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REPORT ON

BLAST DESIGN
MEADOWBANK GOLD PROJECT
NUNAVUT

Submitted to:

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February 10, 2004 03-1413-427

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1.0 INTRODUCTION

Cumberland Resources Ltd. is currently evaluating the development of the Meadowbank Gold Project located some 70 km north of Baker Lake, Nunavut (Figure 1). This report will address the drilling and blasting operations related to open pit mining. This report should be read in conjunction with detailed geotechnical design reports.

1.1 Ore Deposits

The Meadowbank Gold Project consists of several gold bearing deposits within reasonably close proximity to one another (Figure 2). These are:

- Third Portage Deposit (including Bay Zone and Connector Zone).
- North Portage Deposit.
- Goose Island Deposit.
- Vault Deposit.

The Third Portage Deposit is located on a peninsula, and extends northward under Second Portage Lake, and southward under Third Portage Lake. The Goose Island Deposit lies some 1000 m to the south of the Third Portage Deposit, and beneath Third Portage Lake. The North Portage Deposit is located on the northern shore of Second Portage Lake, and is interpreted as an extension of the Third Portage Deposit. The Vault Deposit is located some 5 km to the northeast of the North Portage Deposit.

1.2 Mining

Mining of the deposits will be primarily by open pit production. Many of the deposits are situated adjacent to, or beneath, lakes. Consequently, a series of dikes will need to be constructed to allow mining of the deposits where these occur beneath the lakes.

1.3 Deposit Characteristics

The deposits of the Meadowbank Project generally consist of stratabound gold mineralization associated with fold limbs inclined at steep angles (>60 degrees) to shallow angles (<30 degrees). The gold mineralization at the Goose Island and Portage Deposit areas is generally associated with iron formation rock. The gold mineralization at the Vault Deposit is associated with intermediate volcanic rock.

Drill and blast designs have been developed for the project rather than for individual deposits. This is primarily due to the similarity in rock type, rock mass quality, and structure throughout the various deposits.

2.0 SUMMARY OF GEOMECHANICAL PROPERTIES

As part of the geotechnical investigations information was gathered on both the intact rock and discontinuity properties of the rock units at the project site. For the purposes of developing drill and blast designs summary information has been extracted from the larger geotechnical database. Complete geotechnical assessments for the various deposits have been issued in a series of Technical Memoranda over the period of August to December 2003, and January 2004. Typical cross sections through the deposits are shown on Figures 3 through 6.

2.1 Geotechnical Model

The following summarizes the geotechnical model for the Goose Island, Portage, and Vault Deposit areas.

- There are three main rock types: iron formation, intermediate volcanic, and ultramafic volcanic. A fourth rock type, quartzite, may form substantial portions of the upper west pit wall of the Goose Island and Portage Deposits. The ultramafic volcanic rock may be serpentinized, and where this occurs, may be considerably weaker than the non-serpentinized ultramafic rock.
- The sheared and faulted stratigraphic contacts, and overall foliation orientations for the Third Portage and Goose Island Deposits will dip at steep angles (>60 degrees) to the west at the eastern and western margins of these deposits. They will dip at shallower angles (<30 degrees) to the west through the central portion of the Third Portage Deposit, at the north end of the Third Portage Deposit, through the Connector Zone, and at the North Portage Deposit.
- The sheared stratigraphic contacts and overall foliation orientations at the Vault Deposit will dip to the south and southeast at inclinations between about 20 degrees and 30 degrees.
- The stratigraphic contacts are considered to be continuous structures, and will control bench scale and pit wall stability. The orientation of the contacts can be assumed to follow the general trend of the overall foliation orientations for the deposit area, although the foliation may exhibit a high degree of variability on a local scale.
- The iron formation, intermediate volcanic rock, and quartzite are expected to have good rock mass quality. The ultramafic rock is expected to have fair to good rock mass quality.
- Overall pit slope configurations will be controlled by the sheared and faulted main stratigraphic contacts.

2.2 Rock Properties

The Table 2-1 summarizes the results of laboratory strength testing of rock core samples. These are average values based on valid test results of samples collected from Goose Island, Third Portage, North Portage, and Vault. The values for Young's Modulus have been estimated from quality values for the individual rock types.

Table 2-1: Summary of Rock Strength Properties

Rock Type	Minimum Unconfined Compressive Strength (MPa)	Maximum Unconfined Compressive Strength (MPa)	Average Unconfined Compressive Strength (MPa)	E (GPa)	Density (g/cc)
Intermediate Volcanic	51.0	148.3	94	46	2.75 to 2.89
Iron Formation	137.1	248.3	175	50	3.44
Quartzite	69.5	140.1	107	46	2.70
Ultramafic	40.2	91.6	66	25	2.91

2.3 Discontinuity Properties

The orientation, spacing and condition of discontinuities in the rock mass can influence the determination of drill and blast designs. Table 2-2 is a summary level description of the discontinuity parameters relevant to this design procedure.

Table 2-2: Summary of Main Discontinuity Properties – Portage and Goose Island Deposits

Type	Dip	Dip Direction	Average Spacing (m)	Joint Roughness and Condition	Large Scale Joint Roughness
Foliation	12 – 73	255 – 300	0.5 – 1.5	Smooth to rough and planar, slightly altered.	Rough and Wavy
Orthogonal	76 – 10	067 – 121	1.4 – 12	Smooth and wavy, slightly altered.	Rough and Wavy
CJ1	43 – 79	201 – 237	2.5 – 11.4	Smooth and wavy, slightly altered.	Rough and Wavy
CJ2	36 – 81	025 – 068	2.5 – 8.3	Smooth and wavy, slightly altered.	Rough and Wavy
CJ3	65 – 86	125 – 148	1.2 – 9.5	Smooth and wavy, slightly altered.	Rough and Wavy
CJ4	58 – 73	299 – 340	1.0 – 7.0	Smooth and wavy, slightly altered.	Rough and Wavy
Cross	46 – 63	002 – 031	0.4 – 19.4	Smooth and wavy, slightly altered.	Rough and Wavy
Cross	62 – 88	341 – 350			
Cross	26 – 62	170 – 191			

Table 2-3: Summary of Main Discontinuity Properties – Vault Deposit

Type	Dip	Dip Direction	Average Spacing (m)	Joint Roughness and Condition	Large Scale Joint Roughness
Foliation	21 – 23	136 – 164	0.5 – 0.8	Smooth to rough and planar, slightly altered to staining.	Rough and Wavy
Orthogonal	60 – 70	333 – 336	2.8 – 8.1	Rough planar to smooth wavy, no alteration.	Rough and Wavy
CJ1	83 – 85	197 – 209	1.7 – 7.4	Smooth to rough planar, slightly altered to none.	Rough and Wavy
CJ2	80 – 82	040 – 053			
East Dipping	67 – 81	086 – 108	3.7 – 6.1	Smooth and wavy, slightly altered to none.	No Data
South Dipping	45 – 48	174 – 198	2.8 – 14.3	Smooth to rough planar, slightly altered.	No Data
Cross	73	253	4.4	Rough planar to smooth wavy, no alteration.	No Data
Flat	10 – 13	330 - 335	8.3	Rough planar to smooth wavy, no alteration.	No Data

2.4 Pit Slope Design Configurations

The general bench configurations for the north and south end walls of the Goose Island, Portage, and Vault Deposits, and the west pit walls for the Goose Island and Portage Deposits, are given in the Table 2-4.

Table 2-4: General Bench Configurations

Bench Face Angle	Operating Bench Height, m	Final Bench Height, m	Bench Width, m	General Wall Application		
				Goose Island	Portage Pits	Vault Pit
60° to 70°	12 (6m in ore)	24	8 to 10 m	North South West	North South West	West South East

For the east pit wall of the Goose Island and Portage Pit, and the west pit wall of the Vault Pit, a footwall design philosophy will be used whereby pit slopes will be excavated parallel to the dip of the stratigraphy to avoid undercutting the sheared stratigraphic contacts.

Table 2-5: Footwall Design Criteria

Dip of Faulted Contacts	Slope Configuration	
<30° to 35°	**Unbenched Slope**	Parallel to Bedding/Stratigraphy/Faulted Contacts
>35°	**Bench Face Angle:**	Parallel to Bedding/Stratigraphy/Faulted Contacts to a maximum 70°
	Bench Height:	24 metres
	Catch Bench Width:	10 metres
	Inter-Ramp Angle:	32° to 52° dependent on bench face

For the purposes of production blast design, the proposed pit area has been divided into sectors on the basis of the general orientation of the main structural features that may influence the effectiveness of the blast design. Consequently, there are potentially four wall orientations for the production blasts. These are:

- West facing walls.
- East facing walls.
- North facing walls.
- South facing walls.

The dominant structural influence on blast design will be the orientation of the main stratigraphic contacts, and axial planar foliation. The spacing of the foliation is expected to be on the order of 1 m to 2 m. The secondary structural influence on the blast design will be the orientation of the orthogonal jointing. As discussed previously, the orthogonal joints are expected to be discontinuous but systematically distributed throughout the various rock types in the deposit area. The spacing of these features is expected to be on the order of several metres.

2.5 Permafrost

The site is located in the zone of continuous permafrost. Based on thermistor installations at the site, the permafrost is well developed. The active layer is between 1.5 m and 2 m below the ground surface. Permafrost temperatures beneath the landmass are on the order of –8 degrees C. Permafrost temperatures are expected to be warmer adjacent to and beneath lakes. Where mining occurs in de-watered area of the lake, talik zones will be present. Water inflows to the open pits will therefore occur through the talik.

Successful blast design in Arctic environments carries with it the need to understand the nature of permafrost, and the effect permafrost may have on the blast design. Based on site instrumentation, the permafrost underlying the land mass is expected to be cold;

hence the drilled blast holes are likely to be dry. Where pit walls are excavated within the talik underlying the de-watered lakes, the drilled blast holes are expected to be wet.

The overall strength and modulus of the rock mass may be enhanced by the presence of permafrost, and this may have an effect on blasting results. The presence of permafrost may also influence stress induced fracturing and gas penetration if the fractures are ice filled.

2.6 Groundwater

The current operational plan to develop the Portage Pit will involve initial draw-down of the Second Portage Lake arm to a level approximately 28 m below the current lake surface elevation. Based on the lake bathymetry survey carried out in 2002, a north trending ridge is located to the west of the North Portage deposit. The water will be drawn down below this ridge, which will aid as a natural barrier to restrict flow into the open pit. In addition to drawing down of the lake, a tailings dike will be constructed west of the pit crest. At this time, a minimum setback of 80 m from the proposed crest of the open pits to the inside (pit side) toe of the de-watering dikes has been assumed. The central core of the dike will be located on the order of 100 m back from the pit crest.

The overburden is expected to consist of silt, sand and gravel till, with areas of sand and gravel deposits possibly of glacio-fluvial origin.

The hydraulic conductivity within the overburden is estimated to be 1×10^{-5} m/s. The hydraulic conductivity of the shallow bedrock (less than 25 m) is generally higher than that of the deeper bedrock (greater than 25 m). The geometric mean value of the shallow bedrock is approximately 1×10^{-6} m/s while that of the deeper bedrock is 1×10^{-8} m/s. Based on the hydraulic conductivity testing carried out to date at the site, the hydraulic conductivity of the Bay Zone Fault and Fault Splay is similar to that of the less fractured rock, while the hydraulic conductivity of the Second Portage Fault is higher at 5×10^{-6} m/s.

Potential sources of water inflows to the open pit will be from water stored in the overburden sediments, through potentially hydraulically conductive structures such as the Second Portage Lake Fault, and through the talik beneath Second Portage Lake. Initial estimates of water inflow to the Third Portage pit and North Portage pit through the bedrock talik are on the order of 250 m^3/day and 350 m^3/day, respectively (Ref. "Predictions of Groundwater Inflow to Open Pits – Meadowbank Project", Technical Memorandum, 6 Feb. 2004). Pit inflows along the Second Portage Lake Fault have initially been estimated to be on the order of 50 m^3/day to 100 m^3/day.

Based on this information, blasting will have to be undertaken in both wet and dry conditions. Explosive selection will be influenced by the presence of water.

3.0 BLAST DESIGN

3.1 Lilly's Blastability Index

An empirical method to assess the blastability of a rock mass was developed by Lilly (1986, 1992). The method takes into account both geotechnical factors, geological (structure) factors, and physical properties of a rock mass to arrive at an index rating known as the Blastability Index, or BI.

The following factors determine the Blastability Index:

1. Rock Mass Description (RMD): The Rock Mass Description is concerned with the overall character of the rock, and considers whether the rock is massive with little to no structural character, blocky with systematic jointing, or powdery and friable. The fragmentation of a massive rock will depend largely on the strain energy of the blast inducing fractures in the rock mass. The fragmentation of a heavily jointed rock mass will be controlled more so by the orientation of the joint systems.

2. Joint Plane Spacing (JPS): The Joint Plane Spacing refers to the spacing between all planes of weakness in the rock mass. Lower energy factors are required to break a rock mass having closely spaced joints. This value can be determined as the Block Size Index (Ib) as described by ISRM "Suggested Methods for the Quantitative Description of Discontinuities" (1978). The block size index represents the average dimensions of typical rock blocks, and is based on modal spacing of the joints.

3. Joint Plane Orientation (JPO): The Joint Plane Orientation accounts for the influence of major structural orientations on the distribution of the strain energy in a blast. The orientation of the major joint or bedding planes can significantly impact blasting results.

4. Rock Density Influence (RDI): The Rock Density Influence affects the blastability of the rock as greater energy is required to fragment a heavier rock mass than a lighter rock mass. The RDI is given by:

$$RDI = 25 \times \text{Rock Density } (t/m^3) - 50$$

5. Hardness Factor (HF): The Hardness Factor links the blastability of a rock mass to the Young's Modulus (γ) of weaker rocks where γ is less than 50 GPa (weak confinement). For stronger rock masses (γ > 50 GPa, strong confinement), the Hardness Factor is linked to the Unconfined Compressive Strength of the rock (in MPa). The hardness

The index has a maximum value of 100 corresponding to extremely hard, iron rich cap rock having a specific gravity of 4 t/m^3, while weaker rocks, such as shale, have indices of about 20.

The Blastability Index is defined as:

$$BI = [0.5 \times (RMD + JPS + JPO + RDI + HF)]$$

Where:

RMD = Rock Mass Description
JPS = Joint Plane Spacing
RDI = Rock Density Influence
HF = Hardness Factor

The Blastability Index is used to determine an appropriate powder factor and in the Kuz-Ram model for rock fragmentation to determine the parameter Rock Factor A.

Table 3-1: Blastability Index and Rock Factor for Meadowbank Rock Types

Rock Type	Iron Formation	Intermediate Volcanic	Ultramafic	Quartzite
Rock Mass Description	50	50	20	50
Joint Plane Spacing	50	50	50	50
Joint Plane Orientation	20	20	20	20
Rock Density Influence	30	18	18	18
Hardness Factor	14	15	9	15
BLASTABILITY INDEX, BI	**82**	**76**	**58**	**76**
Rock Factor, A (0.12*BI)	9.8	9.1	7.0	9.1

3.1.1 Blast Hole Diameter, D (mm)

The selection of an appropriate blasthole diameter is important in terms of fragmentation and cost. Ideally, it is desirable to obtain the maximum fragmentation at a minimum cost. The cost of drilling and of explosives decreases as the diameter of the blasthole increases. Other factors must be considered such as bench height, rock structure and rock hardness. Smaller diameter blastholes are more suited to strongly jointed rocks as the decreased spacing results in fewer joints between holes. This will tend to reduce the amount of oversize and result in better fragmentation.

Based on discussions with Cumberland the blasthole diameter will be 165 mm (6½ in.) with the capability of drilling larger diameter blast holes. Alternative designs are presented for larger blastholes of 229 mm (9 in.).

3.2 Explosive Selection

The project is located in the zone of continuous permafrost. Known permafrost temperatures in the area are as low as -8 to -10 degrees C. The depth of the active layer is between 1.5 m and 2 m. Much of the pit wall development will be within talik zones beneath de-watered lakes, and consequently will be unfrozen during development. These conditions will result in wet blast holes. Consequently, the water resistance of the chosen explosive must be considered. Where pit wall development will be within permafrost (i.e., beneath the existing land surface) dry blasthole conditions may exist. Under these circumstances, a product having a lower resistance to water may be considered.

3.2.1 ANFO

The location of the site is remote. Therefore, cost is a consideration. Ammonium nitrate-fuel oil, or ANFO, is the least expensive explosive used by the mining industry. However, the water resistance of ANFO is poor, and it can be desensitized relatively easily even with low water contents. The effect on ANFO of the presence of water in the blasthole has been overcome by a number of methods. Dewatering equipment can be used to dewater the blastholes before loading. The ANFO is then loaded using dryliners, or polythene tubing sealed at the bottom and installed in the blasthole. For surface mining, the ANFO is handled by bulk mix trucks.

3.2.2 ANFO/Emulsion Mixtures

An alternative to ANFO that overcomes some of the problems associated with water resistance, is an ANFO/emulsion mixture. The amount of emulsion added to the mixture varies depending on the energy and water resistance requirements. The use of emulsion improves the bulk strength of the explosive and allows for an increase in breakage capacity. Since the ANFO can be surrounded by emulsion, the water resistance of the product is enhanced considerably from that of straight ANFO.

Table 3-2: Typical Properties of ANFO/Emulsion Mixtures

ANFO (%)	Emulsion (%)	Density (g/cc)	Velocity of Detonation (m/s)	RWS/RBS	Minimum Diameter (mm)	Water Resistance	Loading
30	70	1.3	5700	84/132	115	Excellent	Pump
50	50	1.3	5500	89/141	150	Good	Auger
70	30	1.2	4700	93/131	125	Poor	Auger
75	25	1.1	4600	94/127	100	Poor	Auger

Reference: Dyno Nobel, Inc.

Given that the conditions in the talik areas will be wet and that there will be some water infiltration through and under the dike it is recommended that a "doped" emulsion be used. At this stage a 70:30 (emulsion:ANFO) mixture is recommended. Pumpable blends have better water resistance than augerable blends which tend to lose their water resistance as the percentage of emulsion decreases. Where blasthole conditions are found to be dry, alternative blast designs (30:70 Emulsion:ANFO) can be considered.

3.3 Blast Design Assumptions

The production blast design criteria were formulated on the basis of the engineering geological models for the deposits. Basic assumptions used for the process were:

- A doped emulsion will be used (70:30, emulsion:ANFO) to address potentially wet blasting conditions.

- The available equipment will be capable of drilling blasthole diameters ranging from 165 mm (6½ in) up to 229 mm (9 in). For the 12 m working benches, the larger blasthole size is appropriate to optimize fragmentation, reduce drilling inaccuracy, and reduce the number of blastholes required. For the 6 m high benches in ore, the smaller diameter blasthole is appropriate. **However, it is important to note that the critical diameter of the doped emulsion product is close to 165 mm (6½ in). This could potentially result in incomplete detonation of the product and poor fragmentation of the rock for smaller diameter holes.**

- A staggered pattern with millisecond delays and en echelon firing sequence shooting from a corner is assumed. An inter-hole 25 ms delay is suggested. The staggered pattern will result in better distribution of the explosives energy and consequently better movement of material and a lower muckpile for easier digging. If it is necessary to blast to one free face, a staggered V1 (flat) pattern should be used.

- Operating bench heights within the waste rock will be 12 m. Operating bench heights within the ore will likely be 6 m to facilitate grade control. A high degree of care and attention to blast design will be required.

- Final benches will generally be double-benched to 24 m. Single benching (12 m) in areas that may be susceptible to toppling failure may be required.

- The length of the blasted block will be a minimum of twice the width, which will be between three and five rows for production blasts.

- The bench face angles will generally be steep, between 60 and 70 degrees and hence vertical blastholes have been assumed. Inclined blastholes could improve the consistency of the burden and the efficiency of fragmentation, however, accuracy of drilling angled holes is difficult to achieve, particularly with smaller diameter blastholes.

3.4 Production Blast Design

The following tables summarize the blast designs considered for the Meadowbank Project.

Table 3-3: Blasthole Parameters

	Units	Constant Blasthole Diameter		Blasthole Diameter based on Bench Height	
		Waste	ORE	Waste	ORE
Working Bench Height	m	12	6	12	6
Blasthole Diameter	mm	165	165	229	165
Bench Face Angle	degrees	60 - 70	60 - 70	60 – 70	60 – 70
Hole Inclination	deg	90	90	90	90
Inclined Depth	m	12.0	6.0	12.0	6.0
Subdrill	m	1.3	1.3	1.8	1.3
TOTAL DRILLED DEPTH	**m**	**13.3**	**7.3**	**13.8**	**7.3**

Table 3-4: Blast Patterns

Blasthole Pattern	Staggered
Blast Sequence	En Echelon
Spacing/Burden Ratio	1:1.15
Number of Rows	5
Number of Holes per Row	10

Table 3-5: Charge Table – Wet Blastholes (Emulsion:ANFO 70:30)

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste			229 mm Blasthole, 12 m bench in waste	
		Ore	IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	3.8	5.4	5.4	5.7	5.9
Fallback	m	0.1	0.2	0.2	0.2	0.2
Charge Length	m	3.4	7.7	7.7	7.9	7.7
Linear Charge Density	kg/m	27.8	27.8	27.8	53.6	53.6
Burden	m	5.0	5.0	5.0	6.9	6.9
Spacing	m	5.7	5.7	5.7	7.9	7.9
Burden Volume	m^3	169	338	338	651	651
Explosives Mass per Hole, Q	kg	95	215	215	424	412
Powder Factor, PF	**kg/m^3**	**0.56**	**0.63**	**0.64**	**0.65**	**0.63**

The proposed general blast configuration is shown on Figure 7. Where blasting occurs within the shallow dipping ore and stratigraphy, a conceptual blast design is shown on Figure 8. For areas where toppling may be a concern, a conceptual blast design layout is shown on Figure 9.

In areas where dry blasthole conditions are encountered the following designs can be adopted.

Table 3-6: Charge Table – Dry Blastholes (Emulsion:ANFO 30:70)

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste			229 mm Blasthole, 12 m bench in waste	
		Ore	IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	3.5	4.8	4.7	5.1	5.3
Fallback	m	0.1	0.2	0.2	0.2	0.2
Charge Length	m	3.7	8.3	8.3	8.5	8.3
Linear Charge Density	kg/m	25.7	25.7	25.7	49.4	49.4
Burden	m	5.0	5.0	5.0	6.9	6.9
Spacing	m	5.7	5.7	5.7	7.9	7.9
Burden Volume	m^3	169	338	338	651	651
Explosives Mass per Hole, Q	kg	95	214	216	422	412
Powder Factor, PF	**kg/m^3**	**0.56**	**0.63**	**0.64**	**0.65**	**0.63**

3.4.1 Rock Fragmentation

The predicted fragmentation of the rock mass for the blast designs presented above is based on the Kuz-Ram Model (Cunningham. 1983; Kuznetsov, 1973; Rosin and Rammler 1933). The Rosin-Rammler equation defines the grain size curve for rock fragmentation. The Kuznetsov equation gives the mean fragmentation size when the Rosin-Rammler equation is equal to 0.5, or the point on the grain size curve with the mesh size that 50% of the blasted rock would pass. The following table summarizes the predicted rock fragmentation for the preceding design criteria, and for a five row blast pattern with ten holes per row. The predicted fragmentation curves are contained in Appendix I. The predicted fragmentation assumes a ratio of actual to theoretical VOD of 0.85, although this ratio could be as high as 0.95 if the bulk product is well mixed.

Table 3–7: Predicted Fragmentation (Emulsion:ANFO 70:30)

Rock Type	Bench Height, m	Hole Size, mm	t/blast, t[1]	Powder Factor, kg/m^3	50% passing, m	80% passing, m	Characteristic Size, m
Iron Formation	6 m	165 mm	29,412	0.56	0.51	1.1	0.70
Ultramafic	12 m	165 mm	46,170	0.63	0.38	0.72	0.50
Intermediate Volcanic	12 m	165 mm	47,880	0.64	0.49	0.94	0.65
Ultramafic	12 m	229 mm	88,306	0.63	0.42	0.79	0.55
Intermediate Volcanic	12 m	229 mm	91,577	0.65	0.54	1.01	0.71

1. Assumes 5 rows and 10 holes per row.

3.5 Controlled Blasting for Final Walls

Trim blasting should be used to shape the final wall. Trim blasting uses large-diameter blastholes for both production and final row holes and thus eliminates the additional costs associated with small diameter blasthole drilling. The trim row is designed as the last row of the blast.

The trim row burden volume should be approximately one-third of the volume of the production row and should be loaded with sufficient explosive to maintain the same powder factor as for the production row. The burden volume of the two buffer rows in front of the trim row should be approximately two-thirds of the rock volume of the production holes. The buffer rows should be loaded to maintain the same powder factor as for the production row. A typical layout for a trim and buffer blast for final wall shaping is shown on Figures 7 through 9 and will be applicable to areas of the final pit walls of the Goose Island, Portage, and Vault pits.

Table 3-8: Charge Table – Trim Blast

Rock Type	Units	165 mm Blasthole, 12 m bench		229 mm Blasthole, 12 m bench	
		IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	4.1	4.1	5.7	5.7
Fallback	m	0.2	0.2	0.2	0.2
Charge Length	m	9.0	9.0	7.9	7.9
Linear Charge Density	kg/m	6.3	6.4	13.7	13.4
Burden	m	2.5	2.5	3.4	3.4
Spacing	m	3.0	3.0	4.1	4.1
Burden Volume	m^3	90	90	167	169
Explosives Mass per Hole, Q	kg	57	58	109	107
Powder Factor, PF	**kg/m^3**	0.63	0.64	0.65	0.63

Table 3-9: Charge Table – Buffer Blast

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste		229 mm Blasthole, 12 m bench in waste	
		IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	4.1	4.1	5.7	5.7
Fallback	m	0.2	0.2	0.2	0.2
Charge Length	m	9.0	9.0	7.9	7.9
Linear Charge Density	kg/m	11.7	11.9	26.0	25.2
Burden	m	3.5	3.5	4.8	4.8
Spacing	m	4.0	4.0	5.5	5.5
Burden Volume	m^3	168	168	317	317
Explosives Mass per Hole, Q	kg	106	108	206	200
Powder Factor, PF	**kg/m^3**	0.63	0.64	0.65	0.63

Certain areas of the east pit wall of the Portage and the Goose Island pits will be excavated within shallow dipping structure, with bench face angles paralleling the stratigraphic contacts and foliation orientations. In these areas, the length of the trim holes will be shortened substantially. Pocket charges may be required to improve fragmentation. Alternatively a series of stab holes may be drilled between the trim and buffer rows.

In certain areas of the west wall of the Portage and Goose Island pits, the potential for toppling failure exists. This will be particularly true adjacent to the Bay Fault. In these areas, it may be necessary to alter the geometry of the buffer and trim rows.

3.6 Nitrate/Ammonia Considerations

The use of nitrate based explosives products in a wet environment increases the potential for nitrogen (as nitrate, nitrite or ammonia) to enter the water system. In order to minimize any potential impacts an effective explosives management system should be implemented as part of production startup. The management strategy should include the following:

- An education program for all production employees that outlines the potential problem and appropriate mitigation techniques.
- A spill handling procedure.
- A monitoring program that is integrated with baseline water quality information.
- A review of blasting operations early in production to determine efficiency levels.

3.7 Blast Induced Vibration

Blast induced vibrations have the potential to reduce the stability and performance of nearby earthen structures such as dikes. Where saturated conditions exist within the foundation materials and within the earthen structural fills of the de-watering dikes and the tailings dike, blast induced vibrations could result in the development of increased pore water pressures within the foundation and structural fill materials. This could lead to potential settlement of the structures and consequently impact to the water retaining capacity of the dikes.

As part of the mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting. The data from this program would be assessed in conjunction with continuous measurements from piezometers that would be installed in the dikes, and within the dike foundation materials. From this analysis, the blasting could be adjusted to minimize the impact on the dikes. Mitigative measures to the blast design to minimize the development of blast induced vibration could include modifications to the blasthole patterns, reduction in blasthole size and hence charge weight in critical areas of the pit walls within a certain distance from the proposed de-watering and tailings dike, single blasthole initiation per delay, reduction in operating bench height in critical areas, or a combination of all these measures.

A more comprehensive program of blast vibration modelling and test blasting may be required during operations if blast vibration levels remain high and their frequency (cycles per second) is low.

The effects of blasting are typically assessed in terms of Peak Particle Velocity (PPV).

3.7.1 Estimates of Peak Particle Velocity

The preliminary estimates of Peak Particle Velocity (PPV) are based on the current understanding of the site layout, mine plan, and blast design. Changes to the current site layout, mine plan, and blast design will result in changes to the estimates of PPV. Certain site specific factors that are required to calculate PPV have been estimated based on published values. However, site specific parameters can only be determined by site vibration monitoring of actual blasts. Consequently, the actual PPV values may differ from those presented here.

The US Bureau of Mines has established that the peak particle velocity, PPV, is related to the scaled distance by the following relationship:

$$PPV = k * (R/W^{0.5})^{-b}$$

Where:

PPV	= Peak Particle Velocity, mm/s
R	= Distance from blast to point of concern, m
W	= Charge weight per delay, kg
k	= confinement factor – specific to site
b	= site factor

The constants k and b are specific to the site, and can be determined by blast vibration monitoring.

For this evaluation, a value of b = 1.6 was assumed. The PPV was evaluated for a range of values of confinement, ‘k’, of 400, 800, and 1500, for down hole blasting. This range in values is considered to be reasonable for the site and to provide an estimate of the sensitivity of PPV to different values of confinement. Based on the current understanding of site conditions and experience at two other northern sites, the confinement value of 800 is expected to be the most likely representative value for average conditions at the site. The actual value for confinement can only be determined through a detailed field monitoring program.

3.7.2 Minimum Setback Distance for Canadian Fisheries Guidelines

Design guidelines governing the use of explosives adjacent to Canadian fisheries waters (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998) indicate that no explosive is to be detonated that produces a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.

For the Meadowbank Site, three scenarios have been assessed: the first assumes a charge weight per delay of 420 kg for 229 mm (9 in) blastholes and an operating bench height of 12 m, the second assumes a maximum charge weight of 250 kg for 165 mm (6½ in) blastholes and a bench height of 12 m, and the last assumes a charge weight of 86 kg for 165 mm blasthole and bench height of 6 m. The maximum charge weight determined in the above analyses has been used to assess the PPV. An Emulsion:ANFO ratio of 70:30 has been assumed.

The PPV's were evaluated for the Second Portage Lake East Dike, the Third Portage Peninsula east shoreline, the Bay Dike, and the Goose Island east shoreline. Based on the current mine layout, estimates of the minimum distance from the estimated final production blast near the pit crest, to the point of concern (either shoreline or dike face), and estimates of the distance from the pit centre to the point of concern (either shoreline or dike face) were made. The PPV were evaluated based on these estimated distances. The estimates of PPV will change as a result of further changes to the mine plan, pit optimization, dike alignment optimization, and blast design optimization.

The Table 3-10 summarizes the estimated PPV at points of concern either along the upstream face of the dike, or along the shoreline, whichever is closest.

Table 3-10: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (420 kg charge weight per delay; 12 m bench height, 229 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	7	**14**	**27**
	Pit Centre to U/S Dike Face	375	4	8	**14**
Third Portage Peninsula	Pit Crest to Shoreline	101	**31**	**62**	**117**
	Pit Centre to Shoreline	295	6	11	**21**
Bay Dike	Pit Crest to U/S Dike Face	145	**17**	**35**	**66**
	Pit Centre to U/S Dike Face	355	4	8	**16**
Goose Island	Pit Crest to Shoreline	105	**29**	**59**	**110**
	Pit Centre to Shoreline	335	5	9	**17**

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

To assess the sensitivity of the estimates of PPV to blast design, a charge weight of 250 kg, corresponding to a smaller 165 mm (6½ in) blasthole diameter, was used (decking of the charges could produce a similar result, while maintaining the larger blasthole diameter of 229 mm). The results are presented in the following table, and indicate that optimization and modification of the blast design near the crest areas can result in reduced PPV.

Table 3-11: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (250 kg charge weight per delay; 12 m bench height, 165 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	5	9	**18**
	Pit Centre to U/S Dike Face	375	3	5	9
Third Portage Peninsula	Pit Crest to Shoreline	101	**21**	**41**	**77**
	Pit Centre to Shoreline	295	4	7	**14**
Bay Dike	Pit Crest to U/S Dike Face	145	12	**23**	**43**
	Pit Centre to U/S Dike Face	355	3	6	10
Goose Island	Pit Crest to Shoreline	105	**19**	**39**	**73**
	Pit Centre to Shoreline	335	3	6	11

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

By reducing the working bench height further to 6 m within both the waste rock as well as within the ore, the charge weight can be reduced to approximately 86 kg per blasthole. This reduction in charge weight has the following effect on PPV.

Table 3-12: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (86 kg charge weight per delay; 6 m bench height, 165 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	2	4	7
	Pit Centre to U/S Dike Face	375	1	2	4
Third Portage Peninsula	Pit Crest to Shoreline	101	9	**18**	**33**
	Pit Centre to Shoreline	295	2	3	6
Bay Dike	Pit Crest to U/S Dike Face	145	5	10	**18**
	Pit Centre to U/S Dike Face	355	1	2	4
Goose Island	Pit Crest to Shoreline	105	8	**16**	**31**
	Pit Centre to Shoreline	335	1	3	5

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

The above analysis indicates that the Peak Particle Velocities along the upstream (lake side) face of the de-watering dikes can be managed and minimized, but not eliminated, through modifications to the blast design to adjust the charge weight in specific areas of the pit. These modifications would include reduction of blasthole size, reduction of bench height, or a combination of the two. Figure 10 shows the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 13 mm/s. The figure can be used as a guide to estimate the maximum charge weight per blasthole required so as not to exceed 13 mm/s criteria for fish habitat at a given distance from the blast, and to develop blast designs to minimize potential impacts to fish habitat where the 13 mm/s criteria can not be achieved. The minimum setback distances to achieve a PPV of 13 mm/s have been estimated for the various values of 'k', and for four potential charge weights per delay used in the above PPV estimates. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 13 mm/s.

Table 3-13: Minimum Setback Distance for 13 mm/s Peak Particle Velocity Guideline

k	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 13 mm/s		
400	79 m	135 m	175 m
800	122 m	208 m	269 m
1500	180 m	308 m	399 m

The above analysis suggests that for a charge weight per delay of 420 kg, the minimum setback for a PPV of 13 mm/s will be on the order 269 m, based on an average expected confinement value, k, of 800. The minimum setback distance can be reduced by modifying the bench blast designs and incorporating smaller bench heights, smaller blastholes, or a combination of the two. Figure 11 shows the 13 mm/s isopleth relative to the current dike configuration for the above charge weights and a confinement value, k, of 800.

In some cases it will be impractical to construct the proposed de-watering dikes at the minimum setback distances for fish habitat indicated in the above analyses. This is primarily due to engineering and constructability constraints relating to the proposed method of dike construction. However, during detailed engineering design, the final alignment of the proposed de-watering dikes can be assessed further to consider, among other items, the minimum setback required to minimize the impact of explosives detonation on the potential fish habitat along the upstream dike faces. As discussed previously, the effects on fish habitat of explosives detonation within the open pits can be mitigated to some degree by reducing the charge weight per delay through the use of smaller diameter blastholes or by decking of charges, by reducing the bench height, or through a combination of the two. Other mitigative methods may include the use of 'bubbler' systems along the upstream face of the dikes in areas that will be affected by PPV of 13 mm/s or greater. These systems would be operated during blasting operations to discourage fish from along the upstream embankment face.

3.7.3 Minimum Setback Distance for Threshold Damage Levels

Common threshold vibration levels for damage have been developed relating PPV to potential vibration damage. The following table summarizes additional threshold damage levels typically used in urban areas for assessing the potential for blast damage to occur.

Table 3-14: Peak Particle Velocity Threshold Damage Levels

Velocity (mm/s)	Damage
3 – 5	Vibrations Perceptible
10	Approximate limit for poorly constructed, and historic buildings
33 – 50	Vibrations objectionable
50	Limit below which risk of damage to structures is very slight (less than 5%)
125	Minor damage, cracking of plaster, serious complaints
230	Cracks in concrete blocks
300	Rock falls in unlined tunnel
380	Horizontal offset in cased drillholes
635	Onset of cracking in rock
1000	Shafts misaligned in pumps, compressors
1500	Prefabricated metal buildings on concrete pads, metal twisted and concrete cracked
2500	Breakage of rock

Charlie et al (1987) suggest the following criteria for blasting near dams, based on liquefaction potential.

Table 3-15: General Guidelines to Vibration Damage Thresholds for Blasting Near Dams

	Maximum PPV
Dams constructed of or having foundation materials consisting of loose sand or silts that are sensitive to vibration.	25 mm/s
Dams having medium dense sand or silts within the dam or foundation materials	50 mm/s
Dams having materials insensitive to vibrations in the dam or foundation materials	100 mm/s

Ref. Charlie et al, 1987.

The information presented in the above tables can be used as general guidelines for assessing the potential for blast vibration damage to structures. Due to the inherent variability in site conditions, caution must be exercised in assessing the potential damage from blast induced vibration. Actual vibrations will need to be monitored during construction and operations.

Minimum setback distances based on a maximum PPV of 50 mm/s, representing the situation of a dam having medium dense sands or silts in the dam or foundations, have been calculated for the various values of confinement, ‘k’, and for three potential charge weights per delay. The actual velocities will need to be determined during a vibration monitoring program that will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting. Depending on the actual velocities experienced by the dikes, charge weights may need to be modified during operations. The threshold value of 50 mm/s may be modified once more detailed information is obtained relating to the foundation materials beneath the dikes. Furthermore, in the case of the tailings dike, it is proposed to construct the till core of the dike in compacted lifts. Consequently, a threshold value on the order of 100 mm/s may be more appropriate, and would be on the order of requirements for similar dikes in the north which have used design threshold values of up to 125 mm/s to limit structural damage. However, for this stage of design, a threshold value of 50 mm/s is considered appropriate to limit structural damage.

Figure 12 shows the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 50 mm/s. The Table 3-15 summarizes the estimates of minimum setback required to achieve a PPV value of 50 mm/s.

Table 3-16: Minimum Setback Distance for 50 mm/s Peak Particle Velocity Guideline

k	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 50 mm/s		
400	32 m	58 m	75 m
800	53 m	89 m	116 m
1500	78 m	133 m	172 m

The above analysis suggests that the peak particle velocities that the de-watering and tailings dikes may be exposed to can be managed effectively, if necessary, through the use of lighter charge weights by reducing bench heights, blasthole diameter, or combinations of the two. The table also suggests that the minimum toe setback distance of 80 m that is currently being carried through the feasibility study is a reasonable distance from the perspective of managing PPV. Additional sampling and testing of the till materials may allow refinements to be made to the above estimates of setback distance.

3.8 Instantaneous Pressure Change

Design guidelines governing the use of explosives adjacent to Canadian fisheries waters (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998) indicate that no explosive is to be detonated in or near fish habitat that produces an instantaneous pressure change greater than 100 kPa in the swimbladder of a fish.

The required setback distance for confined explosives to achieve the 100 kPa guideline can be estimated from the following relationships (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998).

The relationship between acoustic impedance and the density and velocity of the medium through which the compression wave travels is given by:

$$Zw/Zr = (Dw*Cw)/(Dr*Cr)$$

Where:

Dw = density of water = 1 g/cm^3
Dr = density of the substrate, g/cm^3
Cw = compression wave velocity in water
= 146,300 cm/s
Cr = compression wave velocity in substrate, cm/s

Typical values used for Dr and Cr for various substrates are:

Table 3–17: Typical Values for Substrate Density and Compression Wave Velocity

Substrate	Dr (g/cm^3)	Cr (cm/s)
Rock	2.64	457,200
Frozen Soil	1.92	304,800
Ice	0.98	304,800
Saturated Soil	2.08	146,300
Unsaturated Soil	1.92	45,700

Reference: Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

The transfer of shock pressure from the substrate to the water can be estimated from:

$$Pw \quad = (2*(Zw/Zr)*Pr)/(1+(Zw/Zr))$$

Where:

Pw	= pressure (kPa) in water
Pr	= pressure (kPa) in substrate
Zw	= acoustic impedance of water
Zr	= acoustic impedance of substrate

The equation can be re-written to solve for the pressure in the substrate, Pr, as:

$$Pr = (Pw*(1+(Zw/Zr)))/(2*(Zw/Zr))$$

The equation is solved by setting the value of Pw to the 100 kPa guideline to determine the pressure in the substrate, Pr, which is required to produce this detonation overpressure in the water. The resulting value for Pr is used to determine the Peak Particle Velocity in the rock for the given conditions based on the following:

$$PPV = (2*Pr)/(Dr*Cr)$$

The relationship between Peak Particle Velocity, charge weight, and distance was described in Section 3.7.1 and is given by:

$$PPV = k * (R/W^{0.5})^{-b}$$

Equating the two equations for Peak Particle Velocity, and solving for distance, R for a given charge weight, W, gives the minimum setback distance from fish habitat required so as not to exceed the 100 kPa overpressure guideline.

The following properties were used to assess the minimum setback distance.

Table 3–18: Properties Used to Assess Setback Distance for Instantaneous Overpressure

Medium	Density, g/cm^3	Compressional Wave Velocity, cm/s
Water	1	146,300[1]
Rock (Intermediate Volcanic)	2.8	457,200[1]

1. Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

Based on the above properties, the range of potential charge weights, and the range in confinement value, k, the following minimum setback distances, below which the 100 kPa overpressure guideline will not be exceeded, are estimated.

Table 3-19: Minimum Setback Distance for Instantaneous Overpressure Guideline

Charge Weight per Delay	Minimum Setback Distance, m		
kg	k=400	k=800	k=1500
86	26 m	40 m	60 m
250	45 m	69 m	102 m
420	58 m	89 m	132 m

The relationship between charge weight per delay and minimum setback distance to achieve the 100 kPa guideline for instantaneous overpressure is shown on Figure 14. The figure can be used as a guide to the development of alternative blast designs in areas that may by affected by instantaneous overpressures greater than 100 kPa.

The analyses indicate that through the use of lighter charge weights, decreased blasthole diameters, and decreased operating bench heights, the guideline of 100 kPa instantaneous overpressure can be achievable for substantial portions of the proposed de-watering dike system, for the charge weights considered. Figure 15 shows the 100 kPa isopleth for the charge weights considered above, and for a confinement value, k, of 800. The figure illustrates that limited lengths of the proposed dikes will be subjected to instantaneous overpressure exceeding 100 kPa. In these areas, mitigative procedures to discourage fish habitat development could be adopted, and might include the use of ‘bubbler’ systems, or alternative means such as the development of an ‘ice barrier’ to prevent fish from spawning or inhabiting specific areas.

4.0 CLOSURE

Production bench blast designs have been presented for the proposed open pits at the Meadowbank Gold Project. The blast designs have been based on standard design methods applied to the specific rock types and structure that is known to exist in the deposit areas. Designs for two blasthole sizes have been presented, 229 mm and 165 mm. Due to the strength of the iron formation and intermediate volcanic rocks, and to the nature of the structure in the proposed open pit area, a smaller blasthole size would provide better fragmentation. However, the smaller blasthole size could result in greater inaccuracy during drilling, particularly for the 12 m working bench heights proposed. The economics of a reduced blasthole diameter would need to be compared with the need to drill more blastholes due to the reduction in spacing and burden. Under these conditions, the drilling costs usually over-ride the fragmentation.

Where the development of the pit walls is beneath the de-watered lakes, wet blasthole conditions can be expected. Where the walls are developed within permafrost beneath the existing land mass, drier blasthole conditions may be encountered, although actual conditions will remain unknown until the development phase. Two charge tables have been presented: one for wet blasthole conditions using a doped emulsion of 70:30 Emulsion/AN, and the other for dry blasthole conditions using a Emulsion/AN ratio of 30:70.

Analyses indicate that Peak Particle Velocities (PPV) along portions of the upstream (lake side) face of the de-watering dikes will exceed the fish spawning habitat guideline threshold of 13 mm/s, based on operating bench height of 12 m and full charge weight. Analyses indicate that the guideline threshold of 100 kPa for instantaneous overpressure is achievable for substantial portions of the dikes for the charge weights considered.

Along portions of the dikes where fisheries guidelines are exceeded, mitigative methods may include modifications to blasting designs to incorporate lower bench heights and lighter charge weights as described above, as well as the use of 'bubbler' systems along the upstream face of the dikes in specific areas. These 'bubbler' systems could be operated during blasting to discourage fish along the upstream embankment face. Alternatively, in areas where fisheries guidelines for blasting may be exceeded, the upstream (lake side) dike width could be increased by dumping of additional rock fill material, and thereby increasing the setback distance from the blasting.

Analyses indicate that peak particle velocity thresholds of 50 mm/s for limiting damage to the dike structures may be exceeded along certain portions of the proposed dike alignments. However, the threshold of 50 mm/s is likely conservative, based on experience with other mines in the north, but is considered to be appropriate for this level of study. Furthermore, the peak particle velocities experienced by the dikes can be effectively managed, if necessary, by modifications to the blast design.

During mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting, and to measure peak particle velocities on the upstream (lake side) of the dikes to assess the blast designs.

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CJC/WWF/vee
03-1413-427

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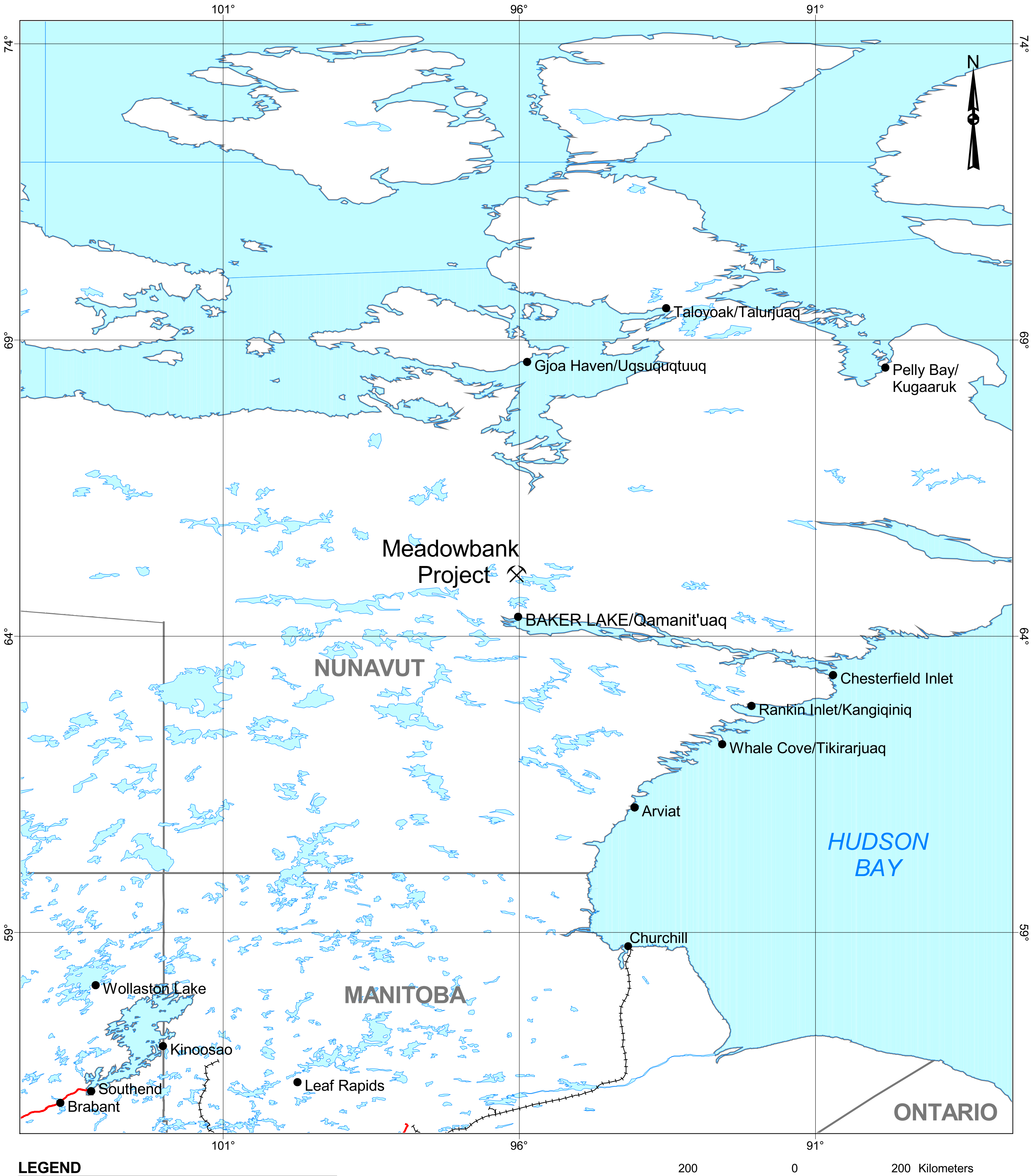

LEGEND

- Meadowbank Project
- Town/Village
- Provincial Border
- Water
- Primary Highway
- Railroad

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

LOCATION PLAN
MEADOWBANK PROJECT

Golder Associates

PROJECT No. 03-1413-427			SCALE AS SHOWN	REV. 0
DESIGN	DH	19 Dec. 2003	**FIGURE 1**	
GIS	CDB	19 Dec. 2003		
CHECK	CJC	19 Dec. 2003		
REVIEW				

REFERENCE
Base digital data obtained from ESRI Inc.,
DATUM: WGS84 PROJECTION: Geographic

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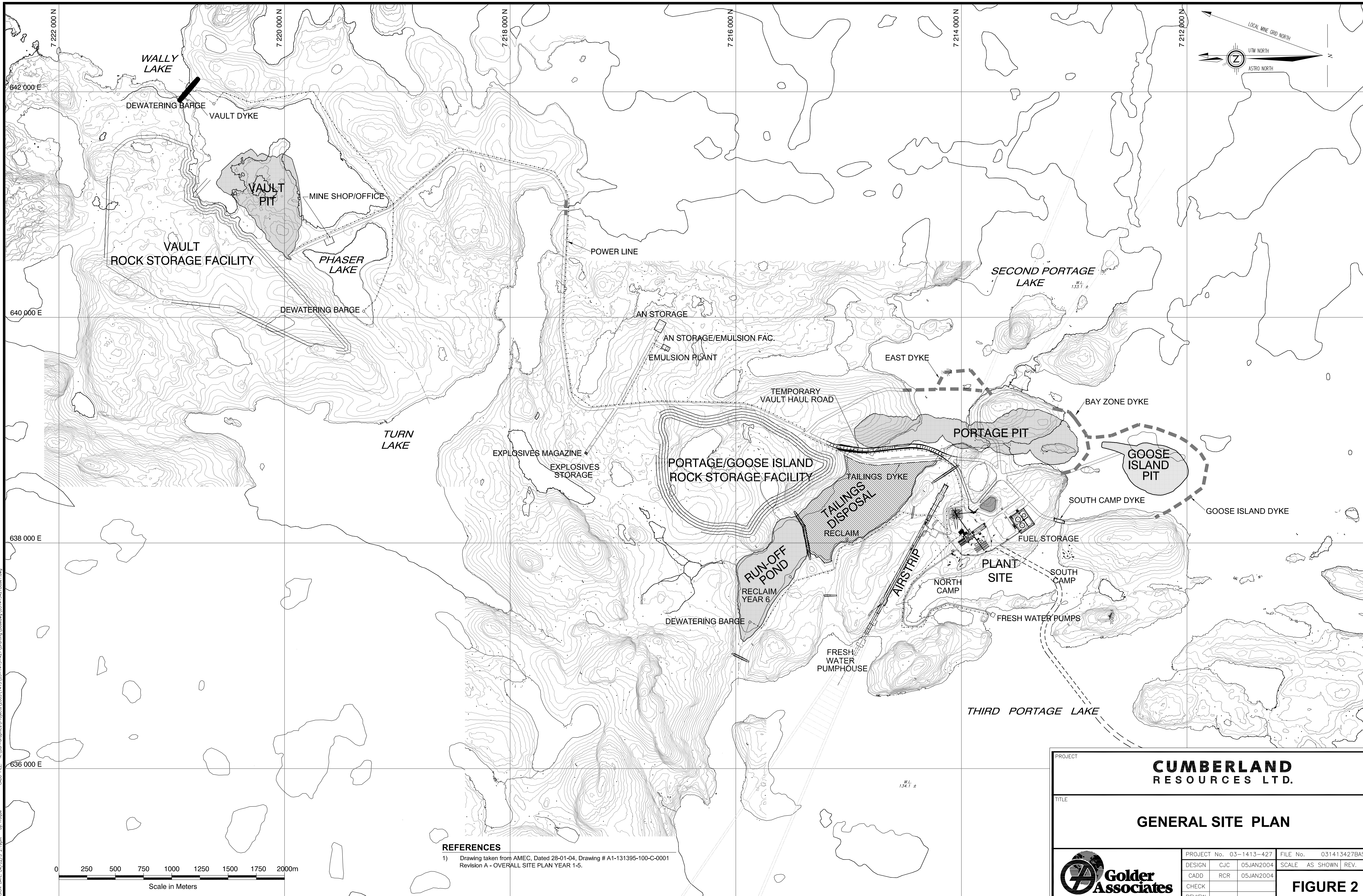

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PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GENERAL SITE PLAN

Golder Associates

PROJECT No. 03-1413-427			FILE No. 031413427BASE1
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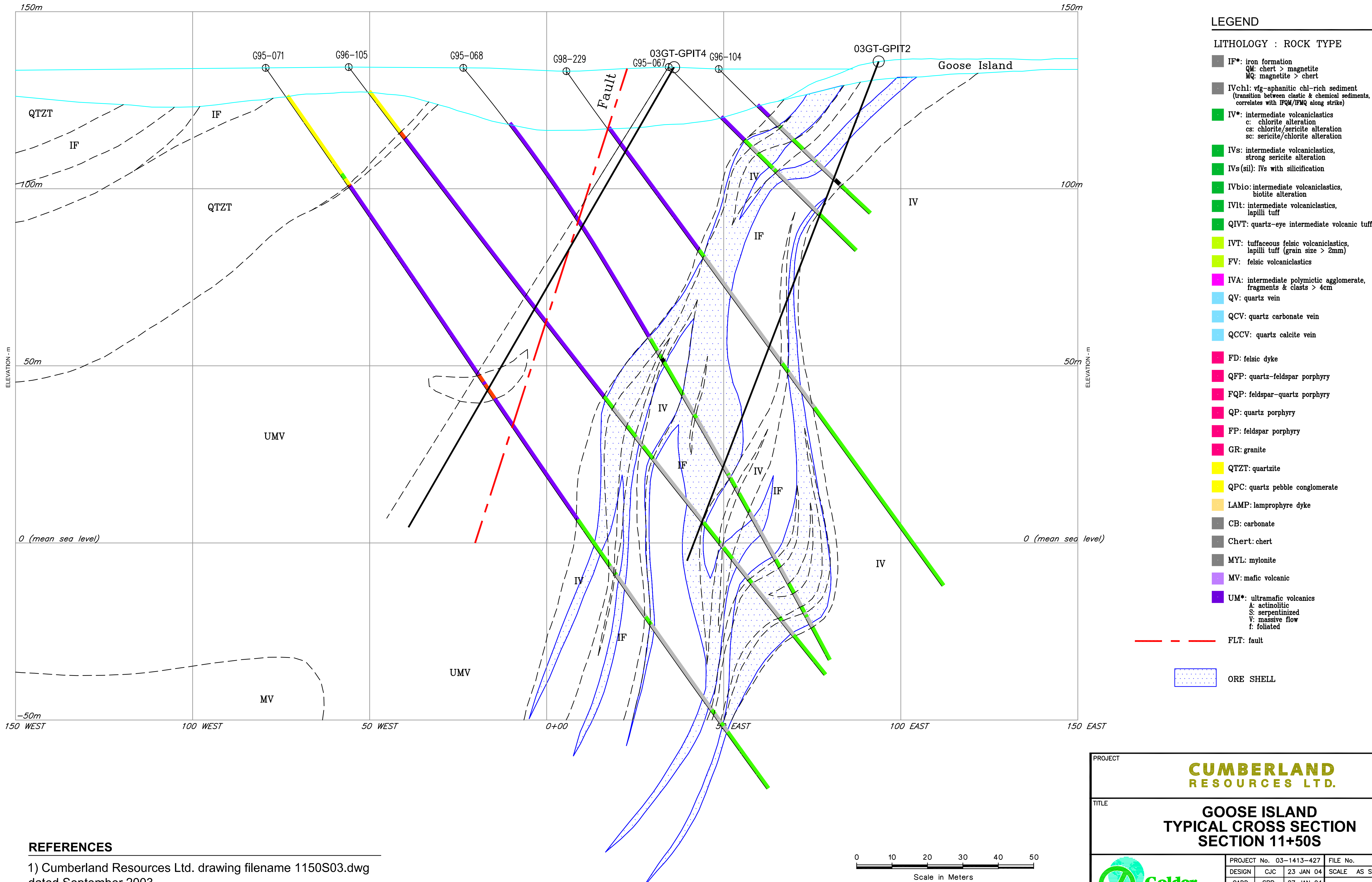
CADD	RCR	05JAN2004	
CHECK			**FIGURE 2**
REVIEW			



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PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GOOSE ISLAND TYPICAL CROSS SECTION SECTION 11+50S

Golder Associates

PROJECT No. 03-1413-427			FILE No. 031413427SK03	
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04	FIGURE 3	
CHECK	CJC	27 JAN 04		
REVIEW				

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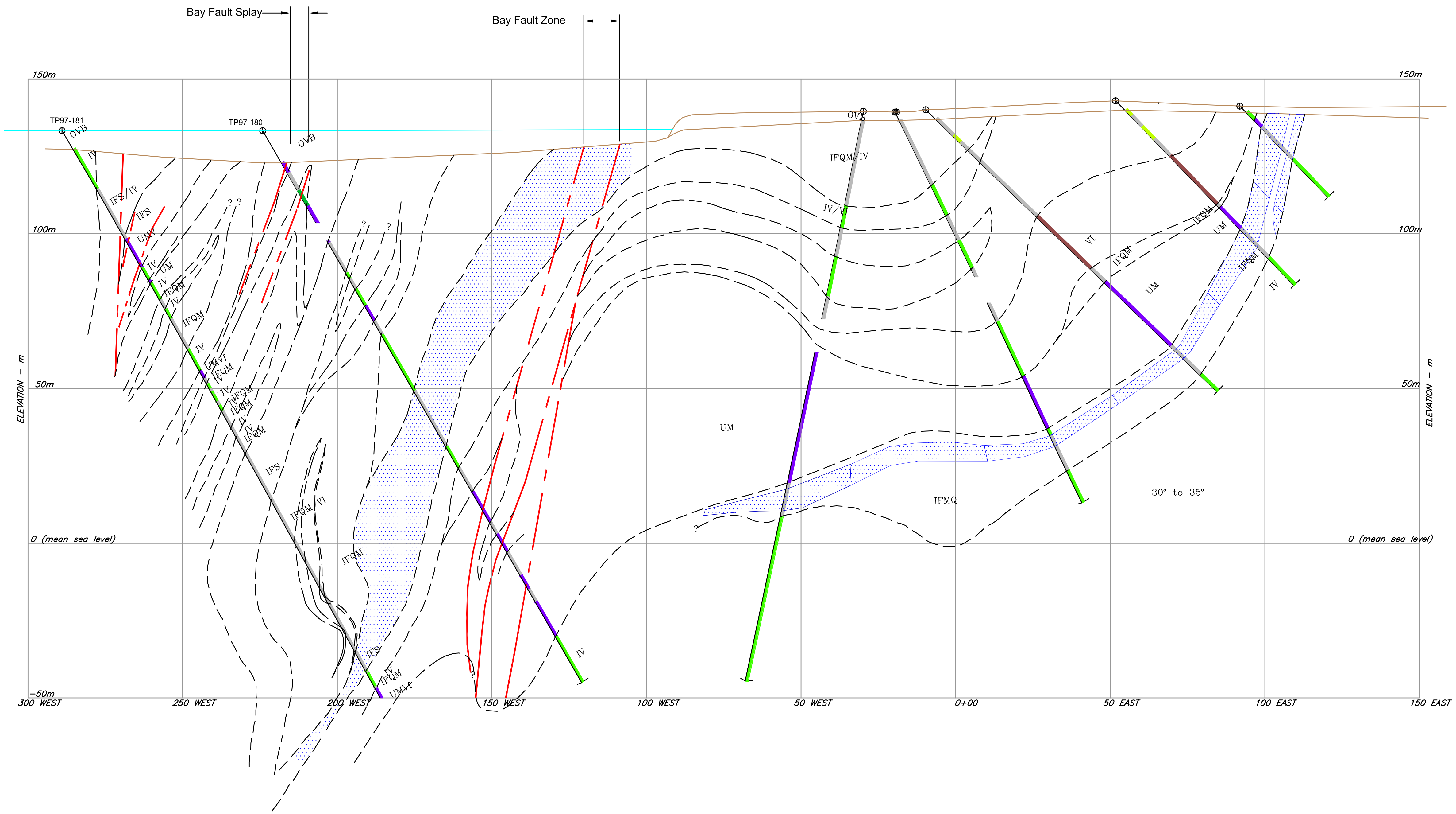


LEGEND

LITHOLOGY : ROCK TYPE

- IF*: iron formation
  - QM: chert > magnetite
  - MQ: magnetite > chert
- IVchl: vfg-aphanitic chl-rich sediment (transition between clastic & chemical sediments, correlates with IFQM/IFMQ along strike)
- IV*: intermediate volcaniclastics
  - c: chlorite alteration
  - cs: chlorite/sericite alteration
  - sc: sericite/chlorite alteration
- IVs: intermediate volcaniclastics, strong sericite alteration
- IVs (sil): IVs with silicification
- IVbio: intermediate volcaniclastics, biotite alteration
- IVlt: intermediate volcaniclastics, lapilli tuff
- QIVT: quartz-eye intermediate volcanic tuff
- IVT: tuffaceous felsic volcaniclastics, lapilli tuff (grain size > 2mm)
- FV: felsic volcaniclastics
- IVA: intermediate polymictic agglomerate, fragments & clasts > 4cm
- QV: quartz vein
- QCV: quartz carbonate vein
- QCCV: quartz calcite vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- FQP: feldspar-quartz porphyry
- QP: quartz porphyry
- FP: feldspar porphyry
- GR: granite
- QTZT: quartzite
- QPC: quartz pebble conglomerate
- LAMP: lamprophyre dyke
- CB: carbonate
- Chert: chert
- MYL: mylonite
- MV: mafic volcanic
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated
- FLT: fault
- ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 120SF99.dwg dated March 30, 2003.

0 10 20 30 40 50
Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

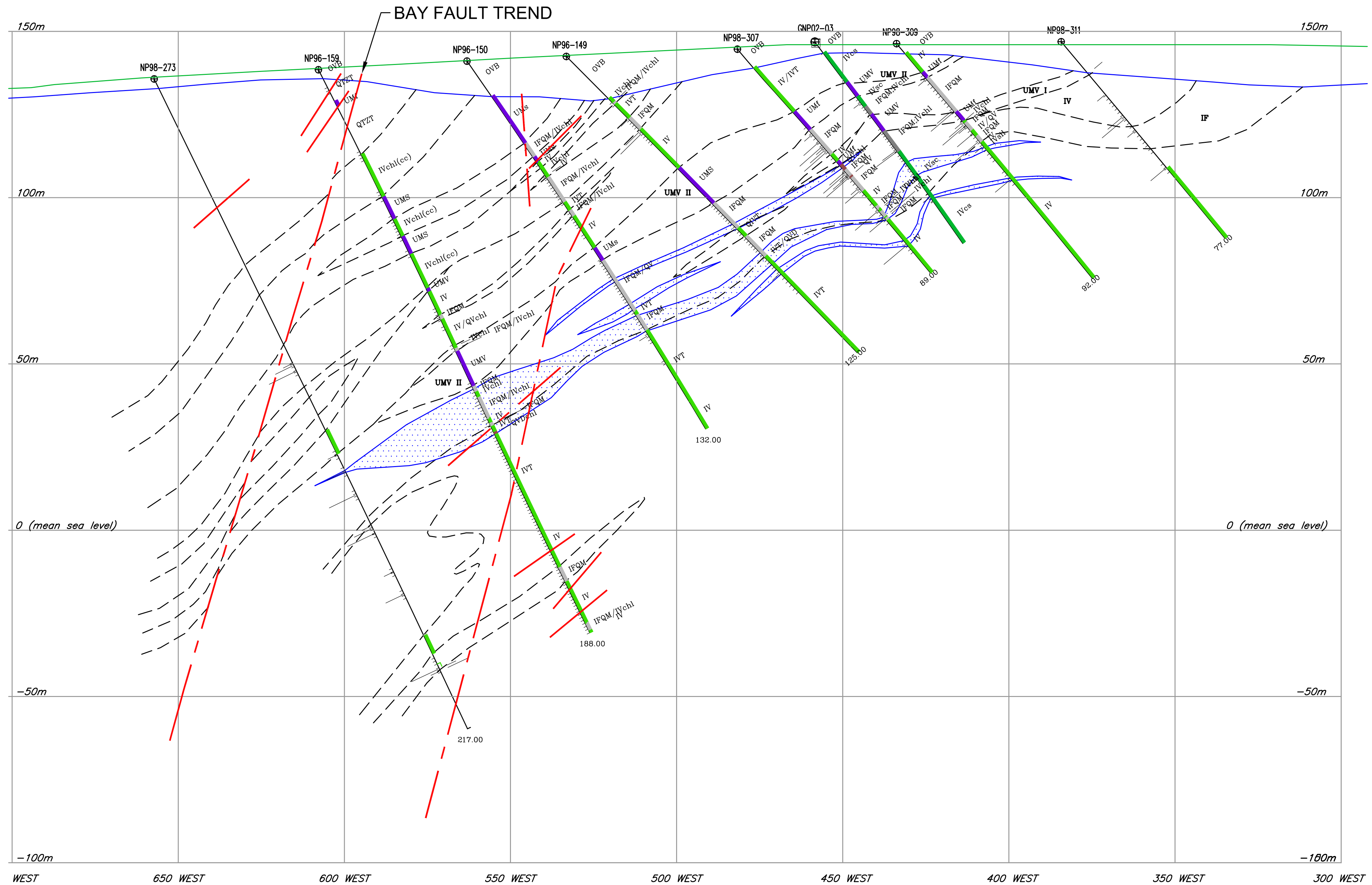
THIRD PORTAGE DEPOSIT TYPICAL CROSS SECTION SECTION 1+20S

Golder Associates

PROJECT No.	03-1413-427		FILE No. 031413427SK04	
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04		
CHECK	CJC	27 JAN 04	FIGURE 4	
REVIEW				

CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK04.dwg

REVISION DATE: 04/01/27 10:26am By: sreddy



LEGEND

LITHOLOGY : ROCK TYPE

- IF*: iron formation
  - QM: chert > magnetite
  - MQ: magnetite > chert
- IVchl: vfg-aphanitic chl-rich sediment (transition between clastic & chemical sediments, correlates with IFQM/IFMQ along strike)
- IV*: intermediate volcaniclastics
  - c: chlorite alteration
  - cs: chlorite/sericite alteration
  - sc: sericite/chlorite alteration
- IVs: intermediate volcaniclastics, strong sericite alteration
- IVs (sil): IVs with silicification
- IVbio: intermediate volcaniclastics, biotite alteration
- IVlt: intermediate volcaniclastics, lapilli tuff
- QIVT: quartz-eye intermediate volcanic tuff
- IVT: tuffaceous felsic volcaniclastics, lapilli tuff (grain size > 2mm)
- FV: felsic volcaniclastics
- IVA: intermediate polymictic agglomerate, fragments & clasts > 4cm
- QV: quartz vein
- QCV: quartz carbonate vein
- QCCV: quartz calcite vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- FQP: feldspar-quartz porphyry
- QP: quartz porphyry
- FP: feldspar porphyry
- GR: granite
- QTZT: quartzite
- QPC: quartz pebble conglomerate
- LAMP: lamprophyre dyke
- CB: carbonate
- Chert: chert
- MYL: mylonite
- MV: mafic volcanic
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated
- FLT: fault
- ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 1225N02.dwg dated April 22, 2003.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

NORTH PORTAGE DEPOSIT TYPICAL CROSS SECTION SECTION 12+25N

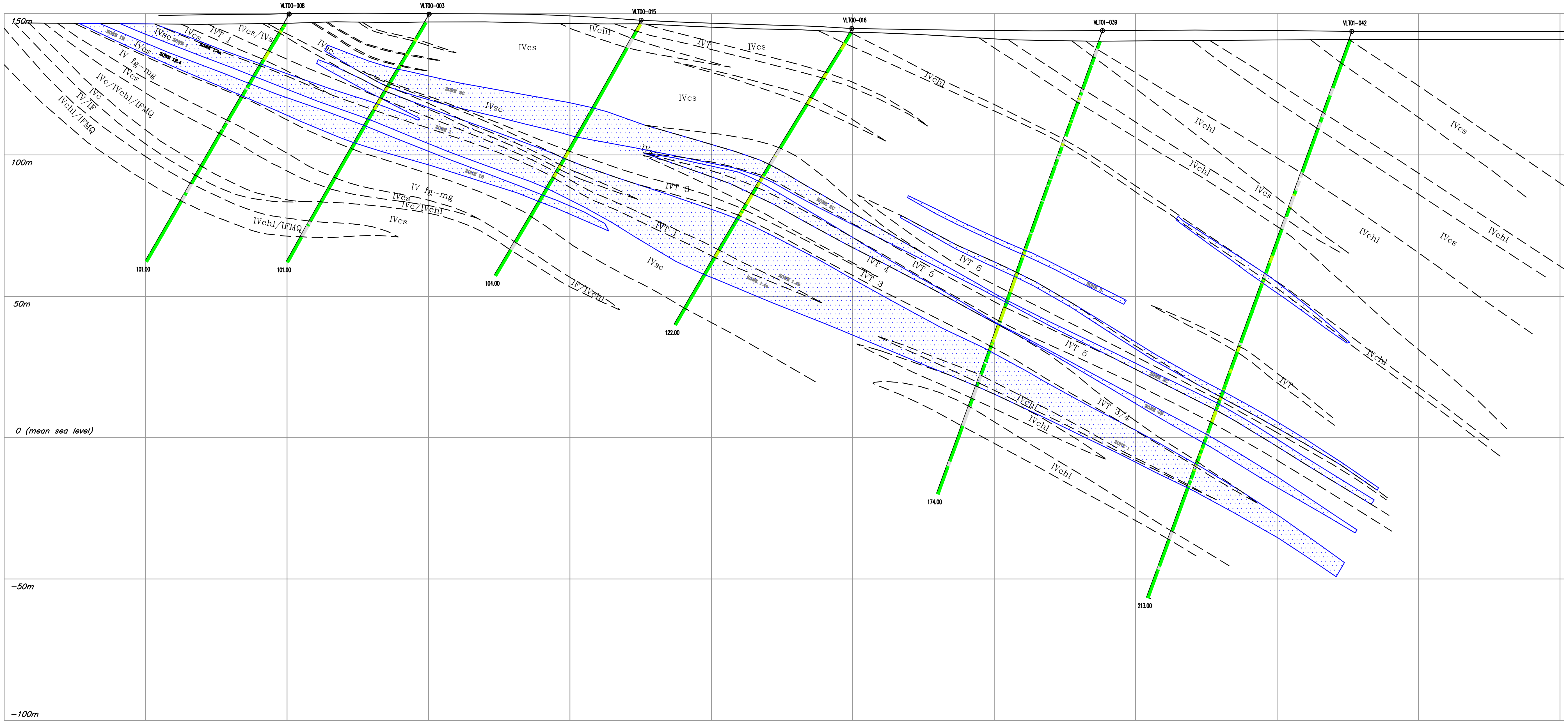
Golder Associates

PROJECT No. 03-1413-427			FILE No.	031413427SK05
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04	FIGURE 5	
CHECK	CJC	27 JAN 04		
REVIEW				

REVISION DATE: 04/01/27 10:11am By: sreddy

CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK05.dwg

REVISION DATE: 04/01/27 9:54am By: sreddy CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK06.dwg



LEGEND

LITHOLOGY : ROCK TYPE

- IF*: iron formation
  - QM: chert > magnetite
  - MQ: magnetite > chert
- IVchl: vfg-aphanitic chl-rich sediment (transition between clastic & chemical sediments, correlates with IFQM/IFMQ along strike)
- IV*: intermediate volcanoclastics
  - c: chlorite alteration
  - cs: chlorite/sericite alteration
  - sc: sericite/chlorite alteration
- IVs: intermediate volcanoclstics, strong sericite alteration
- IVs(sil): IVs with silicification
- IVT: tuffaceous intermediate volcanoclstics (grain size > 2mm)
- IVA: intermediate polymictic agglomerate, fragments & clasts > 4cm
- QIVT: quartz-eye volcanic tuff
- QV: quartz vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated

ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 4675NO1.dwg dated December 6, 2001.

0 10 20 30 40 50
Scale in Meters

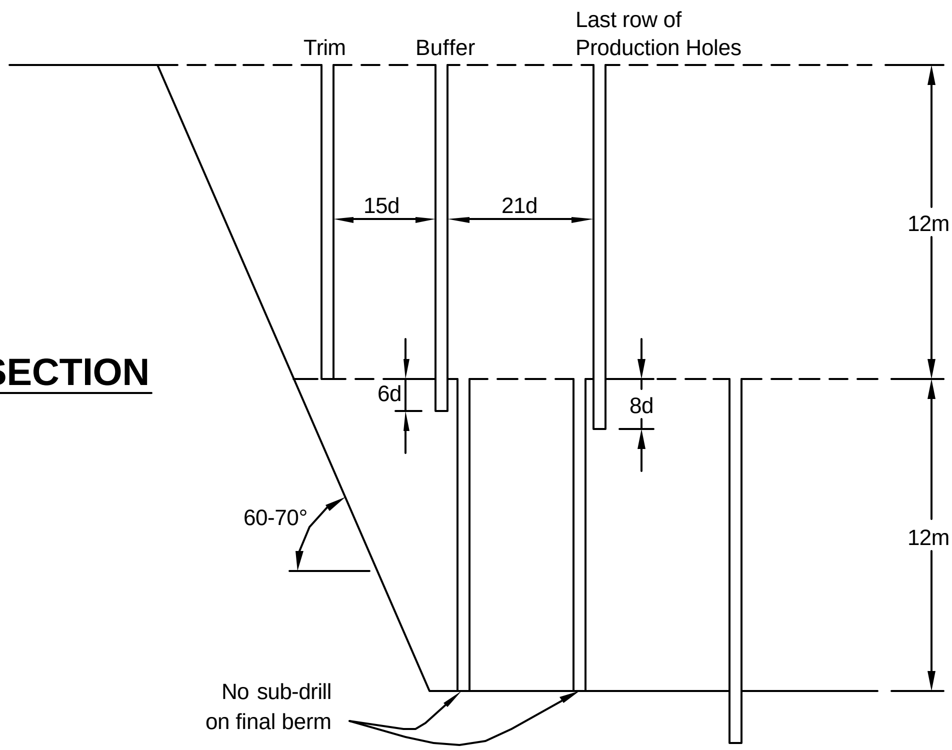
PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
VAULT DEPOSIT
TYPICAL CROSS SECTION
SECTION 46+75N

Golder Associates

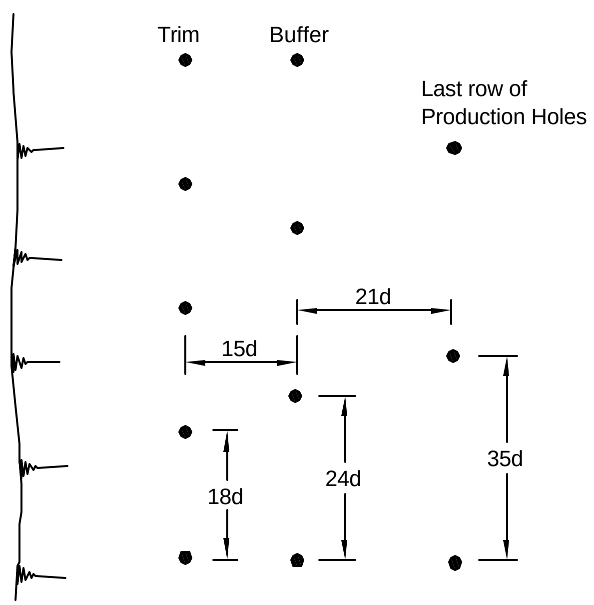
PROJECT No. 03-1413-427			FILE No. 031413427SK06	
DESIGN	CJC	10 DEC 03	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04	**FIGURE 6**	
CHECK	CJC	27 JAN 04		
REVIEW				

SECTION



APPROXIMATE BLAST CONFIGURATION			
	CHARGE (%)	BURDEN d = 229 d = 165	SPACING d = 229 d = 165
PRODUCTION	100	30d 6.9m 5.0m	35d 7.9m 5.7m
BUFFER	67	21d 4.8m 3.5m	24d 5.5m 4.0m
TRIM	33	15d 3.4m 2.5m	18d 4.1m 3.0m

PLAN



SCHEMATIC ONLY

Not to Scale

PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

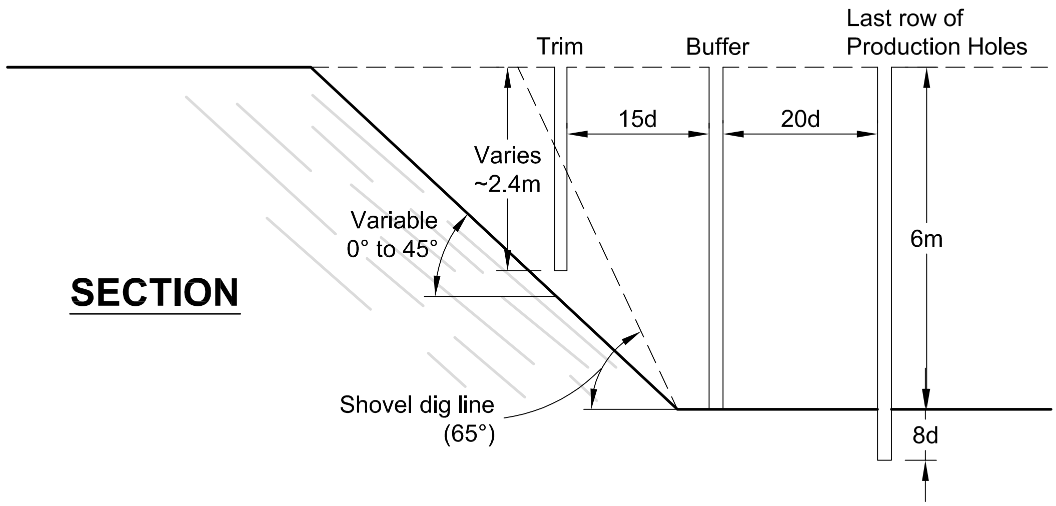
**CONCEPTUAL CONTROLLED
BLAST DESIGN
GENERAL CONFIGURATION**

Golder Associates

PROJECT No. 03-1413-427			FILE No. P427-01	
DESIGN	CJC	02DEC03	SCALE AS SHOWN	REV. A
CADD	SS	02DEC03	FIGURE 7	
CHECK	CJC	02DEC03		
REVIEW				

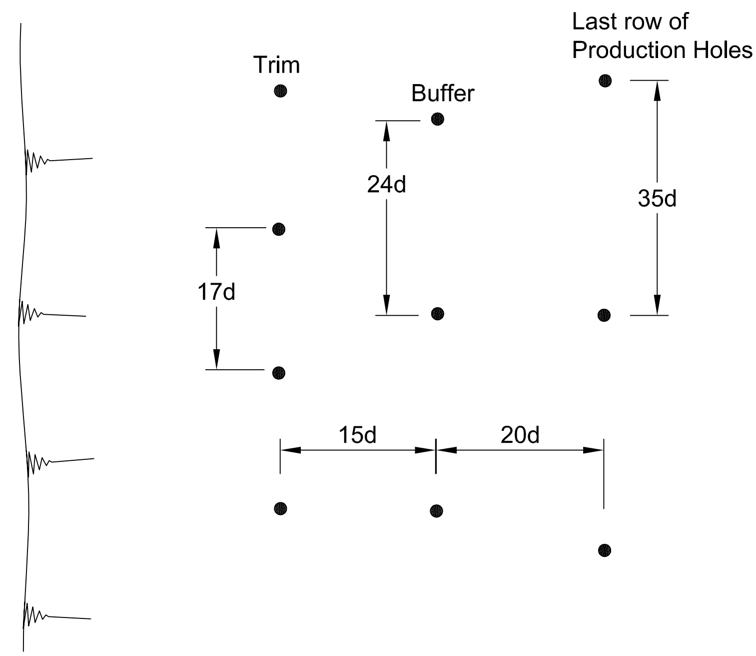
REVISION DATE: 04\02\11 By: sskermer CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\P427-01.dwg

SECTION



APPROXIMATE BLAST CONFIGURATION							
	CHARGE (%)	BURDEN			SPACING		
			d = 229	d = 165		d = 229	d = 165
PRODUCTION	100	30d	6.9m	5.0m	35d	8.0m	5.8m
BUFFER	67	20d	4.6m	3.3m	24d	5.5m	4.0m
TRIM	33	15d	3.4m	2.5m	17d	3.9m	2.8m

PLAN



SCHEMATIC ONLY

Not to Scale

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

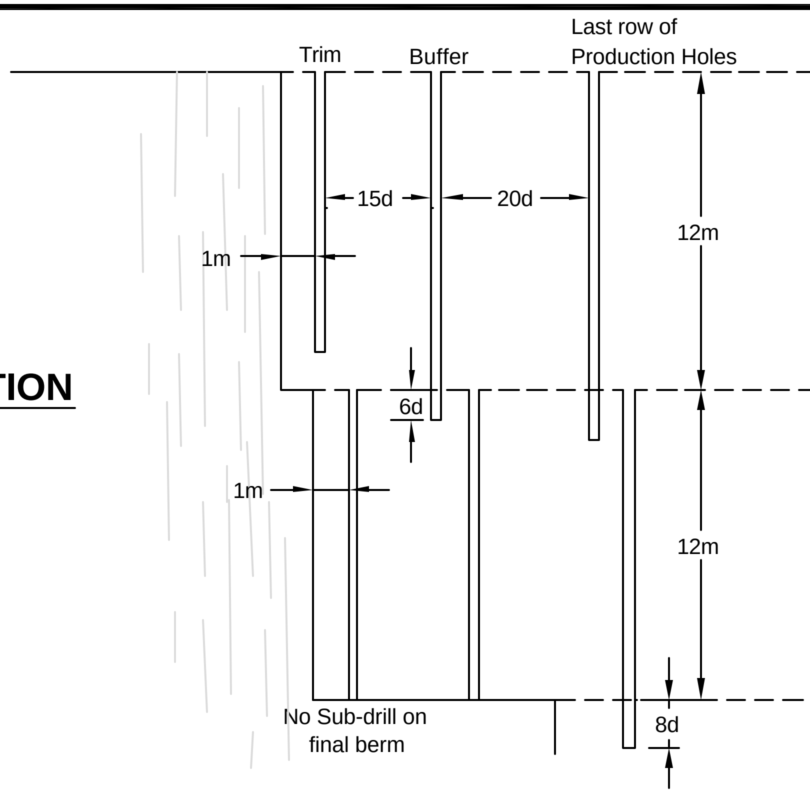
CONCEPTUAL CONTROLLED BLAST DESIGN FOR SHALLOW DIPPING ORE

Golder Associates

PROJECT No.	03-1413-427		FILE No.	P421-01
DESIGN	CJC	02DEC03	SCALE AS SHOWN	REV. A
CADD	SS	02DEC03		
CHECK	CJC	02DEC03	**FIGURE 8**	
REVIEW				

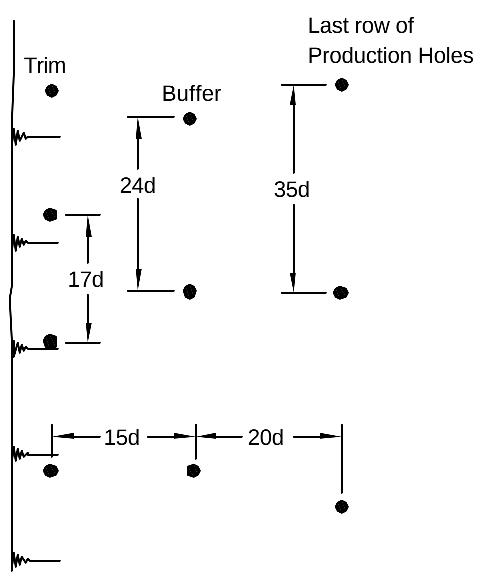
REVISION DATE: 04\02\11 By: sskermer CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\P427-01.dwg

SECTION



APPROXIMATE BLAST CONFIGURATION							
	CHARGE (%)	BURDEN	d = 229	d = 165	SPACING	d = 229	d = 165
PRODUCTION	100	30d	6.9m	5.0m	35d	8.0m	5.8m
BUFFER	67	20d	4.6m	3.3m	24d	5.5m	4.0m
TRIM	33	15d	3.4m	2.5m	17d	3.9m	2.8m

PLAN



SCHEMATIC ONLY
Not to Scale

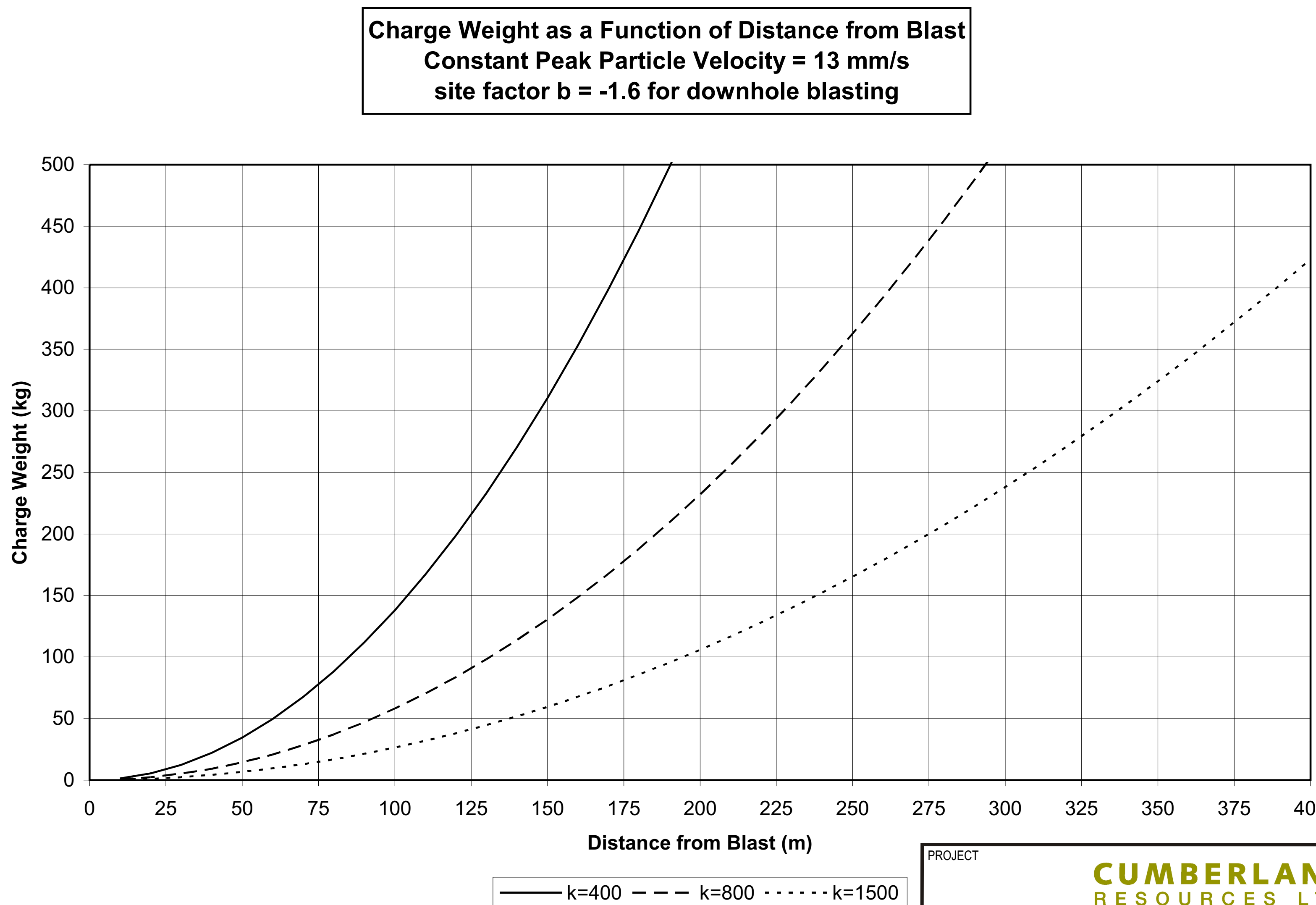
PROJECT
CUMBERLAND
RESOURCES LTD.

TITLE
CONCEPTUAL CONTROLLED
BLAST DESIGN IN
AREAS OF POTENTIAL TOPPLING

Golder Associates

PROJECT No. 03-1413-427			FILE No. P427-01	
DESIGN	CJC	02DEC03	SCALE AS SHOWN	REV. A
CADD	SS	02DEC03	FIGURE 9	
CHECK	CJC	02DEC03		
REVIEW				

REVISION DATE: 04\02\11 By: sskermer CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\P427-01.dwg



PROJECT

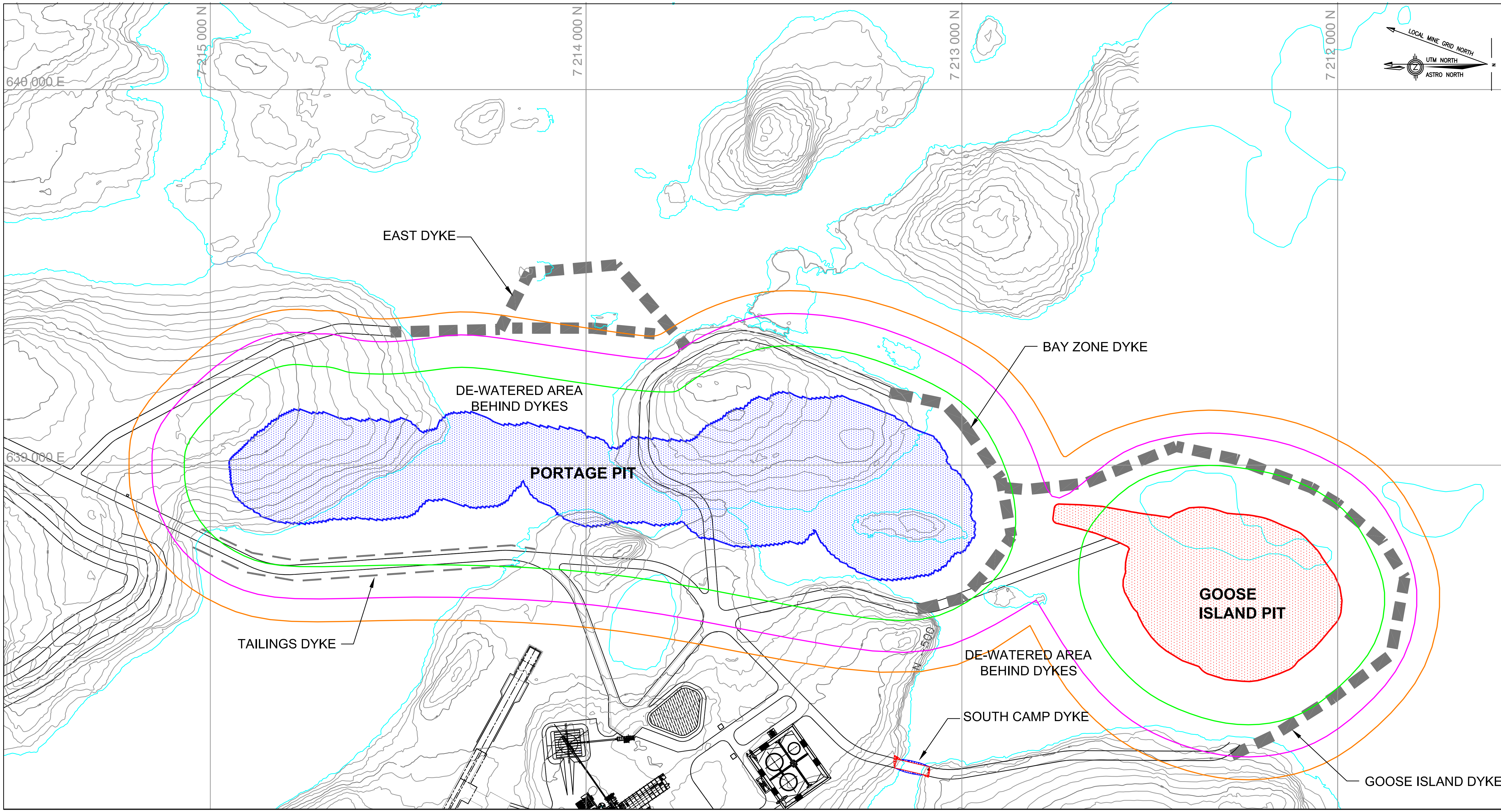
CUMBERLAND RESOURCES LTD.

TITLE

CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 13mm/s

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE NTS	REV.
CADD	SS	28JAN04	**FIGURE 10**	
CHECK	CJC	28JAN04		
REVIEW				



LEGEND

- 86 kg Charge Weight, 122m Offset
- 250 kg Charge Weight, 208m Offset
- 420 kg Charge Weight, 269m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

0 100 200 300 400 500

Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

PEAK PARTICLE VELOCITY
13 mm/s ISOPLETH

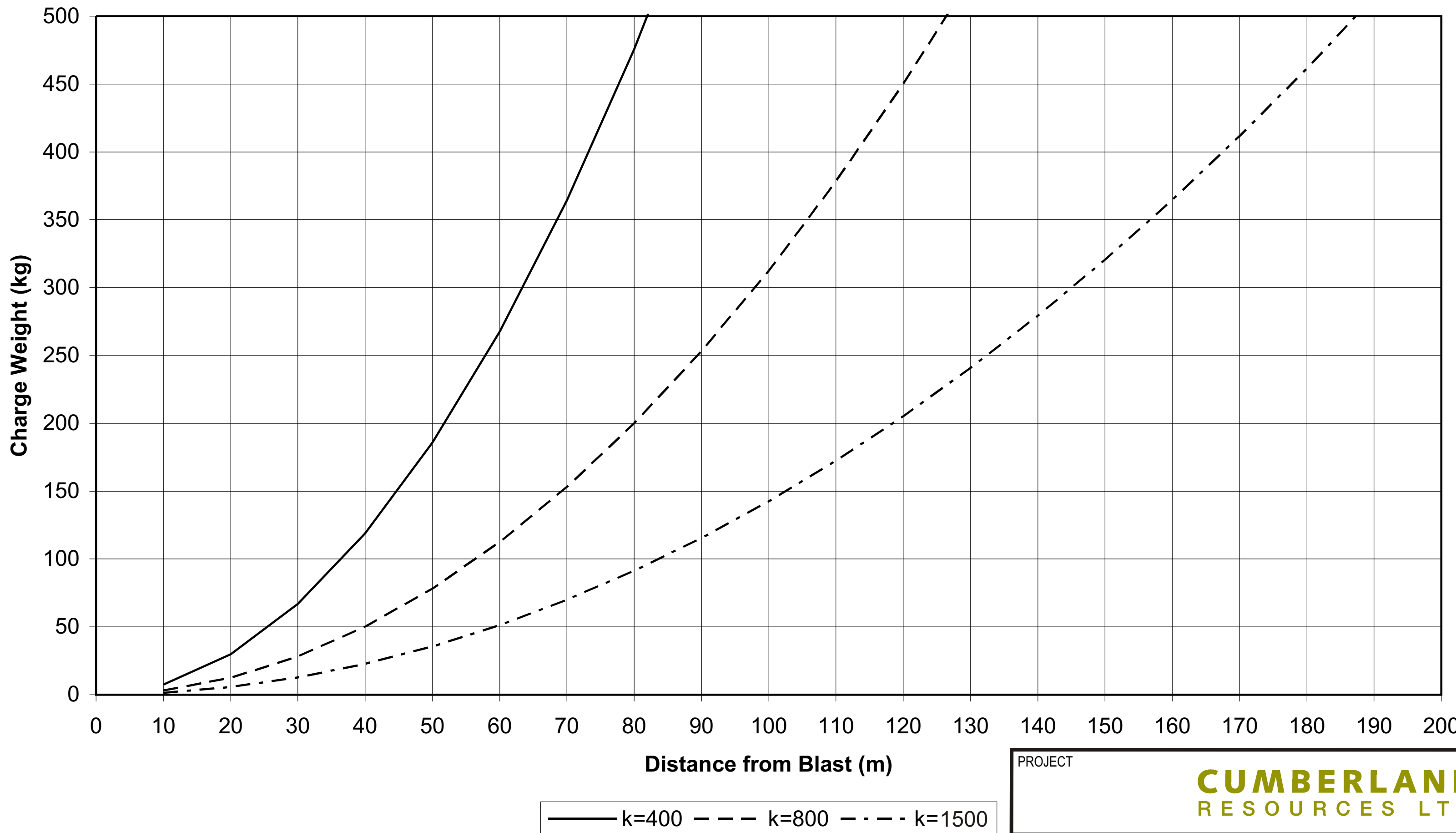
Golder Associates

PROJECT No. 03-1413-427			FILE No. 031413427SK11	
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04		
CHECK	CJC			
REVIEW				

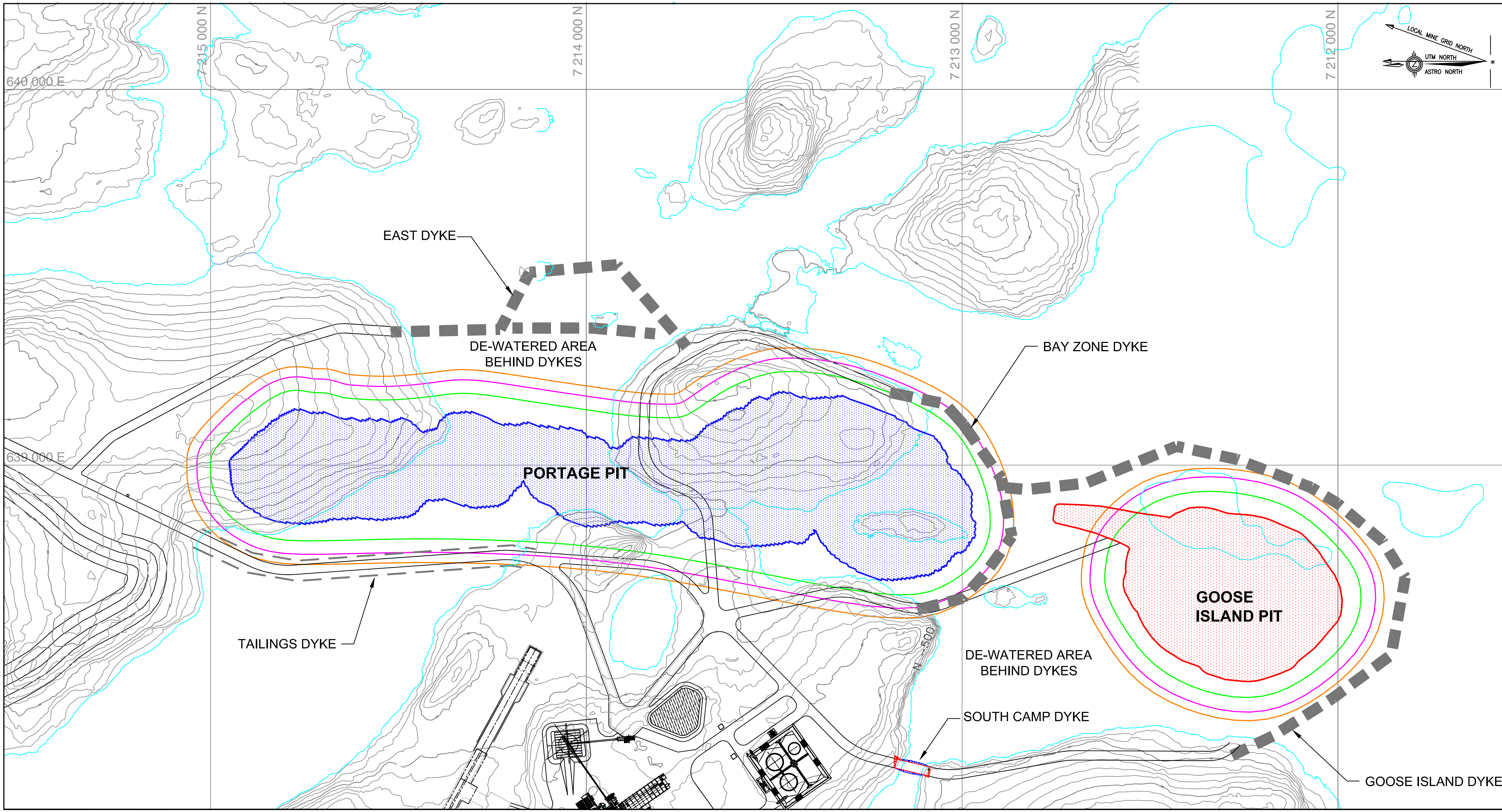
FIGURE 11

CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK11.dwg By: sreddy REVISION DATE: 04/01/27 4:46pm

Charge Weight as a Function of Distance from Blast
Constant Peak Particle Velocity = 50 mm/s
site factor b = -1.6 for downhole blasting



PROJECT	CUMBERLAND RESOURCES LTD.			
TITLE	CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 50mm/s			
Golder Associates	PROJECT No.	03-1413-427		FILE No. FIGURE 3
	DESIGN	CJC	28JAN04	SCALE / REV.
	CADD	SS	28JAN04	FIGURE 12
	CHECK	CJC	28JAN04	
	REVIEW			



LEGEND

(green line)	86 kg Charge Weight, 53m Offset
(magenta line)	250 kg Charge Weight, 89m Offset
(orange line)	420 kg Charge Weight, 116m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

0 100 200 300 400 500

Scale in Meters

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

PEAK PARTICLE VELOCITY 50 mm/s ISOPLETH

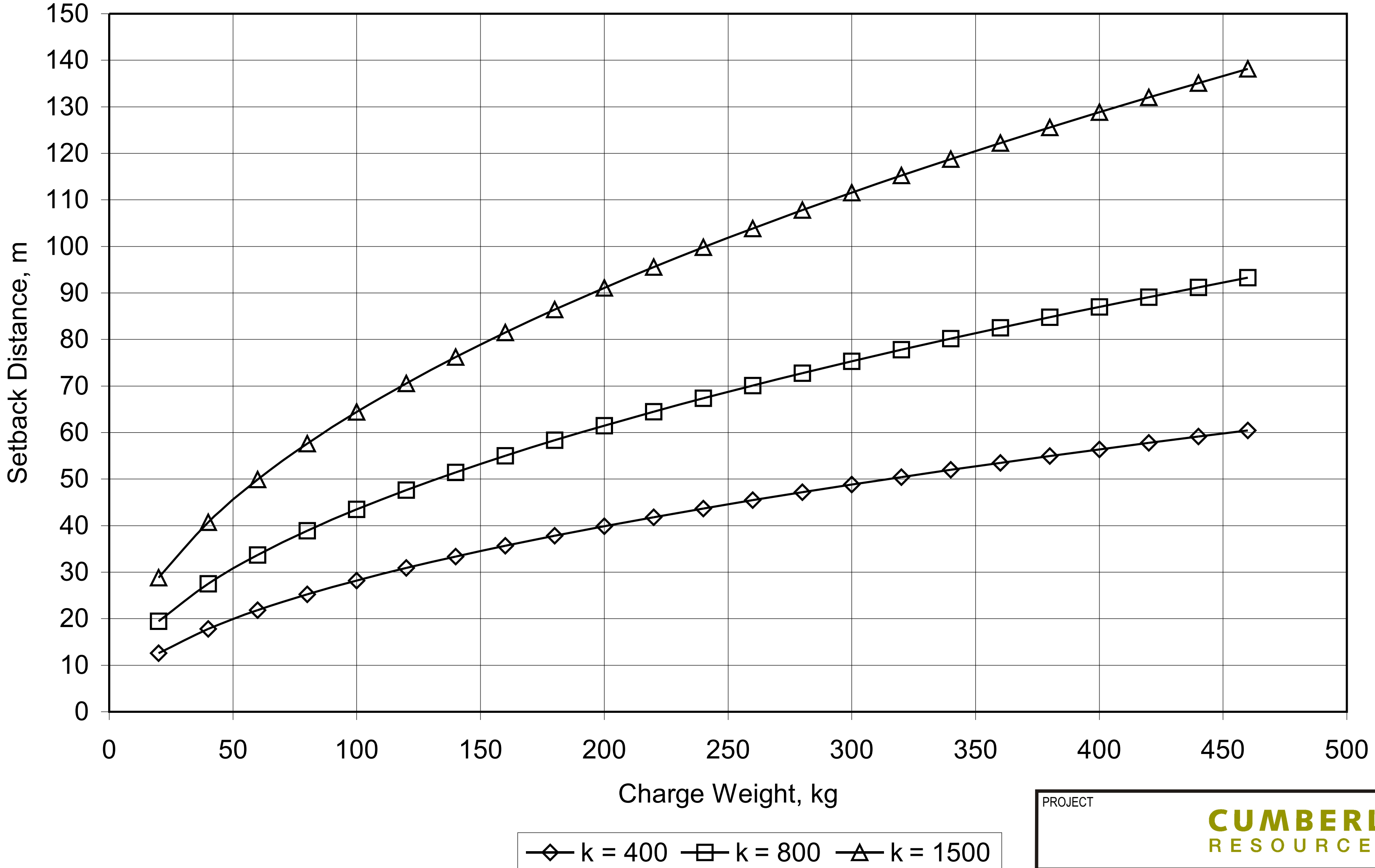
Golder Associates

PROJECT No.	03-1413-427		FILE No.	031413427SK13
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04		
CHECK	CJC		**FIGURE 13**	
REVIEW				

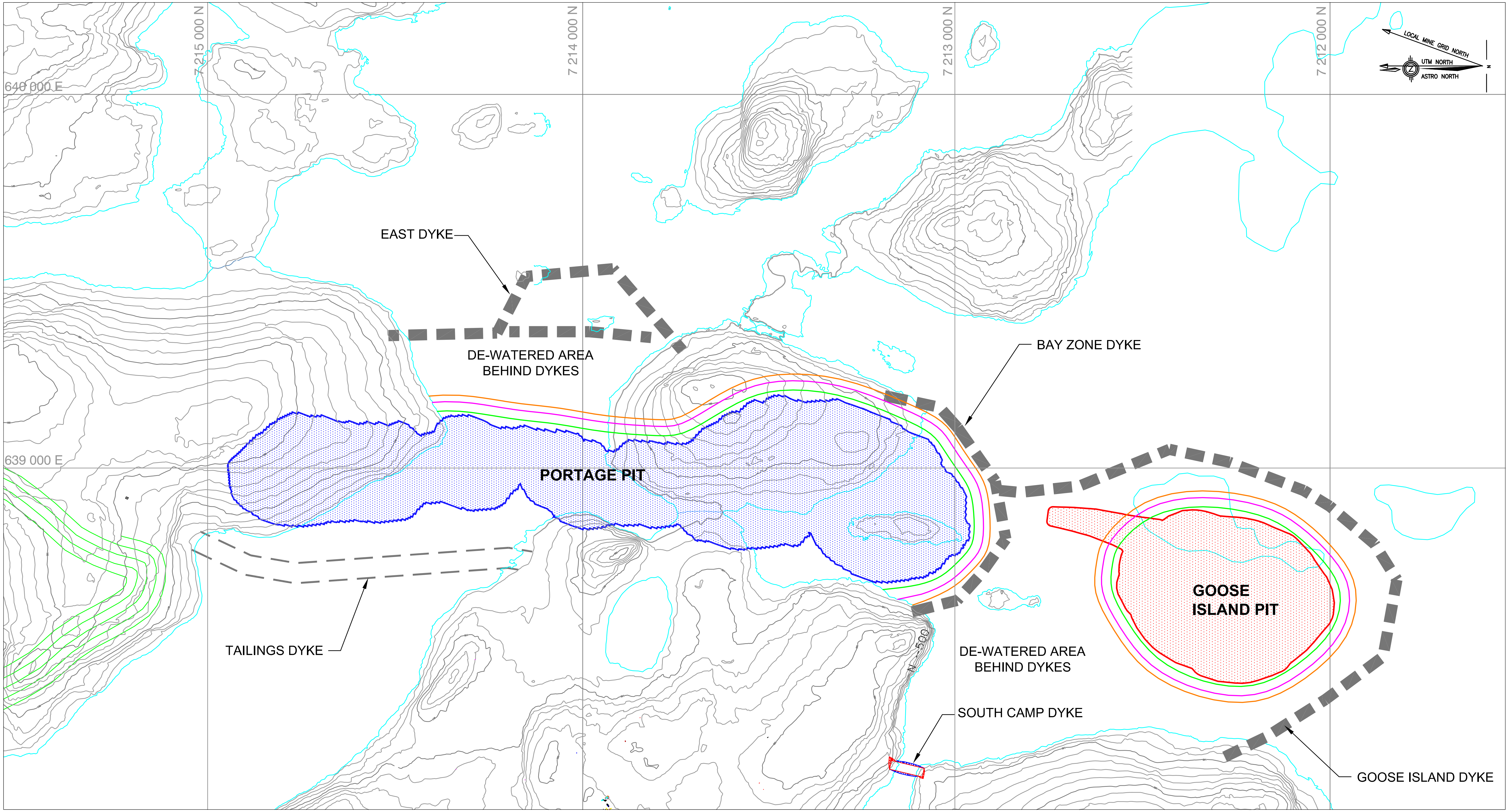
REVISION DATE: 04/01/27 4:46pm By: sreddy CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK13.dwg

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr

Setback Distance as a Function of Charge Weight
to Achieve 100 kPa Instantantaneous Overpressure
site factor b = -1.6 for downhole blasting conditions



PROJECT	CUMBERLAND RESOURCES LTD.				
TITLE	CHARGE WEIGHT vs SETBACK DISTANCE FOR 100 kPA OVERPRESSURE				
Golder Associates	PROJECT No.	03-1413-427		FILE No. FIGURE 3	
	DESIGN	CJC	28JAN04	SCALE	REV.
	CADD	SS	28JAN04	FIGURE 14	
	CHECK	CJC	28JAN04		
	REVIEW				



LEGEND

Green line	86 kg Charge Weight, 40m Offset
Magenta line	250 kg Charge Weight, 69m Offset
Orange line	420 kg Charge Weight, 89m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

0 100 200 300 400 500
Scale in Meters

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

INSTANTANEOUS OVERPRESSURE
100kPa ISOPLETH

Golder Associates

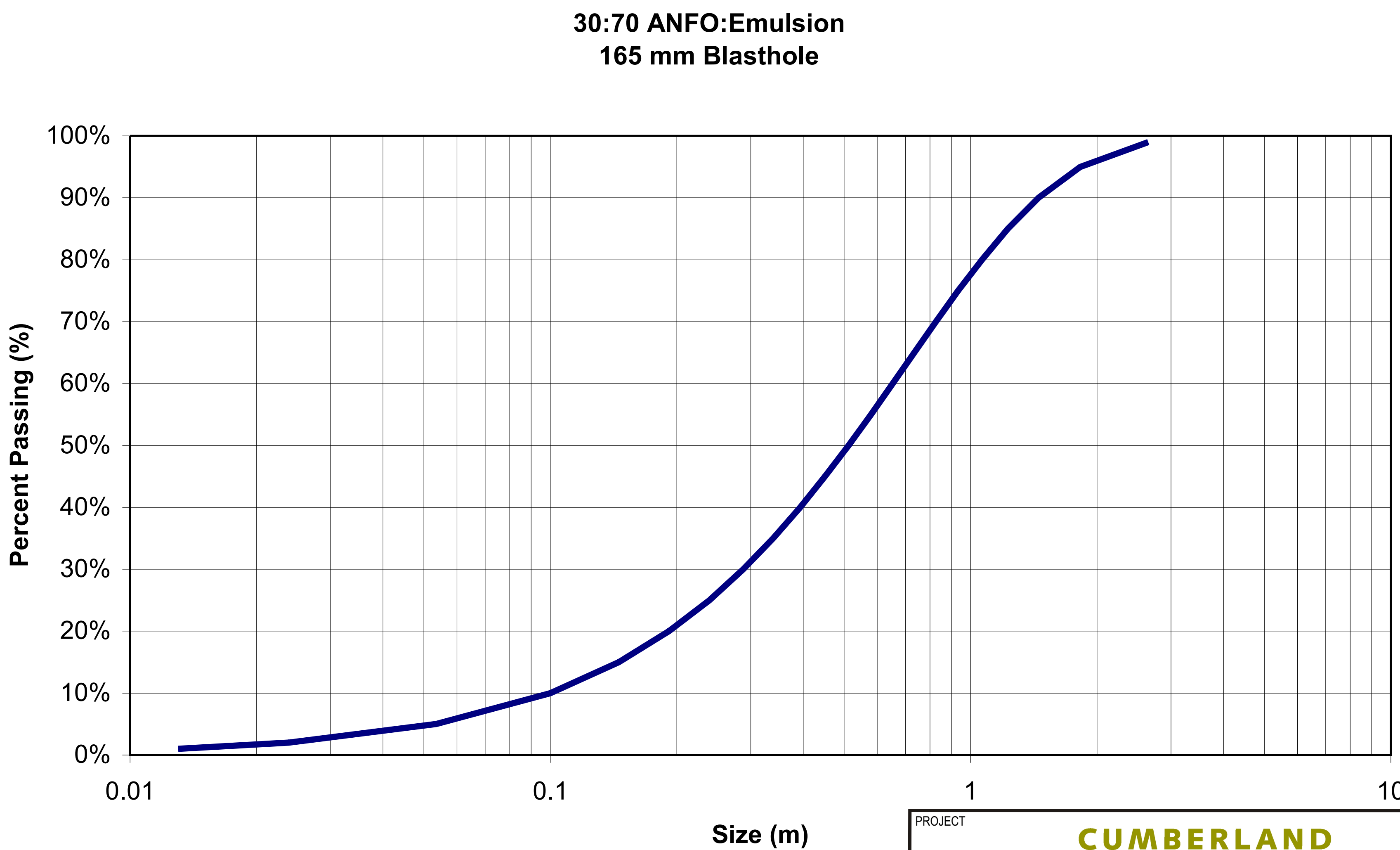
PROJECT No.	03-1413-427		FILE No.	031413427SK15	
DESIGN	CJC	23 JAN 04	SCALE	AS SHOWN	REV. A
CADD	SRR	27 JAN 04			
CHECK	CJC		FIGURE 15		
REVIEW					

REVISION DATE: 04/01/27 4:04pm By: sreddy CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK15.dwg

APPENDIX I

FRAGMENTATION PREDICTIONS

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr



PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

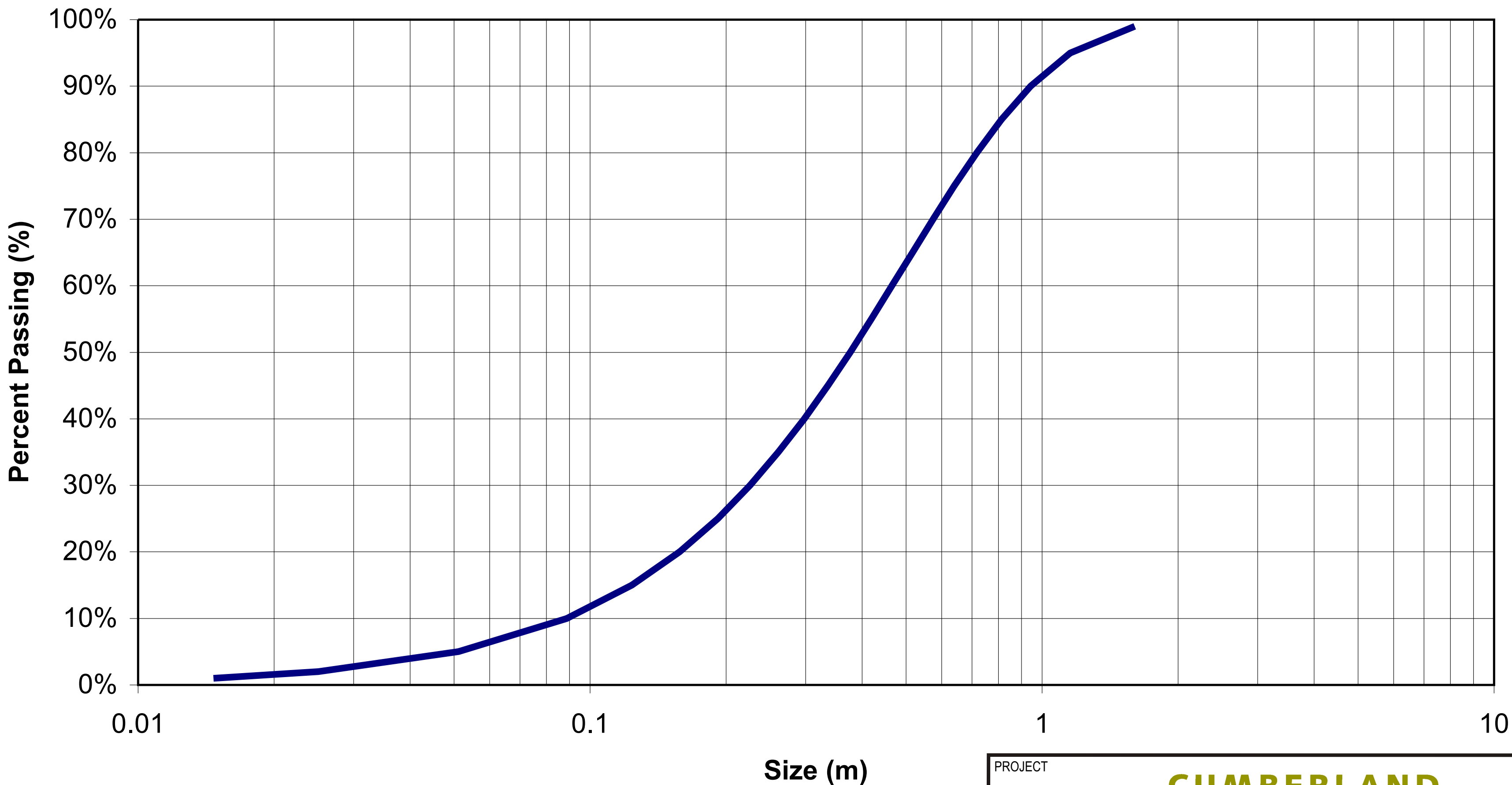
IRON FORMATION
FRAGMENTATION PREDICTION
6m BENCH - 165mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	**FIGURE I-1**	
CHECK	CJC	28JAN04		
REVIEW				

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr

30:70 ANFO/Emulsion
165mm Blasthole



PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

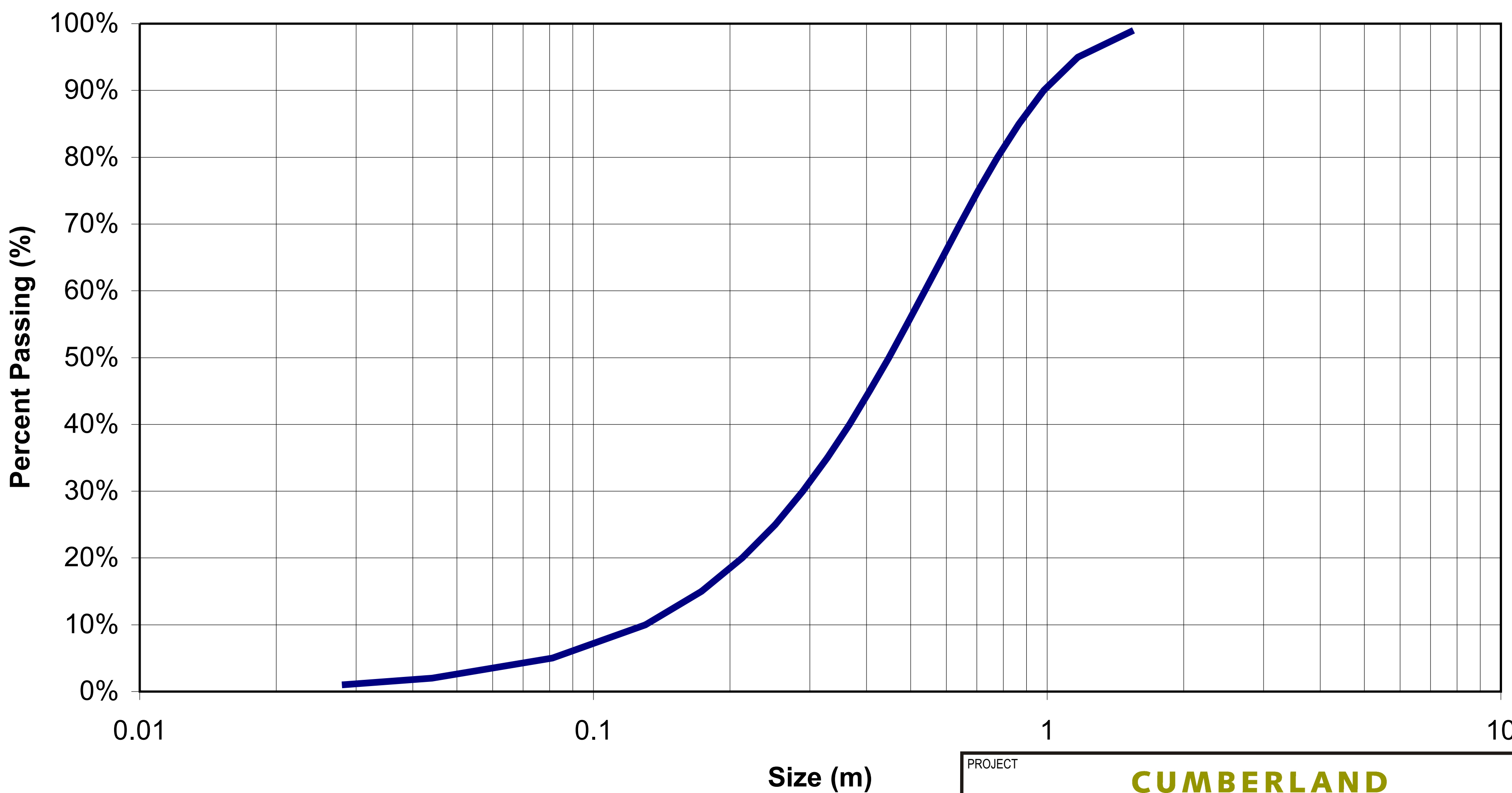
ULTRAMAFIC VOLCANIC
FRAGMENTATION PREDICTION
12m BENCH - 165mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3
DESIGN	CJC	28JAN04	SCALE / REV.
CADD	SS	28JAN04	**FIGURE I-2**
CHECK	CJC	28JAN04	
REVIEW			

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr

30:70 ANFO/Emulsion
165 mm blasthole

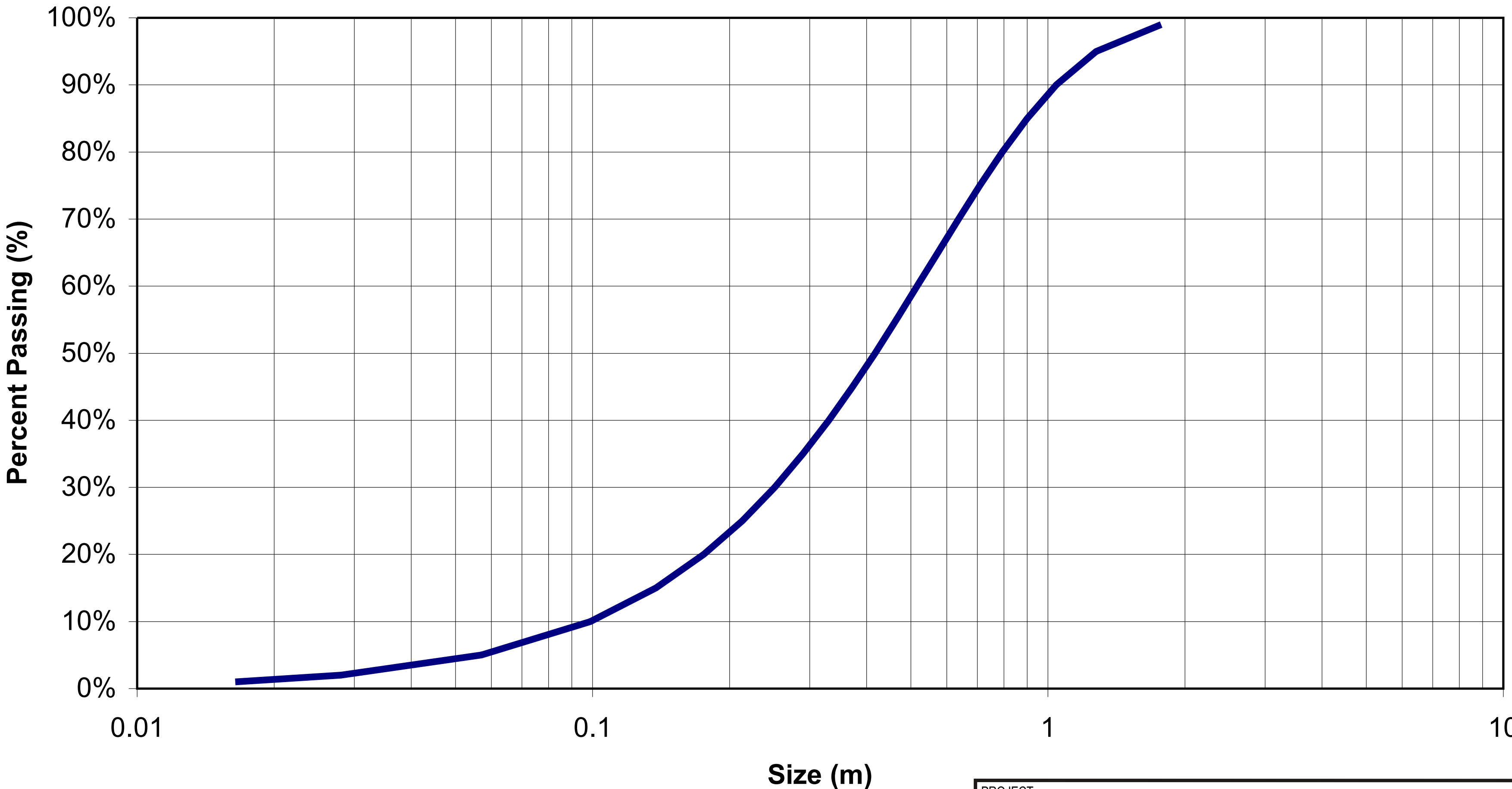


PROJECT	CUMBERLAND RESOURCES LTD.
TITLE	INTERMEDIATE VOLCANIC FRAGMENTATION PREDICTION 12m BENCH - 165mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	FIGURE I-3	
CHECK	CJC	28JAN04		
REVIEW				

30:70 ANFO/Emulsion
229 mm Blasthole



PROJECT

CUMBERLAND
RESOURCES LTD.

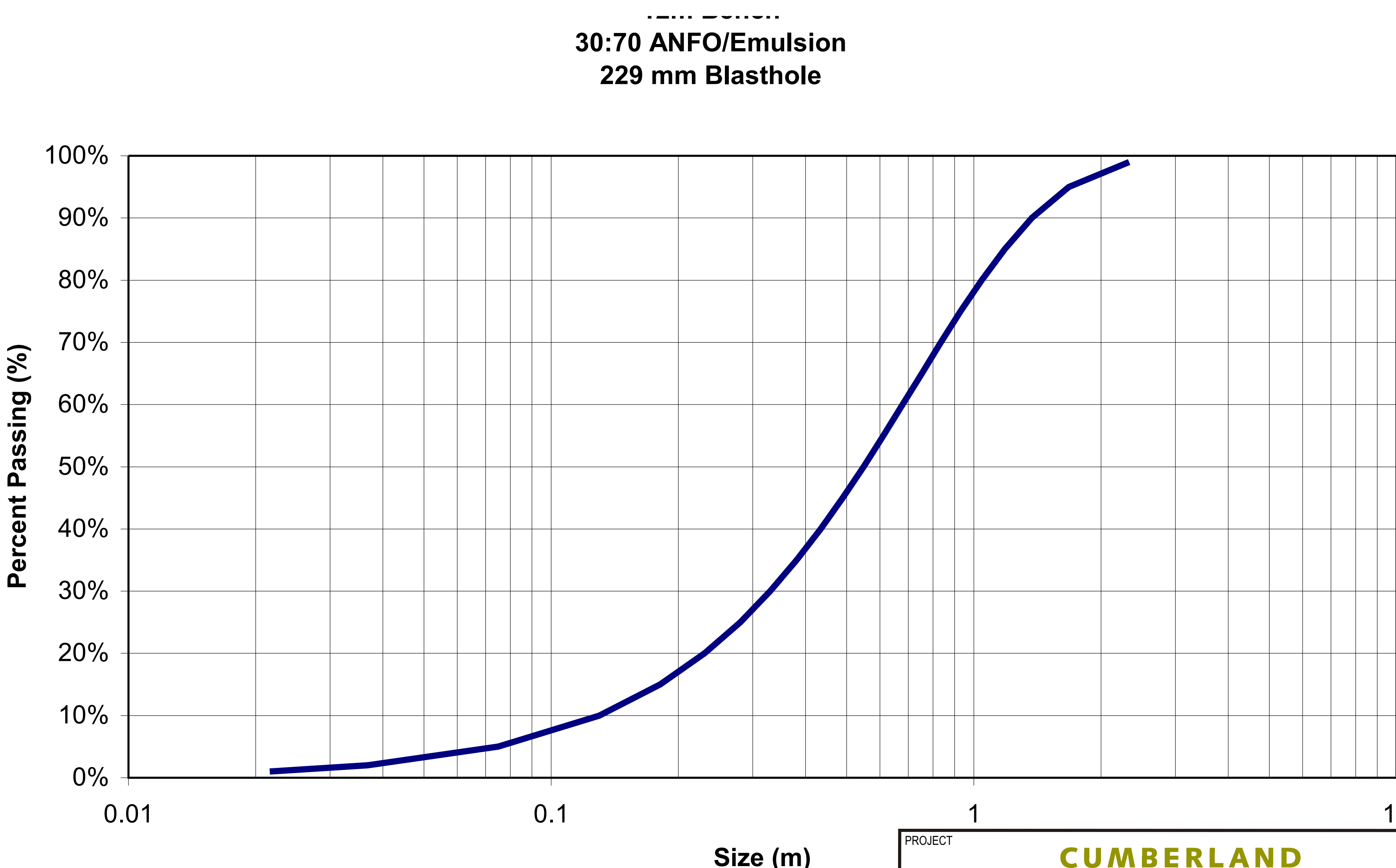
TITLE

ULTRAMAFIC VOLCANIC
FRAGMENTATION PREDICTION
12m BENCH - 229mm BLASTHOLE

Golder Associates

PROJECT No.		03-1413-427	FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	**FIGURE I-4**	
CHECK	CJC	28JAN04		
REVIEW				

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr



PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

INTERMEDIATE VOLCANIC FRAGMENTATION PREDICTION 12m BENCH - 229mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	FIGURE I-5	
CHECK	CJC	28JAN04		
REVIEW				