdam. This structure is absent in any maintenance activities, although the conditions at the gated culvert should be checked to ensure runoff from the northern half of the tailings impoundment may be conveyed to the southern half.

Table 9: Summary of Routine Maintenance and Frequencies (SRK 2004a)

Item	Activity	Frequency	Comment
North, South and Reclaim Dam; North Creek Dyke	Remove trees ≥75 mm diameter.	Annual	Small plants and trees that grow on the slopes are acceptable, ≤25 mm diameter.
	Repair erosion gullies/rills on slope and along crest.	As required	Use angular, granular backfill.
	Investigate any large sized cracks on crest or slope; notify Site Manager & Geotech. Consultant. Grade over minor cracks.	As required	
	Raise dam crests as needed based on annual settlement survey or freeboard requirements.	As required	Crest raise would only be needed if settlement > 0.075 m.
Spillways, Diversion and Interceptor Ditches	Remove debris from channel and spillway pipes, including entrances and outlets.	2 times per year (Spring/ Fall)	Based on annual inspection by Geotechnical Consultant.
	Repair sloughing on channel slopes.	Annual	
	Repair riprap erosion protection.	As required	
	Remove snow and ice.	As required	
Decant System	▪ Check stop logs and seal, ▪ Check walkway to Tower, if provided, ▪ Check decant pipe inlet and outlet.	Monthly	
Valves	Grease and maintain valves	Monthly	
Tails Pipelines	Check pipe wall thicknesses	Annual	Rotate pipe, if required.
Siphons	▪ Check welds, ▪ Keep pipe clear of ice and snow, ▪ Check valves and air suction inlet, ▪ Check for pipe collapse.	Annual	
Seepage at North Dam, Reclaim Dam and North Creek Dyke.	Check seepage rates.	Monthly	Advise Site Manager and Geotechnical Consultant if seepage becomes cloudy.
Piezometers	▪ Check and replace damaged plastic caps, ▪ Check ID is readable on pipe, ▪ Check water level indicator is functional, ▪ Check protective steel casings.	Annual	These items are normally identified in Annual Inspection Report.
Settlement Gauges	▪ Check gauges for damage, ▪ Check ID is readable, ▪ Check bench mark ▪ Check protective steel casings.	Annual	These items are normally identified in Annual Inspection Report.

Event driven maintenance recommendations are also provided for cases of tailings slurry pipeline blockages and storm and seismic events. A step by step procedure is given for addressing pipeline blockages and is considered reasonable.

Handling of storm and seismic events are summarized in a table, which is replicated herein (Table 10). The section addressing these events (Section 4.3.3, SRK 2004a) should be named “Storm and Seismic Events” for the sake of clarity. Action to be taken in the case of an earthquake of magnitude 6 or higher should also include an immediate inspection by site personnel, as is recommended for a seismic event of magnitude 5 or higher. Assessment of incident level as part of the emergency preparedness and response plan should also be included as action items for storm and seismic events in the maintenance section of the OMS manual.

Table 10: Event Driven Maintenance (SRK2004a)

Item	Event	Action	Comment
North, South and Reclaim Dam, North Creek Dyke	Earthquake M5 or bigger within 100 km	▪ Immediate inspection by site staff	Call Site Manager and Geotechnical Consultant if damage is noted.
		▪ Read all instruments within 1 week	Send instrument data to Geotechnical Consultant
	Earthquake M6 or bigger within 100 km	▪ Notify Site Manager and Geotechnical Consultant ▪ Read all instruments	
	Rainfall (10 year event): ▪ 24 hour > 42 mm	▪ Check and record water pond levels ▪ Check decant for blockage ▪ Check faces of dams for erosion ▪ Check dam toe seepage daily	
	Discharge through spillways	▪ Notify Site Manager and Geotechnical Consultant ▪ Draw down pond level	
Water Management Systems	Rainfall (10 year event): ▪ 24 hour > 42 mm	▪ Check and record flows in EID, WID and Camp Creek Diversions ▪ Check diversion channel for debris ▪ Check channel for damage to riprap lining	

Reporting of routine and event driven maintenance is indicated as a required process in the OMS manual, and would be the responsibility of the site caretaker during the care and maintenance period and of the Concentrator Superintendent when the mine is in operation.

4.1.3 Surveillance

The OMS manual provides details on monitoring actions and schedules, and summarize them in tables that are replicated herein (Tables 11 and 12) for routine and event-triggered activities. The surveillance program appears to cover almost all of the infrastructure of the TMF, including the North Creek Dyke. No specific reference to the East and West Interceptor Ditches has however been identified in the surveillance section of the manual. Surveillance activities on the identified infrastructure appear to cover all reasonably foreseeable components affecting the integrity and safety of the TMF.

Annual geotechnical inspections of the TMF by an accredited geotechnical engineer is included as part of the surveillance program in the OMS manual. Details on surveillance activities following storm or seismic events are provided in the text of the OMS manual; however these activities should also include an assessment of the incident level (see Section 4.2 on the emergency preparedness and response plan).

Daily, weekly, monthly and annual surveillance activities are listed in log sheets that may be taken by site personnel to record observations and measurements. The log sheets are provided in Appendix B. To improve effectiveness and understanding of the surveillance program, it is recommended that the surveillance monitoring activities on the log sheets matches those listed in the OMS manual. For example, the daily log sheets list 16 and 5 surveillance items, respectively during mine operations and shutdown, while the text in the OMS manual refer to 15 and 9 items. Other similar discrepancies exist in the daily activities. Checking for seepages on a weekly basis is not identified on the weekly log sheets, although this activity is mentioned in the surveillance summary table in the manual.

The log sheets require inspection of the Camp Creek Diversion; however there is no indication on the extent of the channel in need to be checked. Focusing the inspection of the channel near the Camp Creek Diversion Culverts and the spillway chute may be sufficient on a daily and weekly basis for identifying possible blockages. However, annual and monthly inspections should be made over the entire length of the diversion channel for an assessment of side slope stability and erosion. The monthly and annual log sheet should also include inspection of the interceptor ditches.

The surveillance section of the OMS manual provides specific details on: 1) rates of rise of tailings; 2) water balance; 3) freeboard; 4) seepage flows; 5) piezometers and pond water levels; 6) precipitation; 7) diversion structures; and 8) settlement gauges. It is recommended that a clear distinction be made in the text as to which of these components are addressed in the log sheets (likely components 3, 4, 5, 7, and 8) and which are not (likely components 1, 2 and 6). Additional details should be given in the text on the components not addressed in log sheets, notably, who is responsible for collecting the information, and how the information must be processed and filed.

Table 11: Summarized Monitoring Schedule (SRK 2004a)

Inspection Item	TMF Operator	TMF Supervisor	TMF Designers
Slurry pipelines, valves and deposition locations	Daily	Weekly	Quarterly
Decant tower	Daily	Weekly	Quarterly
Supernatant pool location and levels	Daily	Weekly	Quarterly
Piezometers	Monthly	Monthly	Quarterly
Rate of rise of tailings	Quarterly	Quarterly	Quarterly
Seepage rates	Weekly	Monthly	Quarterly
Outer slopes and crest	Weekly	Monthly	Quarterly
Rainfall	After every storm	Monthly	Quarterly
Reclaim pipeline	Daily	Weekly	Quarterly
Roads	Daily	Weekly	Quarterly
Freeboard	Daily	Monthly	Quarterly
Water balance	Monthly	Quarterly	Annually
Settlement gauges	Annually	Annually	Annually
Flow gauges	Monthly	Quarterly	Annually
Reclaim Pond levels	Daily	Weekly	Quarterly

Table 12: Monitoring Trigger Actions (SRK 2004a)

Trigger Levels	Action	Remarks
Supernatant pool reaches 250 m of the North dam crest	Increase decant of supernatant water to Reclaim Pond.	Normally, this may be required after a storm event.
Dam Piezometer levels rising	Check pond level; Decant free water, if required; Reread instrument; Go to next category of reading frequency; and Notify Site Manager and Geotechnical Consultant.	This will occur if pond level rises.
Piezometer trigger levels exceeded	Reduce pool size and move tailings deposition to another area of the impoundment. Notify Site Manager and Geotechnical Consultant.	
Minimum freeboard reached	May require raising of crests Notify Site Manager and Geotechnical Consultant	
Settlement gauges indicate annual settlement ≥ 0.075 m	May require rising of crests.	

4.2 Emergency and Preparedness

An emergency preparedness and response plan (EPRP) is incorporated in the OMS manual and classifies incidents into three levels:

- **Alert Level**: typical operations and maintenance conditions addressed in the operations and maintenance sections of the OMS manual. Actions are performed internally and would not require external notification.
- **Emergency Level**: incidents resulting in an immediate and significant threat to the safety of the structure and would therefore involve activation of the EPRP. The EPRP addresses emergency situations that require actions outside the normal scope of OMS activities. External communication is required if non-compliant water must be released (Yukon Spill line).
- **Failure Level**: the incident has progressed to the point where failure of the structure is imminent. Immediate external notification is required by means of the general and local warning systems. The failure level response should be implemented immediately upon verification of the conditions that a dam is failing, about to fail, or assessed with a significant probability of failure.

Incidents identified in the EPRP are:

- Dam Overtopping: water flowing over the crest dam;
- Dam Embankment Instability: development of tension cracks, displacement or bulging of the dam;
- Piping: Seepage waters from the dam carrying suspended material in excessive or abnormal quantities;
- Seismic Events: earth motion;
- Overtopping of Camp Creek Diversion Channel: water levels exceeding the elevation of the channel banks;
- Puncture/Burst Tailings Distribution Pipeline: uncontrolled discharge of the tailings slurry; and
- Channel Slope Instability: material displacement or movement of the channel alignment.

These incidents represent reasonably foreseeable events that may impact the integrity and safety of the TMF. The EPRP is structured to describe the typical characteristics of these incidents as well as detailing response plans based on the incident level. The treatment of each incident is consistent and sufficient, except for the following:

- The description of the characteristics of Channel Slope Instability is not provided; and
- The response plan for Puncture/Burst Tailings Distribution Pipeline is not provided.

Internal and external notifications based on incident level are part of the response plan and presumably summarized in a figure in the OMS manual. This figure was absent in the copy of the manual provided for the DSR. Care should be given to ensure all available copies of the OMS manual are complete. It is understood that external notification is required at Emergency Level only if non-compliant water is discharged (Yukon Spill line). External notification is required in all instance of Failure Level. Contact information for the mine operator, emergency response agency, regulators and engineering consultant are provided in the OMS manual, and would presumably be updated as required.

4.3 Public Safety and Security

The mine site is under active care and maintenance and includes at least one caretaker present at all time on site. The emergency preparedness and response plan (EPRP) provide guidelines for reasonably foreseeable incidents at the mine site. Inquiries to local authorities will be made by Teck if the caretaker has not followed is regular contact schedule and cannot be reached.

Equipment used for voluntary releases of water (*i.e.,* the decant tower and the water pumping stations the Reclaim Dam and North Creek Dyke) is locked and is only accessible by mine site personnel.

4.4 Dam Safety Management System

The tailings and water management facilities at the Sä Dena Hes Mine have been subjected to a formal Dam Safety Review in the past (KC 2003). Furthermore, the facilities have been inspected annually by SRK since 1992, and the observations and recommendations are documented in the annual review reports. A review of recent geotechnical inspection reports (SRK 2000, 2001, 2003, 2004b, 2005a, 2006 to 2009) indicate that recommendations by SRK have been acted upon by Teck in their routine maintenance and special remedial works according to the priority of the issues identified. To date, these annual reviews and ongoing maintenance have been effective to keep the tailings and water management facilities at the mine in a satisfactory condition.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The dam safety review for the Sä Dena Hes mine site was established based on the available site information and data and on a site visit conducted on June 23 to 24, 2009. This mine site is under active care and maintenance and the dam and water management infrastructure have been subjected to annual geotechnical inspections. In general this infrastructure is considered to be maintained in good condition.

Based on the CDA (2007) dam classification, the North, South and Reclaim Dams are in the Significant class. Consequently, these dams and their associated water management infrastructure (*i.e.,* the South Dam Emergency Spillway, the Reclaim Dam emergency spillway channel and Camp Creek Diversion) must be able to sustain flood events of 200 years (Reclaim Dam) or 1000 years (South and North Dams). It was estimated that the water management infrastructure has the capacity to manage these extreme flow events while providing some freeboard to prevent overtopping of the South and Reclaim Dams. The freeboard available for the North Dam would be dependent on the conveyance capacity of the gated culvert at the Cofferdam. However, the northern half of the tailings impoundment would presumably have sufficient storage capacity to collect water from a 1000 years flood event without overtopping of the North Dam.

The North Creek Dyke and the Cofferdam are in the Low dam class, and their associated water management infrastructure (*i.e.,* the North Creek Dyke Culvert and the Cofferdam gated culvert) must be able to sustain a flood event of 100 years. It was estimated that the North Creek Dyke culvert can pass a 200 year flood event and therefore the North Creek Dyke meets the flood requirement of the dam class. The capacity of the gated culvert at the cofferdam needs to be verified with a flood routing analysis. However, as indicated above, the northern half of the tailings impoundment would have that ability to store water from a 100 year flood event.

All dams (North, South and Reclaim Dams, Cofferdam and North Creek Dyke) would satisfy the seismic requirement corresponding to their respective dam class. Since the previous dam safety review (KC 2003), an operating, maintenance and surveillance manual (SRK 2004) was developed to describe the operation and maintenance of these dams and related water management infrastructure as well as to provide guidelines for the monitoring of these structures. The manual also include an emergency and preparedness response plan that address actions to be taken for several possible incidents.

Recommendations provided as a result of this dam safety review are as follows:

- An inspection of the seal of the pipe inlet at the decant structure (South Dam) would be recommended to determine if repairs or a replacement are required. Detail design of a permanent seal will be needed if the decant tower is expected to remain in place following permanent closure of the mine.
- Repair to the weir at water quality monitoring station MH-07 should be made when possible to ensure that all water pass through the V-notch and the seepage flow from the Reclaim Dam are not underestimated.
- The conditions of the steel plate armour in the Camp Creek Diversion should be monitored on a regular basis and repairs undertaken as soon as possible, if needed. Alternate and more stable armouring options must be considered in plans for permanent closure of the mine site.
- The siphon systems at both the Reclaim Dam and the South Dam should be maintained in a working condition so that the water levels in the Reclaim and Tailings Ponds can be positively controlled.

- Sand bags are used as erosion control measure on the upstream face of the North Creek Dyke. Any damage sand bags should be replaced as early as practical.
- It is important that the capacity of the conveyance structures be maintained to their full potential. Any material accumulating in culvert entrance should be removed (e.g. gated culvert). Shrubs and trees should also be removed from channels (*e.g.,* Reclaim Dam emergency spillway channel and Camp Creek Diversion).
- Flood routing analysis should be undertaken to verify the capacity of the Cofferdam gated culvert to pass the 200 flood event. The result of this analysis will determine if the capacity of that conveyance structure needs to be increased (*i.e.,* add culverts or develop low point on cofferdam to allow overflow or controlled breach of the Cofferdam).
- Flood routing analysis should be undertaken to verify water levels in the Reclaim Dam emergency spillway channel during 200 year flood event. This analysis is intended to verify if the banks of this channel can be overtopped and eroded during this event. The channel bank height should be increased if overtopping is predicted to occur.
- Flow velocities in the Camp Creek Diversion channel should be estimated for average and extreme flow conditions to assess the suitability of unlined bank and bed material to resist erosion. The result of this estimation will determine the need of riprap lining.
- It must be ensured that surveillance activities in the log sheets match activities listed in the OMS manual. For example, the daily log sheets list 16 and 5 surveillance items, respectively during mine operations and shutdown, while the text in the OMS manual refer to 15 and 9 items. Other similar discrepancies exist in the daily activities. Checking for seepages on a weekly basis is not identified on the weekly log sheets, although this activity is mentioned in the surveillance summary table in the manual.
- The log sheets should details the extent of the monitoring for the Camp Creek Diversion channel. Monitoring near the Camp Creek Diversion Culverts and spillway chute may be sufficient on a daily and monthly basis. Monitoring the entire length of the diversion channel would be recommended on a monthly and annual basis.
- The monthly and annual log sheet should include inspection of the interceptor ditches.
- The surveillance section of the OMS manual provides specific details on: 1) rates of rise of tailings; 2) water balance; 3) freeboard; 4) seepage flows; 5) piezometers and pond water levels; 6) precipitation; 7) diversion structures; and 8) settlement gauges. It is recommended that a clear distinction be made in the text as to which of these components are addressed in the log sheets (likely components 3, 4, 5, 7, and 8) and which are not (likely components 1, 2 and 6). Additional details should be given in the text on the components not addressed in log sheets, notably about who is responsible for collecting the information, and how the information must be processed and filed.
- Details on surveillance activities following storm or seismic events should also include assessment of incident level as part of the emergency preparedness and response plan.

- The emergency preparedness and response plan describe the typical characteristics of several possible incidents as well as detailing response plans based on the incident level. The treatment of each incident is consistent and sufficient, except for the following:
  - The description of the characteristics of Channel Slope Instability is not provided;
  - The response plan for Puncture/Burst Tailings Distribution Pipeline is not provided.
- Internal and external notifications based on incident level are part of the response plan and presumably summarized in a figure in the OMS manual. This figure was absent in the copy of the manual provided for the DSR. Care should be given to ensure all available copies of the OMS manual are complete.

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REFERENCES

AECOM (AECOM Canada). 2009. Sä Dena Hes Mine, YT, 2008 Geotechnical Inspections. Prepared for Government of Yukon, Water Resources Branch, by AECOM, Winnipeg, MB, January.

AISI (American Iron and Steel Institute). 1984. Handbook of Steel Drainage & Highway Construction Products, Canadian Edition. Washington, DC.

CDA (Canadian Dam Association). 2007. Dam Safety Guidelines. Canadian Dam Association.

DSO (Dam Safety Office), 1998. Prediction of Embankment Dam Breach Parameters – A Literature review and Needs Assessment. DSO-98-004, Water Resources Research Laboratory, Bureau of Reclamation, U.S. Department of the Interior.

EC (Environment Canada). 2009. Archived Hydrometric Data. Water Survey of Canada. Retrieved December 2009 from: http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm?cname=main_e.cfm

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

Henderson, F.M. 1966. Open Channel Flow. MacMillan Publishing Company, New York, NY, USA.

ICOLD (International Commission on Large Dams), 1995. Dam Failure Statistical Analysis. Bulletin 99, International Commission on Large Dams, Paris, France.

INAC (Indian and Northern Affairs Canada). 1992. Mine Reclamation in Northwest Territories and Yukon. Northern Water Resources Studies Program, April.

KC (Klohn Crippen). 2003. Sä Dena Hes Mine, Dam Safety Review. Prepared for Teck Cominco Metals Ltd, by Klohn Crippen, Vancouver, BC, November.

MAC (Mining Association of Canada), 2005. Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities. Ottawa, ON, December.

Petrascheck, A.W. and P.A. Sydler. 1984. Routing of Dam Break Floods. International Water Power & Dam Construction, 36: 29-32.

SRK (Steffen Robertson and Kirsten Consulting). 1990a. Mt. Hundere Project, Initial Environmental Evaluation, Volume I – Project Description and Volume V – Appendices A to D. Prepared for Mt. Hundere Joint Venture, by SRK, Vancouver, BC, May.

SRK. 1990b. Mt. Hundere Project, Geotechnical Investigations and Final Design for Mill and Tailings Disposal Facilities. Prepared for Mt. Hundere Joint Venture, by SRK, Vancouver, BC, December.

SRK. 1992a. Sä Dena Hes Mine, As-Built Construction Report for North, South and Reclaim Dams. Prepared for Sä Dena Hes, by SRK, Vancouver, BC, January.

SRK. 1992b. Sä Dena Hes Mine, Reclaim Dam Toe Buttress. Prepared for Sä Dena Hes, by SRK, Vancouver, BC, February.

SRK. 1992c. Sä Dena Hes Mine, Design Report, South Dam Expansion. Prepared for Sä Dena Hes, by SRK, Vancouver, BC, July.

SRK. 1994. Sä Dena Hes Mine, Construction Report, Remedial Work. Prepared for Cominco, by SRK, Vancouver, BC, November.

SRK. 1995. Sä Dena Hes Mine, North Creek Dyke. Prepared for Cominco, by SRK, Vancouver, BC, February.

SRK. 1997a. Sä Dena Hes Mine, Design Report, South Dam Toe Buttress. Prepared for Cominco, by SRK, Vancouver, BC, September.

SRK. 1997b. Sä Dena Hes Mine, Construction Report, South Dam Extension (1992) and Toe Buttress (1997). Prepared for Cominco, by SRK, Vancouver, BC, November.

SRK. 1998. Sä Dena Hes Mine, Design Report, Completion of the 1992 South Dam Extension. Prepared for Cominco, by SRK, Vancouver, BC, March.

SRK. 1999. Sä Dena Hes Mine, Addendum to 1997 Construction Report, South Dam Toe Buttress. Prepared for Cominco, by SRK, Vancouver, BC, February.

SRK. 2000. Sä Dena Hes Mine, 2000 Geotechnical Inspection, Tailings Management Facility. Prepared for Cominco, by SRK, Vancouver, BC, November.

SRK. 2001. Sä Dena Hes Mine, 2001 Geotechnical Inspection, Tailings Management Facility. Prepared for Cominco, by SRK, Vancouver, BC, December.

SRK. 2003, Sä Dena Hes Mine, 2002 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco, by SRK, Vancouver, BC, March.

SRK. 2004a. Sä Dena Hes Mine, Operating, Maintenance and Surveillance Manual for the Tailings Management Facility. Prepared for Teck Cominco, by SRK, Vancouver, BC, December.

SRK. 2004b, Sä Dena Hes Mine, 2003 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco, by SRK, Vancouver, BC, June.

SRK. 2005a, Sä Dena Hes Mine, 2004 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco Metals, by SRK, Vancouver, BC, February.

SRK. 2005b. Updates on the 2000 Sä Dena Hes Closure Plan, Climate and Hydrology. Prepared for Teck Cominco, by SRK, Vancouver, BC, December.

SRK. 2006, Sä Dena Hes Mine, 2005 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco Metals, by SRK, Vancouver, BC, March.

SRK. 2007, Sä Dena Hes Mine, 2006 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco Metals, by SRK, Vancouver, BC, March.

SRK. 2008, Sä Dena Hes Mine, 2007 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco Metals, by SRK, Vancouver, BC, March.

SRK. 2009, Sä Dena Hes Mine, 2008 Geotechnical Inspection, Tailings Management Facility. Prepared for Teck Cominco Metals, by SRK, Vancouver, BC, March.

SRK and AMC (Steffen Robertson and Kirsten Consulting Engineers and Access Mining Consultants). 2000. Sä Dena Hes Mine, Detailed Decommissioning & Reclamation Plan, Volume I – Main Report and Appendices A and B. Prepared for Cominco, by SRK, Vancouver, BC, and AMC, Whitehorse, YT, February.

Bureau of Reclamation, 1988, Downstream Hazard Classification Guidelines, ACER Technical Memorandum No. 11, Assistant Commissioner-Engineering and Research, Denver, Colorado, December 1988, 57 p.

Von Thun, J.L. and D.R. Gillette. 1990. Guidance on Breach Parameters. Unpublished internal document, U.S. Bureau of Reclamation, Denver, CO, March 1990, 17p.

Watt, E.W., K.W. Lathem, C.R. Neil, T.L. Richards, and J. Rousselle. 1989. Hydrology of Floods in Canada – A Guide to Planning and Design. National Research Council Canada, Associate Committee on Hydrology, Ottawa, ON.

YTWB (Yukon Territory Water Board). 2002. Water Licence Number QZ99-045. Granted to Sä Dena Hes Operating Corporation, Teck Cominco Metals Ltd., January 28.

YTWB. 2005. Amendment to Water Licence Number QZ99-045. Submitted to Sä Dena Hes Operating Corporation, Teck Cominco Metals Ltd., September 30.

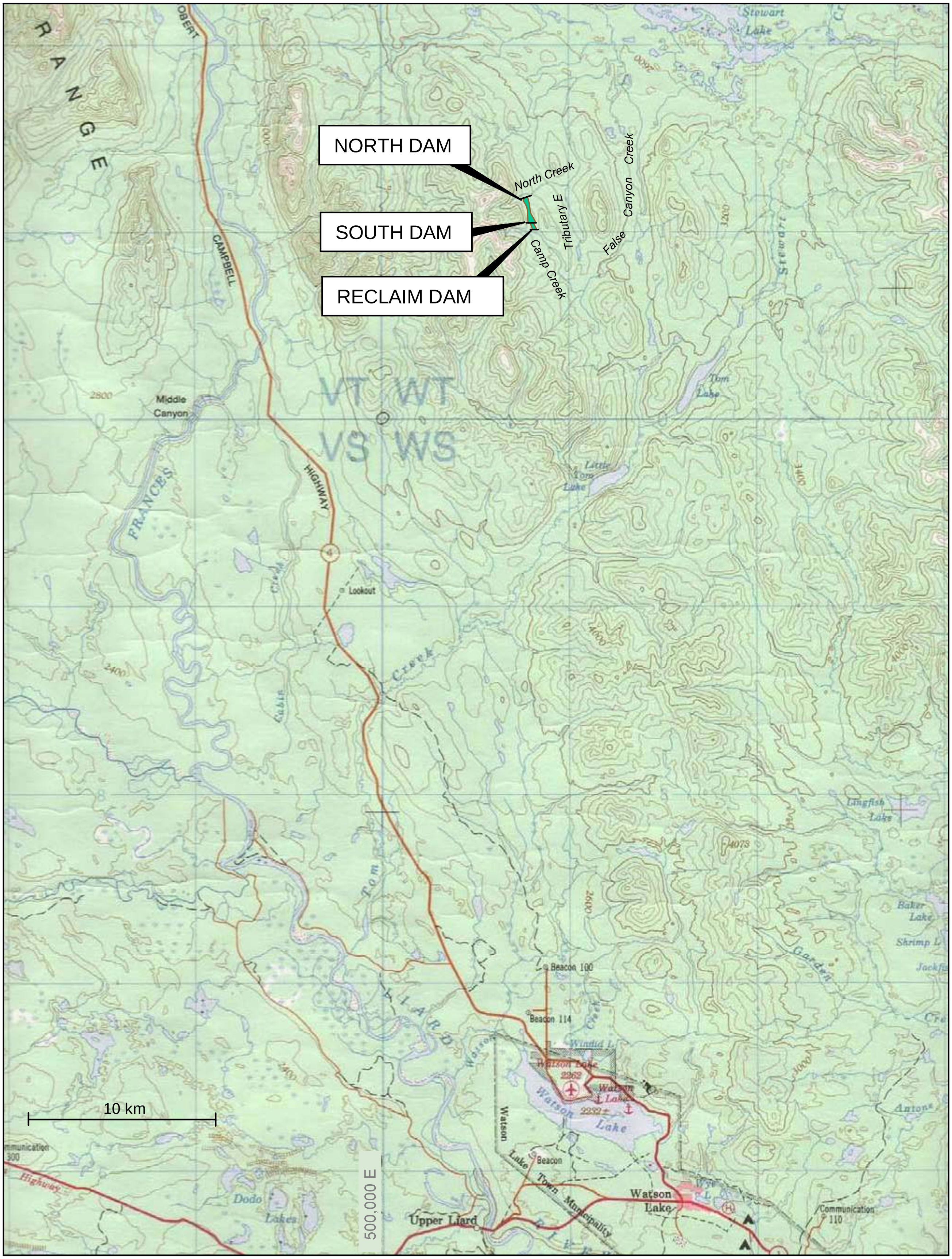
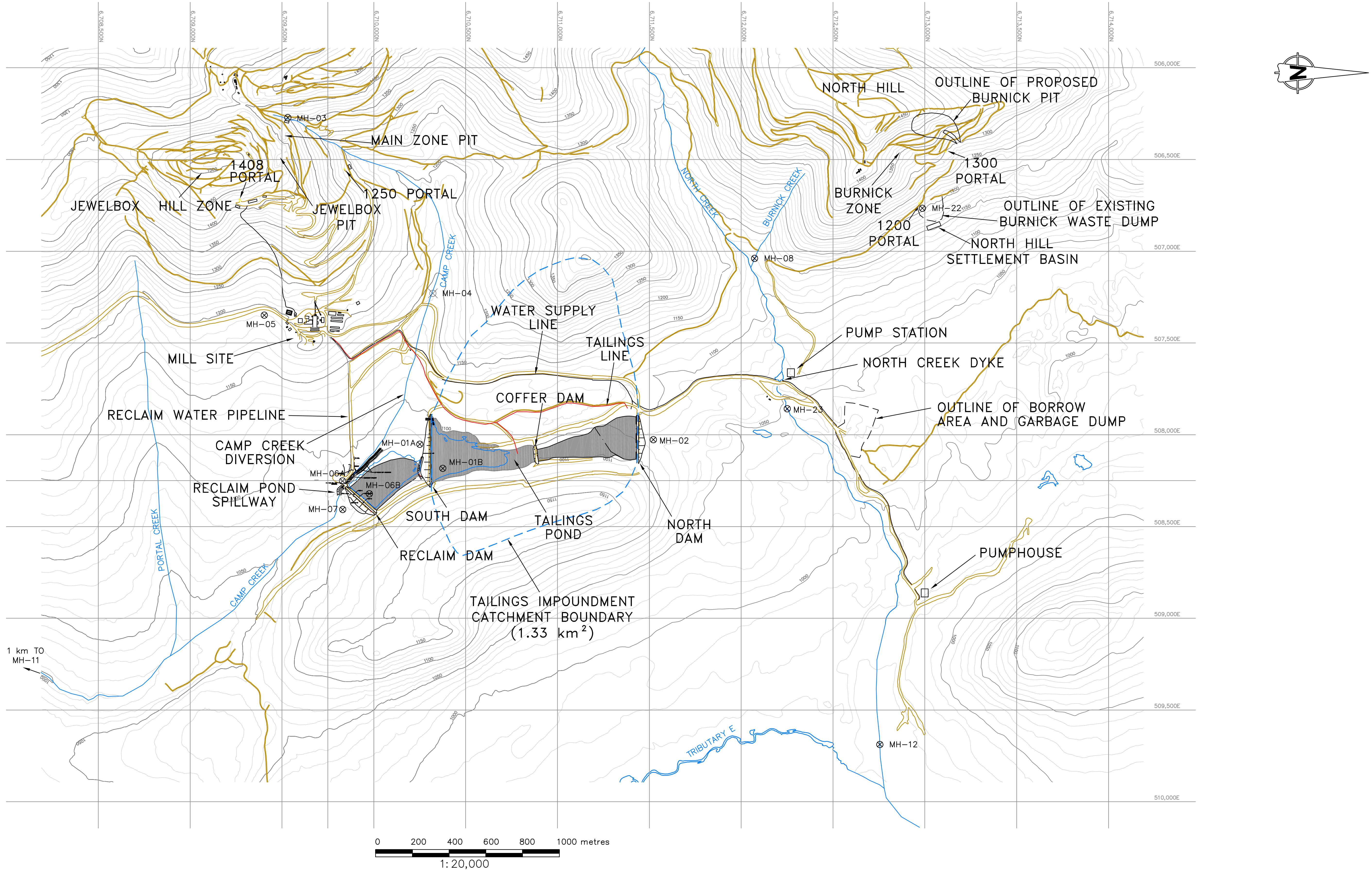


Figure 1

Location Map (SRK 2004)



NOTES:
BASE TOPOGRAPHY FROM NORTH AMERICAN DATUM 1983
ALL SURFACE FACILITIES AND BOUNDARIES HAVE BEEN ADJUSTED FROM NAD 1927

Figure 2

General Arrangement Plan (SRK 2009)

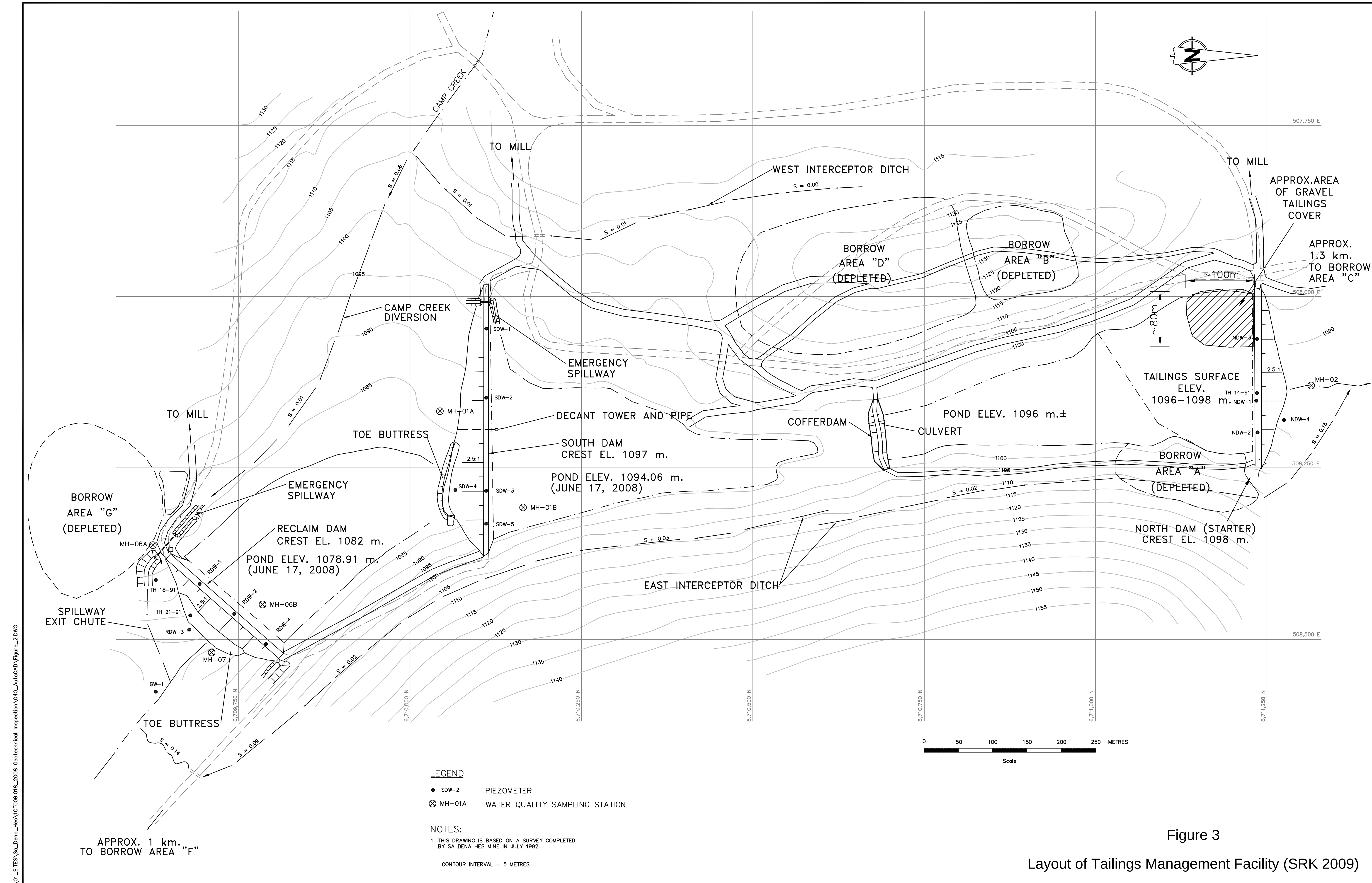


Figure 3

Layout of Tailings Management Facility (SRK 2009)

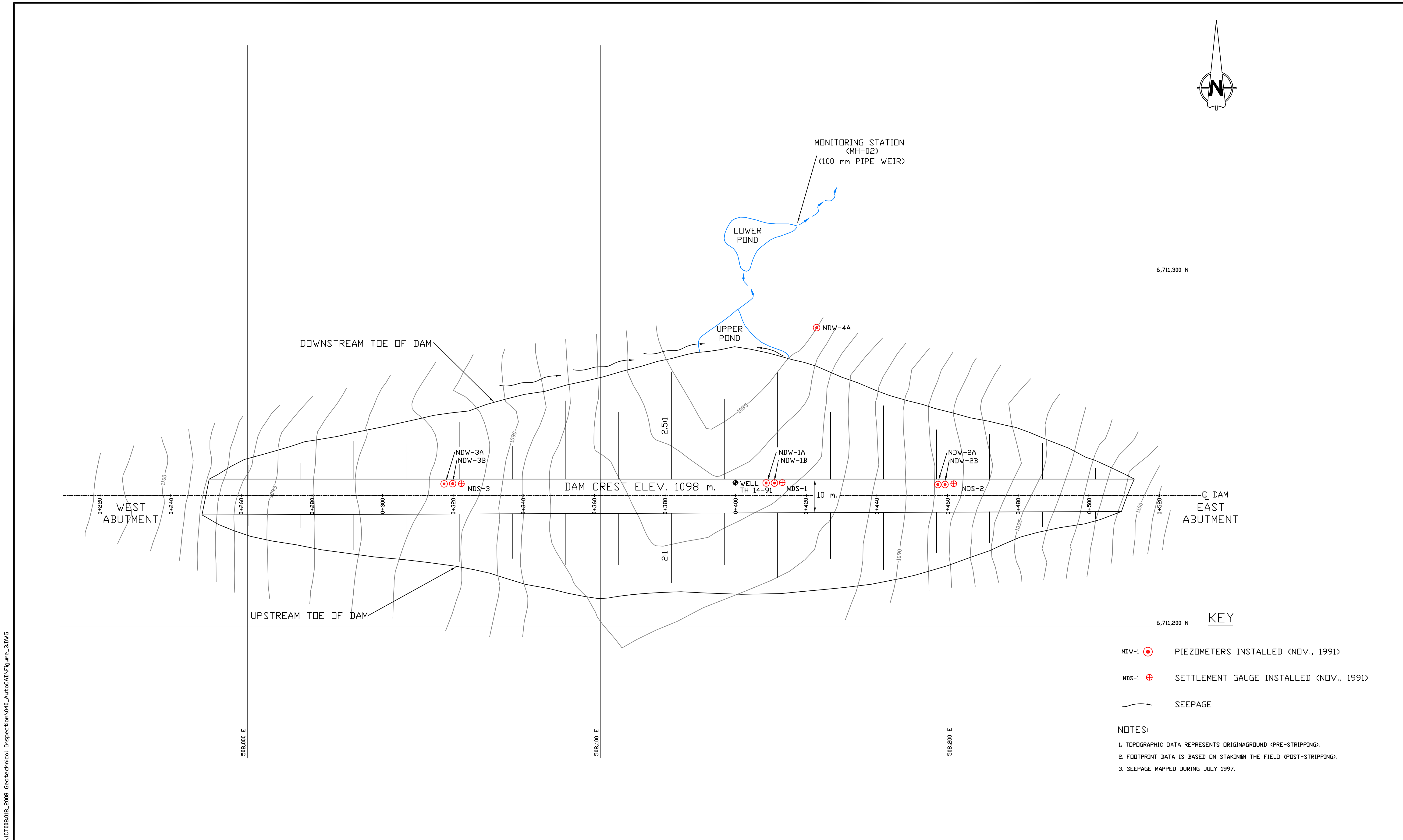
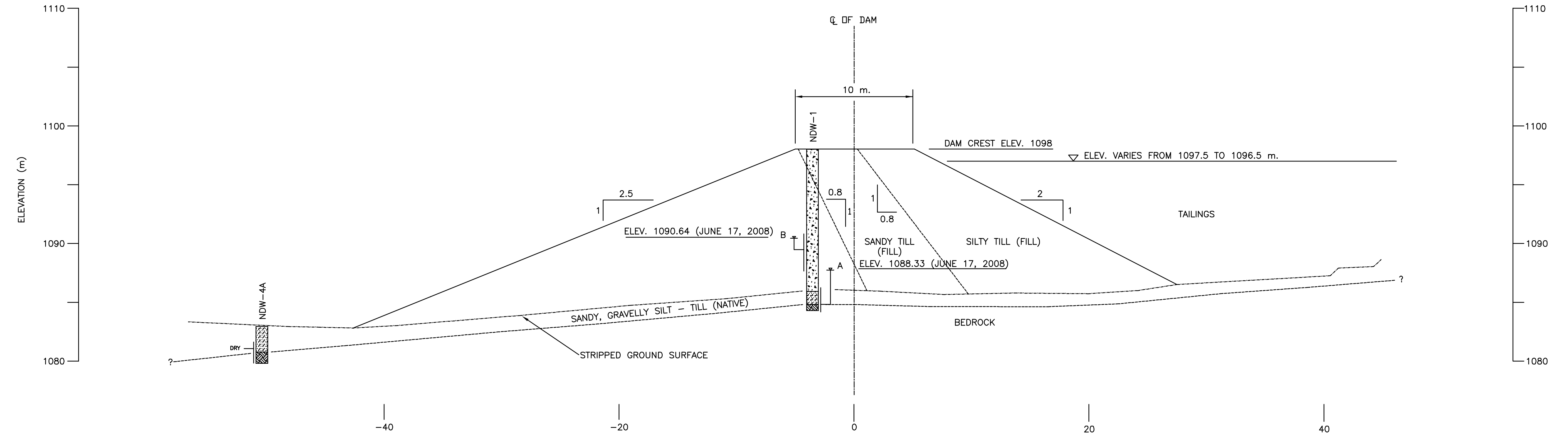
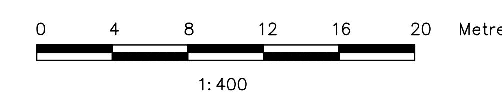


Figure 4

North Dam Site Plan (SRK 2009)



	DATE	T.O.P.	READING	ELEV.
NDW-1B	JUNE 17, 2008	1098.57	7.93	1090.64
NDW-1A	JUNE 17, 2008	1098.69	10.36	1088.33



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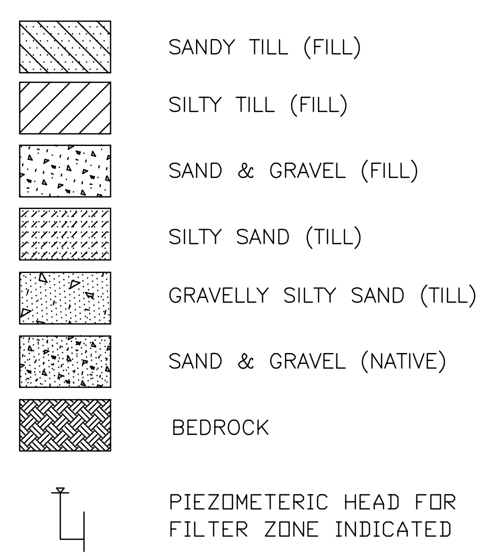

Figure 5

Section 4+00 - North Dam (SRK 2009)

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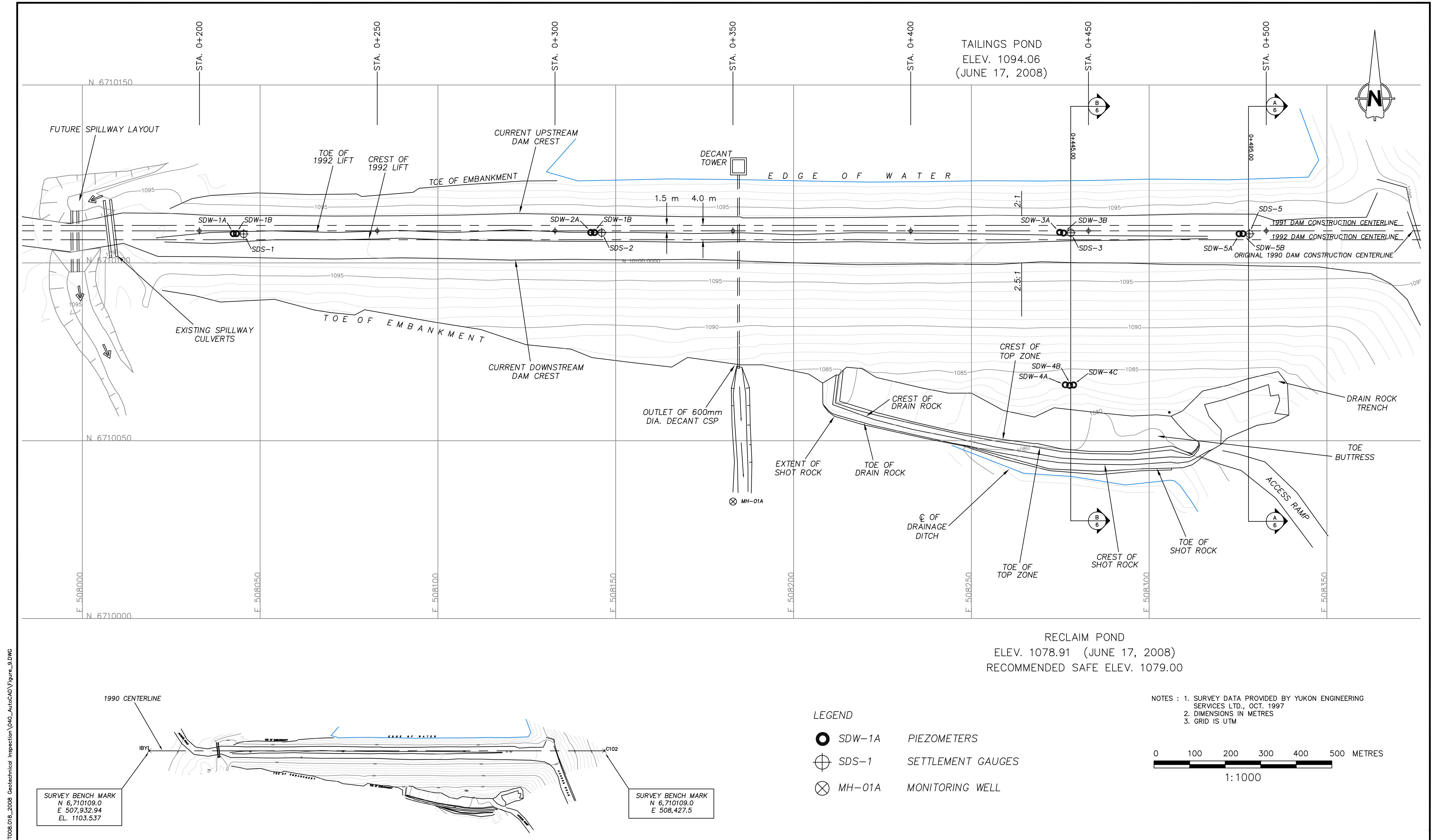
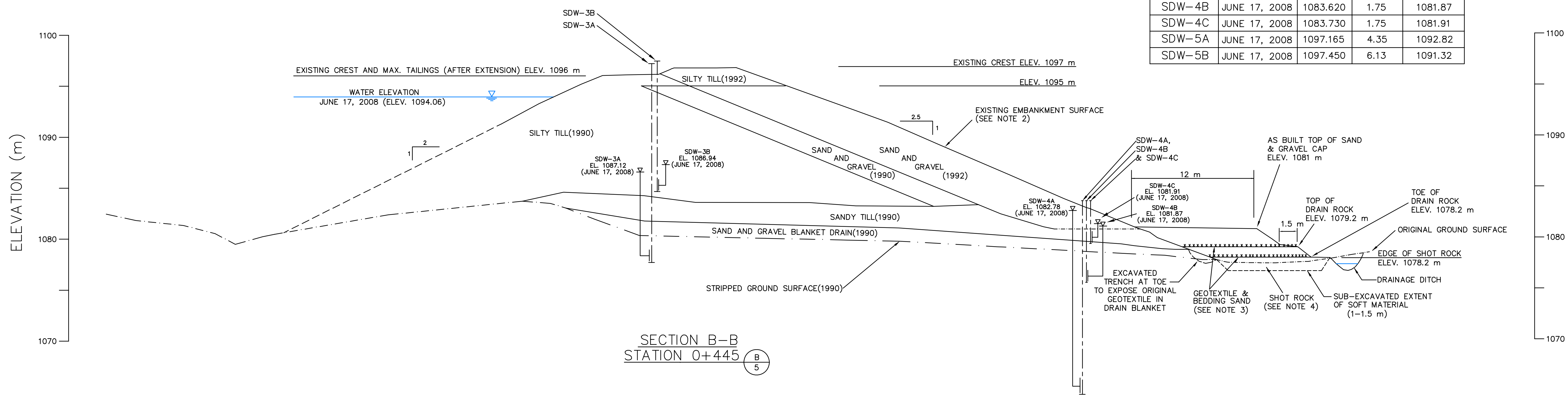
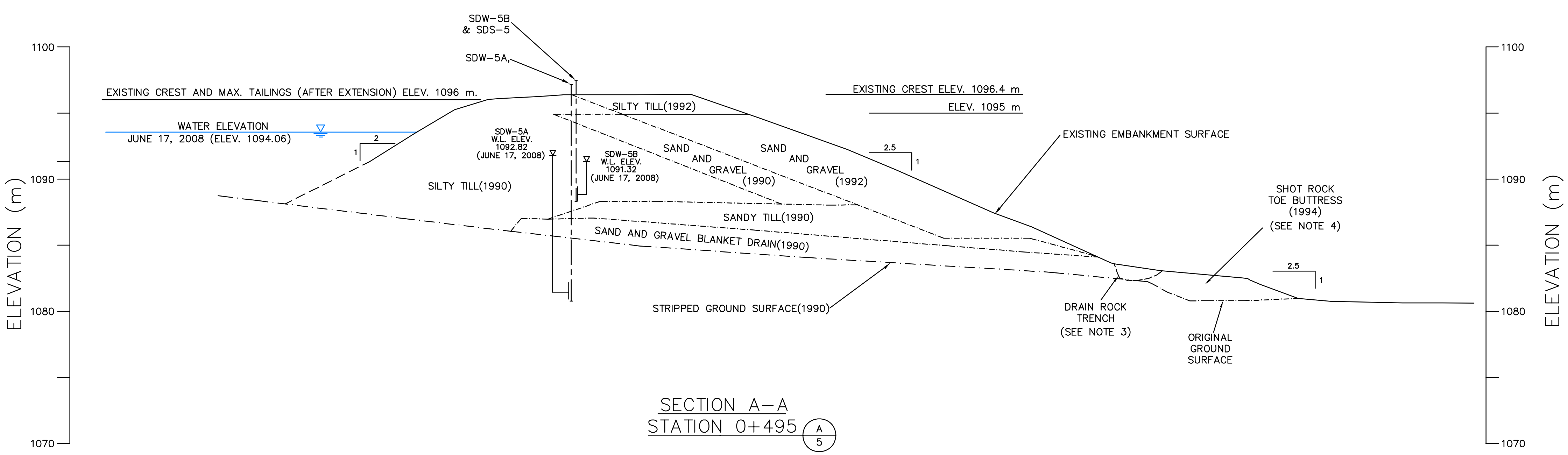


Figure 6

South Dam Site Plan (SRK 2009)

PIEZOMETER	DATE	TOP	READING	ELEVATION
SDW–3A	JUNE 17, 2008	1097.215	10.10	1087.12
SDW–3B	JUNE 17, 2008	1097.479	10.54	1086.94
SDW–4A	JUNE 17, 2008	1083.970	1.00	1082.78
SDW–4B	JUNE 17, 2008	1083.620	1.75	1081.87
SDW–4C	JUNE 17, 2008	1083.730	1.75	1081.91
SDW–5A	JUNE 17, 2008	1097.165	4.35	1092.82
SDW–5B	JUNE 17, 2008	1097.450	6.13	1091.32





NOTES
1. STRIPPED GROUND SURFACE AND EXISTING DAM ZONES FROM Y.E.S. AS–BUILT DRAWINGS, JULY 1991.
2. EXISTING DAM SURFACE FROM SURVEY COMPLETED AUGUST 1997.
3. DRAIN ROCK FILTER CRITERIA – 5mm $< D_{15} <$ 25mm
   0.3m THICK BEDDING LAYER OF PIT RUN SAND AND GRAVEL OVER SHOT ROCK PLATFORM.
4. SHOT ROCK CONSISTS OF BLASTED LIMESTONE FROM JEWELBOX PIT.

0 5 10 15 20 25 METRES

SCALE – 1:400

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Figure 7

Sections 0+445 and 0+495 - South Dam (SRK 2009)

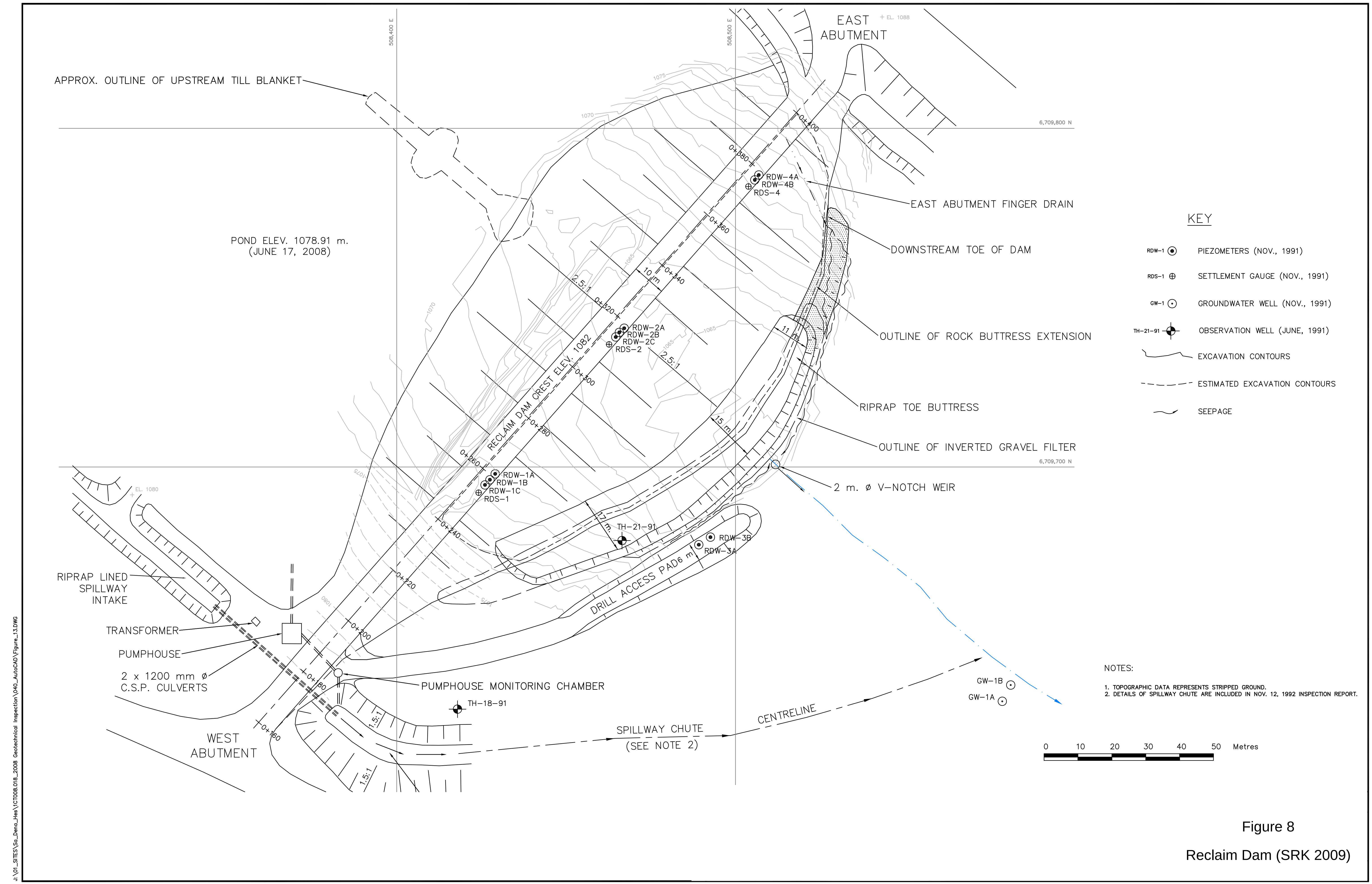
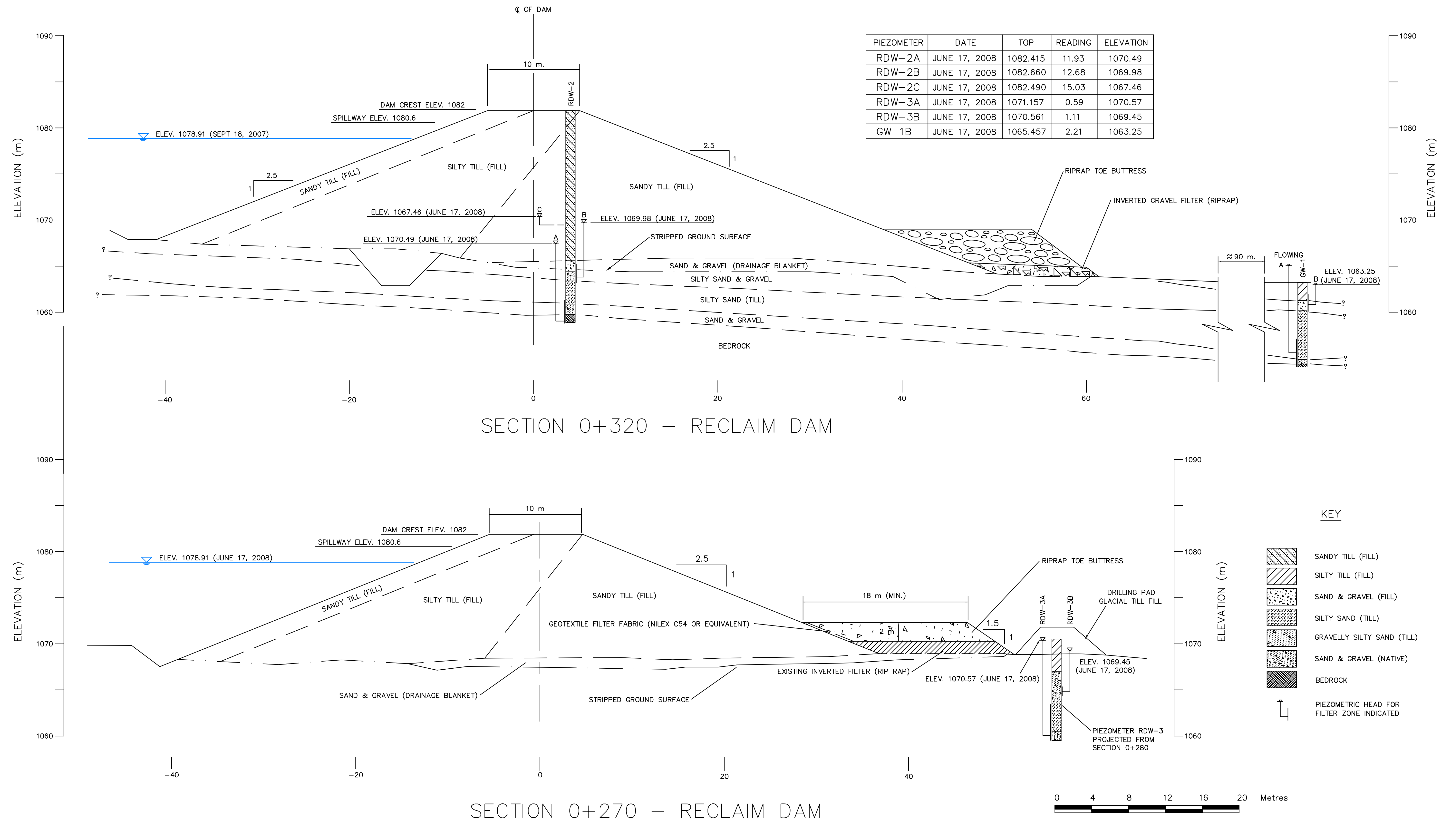


Figure 8

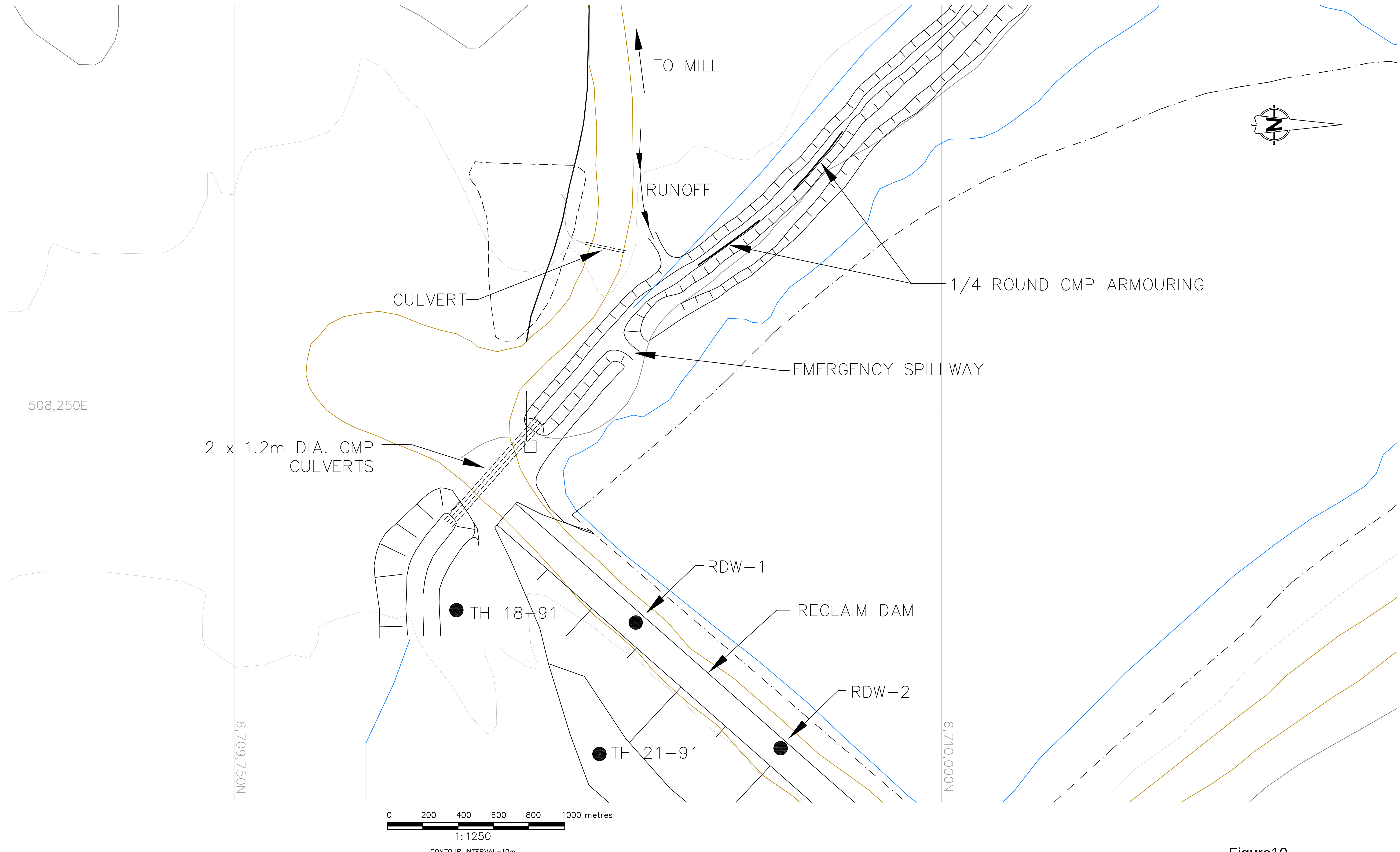
Reclaim Dam (SRK 2009)



PIEZOMETER	DATE	TOP	READING	ELEVATION
RDW–2A	JUNE 17, 2008	1082.415	11.93	1070.49
RDW–2B	JUNE 17, 2008	1082.660	12.68	1069.98
RDW–2C	JUNE 17, 2008	1082.490	15.03	1067.46
RDW–3A	JUNE 17, 2008	1071.157	0.59	1070.57
RDW–3B	JUNE 17, 2008	1070.561	1.11	1069.45
GW–1B	JUNE 17, 2008	1065.457	2.21	1063.25

Figure 9

Sections 0+320 and 0+270 - Reclaim Dam (SRK 2009)



NOTES:
BASE TOPOGRAPHY FROM NORTH AMERICAN DATUM 1983
ALL SURFACE FACILITIES AND BOUNDARIES HAVE BEEN
ADJUSTED FROM NAD 1927

Figure10

Camp Creek Diversion (SRK 2009)

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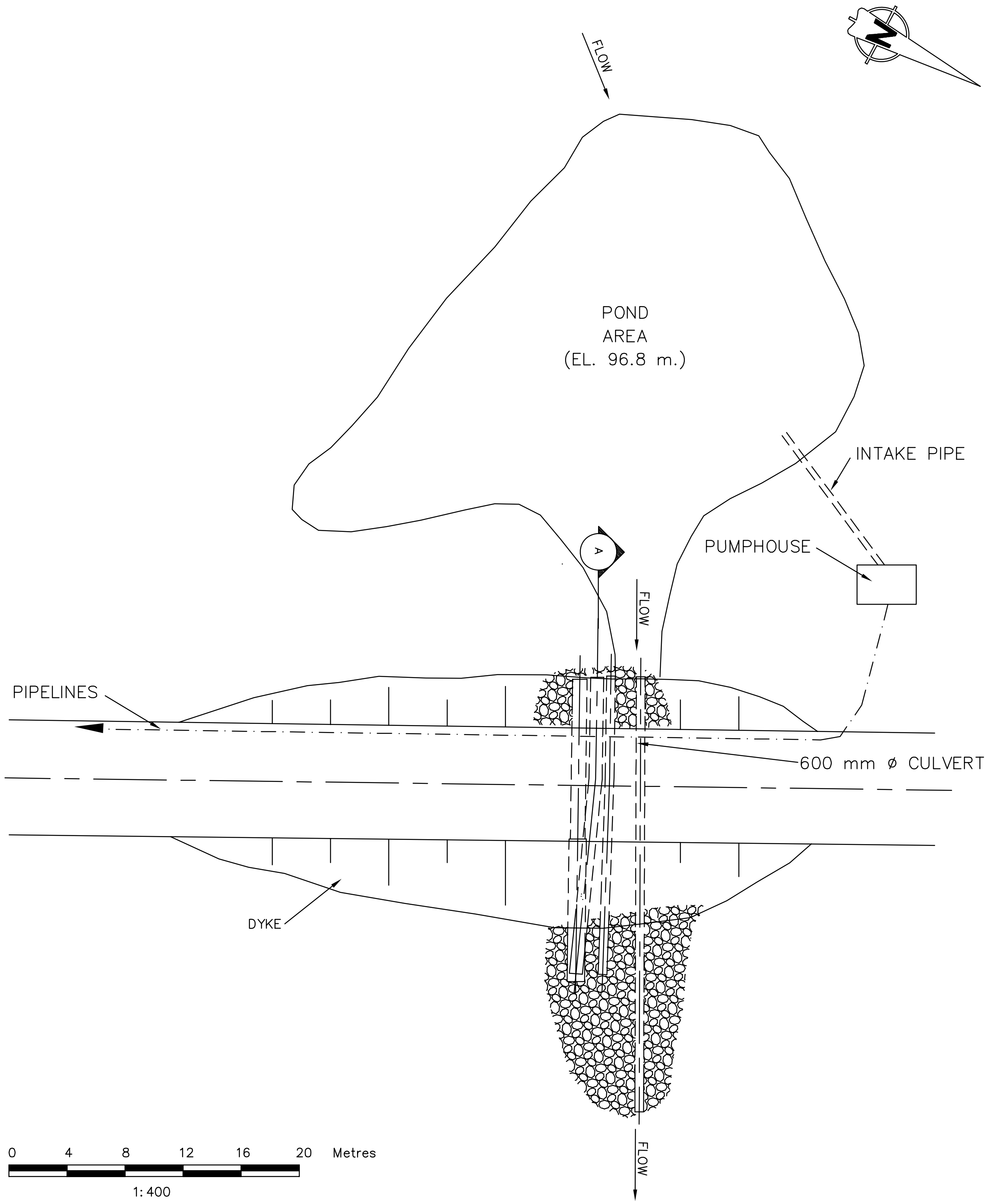

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Figure 11

Site Plan of North Creek Dyke and Pond (SRK 2009)

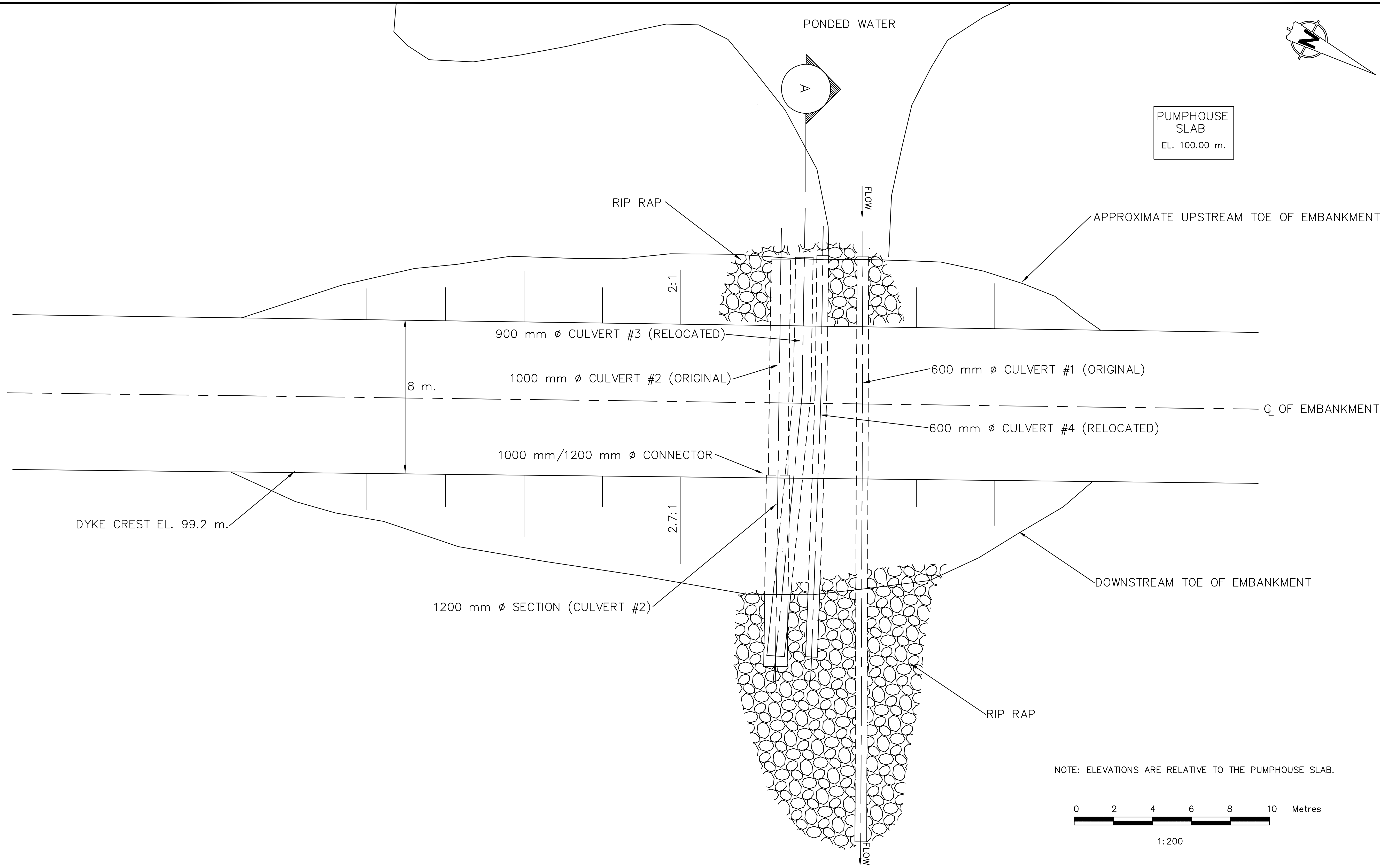


Figure 12

Plan of North Creek Dyke (SRK 2009)

J: \01_SITES\Sa_Dena_Hes\1CT008.018_2008 Geotechnical Inspection\040_AutoCAD\Figure_6.dwg

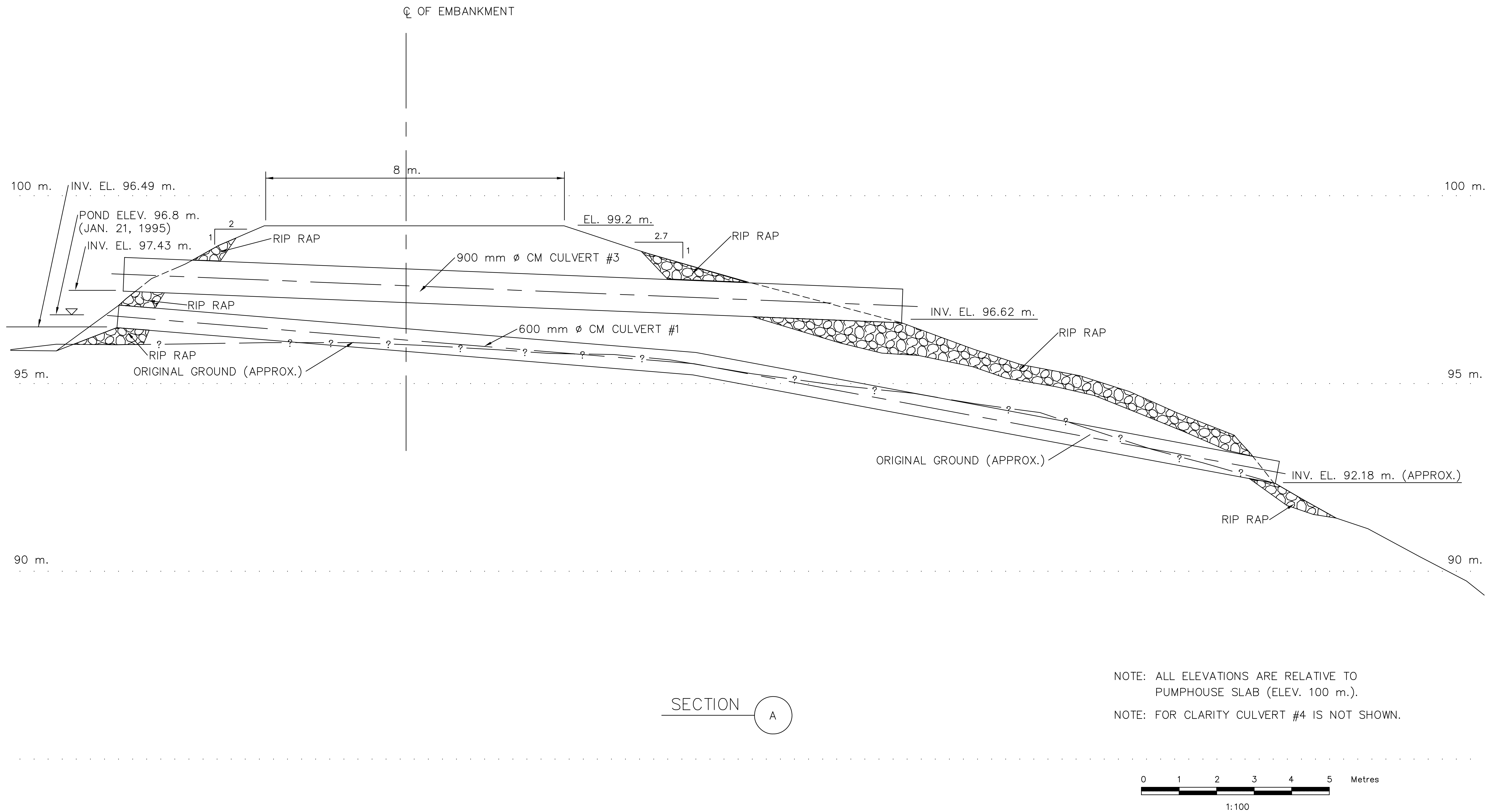
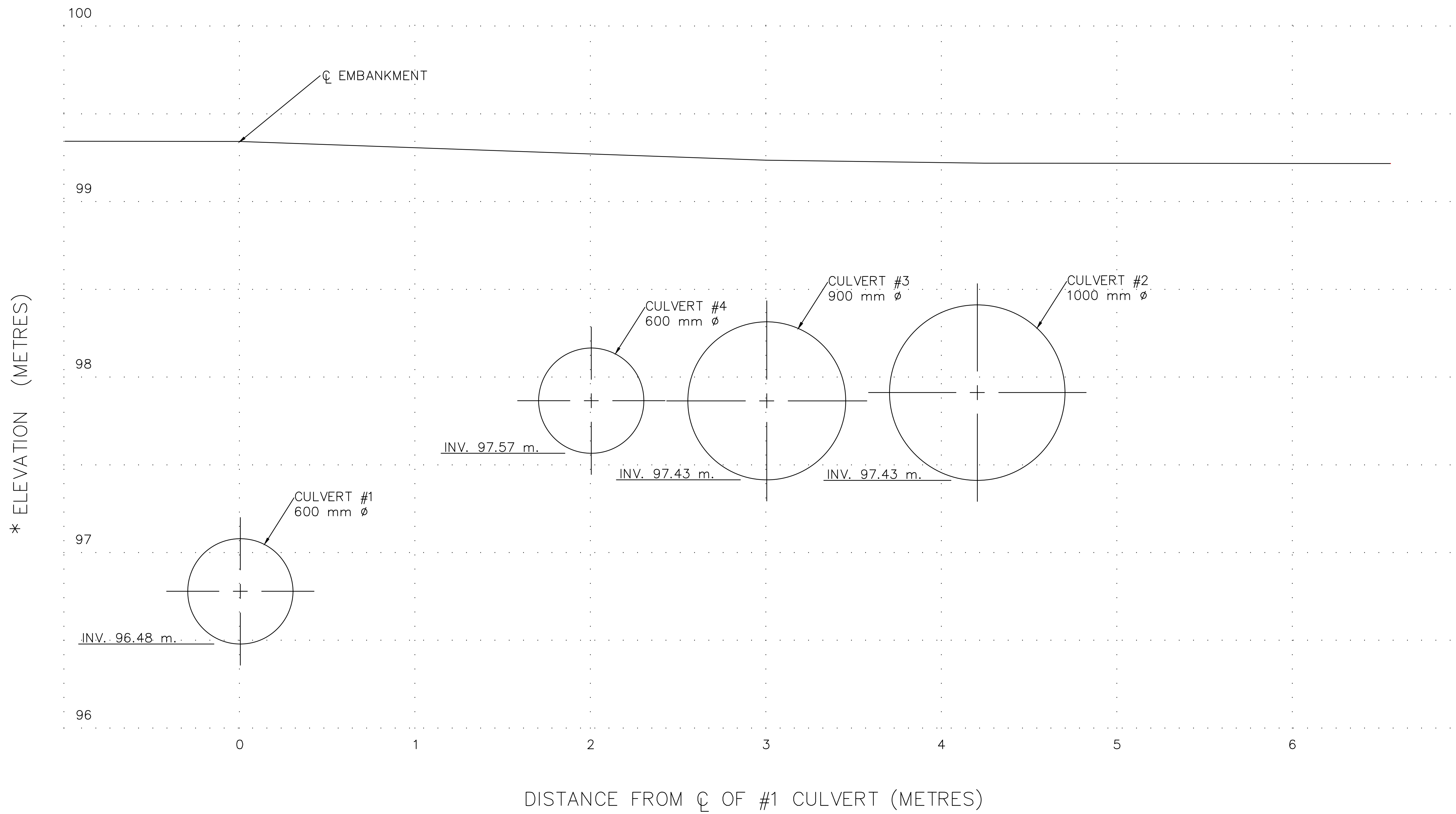
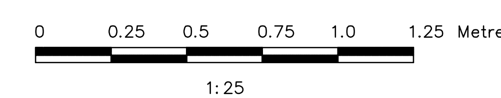


Figure 13

North Creek Dyke Section through Culvert #3 at Crossing (SRK 2009)





NOTE: ALL ELEVATIONS RELATIVE TO NORTH CREEK DAM PUMPHOUSE SLAB (REL. ELEV= 99.94 m.).

Figure 14

North Creek Dyke Profile along Centreline of Crossing (SRK 2009)

J:\01_SITES\So_Deno_Hes\1CT008.018_2008 Geotechnical Inspection\040_AutoCAD\Figure_8.dwg

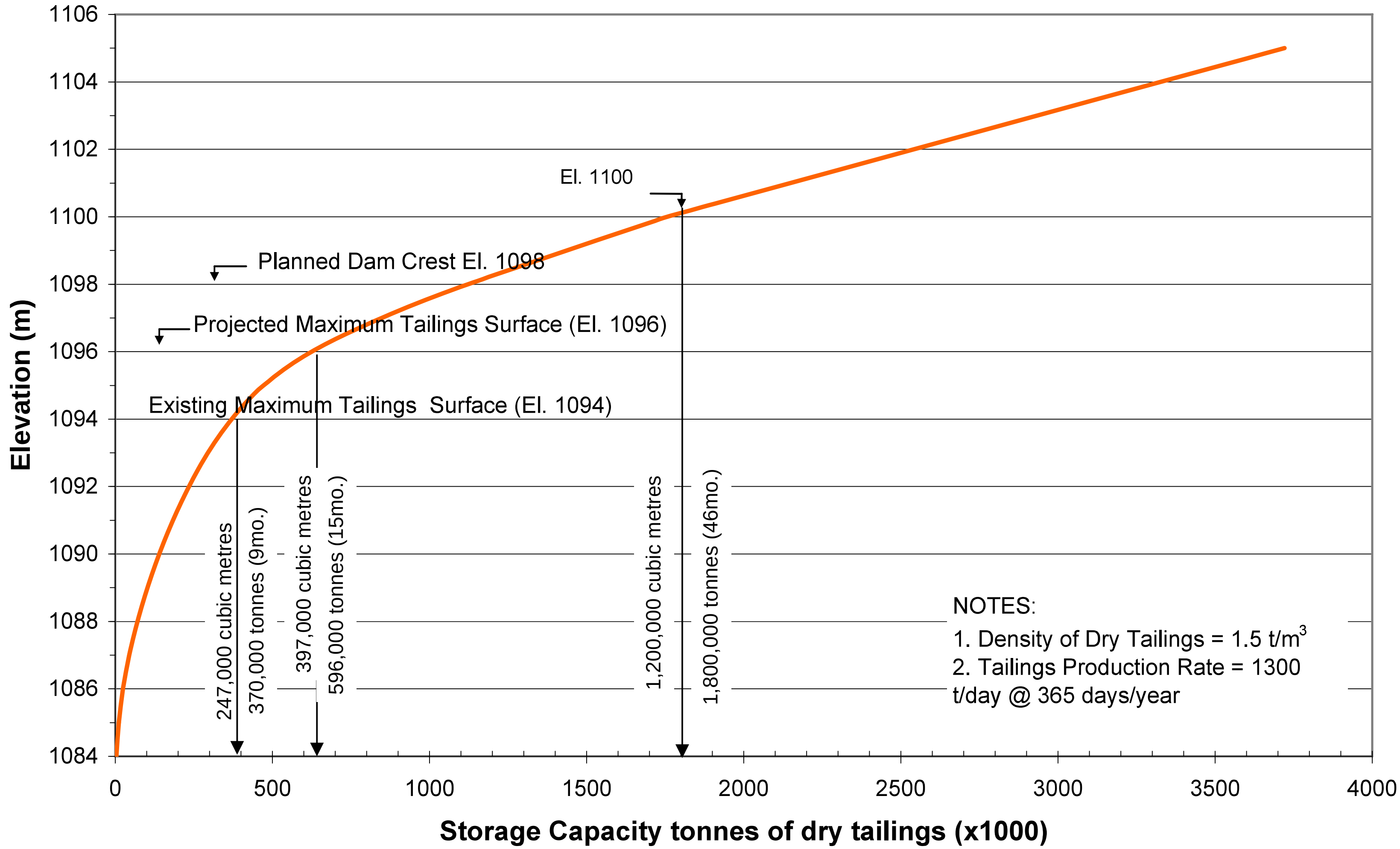


Figure 15

Storage Capacity Curve - Combined TMF (SRK 2004)

Figure 2.6_Copy of Stor_cap_1105_elev_JCP_20040528.xls 5/28/200411:41 AM

APPENDIX A

Photographs of the Site Visit, June 23 to 24, 2009

Photograph 1: Overview of the TMF with, from left to right, the North Dam, the Cofferdam, the South Dam and the Reclaim Dam.

Photograph 2: North Dam – Tailings beach with view toward water impoundment and the Cofferdam.

Photograph 3: North Dam – Tailings beach at the upstream face of North Dam (lower left corner).

Photograph 4: North Dam – Seepage at the dam abutment on the west side.

Photograph 5: North Dam – Seepage at the toe of the dam on the west side.

Photograph 6: North Dam – Seepage collection at the toe of the dam.

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Photograph 7: South Dam – Dam crest, looking east.

Photograph 8: South Dam – Dam crest, looking west.

Photograph 9: South Dam – Seepage at the toe of the dam, on the east side.

Photograph 10: South Dam – East abutment, dry area.

Photograph 11: South Dam – Looking east from the dam crest to the decant tower.

Photograph 12: South Dam – Outlet from the decant tower on the downstream face of the dam.

Photograph 13: South Dam – Channel to the spillway on the west side of the dam.

Photograph 14: South Dam – Culvert inlet of the dam spillway.

Photograph 15: Cofferdam Dam – Gate at the culvert inlet.

Photograph 16: Cofferdam Dam – Inlet channel to gated culvert.

Photograph 17: Cofferdam Dam – Outlet channel to gated culvert.

Photograph 18: Reclaim Dam – Looking west on the dam crest.

Photograph 19: Reclaim Dam – Looking east on the dam crest.

Photograph 20: Reclaim Dam – East toe area with seepage in the gulley.

Photograph 21: Reclaim Dam – Toe buttress road.

Photograph 22: Reclaim Dam – Monitoring weir at the toe of the dam.

Photograph 23: Reclaim Dam – Spillway channel with the Reclaim pond behind the tree line.

Photograph 24: Camp Creek Diversion – Channel above Reclaim Dam (water erosion below the steel plates).

Photograph 25: Camp Creek Diversion – Channel at Reclaim Dam.

Photograph 26: Camp Creek Diversion – Spillway channel downstream of Reclaim Dam.

Photograph 27: North Creek Dike – Culvert inlets.

Photograph 28: North Creek Dike – Culvert outlet.

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APPENDIX B

Teck Metals – Sä Dena Hes – Log Sheets for Daily, Weekly, Monthly and Annual Inspections

SHEET A-1
DAILY LOG SHEET (OPERATIONS)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________

ITEM NO	DESCRIPTION	TIME	MEASUREMENT	COMMENTS/NOTES
1	**Tailings Impoundment**			
1.1	Visual inspection of tailings impoundment embankments slopes and crest.			
1.2	Visual inspection of seepage from embankments			
1.3	Tailings deposition location.			
1.4	Maximum and Minimum Distance and Position of Supernatant Pool.			
1.5	Cofferdam – is there water on the north side.			
1.6	Elevation of water at decant tower.			
1.7	Depth of water at decant tower.			
1.8	Time water decanted from tailings impoundment.			
1.9	Check valves for leaks.			
1.10	Check spigots from valves to tailings surface for abnormalities.			
1.11	Record any safety hazard, e.g.: cracks in roads and embankments, spillages of any nature, wet areas being formed as a result of seepage, etc.			
1.12	Check the state of the cofferdam, slopes and decant pipe. Is the pipe inlet and outlet open and free of debris and tailings?			
1.13	Raise stoplogs within the decant tower to retain tailing within the TMF and to decant clear water.			
1.14	Check water surfaces for any debris.			
1.15	Check spillway inlets for any debris.			
1.16	General			

SHEET A-1
DAILY LOG SHEET (OPERATIONS)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

ITEM NO	DESCRIPTION	TIME	MEASUREMENT	COMMENTS/NOTES
2	**Reclaim Pond**			
2.1	Visual inspection of embankment slopes and crest.			
2.2	Visual inspection of seepage.			
2.3	Water elevation /Depth of water in reclaim dam (before and after decanting from tailings impoundment).			
2.4	Record operations of the reclaim pumps.			
2.5	Record any safety hazard, e.g.: cracks in roads and embankments, spillages of any nature, wet areas being formed as a result of seepage, etc.			
2.5	Check for leaks along discharge pipes from the Reclaim Pond to the mill.			
2.7	Check spillway inlets for any debris.			
2.8	Check water surface for any debris.			
2.9	General			
3	**Pipelines**			
3.1	Visual inspection of slurry pipeline, mill to tailings impoundment.			
3.2	Visual inspection of reclaim pipeline.			
3.3	General			
4	**Water Diversions**			
4.1	Inspect water level in the North Creek Dyke, and status of the culverts.			
4.2	Inspect the Camp Creek diversion culverts, sideslopes, rip rap.			
4.3	Inspect second culvert of North Creek for blockage.			

SHEET A-2
DAILY LOG SHEET (DURING SHUTDOWN)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________

ITEM NO	DESCRIPTION	TIME	MEASUREMENT	COMMENTS/NOTES
1	**Tailings Impoundment**			
1.1	Check any changes in the appearance of the TMF.			
1.2	Note location and level of the supernatant pool and depth of water over tailings at decant tower.			
1.3	Check water surface for any debris.			
1.4	Check spillway inlets for any debris.			
1.5	NB: Wear life jacket when accessing, operating and leaving the decant tower.			
2	**Reclaim Pond**			
2.1	Is there a requirement to discharge excess water?			
2.2	Record any safety hazards, e.g.: cracks in roads and embankments, spillages of any nature, wet areas formed as a result of seepage, etc.			
2.3	Check spillway inlets for any debris.			
2.4	Check water surface for any debris.			
2.5	NB: Wear life jacket when accessing, operating and leaving barge.			
3	**Water Diversions**			
3.1	Inspect water level in the North Creek Dyke, and status of culverts.			
3.2	Inspect the Camp Creek diversion culverts, sideslopes, rip rap.			
3.3	Inspect second culvert of North Creek for blockage.			

SHEET A-3
WEEKLY LOG SHEET (OPERATIONS)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________

ITEM NO	DESCRIPTION	TIME	MEASUREMENT	COMMENTS/NOTES
1	**Tailings Impoundment, Reclaim Pond and Water Diversion Structures**			
1.1	Check for tension cracks on the dam crest or slopes.			
1.2	Check for settled or depressed areas where there is standing water.			
1.3	Check for significant erosion gullies or rills on the slopes or crest.			
1.4	Check for new or increasing amounts of seepage, changes of colour or turbidity.			
1.5	Check for debris or ice in diversions or spillways.			
1.6	Check for sloughing of diversion channel sideslopes.			
1.7	Water levels in TMF and Reclaim Pond.			
1.8	Tailings management and deposition issues.			
2	**Deposition Summary Tonnage**			
2.1	North Dam – East			
2.2	North Dam – West			
2.3	Cofferdam – East			
2.4	Cofferdam - West			
3	**Decant, Reclaim and Release Summary**			
3.1	Water decanted from the tailings impoundment			
3.2	Water reclaimed to the mill			
3.3	Water released from the system			
4	**Comments on Valves**			
5	**Comments on Tailings Delivery Pipelines**			

SHEET A-4
WEEKLY LOG SHEET (DURING SHUTDOWN)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________

ITEM NO	DESCRIPTION	TIME	MEASUREMENT	COMMENTS/NOTES
1	**Tailings Impoundment, Reclaim Pond and Water Diversion Structures**			
1.1	Check for tension cracks on the dam crest or slopes.			
1.2	Check for settled or depressed areas where there is standing water.			
1.3	Check for significant erosion gullies or rills on the slopes or crest.			
1.4	Check for new or increasing amounts of seepage, changes of colour or turbidity.			
1.5	Check for debris or ice in diversions or spillways.			
1.6	Check for sloughing of diversion channel sideslopes.			
1.7	Water levels in TMF and Reclaim Pond.			

SHEET A-5
MONTHLY LOG SHEET (OPERATIONS AND SHUTDOWN)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

Date: _______________ **Inspection by:** __________________________

SA DENA HES – MONTHLY INSPECTION CHECK LIST OF TAILINGS AND WATER MANAGEMENT FACILITIES														
STRUCTURES	Any development of further erosion on slopes? Significant changes to existing erosion gullies?	Any noticeable settlement of embankment crest	Any new subsidence on the embankment upstream and downstream faces	Any new tension cracks on the embankment slope or crest	Any new wet spots or seeps on the embankment face	Any new seeps, boils or soft areas at toe of the embankment	Any changes in rate, colour, or turbidity in seepage at toe of embankment	Quantify seepage flow rate	Are inlets and outlets of the embankment spillways or road culverts clear of debris or ice	Are the insides of spillway or culvert pipes clear and stable	Has there been any loss of riprap around the inlet and outlet of any spillway or culvert pipe	Any new sloughing of diversion channel sideslopes	Any new tension cracks, scarps or subsistence or further movement of waste dump crest	Explanation / Observations / Comments
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	No Change or Explanation	High, Medium, Low or None	Y/N	Y/N	Y/N	Y/N	Y/N	
North Creek Dyke														
Coffer Dam														
Lower North Creek Culvert														
Culvert at Second Crossing on North Creek														
North Dam*														
South Dam*														
Reclaim Dam*														
Camp Creek Diversion														
Reclaim Dam Spillway Exit Chute														
Burnick Waste Dump														

*Record Water Levels in Piezometers Log Sheet (Monthly)

SHEET A-6
MONTHLY LOG SHEET (OPERATIONS AND SHUTDOWN)
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________ **MEASURED BY ____________________**

Piezometer No.	Dam Crest Elevation*	Top of Pipe (A)	Measure from Top of Pipe to Water (metres) (B)	Calculate Piezo Water Elev. (A-B) = C	Trigger Elevation (D)	Trigger Alarm if Reading C – D > 0.00	Record Pond Elevation	Trigger Alarm if Pond Elevation is > than below
North Dam								
NDW-1A	1098	1098.7			1091.0			1097.0
NDW-1B	1098	1098.6			1091.0			
NDW-2A	1098	1098.5			1091.0			
NDW-2B	1098	1098.5			1094.0			
NDW-3A	1098	1098.6			1091.0			
NDW-3B	1098	1098.5			1094.0			
NDW-4A	1098	1086.5			1083.0			
South Dam								
SDW-1A	1096	See Note 1			1092.0			1094.0
SDW-1B	1096	See Note 1			1093.0			
SDW-2A	1096	See Note 1			1090.0			
SDW-2B	1096	See Note 1			1090.0			
SDW-3A	1096	1097.2			1088.0			
SDW-3B	1096	1097.5			1087.5			
SDW-4A	1096	1083.8			1084.0			
SDW-4B	1096	1083.6			1082.0			
SDW-4C	1096	1083.7			1082.0			
SDW-5A	1096	1097.2			1091.5			
SDW-5B	1096	1097.5			1091.5			
Reclaim Dam								
RDW–1A	1082	1082.5			1073.5			1079.5
RDW–1B	1082	1082.5			1073.0			
RDW–1C	1082	1082.6			1074.0			
RDW–2A	1082	1082.4			1073.0			
RDW–2B	1082	1082.7			1072.0			
RDW–2C	1082	1082.5			1072.5			
RDW–3A	1082	1071.2			1069.0			
RDW–3B	1082	1070.6			1069.0			
RDW-4A	1082	1082.5			1075.5			
RDW-4B	1082	1082.5			1076.0			

* metres above mean sea level (mamsl)
Note 1: to be resurveyed

SHEET A-7
ANNUAL LOG SHEET
SA DENA HES, TAILINGS AND WATER MANAGEMENT

DATE______________

Gauge No.	Original T.O.G	Reading	Difference	Comments

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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