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REPORT ON

Conceptual Design for Ore and Special Waste Pads and Ponds, Kiggavik Project

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REPORT

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Executive Summary

This report presents conceptual designs for ore and special waste pads and associated sedimentation ponds for the Kiggavik site at AREVA Resources Canada Inc.'s proposed Kiggavik Project located near Baker Lake, Nunavut. Ore and special waste that are stockpiled during operations require control and collection of drainage to prevent release of contact water to the environment. The design includes plan layouts, sections and quantities for pads and ponds including a 1.5 m thick rockfill pad to limit thaw of permafrost foundations, liner systems and also leakage detection and monitoring systems.

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Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

AREVA Resources Canada Inc. (AREVA) has retained Golder Associates Ltd. (Golder) to prepare concept level designs for an ore pad, a special waste pad, and associated sedimentation ponds required for the Kiggavik site as part of the Kiggavik Project, Nunavut.

This report presents the conceptual design including a brief project description, site conditions, design criteria, design assumptions, and drawings with layouts, sections, and typical details.

This report should be read in conjunction with the Study Limitations which precede the text and form an integral part of this report.

1.1 Project Description

The Kiggavik Project is described in the 2008 Project Proposal submitted to the Nunavut Impact Review Board (NIRB) as a proposed uranium (U) ore mining and milling operation located in the Kivalliq region of Nunavut approximately 80 km from the Hamlet of Baker Lake. The ore will be mined using open pit and underground methods and milled at the Kiggavik site to produce 4,000 tonnes per year of uranium as a concentrate, commonly referred to as yellow cake.

The mining plan includes:

- An ore pad to stockpile ore from mining operations prior to being fed into the mill for processing; and
- A special waste pad to temporarily stockpile sub-economic mineralized waste rock.

These pads require systems to collect runoff water for treatment.

At the end of mine life, the special waste material is placed as backfill in a mined-out open pit and the pads and ponds are decommissioned. The proposed layout of the Kiggavik site is shown on Drawing 1 in Appendix A.

1.2 Project Reports and Documents Reviewed

Project reports and documents reviewed for this study are listed in Table 1.1.

Table 1-1: Summary of Project Documents

Report Title	Author	Document Ref.	Date
2009 Kiggavik Geotechnical and Hydrogeological Investigation	Golder	09-1362-0613	December 2009
AREVA Kiggavik Project, Hydrology Baseline Document	Golder	09-1362-0612	April 2011
Environmental Assessment – Soils and Vegetation. Supporting Document No. 2.	Urangesellschaft Canada Ltd.,		January 1990
Geotechnical Recommendations for the Proposed Kiggavik Main and Kiggavik Centre Open Pits – Draft Report	Golder	09-1362-0613/3200(A)	December 2009
Geotechnical Summary 2009 – Draft Report	Golder	09-1426-0001/2000	December 2009
Kiggavik Project Environmental Impact Statement – Hydrogeology Baseline.	AREVA Resources Canada Inc.		August 2010
Kiggavik Project Haul Road Report	EBA Engineering Consultants Ltd.	V33101016	October 2010
Kiggavik Project Mine Site Airstrip Report	EBA Engineering Consultants Ltd.	V33101016	October 2010
Kiggavik Uranium Project Environmental Assessment – Soils and Vegetation	G.M. Wickware & Associates Inc.	BEAK Ref. 2305.3	December 1989
The Kiggavik Project, Project Proposal	AREVA Resources Canada Inc.		November 2008
Report to Urangesellschaft Canada Limited on the Mining Aspects of the Proposed Kiggavik Uranium Operations	Golder	882-1421/881-1814G	August, 1989

2.0 DESIGN CRITERIA

Design criteria for the pads and sedimentation ponds based on the applicable regulations are listed in Table 2.1.

Water from precipitation and snowmelt that contacts the ore and the special waste requires containment, collection and pumping to the site water treatment plant for treatment prior to release to the environment.

The liner systems for ore and special waste pads and for the associated sedimentation ponds must therefore retain contact water and prevent release to the environment.

The ore pad and ponds are double lined with a leakage detection system. The special waste pad is single lined and does not require a leakage detection system.

Table 2-1: Design Criteria and Considerations for Pads and Sedimentation Ponds

Sedimentation Pond Design Criteria		
Pond Liner	Double lined with 80 mil HDPE and leakage detection system	HDPE recommended by SERM* (2000). The design considers the use of LLDPE.
Pond Sizing		
Maximum operating capacity of water treatment plant (WTP)	5,500 m^3/d	Provided by AREVA
Storage capacity	Sum of following four items	
1) Maximum anticipated inflow	Based on 24 hour PMP event	SERM (2000) PMP = Probable Maximum Precipitation
2) WTP failure design event	24 hours duration	SERM (2000)
3) Freeboard during design event	1 m	SERM (2000)
4) Snowmelt during 24 PMP event	6.5 mm (water-equivalent)	Assumed
Inner batter slopes	2H: 1V to 3H:1V	3H:1V for traffic surfaces
Pumping capacity	5,500 m^3/d	Based on maximum treatment rate
Clean-out	Must allow periodic cleanout of sediment without damage to liner	
Hydrology		
PMP design event	184 mm in 24 hour	Golder (2011)
Runoff factors	100%	
Ore and Special Waste Pad Design Criteria		
Pad liner – ore	Double lined with 80 mil HDPE	HDPE recommended by SERM (2000). The design considers the use of LLDPE.
Pad liner – special waste	Single lined with 80 mil HDPE	HDPE recommended by SERM (2000). The design considers the use of LLDPE.
	Adequate base and cover to protect liner	SERM (2000)
Ore pad	Drainage collection between double liners with leakage detection	SERM (2000)
Ore slope angle	1.3H:1V	Angle of repose for end dumped rockfill materials

Ore and Special Waste Pad Design Criteria		
Special waste slope angle	1.3H: 1V with benches to a maximum of 2H:1V overall slope	Angle of repose for end-dumped rockfill materials
Maximum height of ore on pad	15 m	Assumed value based on on/off load on the liner system
Maximum height of special waste on pad	40 m	Assumed value based on some traffic and higher static load over longer term on the liner system
Unit weight for ore and special waste	20 kN/m^3	Assumed
Seismic Hazard Peak Ground Acceleration (1/1000 year earthquake)	0.035	2005 National Building Code Seismic Hazard Calculation
Ore and Special Waste Pile Factors of Safety for Slope Stability		
Static Loading Conditions	1.3	BC MWRPRC (1991)
Pseudo-static Loading Conditions	1.0	CDA (2007)
Monitoring	Groundwater monitoring well network required	SERM (2000)
	Leak detection between double liner layers required	SERM (2000)

*SERM: Saskatchewan Environment and Resource Management

Other general considerations include:

- Storage and freeboard requirements must consider ice accumulation in the ponds during winter;
- Settlements in the foundation, including thaw induced differential settlement of permafrost foundation conditions must be considered. Ice rich permafrost in foundations must be either removed or protected against thaw settlement and instability. Similarly, active layer penetration into frost active soils should be prevented to minimize differential frost heaving and thaw settlements. Excavation of permafrost ground should be avoided where possible to prevent permafrost thaw degradation;
- Creep of ice-rich foundations must be considered;
- Sedimentation ponds must be designed to allow periodic removal of accumulated sediment. Sediment ponds can be lined with concrete with an access ramp, or a portion of the facility lined with concrete and access ramp;
- Liners on ore pad must accommodate on-off heavy equipment traffic and static loading of overlying ore without damage to the liner system;
- Liners on special waste pad must accommodate infrequent on-off heavy equipment traffic and static loading due to height of overlying special waste without damage to the liner system;
- Piles must remain stable with respect to global slope stability;
- Toe berms are required to capture rolling particles of ore and special waste that ravel off the piles; and
- Wind considerations/dusting.

2.1 Applicable Regulations and Guidelines

A summary of regulations and guidelines that are applicable to the design are summarised in Table 2.2.

Table 2-2: List of Applicable Regulations and Guidelines

Document Title	Author	Document No.	Date
Construction Guidelines for Pollution Control Facilities at Uranium Mining and Milling Operations	SERM (Saskatchewan Environment and Resource Management)	Draft	October 2000
Environmental Guideline for the General Management of Hazardous Waste	Department of Environment, Government of Nunavut		October 2010
Environmental Protection Act	Department of Justice (Nunavut)	R.S.N.W.T 1999,c.E-7	August 2010
Spill Contingency Planning and Reporting Regulations	Department of Justice (Nunavut)	R-068-93	July 1998
Metal Mining Effluent Regulations	Minister of Justice	SOR/2002-222	January 10, 2011
Uranium Mines and Mills Regulations	Minister of Justice	SOR/2000-206	January 10, 2011
Northwest Territories Mine Health and Safety Regulations	Department of Justice, Legislation Division	R-125-95	-
Mined Rock and Overburden Piles Investigation and Design Manual Interim Guidelines.	BC MWRPRC (British Columbia Mine Waste Rock Pile Research Committee).	-	1991
Dam Safety Guidelines	CDA (Canadian Dam Association)	-	November 2007

3.0 SITE DESCRIPTION

Conditions at the site including climatic, geotechnical and permafrost conditions are presented.

3.1 Climate

The following climatic information is taken from Golder (2011), and is based on climate data for the Baker Lake weather station, located approximately 80 km to the east of the Kiggavik Project site.

3.1.1 Precipitation

Adjusted precipitation data derived by Environment Canada are used for design and water balance purposes. Adjusted total precipitation monthly statistics were calculated for the Baker Lake climate station for the years 1949 to 2007 and are provided in Table 3.1. The main adjustment was made for snow gauge under-catch caused by elevated wind speeds. The adjusted precipitation for the Baker Lake climate station was 40% greater than reported in climate normals. From the adjusted dataset, mean annual precipitation was estimated to be 344 mm, 168 mm (49%) of which falls as rain. Total annual precipitation is estimated to range between 195 mm and 520 mm. The highest amounts of precipitation tend to occur between July and October.

Table 3-1: Mean, Maximum, and Minimum Monthly Adjusted Precipitation for Baker Lake, 1949 to 2007

Month	Mean (mm) (rain/snow)	Maximum (mm)	Minimum (mm)
January	13.2 (0.1/13.2)	36.8	1.3
February	12.2 (0.1/12.2)	35.4	2.2
March	17.0 (0.0/17.0)	58.5	2.9
April	22.0 (0.6/21.5)	93.9	3.2
May	20.0 (6.7/13.3)	54.3	1.5
June	26.3 (21.9/4.4)	66.7	3.6
July	43.6 (43.6/0.0)	96.3	2.9
August	47.1 (46.2/1.0)	95.1	6.3
September	48.0 (37.3/10.6)	104.4	8.1
October	43.0 (8.0/34.9)	113.1	8.6
November	27.8 (0.3/27.5)	90.1	6.7
December	17.7 (0.1/17.6)	51.1	2.6
Annual	344.4 (168.9/175.5)	519.7	195.4

Rainfall intensity duration-frequency curves (IDF) were developed for Baker Lake. These data were developed by Environment Canada (2010) and are based upon historical rainfall records. The rainfall event with a 1 in 100 year return period and 24-hour duration for the Baker Lake area is 74.7 mm (Table 3.2).

The probable maximum precipitation (PMP) event estimated value for the Kiggavik area is 184 mm over a 24 hour period (Golder 2011).

Table 3-2: Intensity Duration and Frequency Rainfall Statistics for Baker Lake (mm)

Duration	Return Period (years)					
	2	5	10	25	50	100
5 Min	1.6	2.6	3.3	4.1	4.7	5.3
10 Min	2.3	3.3	3.9	4.7	5.3	5.9
15 Min	2.8	3.8	4.5	5.3	6	6.6
30 Min	4.1	5.5	6.4	7.6	8.5	9.3
1 Hr	6.3	8.7	10.2	12.2	13.6	15.1
2 Hr	9.3	13.5	16.3	19.8	22.4	25
6 Hr	16.7	22.8	26.8	32	35.8	39.5
12 Hr	22.4	32.4	39.1	47.5	53.8	60
24 Hr	27.3	40	48.4	59	66.9	74.7

IDF calculated using a historical record from 1987 to 2006.

3.1.2 Air Temperature

The mean annual air temperature for Baker Lake climate station was estimated to be -12 °C. Mean, maximum, and minimum monthly temperatures are presented in Table 3.3. Mean temperatures range between -32.4°C in January and 11.2°C in July. Extreme temperatures have ranged between -50.6°C and 33.6°C in January and July, respectively.

Table 3-3: Air Temperatures for Baker Lake, 1946 to 2008

Month	Warmest and Coldest Day in the Month				Monthly Mean (°C)
	Extremes		Means		
	Maximum (°C)	Minimum (°C)	Maximum (°C)	Minimum (°C)	
January	-1.7	-50.6	-28.9	-35.8	-32.4
February	-4.1	-50.0	-28.6	-35.5	-32.0
March	1.5	-50.0	-22.9	-31.3	-27.1
April	19.2	-41.1	-12.7	-22.1	-17.4
May	13.9	-27.8	-2.7	-9.9	-6.3
June	28.1	-13.9	8.3	0.2	4.3
July	33.6	-1.7	16.4	5.9	11.2
August	30.9	-3.4	14.1	5.3	9.7
September	22.6	-14.4	5.8	-0.5	2.7
October	9.8	-30.6	-3.9	-10.4	-7.2
November	2.2	-42.7	-16.0	-23.8	-20.0
December	-1.1	-45.6	-24.0	-31.2	-27.7

3.1.3 Runoff

The following hydrological information has been obtained from Golder (2011).

Using long-term records for two decommissioned WSC hydrometric stations that were located within 70 km of the Kiggavik site, annual mean runoff the Kiggavik site is estimated at 0.0061 $m^3/s/km^2$. This translates to an annual mean runoff value of 192 mm per year, which is about 56% of the long term mean precipitation value of 344 mm. Most of the runoff occurs during the snowmelt period. Table 3.4 indicates that more than half of the annual runoff occurs in June, and this proportion is higher in smaller drainage areas. Short-term records from the site stream discharge monitoring program indicate that snowmelt runoff in June can be 70 to 80% of the annual runoff volume for smaller watersheds (15 km to 50 km), and even greater for drainages with little or no lake storage and watersheds smaller than a few square kilometres.

Table 3-4: Monthly Distribution of Runoff

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Runoff (mm)	0	0	0	0	4	101	35	15	21	4	0	0	192

3.2 Geotechnical Conditions

No investigations have been conducted for the current configuration of the proposed ore pad, special waste pad or sedimentation ponds. However, geotechnical data from previous investigations conducted in 1988 include boreholes near proposed infrastructure locations. Available data are summarized here.

3.2.1 Near Surface Soils

Golder (1989) reported results of investigations at the Kiggavik site including a previous version of the site layout with a proposed haul road alignment. Borehole locations are summarized on Drawings 1 and 2 in Appendix A with the current proposed site layout. Results of laboratory testing reported in Golder (1989) are listed in Table 3.5. Average soil thickness included 0.1 m of organic topsoil, 0.45 m of silty fine sand and then till to an expected total depth of 5.5 m. The till had a variable texture with silty to gravelly sand with a trace of clay and also cobble and boulder sizes. All till samples collected were non-plastic. Water content of the till ranged from 8.4% to 54.2%.

Moisture contents in excess of 30% can be considered to have the potential to be classified as ice-rich material. One of the sixteen samples tested was considered to be ice-rich. The sample was collected 1.5 m below surface in borehole BH88-MZ1 which is located at a low elevation area and 650 m to the south of the special waste pad.

Table 3-5: Summary of Laboratory Test Results from Golder (1989)

Borehole	Depth (m)	Grain Size (%) (Gravel-Sand-Silt-Clay)	Unified Soil Classification	Moisture Content (%)	Other Tests
Main Zone					
BH88-MZ1	0.7 - 1.3	13-73-1-13 SAND TILL, some Gravel, some Clay, trace Silt	SM	23.7	γ_{bf} 1,920, γ_d1,552
BH88-MZ1	1.5 - 1.6	40-30-24-6 SANDY GRAVEL TILL, some Silt, trace Clay	GM	54.2	γ_{bf}1,640, γ_d1,064
BH88-MZ1	1.7 - 2.3	21-48-22-9 SAND Till, some Gravel, some silt trace Clay	SM	9.0	
BH88-MZ2	0.5 - 1.3	17-32-40-11 SANDY SILT TILL, some Gravel, some Clay	ML	10.5	
Centre Zone					
BH88-CZ1	0.4 - 0.9	16-43-30-11 SILTY SAND TILL, some Gravel, some Clay	SM	6.4	
BH88-CZ1	0.9 - 1.1	30-39-21-10 GRAVELLY SAND TILL, some Silt, some Clay	SM	22.8	γ_{bf} 2,109, γ_d1,717
BH88-CZ1	1.1 - 1.9	15-44-30-11 SILTY SAND TILL, some Gravel, some Clay	SM	6.6	
Waste Dumps					
BH88-1WD1	0.5 - 1.3	17-45-25-13 SILTY SAND TILL, some Gravel, some Clay	SM	7.7	
BH88-1WD1	1.3 - 1.5	35-56-5-4 GRAVELLY SAND TILL, trace Silt, trace Clay	SP	4.4	
Mine Haul Road					
BH88-1MHR1	0.9 - 1.5	17–45–26-12 SILTY SAND TILL, some clay, some Gravel	SM-SC	9.5	
BH88-1MHR2	0.9 - 1.5			13.1	
BH88-1MHR3	0 - 0.6			9.2	
BH88-1MHR3	1.4 – 1.5	32-38-22-8 GRAVELLY SAND TILL, some Silt, trace Clay	SM-SC	23.2	γ_{bf}1,324, γ_d1,074
BH88-1MHR3	1.5 – 2.0			8.4	
BH88-1MHR5	0.9 – 1.4	22-41-24-13 SAND TILL, some Silt, some Gravel, some Clay	SM-SC	10.5	
BH88-1MHR6	1.3 – 2.8	25-41-22-12 GRAVELLY SAND TILL, some Silt, some Clay	SM-SC	9.1	

γ_{bf} = Bulk Frozen Density (kg/m^3), γ_d = Dry Density (kg/m^3)

3.2.2 Ground Thermal Conditions

The Kiggavik site is located in the zone of continuous permafrost.

Based on shallow multi-level thermistor data collected at the Kiggavik site, the depth at which the ground temperatures are not affected by seasonal changes in surface temperatures is estimated at between 20 and 25 metres below ground surface (mbgs) (AREVA, 2010). Recent data indicate the depth of permafrost is between 210 mbgs at the Main Zone, Centre Zone and East Deposits, while historic data indicated permafrost depths of 220 to 240 mbgs (AREVA 2010). The expected ground temperature at the depth of zero annual amplitude is near -5 to -6 degrees Celsius. Depth of the active layer that thaws each year is expected to vary between 1 to 5 m, depending on foundation materials and moisture contents, surface cover, aspect and slope angle. Golder (1989) reported frost boils, a peri-glacial or cold-weather phenomenon, where soils are transported from depth to surface due to frost action.

Recorded instances of ground ice are summarized in Table 3.6.

Table 3-6: Recorded Instances of Ground Ice at Kiggavik

Borehole	Depth (m)	Permafrost Description
BH88-MZ1 (Main Zone)	0.7 to 0.8	Nbe (ice not visible by eye, well bonded excess ice)
	0.8 to 1.25	Vs (visible, stratified or distinctly oriented ice formations) 1-3 mm, thick, clear, hard
	1.45 to 1.7	Vs (visible, stratified or distinctly oriented ice formations) to Vr (visible, random or irregularly oriented ice formations) 2-3 mm thick, hard, light brown
BH88-CZ1 (Centre Zone)	0.9 to 1.12	Vs, (visible, stratified or distinctly oriented ice formations) 2-4 mm, thick, clear, hard
BH88-1WD1 (Waste Dump)	0.5 to 1.25	Nbn (ice not visible by eye, well bonded, no excess ice)
BH88-1WD2 (Waste Dump)	1.0 to 1.7	Nbe (ice not visible by eye, well bonded excess ice)
BH88-2WD1	1.0	Permafrost (est.)

Permafrost descriptions based on the NRC "Guide to a Field Description of Permafrost for Engineering Purposes" NRC 7576.

3.2.3 Seismic Hazard

Seismic hazard at the site was determined using fourth generation seismic hazard maps of Canada interpolated for use with the 2005 National Building Code of Canada. A summary of seismic hazard values is presented in Table 3.7.

Table 3-7: Seismic Hazard Assessment

Return Period (years)	Peak Ground Acceleration[(a)] (PGA, g)
100	0.007
475	0.021
1,000	**0.035** [(b)]
2,500	0.059

(a) Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C – average shear wave velocity 360-750 m/s).

(b) Bold text denotes design event.

4.0 RUNOFF MANAGEMENT STRATEGY

Topographic gradients from upland areas direct drainage from the north toward the Kiggavik site, while areas to the west and east side will drain primarily away from the site. The Kiggavik site includes a fresh water diversion channel located around the west, north and eastern site boundaries and two clean waste rock pile runoff collection channels. Drawing 1 in Appendix A indicates the channel alignments and flow directions. The freshwater diversion channels will report to natural stream channels which carry flows from the same drainage areas prior to development. Both receiving channels report to Pointer Lake, located approximately 2 km south of the Kiggavik site. The channels are designed to carry runoff from a PMP (184 mm in 24 hr storm). Update of the design of these channels is required to accommodate the pond and pad configuration shown on Drawing 1.

LiDAR topographic surfaces and the GIS application ARC-Hydro were used to define drainage areas and create flow pathways. The PMP is conservative and the collection channel designs will be more than adequate for managing heavy rainfall and maximum snowmelt runoff. Part of the runoff management strategy within the site boundary consists of the construction of drainage channels around the clean waste rock piles to collect runoff water for passive treatment in unlined sediment ponds to reduce potential sediment loads prior to releasing flow to the natural receiving drainages. Runoff generated from outside the core facilities area, but draining toward the site will be collected in a perimeter diversion channel and redirected around the site to be discharged to the same natural pre-development drainage system.

5.0 PADS AND PONDS DESIGN

The design concept for the pads is to provide containment for the required volume of ore or special waste, and allow for the collection of any precipitation and snow melt runoff that contacts the ore or special waste materials. Excess runoff will be directed to the sedimentation ponds for collection. The design concept for the ponds is to collect runoff for sedimentation, followed by pumping to transfer the runoff water to the site water treatment plant for treatment and release to the environment. Pond and pad liner systems are built on rockfill pads to limit thaw and degradation of permafrost foundations. Both HDPE and LLDPE liner materials are considered suitable for this conceptual design.

The conceptual designs for the pads and ponds are illustrated on Drawings 1 through 4 in Appendix A.

5.1 Ore and Special Waste Pads

Ore and special waste pads have been sized by AREVA to store the required volumes to support the mine plan.

5.1.1 Pad Design

The design concept for the ore pad for Kiggavik includes a double liner with a leakage detection system, consistent with design criteria for uranium mine sites located in Saskatchewan (SERM 2000). The special waste pad includes a single liner system. Due to the permafrost foundation conditions at the Kiggavik site, the liners are required to be constructed on a rockfill pad. The pad footprints are stripped of organic materials and ice-rich soils (soils containing ice lenses or high ice contents) which may be prone to creep when loaded. Excavations in permafrost ground are covered immediately using clean rock fill to prevent permafrost degradation. Fill material will include non-potentially acid generating (non-PAG) free draining rock materials. The minimum thickness of the rock pad is 1.5 m. The pad grading is designed to drain into the sedimentation ponds.

A double liner system will be installed on the surface of the ore pad and will include the following layers (from top to bottom):

1) Transition layer of 100 mm minus rockfill;
2) Cover sand over liner;
3) Non-woven filter cloth as cushion between sand cover and liner;
4) 80 mil HDPE or LLDPE liner;
5) Drainage net geogrid;
6) 80 mil HDPE or LLDPE liner;
7) Non-woven filter cloth as cushion between sand bedding and liner;
8) Base sand/liner bedding;
9) Transition layer of 100 mm minus rockfill; and
10) Minimum 1.5 m thick non-PAG rockfill pad.

The special waste pad requires a single liner system and therefore includes all of the above listed layers, except for layers 5 and 6.

The rockfill pads include perimeter berms to 1 m height. The pad liner system runs up the perimeter berms and is anchored in a trench at the berm crest to provide drainage control for runoff. Additional rockfill is placed over the liner to raise the perimeter berms to protect against roll-out from stockpiled ore or special waste. Proposed conceptual layouts are shown in Drawing 2 in Appendix A. Sections through the pads and details are shown on Drawings 3 and 4 in Appendix A.

Roads for equipment access can be placed over the perimeter berm at any point, provided sufficient protection is provided to the liner system, shown as a detail on Drawing 4 in Appendix A.

The liner systems extend from pads into sedimentation ponds.

5.1.2 Stability Analysis

The pads will store ore and special waste materials over a frozen foundation. Global stability of the pad and pond systems was examined against design criteria in Table 2.1.

Stability analyses were performed using the limit equilibrium slope stability program SLOPE/W (GEOSLOPE 2010), applying the Morgenstern-Price Method to compute factors of safety for selected failure surfaces. The critical section for stability examined is the special waste pile and sedimentation pond with a maximum design height of 40 m, shown in Figure 5.1. Material properties used in the analysis are presented in Table 5.1.

Table 5-1: Material Properties for Stability Analysis

Material	Condition	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Ore / Special Waste	unsaturated	20	38	0
Rockfill Pad	saturated	23	38	0
Rockfill Pad	unsaturated	20	38	0
Liner System		15	17	0
Till	saturated	22	32	0
Bedrock	Impenetrable			

Materials are expected to be frozen, but thawed parameters were used for analyses. Generally, freezing of materials will add strength and increase factors of safety for stability. Static and seismic loading conditions were examined. Pseudo-static analyses considered the 1/1000 year return period event including a PGA of 0.035 g in Table 3-7. One-half of the PGA, or 0.02 g was applied in stability analyses as the horizontal seismic coefficient.

Table 5.2 presents the results of stability analysis.

Table 5-2: Stability Analysis Results

Locations	Factor of Safety			
	Static	Design Criteria Minimum	Pseudo-Static	Design Criteria Minimum
Special Waste Pile	1.3	1.3	1.2	1

A friction angle of the liner system of 17 degrees was assumed based on experience and testing for soil – liner interactions at other projects in the north. Laboratory testing of liner system friction is recommended for future design stages. Use of textured liner systems will likely be required.

5.2 Sedimentation Ponds

5.2.1 Pond Sizing

The sedimentation ponds are sized to provide storage capacity according to the criteria from SERM (2000) shown in Table 2-1 and summarized below.

- 24 hour PMP, 184 mm.
- 24 hour, or one day duration, water treatment plant (WTP) failure. The WTP has a capacity of 5,500 m^3 assuming 2,500m^3 pumped from ore sedimentation pond and 3,000m^3 from special waste pond.
- 6.5 mm snowmelt during the 24 hour PMP. While the PMP is unlikely to happen during the freshet, it is assumed that PMP coincides with the snowmelt event. The approach is conservative.
- 1 m free board.

Based on the design criteria, the storage requirement for the ore pond is 22,400 m^3. The design of the ore pond shown in Drawing 2 provides storage capacity of 29,300 m^3 at the design crest elevation 208 m.

Similarly, the storage requirement for the special waste pond is 40,100 m^3. The design of the special waste pond will store 49,000 m^3 at the design crest elevation 198 m.

Both pond designs exceed the design criteria for storage volume.

5.2.2 Pond Design

The ponds are double lined, with the liner systems extending from pad into pond. The liner system in the ponds generally includes the same layers as the pads, with the exceptions that the upper rockfill transition layer is replaced by gravel, and the special waste sedimentation pond is double lined, while the special waste pad is single lined. The sedimentation ponds require pumping facilities and periodic cleanout but otherwise are not subject to regular traffic by equipment.

The ponds will accumulate sediment that must be periodically removed. One inner pond batter is sloped at 3 horizontal: 1 vertical as a ramp to allow equipment access to muck out the pond. A protective layer will be necessary to protect the liner system from light mobile plant equipment. The lower portion of the sediment pond basin and the equipment ramp are therefore covered with a thin slab of concrete. The remaining portion of the liner is covered with a protective layer of gravel.

5.2.3 Leakage Detection System

The two layers of HDPE or LLDPE liner are separated by a drainage net geogrid that reports to a lower, leakage detection sump as part of a leakage monitoring system for the ore pad and ponds. The leakage detection sump is filled with gravel and contained by the lower HDPE or LLDPE liner. The leakage detection sump is accessed by two heat traced pipes placed along the batter between the two liner layers. One pipe is placed for redundancy. It is noted that the leakage detection sump cannot be completely dewatered using a pump lowered into the pipe, as some water will remain in the leakage detection sump below the pump intake level.

Additional shallow groundwater monitoring wells should be installed down gradient of both the ore and special waste pads and ponds. Proposed monitoring well locations are shown on Drawing 2 in Appendix A. Deeper wells in the permafrost are not proposed.

Regular monitoring of the leakage detection sumps and pond levels would be carried out. Should a leak occur through the upper liner, water would report to the leakage detection sump. In general, the rate of leakage would be estimated by measuring the water level rise in the sump with time. Management strategies for slow or low rates of leakage may include periodically pumping out the leakage detection sump using a vacuum truck. High rates of pumping from the sump would trigger an investigation into the cause of the leakage. High rates of leakage could be associated with damage to the primary or upper liner system and would require a dedicated sump pump to transfer water to a mined out pit or to the water treatment plant. If the leak is large and cannot be managed with periodic pumping, this could be addressed by closing the pond and pumping the entire volume of water to the pit, followed by exposing and repairing the liner. Repairs to the liner system could be carried out as part of pond maintenance and should be carried out in a manner judged to be appropriate by a qualified Engineer.

A review of available designs for mines in northern Canadian locations indicates that the use of a leakage detection sump is a common practice although the design details of the sump vary by site.

Cameco (2008) designed a leakage detection system including sumps for the Phase III and IV ore pads of the Key Lake Uranium Mine. The design included the following main components:

- A dual HDPE containment system connected to dual liners collecting leakage and discharging it to a manhole/sump system; and
- A float system and pump inside the sump for detecting and pumping the leakage for treatment.

Robertson and Clifton (1985) presented two cases of leakage collection system including sumps.

Case 1, Key Lake tailings storage system included pipes collecting leak from a tailings impoundment area and discharging it to sumps located downstream toe of the impoundment dike.

Case 2, Rabbit Lake in-pit disposal of tailings used a sump at the bottom of the pit. The sump collected the leakage and let it drift to a dewatering well for pumping and treatment.

The Key Lake and Rabbit Lake uranium mines are both located in Saskatchewan, Canada. Currently, there are no uranium mines in Nunavut or Northwest Territories (NT), Canada. Using lined sumps to collect seepage or leakage is a common practice in diamond mines in the north, such as Diavik mine and Snap Lake mine in NT, Canada, however, these sumps do not require double liner systems as required at the uranium mines.

5.3 Quantity Estimate

Estimated quantities for materials are listed in Table 5.3.

Table 5-3: Material Quantities (+/- 20%)

Material	Unit	Ore Pad	Ore Pond	Special Waste Pad	Special Waste Pond	Total
Catchment (Liner) area	(m^2)	54,700	9,000	123,600	12,600	199,900
Stripping area	(m^2)	71,700		148,400		220,100
3D Liner System Area	(m^2)	54,800	9,300	123,700	13,000	200,800
Cut	(m^3)	-	9,700	-	18,600	28,300
Rockfill (NPAG)	(m^3)	116,600	13,000	302,100	15,800	447,500
Sand	(m^3)	11,000	1,900	24,800	2,600	40,300
Non-Woven Filter Cloth*	(m^2)	126,100	21,400	284,600	29,900	462,000
80 mil (2mm) HDPE or LLDPE Liner*	(m^2)	126,100	21,400	142,300	29,900	319,700
Geogrid*	(m^2)	63,100	10,700	-	15,000	88,800
Rockfill (100 mm minus)	(m^3)	16,500	1,400	37,200	2,000	57,100
19 mm minus Gravel	(m^3)	-	1,400	-	2,000	3,400
Concrete	(m^3)	-	120	-	110	230

*Quantities include 15% contingency for seaming, wastage, and overlap.

6.0 DATA GAPS AND RECOMMENDATIONS

This conceptual design has been advanced based on available geotechnical data in the reports listed in Table 1.1. The following studies are recommended to address data gaps identified during the study.

- Geotechnical investigations of pad and pond foundations to define depth to bedrock at excavation locations, ground ice content and thermal regime.
- Laboratory testing to define the frictional strength of the liner system configurations should be undertaken to support feasibility level design.
- Assumptions for water quality of the sedimentation ponds, including potential for ARD, ML or content of radioisotopes are conservative. Further design stages may consider water quality predictions and the requirement for a double lined system may be reviewed.
- Further studies should consider the alignments and layouts of roads, diversion ditches, power lines and piping.

7.0 CLOSURE

We trust that this conceptual design meets your needs at this time. Should you have any questions, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

REGISTERED PROFESSIONAL ENGINEER
Sept 18/14
B.E. WICKLAND
LICENSEE
NWT/NU

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BEW/JCC/cf/dk/rs/jlj/ls

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PERMIT NUMBER
P 049
GOLDER ASSOCIATES LTD.

September 2014

REFERENCES

Cameco, 2008. A set of construction drawings for Phase III & IV Ore Pad, Key Lake Uranium Mine, prepared by EarthTech, a Tyco international Ltd. company for Cameco in April, 2008.

Golder (Golder Associates Ltd.), 2011. Kiggavik Project, Hydrology Baseline Document . Golder reference number: 09-1362-0612. Submitted to Areva Resources Canada Inc. in April 2011.

Robertson, A. MacG. and Clifton, A. (1985): "Design Concepts in Uranium Waste Management". Proceedings of Seminar on Waste Management, Saskatoon, Saskatchewan. 1985.

SERM (Saskatchewan Environment and Resource Management), 2000. Construction Guidelines for Pollution Control Facilities at Uranium Mining and Milling Operations. Drafted in October, 2000.

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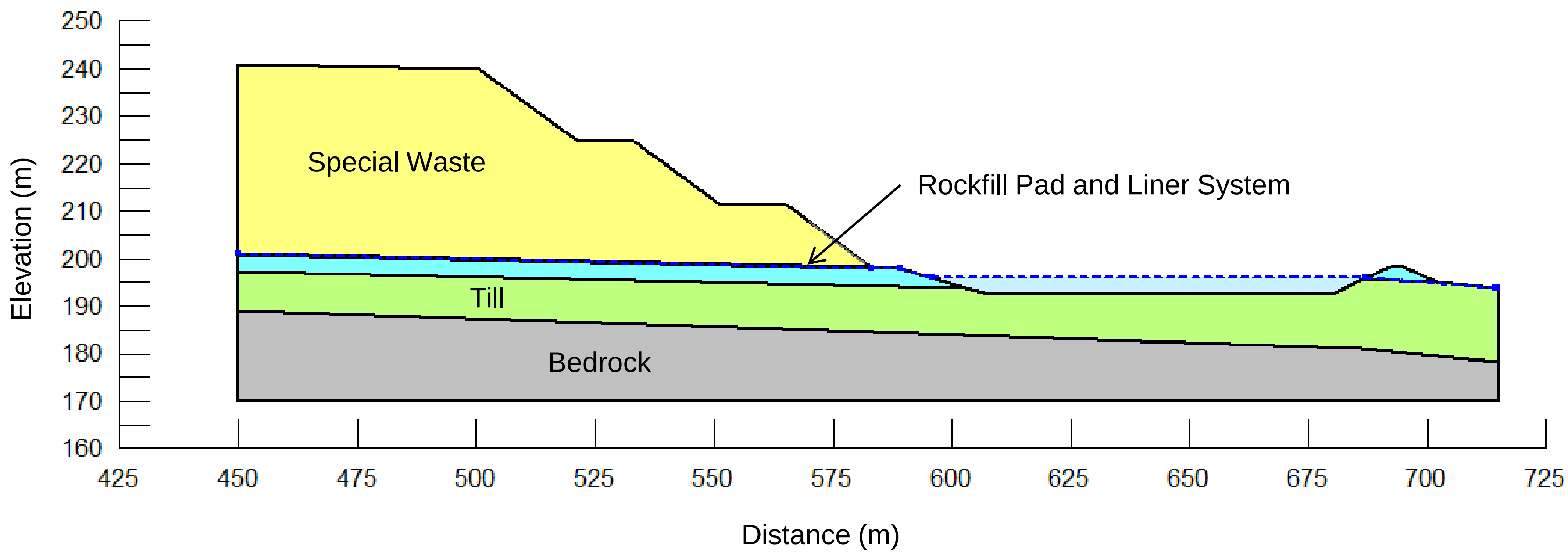

Material	Condition	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)	
Ore / Special Waste	unsaturated	20	38	0	
Rockfill Pad	saturated	23	38	0	
Rockfill Pad	unsaturated	20	38	0	
Liner System		15	17	0	
Till	saturated	22	32	0	
Bedrock	Impenetrable				

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STABILITY ANALYSIS SECTION

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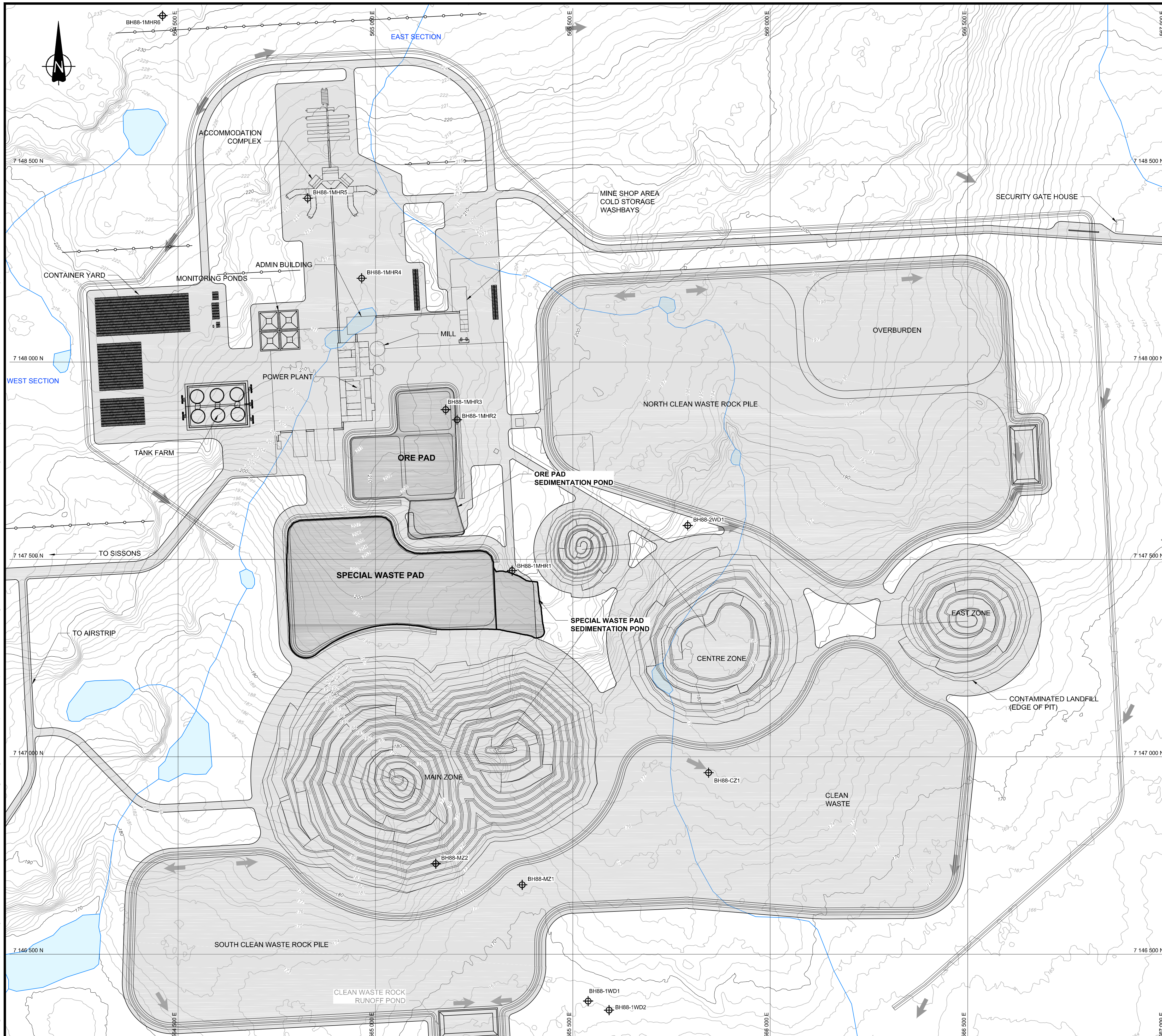
DESIGN	BW	14SEP11	SCALE NTS / REV. 0
CADD	BW	14SEP11	
CHECK			
REVIEW			

FIGURE 5.1

APPENDIX A

Drawings



LEGEND

- BH88-2WD1 — BOREHOLE LOCATION
- MAJOR CONTOUR
- MINOR CONTOUR
- STRUCTURE OUTLINE
- FENCELINE
- PROPOSED WATER DIVERSION CHANNELS
- FLOW DIRECTION

NOTES

1. ALL UNITS ARE IN METRES UNLESS OTHERWISE STATED.
2. TOPOGRAPHIC CONTOURS GENERATED FROM LIDAR SURVEY (SUMMER 2008 & 2009).
3. CONTOURS SHOWN AT 1m INTERVALS.
4. ELEVATIONS ARE REFERENCED T0 GEODETIC DATUM: NAD83 UTM, ZONE 14.
5. SITE PLAN: project_layout_revC.dwg.
6. PROPOSED WATER DIVERSION CHANNELS TO BE FINALIZED BY OTHERS.

NOT FOR CONSTRUCTION

0 50 100 150 200 250

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KIGGAVIK PROJECT
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TITLE
ORE AND SPECIAL WASTE PADS AND SEDIMENTATION PONDS KIGGAVIK SITE PLAN

PROJECT No.		10-1345-0026	PHASE 4	TASK -
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REVIEW	-	-		

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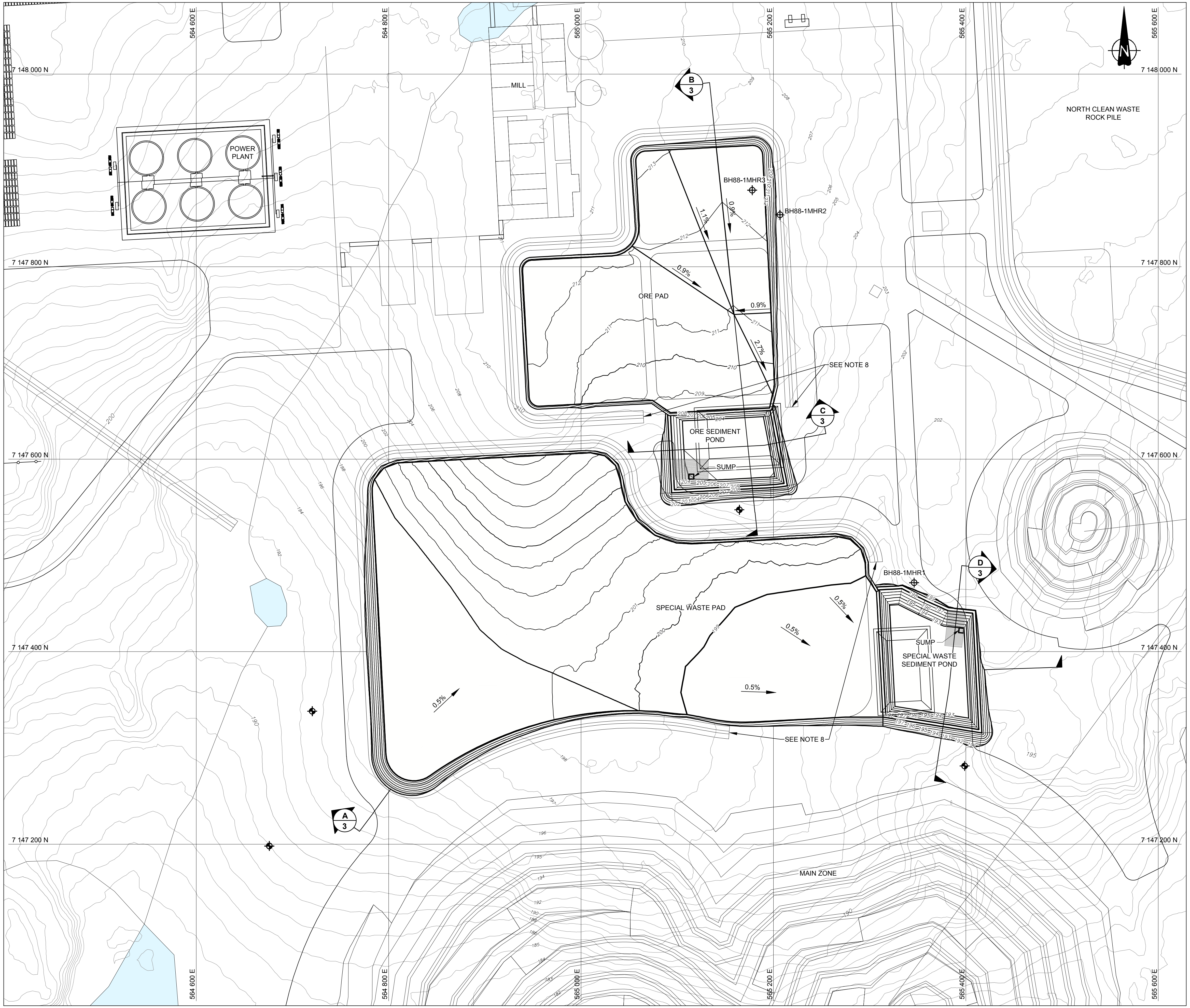

LEGEND

EXISTING MAJOR CONTOUR
EXISTING MINOR CONTOUR
DESIGN MAJOR CONTOUR
DESIGN MINOR CONTOUR
CREST
PROPOSED WATER DIVERSION CHANNELS
CONCRETE
BH88-2WD1 BOREHOLE LOCATION
PROPOSED MONITORING WELL

NOTES

1. ALL UNITS ARE IN METRES UNLESS OTHERWISE STATED.
2. TOPOGRAPHIC CONTOURS GENERATED FROM LIDAR SURVEY (SUMMER 2008 & 2009).
3. CONTOURS SHOWN AT 1m MINOR AND 5m MAJOR INTERVALS.
4. ELEVATIONS ARE REFERENCED T0 GEODETIC DATUM: NAD83 UTM, ZONE 14.
5. SEE DETAIL 2 FIGURE 4 FOR BERM CROSSING DETAIL.
6. ROCKFILL BERM SEPARATING PAD AND POND NOT SHOWN.
7. SITE PLAN: project_layout_revC.dwg
8. PROPOSED WATER DIVERSION CHANNELS TO BE FINALIZED BY OTHERS.

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0 20 40 60 80 100
SCALE IN METRES (SCALE 1:5)

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PROJECT No.		10-1345-0026	PHASE	4	TASK	-
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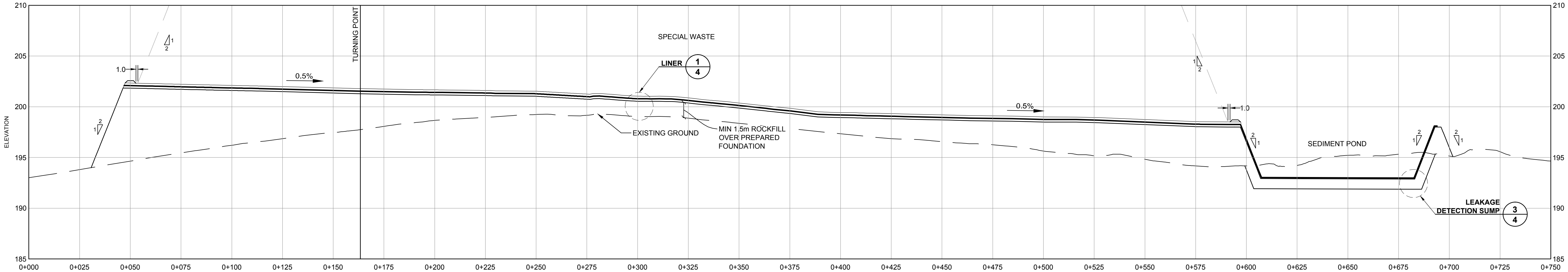
CHECK	-	-	DRAWING 2			
REVIEW	-	-				

Drawing File: N:\bur-graphics\Projects\2010\1345\10-1345-0026\Drafting\4\Figures\Conceptual Ore-Special Waste Design\10-1345-0026-4 ### DRAWING 2.dwg Tuesday, September 13, 2011 8:09:47 AM By: MHeal



A/2 **SPECIAL WASTE PAD SECTION**
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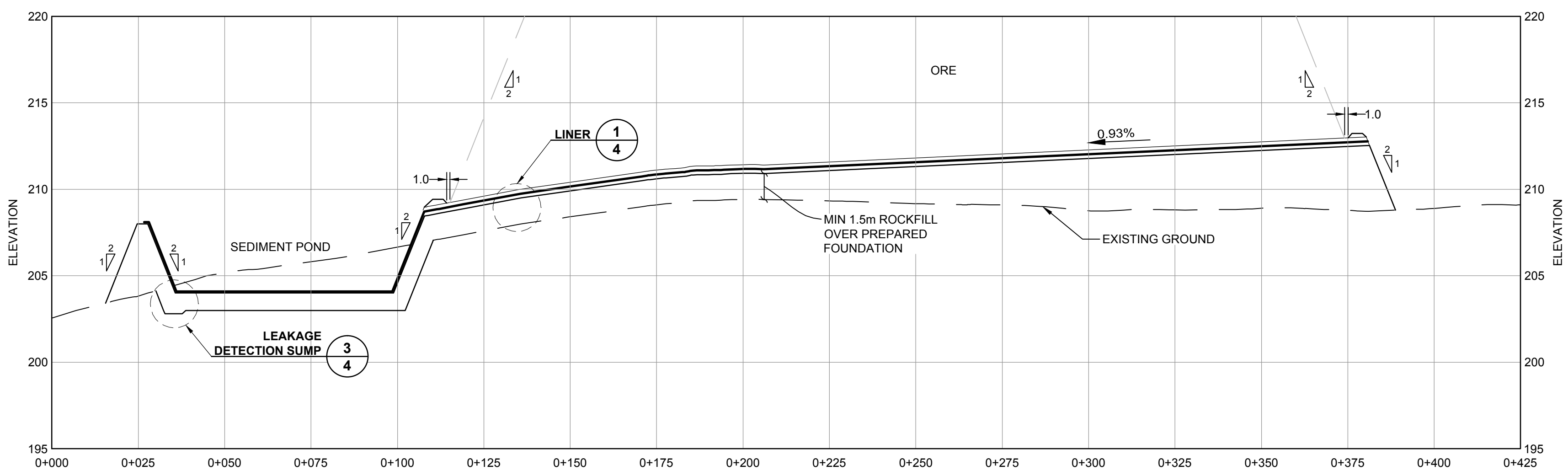

B/2 **ORE PAD SECTION**
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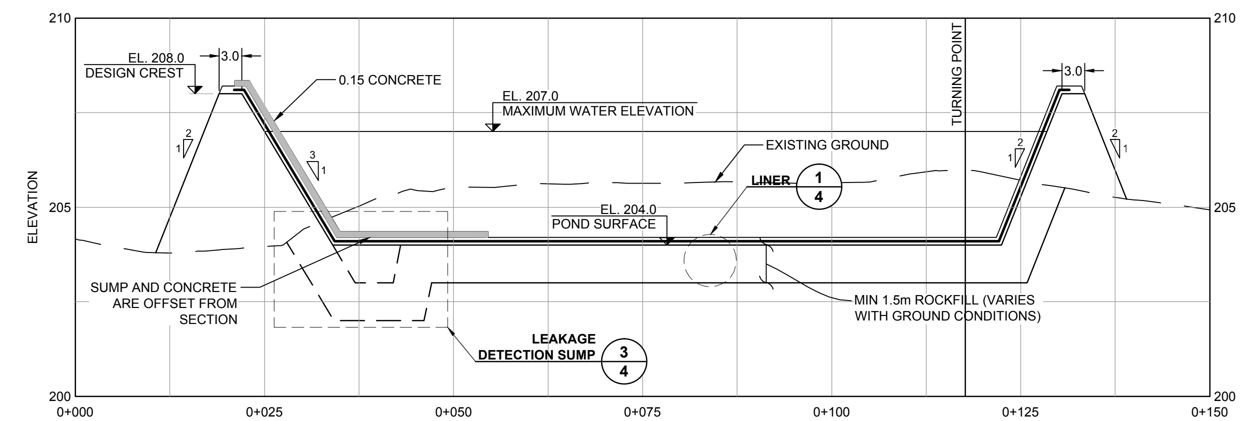

C/2 **ORE SEDIMENT POND SECTION**
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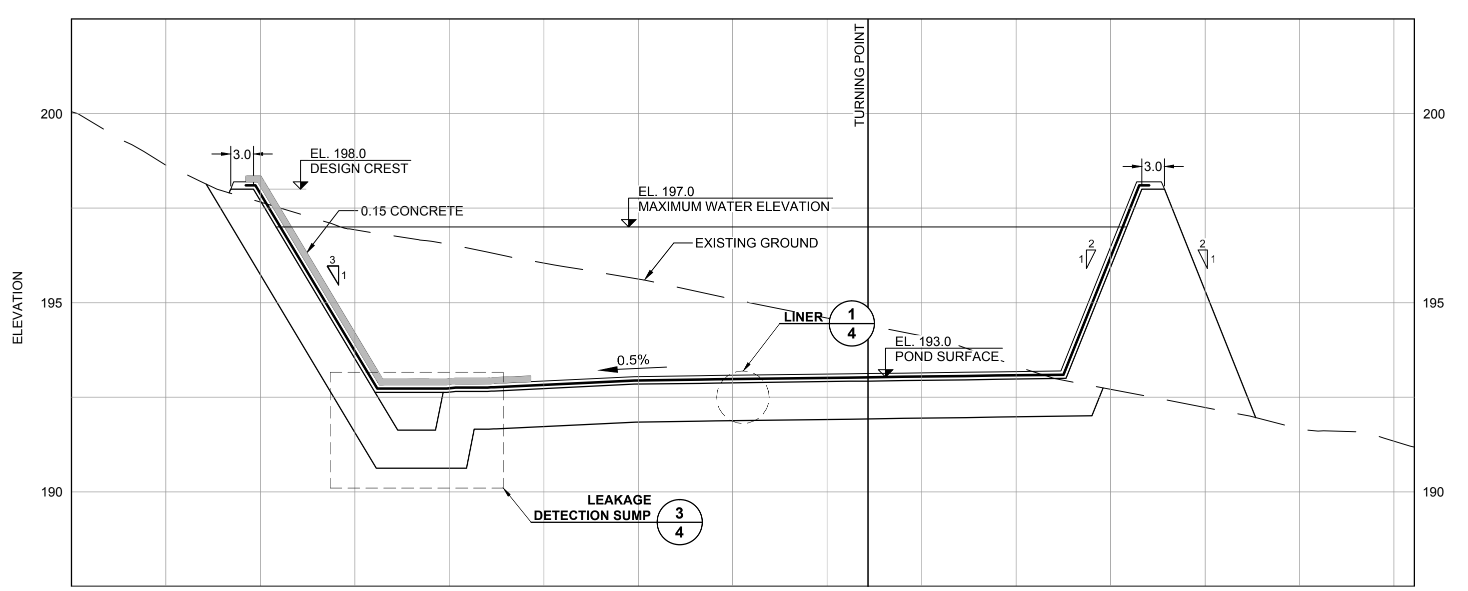

D/2 **SPECIAL WASTE SEDIMENT POND SECTION**
SCALE B (5X VERTICAL EXAGGERATION)

NOT FOR CONSTRUCTION

SCALE A (0 10 20 30 40 50)

SCALE B (0 5 10 15 20 25)

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PROJECT No.		10-1345-0026	PHASE 4	TASK -
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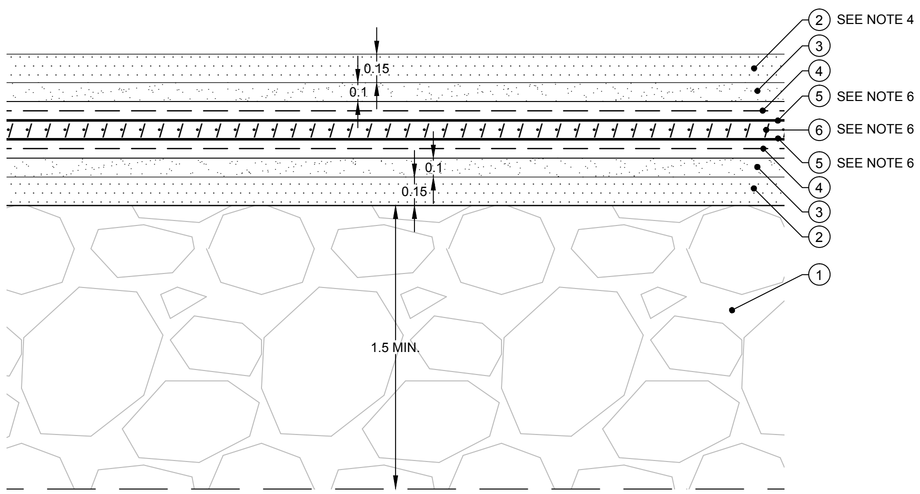
CHECK	-	-	DRAWING 3	
REVIEW	-	-		

MATERIAL LEGEND

1. ROCKFILL (NPAG)
2. ROCKFILL (100mm MINUS) (TRANSITION)
3. SAND
4. NON-WOVEN FILTER CLOTH
5. 80 mil (2mm) HDPE OR LLDPE LINER
6. GEOGRID
7. 19mm MINUS GRAVEL

NOTES

1. ALL UNITS ARE IN METRES UNLESS OTHERWISE STATED.
2. GEOTECHNICAL CONDITIONS TO BE CONFIRMED.
3. PUMPING THERMISTOR AND ELECTRICAL NOT SHOWN.
4. POND SURFACE REPLACE ROCKFILL TRANSITION WITH GRAVEL.
5. CONCRETE AND REINFORCEMENT TO BE DESIGNED AT LATER STAGE.
6. SPECIAL WASTE PAD INCLUDES 1 LAYER OF 80mil (2mm) HDPE OR LLDPE LINER ONLY.



1/3 **TYPICAL LINER SYSTEM DETAIL**
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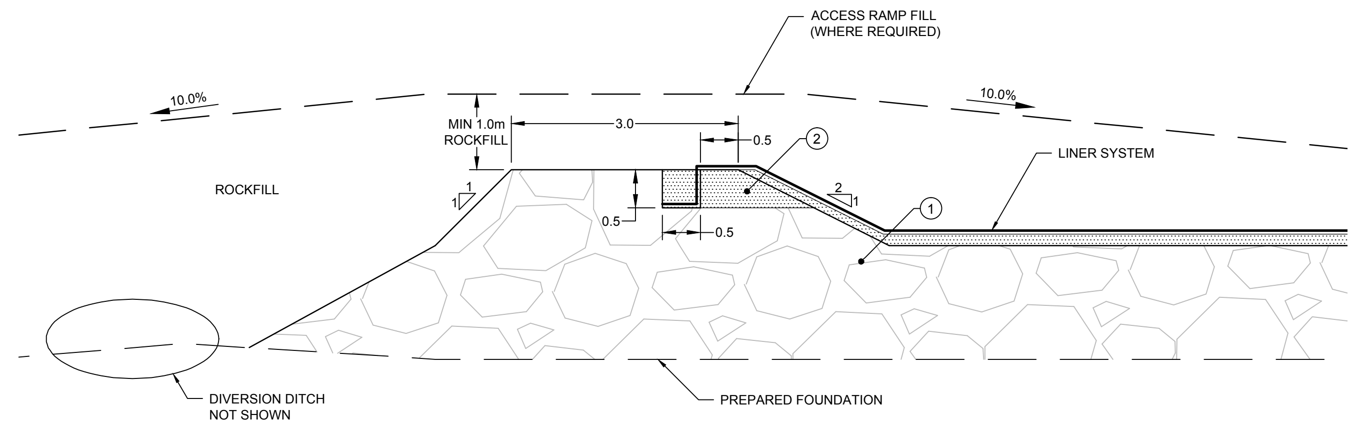
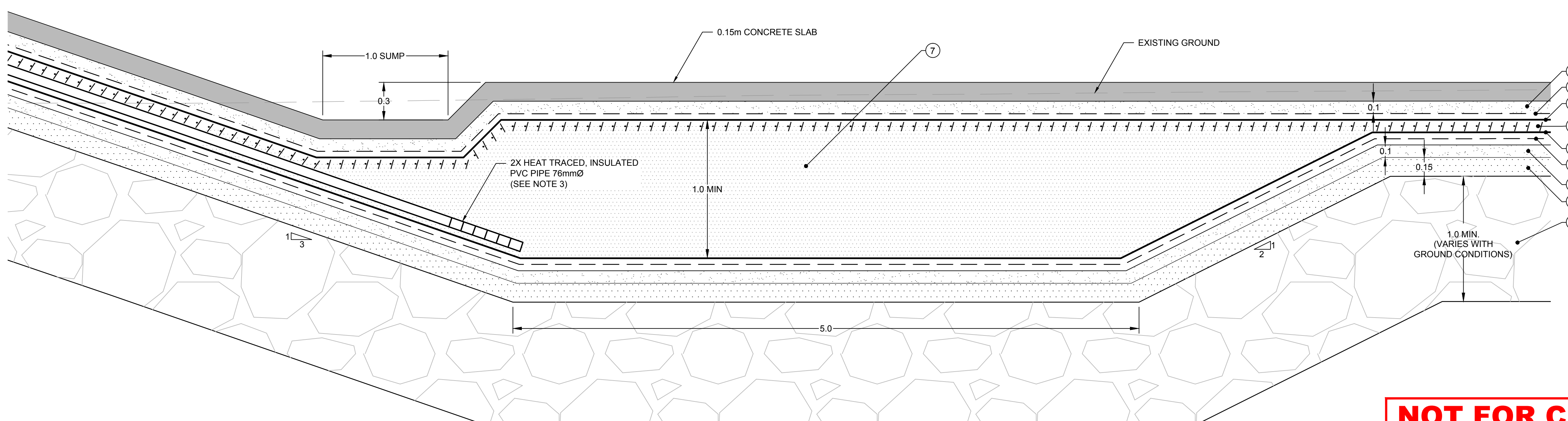


2/- **TYPICAL PAD LINER BERM TIE-IN AND BERM CROSSING DETAIL**
SCALE B



3/3 **LEAKAGE DETECTION SUMP TYPICAL SECTION**
SCALE A

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SCALE A

0 0.5 1.0 1.5 2.0 2.5
SCALE B

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CHECK	-	-			
REVIEW	-	-	**DRAWING 4**		

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