APPENDIX 8.I

HYDROLOGY ASSESSMENT UPDATE

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8.I EFFECTS TO WATER QUANTITY – UPDATED ASSESSMENT

This appendix presents updates to the assessment provided in Section 8.7 of the 2011 Environmental Impact Statement (EIS) Update (De Beers 2011), resulting from changes in project footprint associated with the Fine Processed Kimberlite Containment (PKC) Facility and diversion of the A watershed during operations.

8.I.1 Construction and Operations

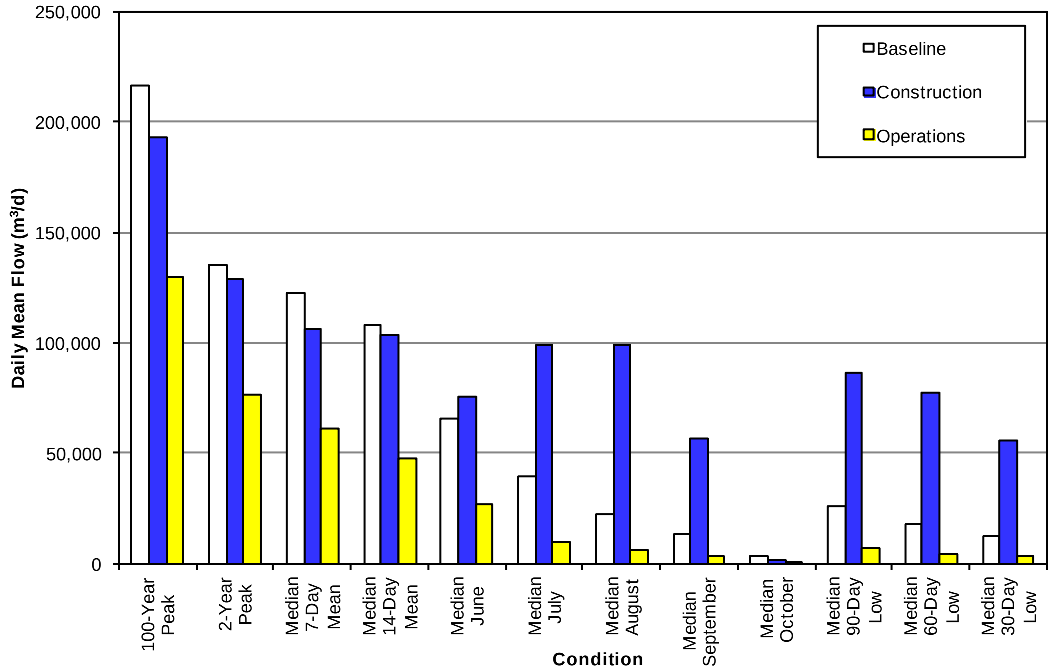
8.I.1.1 Effects of Dewatering of Kennady Lake to Flows, Water Levels and Channel/Bank Stability in Area 8

The diversion of the A watershed through the J watershed has slightly modified predicted flows and water levels to those presented in the 2011 EIS Update (De Beers 2011) for the outlet and waterbody of Area 8, during construction and operations. The updated analysis is presented below.

Construction: The water balance results for Area 8 show that monthly mean flows will be slightly greater than baseline during the natural high water month of June, and will be greater than baseline during the natural low water months of July to September. The 100-year and 2-year flood discharges will be lower than baseline due to the reduction in upstream drainage area and low pumping capacity relative to the natural flood discharges. Under median conditions, low flows will increase during construction.

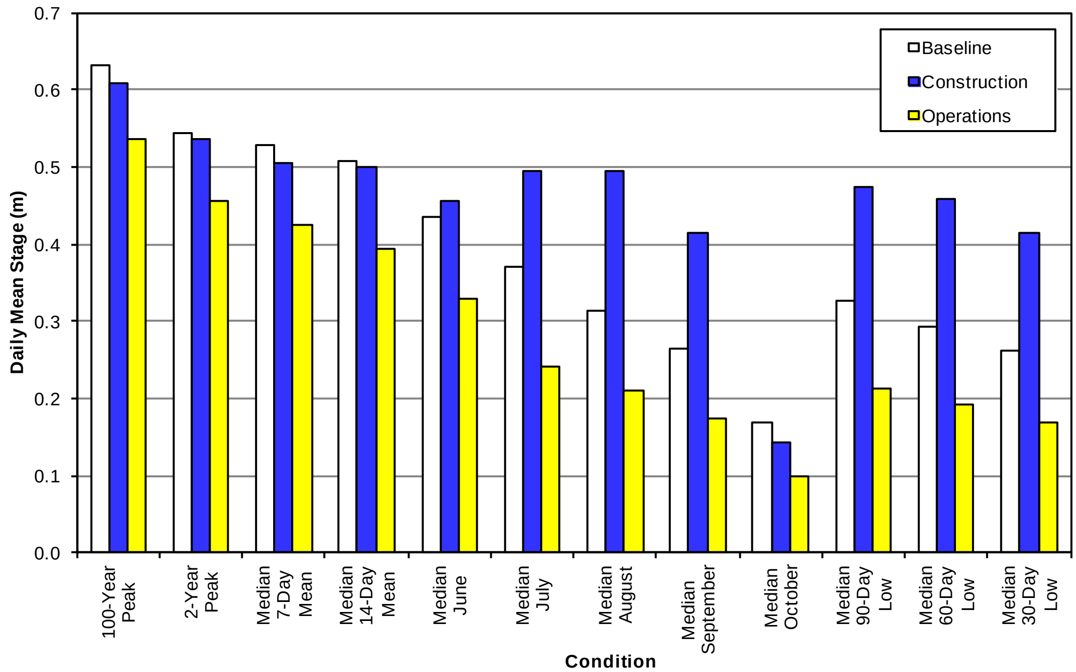
Operations: The water balance results for Area 8 show that when pumped discharge from Area 7 ceases, flows will be reduced from baseline. Results for the month of November are not shown because conditions during construction and operations for that month are expected to be similar to baseline, due to frozen conditions.

Figure 8.I-1 Comparison of Effects on the Outlet of Kennady Lake (Stream K5) Discharges during Construction and Operations



m^3/d = cubic metres per day.

Figure 8.I-2 Comparison of Effects on the Outlet of Kennady Lake (Stream K5) Water Level during Construction and Operations



m = metres.

Table 8.I-1 Mean Daily Outflow Volumes at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Daily Outflow Volume (m^3)				
			June	July	August	September	October
Wet	100	baseline	121,000	86,500	59,600	68,600	13,500
		construction	102,000	103,000	104,000	106,000	9,710
		operations	44,000	26,500	18,600	21,900	3,040
	10	baseline	97,600	61,900	38,100	29,200	6,640
		construction	93,600	101,000	101,000	83,900	4310
		operations	37,600	16,900	11,400	8,770	1,420
Median	2	baseline	65,900	39,300	22,800	13,200	3,070
		construction	76,000	99,500	98,900	56,300	1,830
		operations	26,800	9,790	6,190	3,360	546
Dry	10	baseline	36,900	23,100	13,900	6,880	1,430
		construction	45,400	98,100	97,800	28,200	1,000
		operations	15,300	5,400	3,310	1,350	147
	100	baseline	12,900	12,000	9,420	4,910	878
		construction	4,720	97,200	97,300	4,940	757
		operations	4,440	2,850	2,210	811	40

m^3 = cubic metres.

Table 8.I-2 Representative Discharges at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.51	192,000	167,000	48,900	52,500	59,000
		construction	2.23	118,000	111,000	103,000	103,000	103,000
		operations	1.50	93,400	69,800	13,600	17,400	19,100
	10	baseline	2.14	166,000	145,000	26,200	32,300	41,000
		construction	1.73	111,000	107,000	85,300	91,800	95,500
		operations	1.23	80,500	61,500	6,980	9,360	11,500
Median	2	baseline	1.56	123,000	108,000	12,800	18,300	26,000
		construction	1.49	106,000	104,000	55,900	77,800	86,100
		operations	0.891	61,000	47,700	3,040	4,710	6,630
Dry	10	baseline	0.801	65,100	60,000	6,560	10,900	16,100
		construction	1.41	103,000	101,000	28,400	63,400	76,200
		operations	0.528	36,300	28,500	1,340	2,610	3,910
	100	baseline	0.152	14,900	17,300	5,000	9,340	13,200
		construction	1.39	102,000	101,000	15,500	51,400	67,700
		operations	0.26	11,400	7,240	787	1,850	2,410

m^3/s = cubic metres per second; m^3/d = cubic metres per day; Q = discharge

Table 8.I-3 Mean Daily Water Levels at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.526	0.474	0.422	0.441	0.266
		construction	0.500	0.501	0.502	0.505	0.241
		operations	0.385	0.328	0.294	0.310	0.168
	10	baseline	0.492	0.427	0.368	0.339	0.214
		construction	0.486	0.498	0.497	0.470	0.187
		operations	0.366	0.286	0.253	0.233	0.133
Median	2	baseline	0.436	0.371	0.314	0.265	0.168
		construction	0.455	0.495	0.494	0.415	0.143
		operations	0.330	0.241	0.209	0.173	0.098
Dry	10	baseline	0.364	0.315	0.269	0.216	0.133
		construction	0.388	0.493	0.493	0.335	0.119
		operations	0.277	0.201	0.172	0.130	0.065
	100	baseline	0.263	0.257	0.238	0.195	0.114
		construction	0.192	0.492	0.492	0.195	0.109
		operations	0.189	0.164	0.152	0.111	0.044

m = metre.

Table 8.I-4 Representative Water Levels at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.631	0.607	0.582	0.397	0.406	0.421
		construction	0.608	0.522	0.513	0.500	0.501	0.500
		operations	0.537	0.486	0.444	0.267	0.288	0.297
	10	baseline	0.601	0.580	0.556	0.327	0.349	0.376
		construction	0.562	0.513	0.507	0.472	0.483	0.489
		operations	0.506	0.464	0.427	0.217	0.238	0.254
Median	2	baseline	0.544	0.529	0.508	0.262	0.293	0.326
		construction	0.537	0.505	0.501	0.414	0.459	0.474
		operations	0.457	0.426	0.394	0.168	0.192	0.214
Dry	10	baseline	0.442	0.434	0.423	0.213	0.250	0.281
		construction	0.527	0.501	0.498	0.336	0.431	0.456
		operations	0.389	0.362	0.336	0.130	0.160	0.181
	100	baseline	0.264	0.275	0.288	0.196	0.238	0.265
		construction	0.525	0.499	0.497	0.278	0.403	0.439
		operations	0.312	0.253	0.220	0.110	0.144	0.156

m = metre.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - Construction of dyke A across the narrows will reduce the outflow from Area 7 into Area 8 to zero. All discharges from Area 7 to Area 8

during construction and operations will be by direct discharge during dewatering.

- Diversion of the A Watershed to Lake J1b will augment flows at the outlet of Lake J1b during construction and operations.
- During dewatering, flows from Area 8 will generally be increased and the duration of the flood period will be extended through September; however, flows will be limited so that dewatering does not cause the total flow to exceed the 2-year flood discharge.
- During Operations, when dewatering has ceased, flows from Area 8 will be reduced from baseline, because only the local tributary area (Watersheds I, J and Ke) will contribute runoff to Area 8. Flows through Waterhsed J will be supplemented by diverted Watershed ruonff through direct pumping from Lake A1.

• Effects on water levels:

- Water levels in Areas 3 to 7 will be managed to allow mining and changes in water levels will follow the schedule presented in Table 8.7-6 of the 2011 EIS Update (De Beers 2011).
- Changes to water levels in Area 8 will correspond to changes in flows. For median conditions, the greatest changes in June to October mean monthly stage are expected to occur in August during construction (+0.181 metres [m]) and July for operations (-0.130 m).

• Effects on channel/bank stability:

- No effects on channel stability in the Kennady Lake watershed are anticipated, as all dewatering flows will be pumped via pipeline to receiving waterbodies or pumped to receiving streams rather than conveyed by natural channels. No effects on bank stability are anticipated, due to the drop in water levels. Exposed lake-bed areas may be subject to erosion by runoff, depending on the type of substrate present. However, all water within Areas 3 to 7 will be managed to prevent the release of water to the natural receiving environment if specific water quality discgarhe thresholds are not met.
- Water levels in Area 8 and discharges from its outlet channel (Stream K5) will be maintained below baseline 1 in 2 year flood levels throughout construction and operations, except where natural exceedences occur while pumped diversions are suspended. No adverse effects on channel or bank stability are anticipated.

8.I.1.2 Effect of Watershed Diversion in Watersheds A, B, D and E on Flows, Water Levels and Channel/Bank Stability in Streams and Smaller Lakes in the Kennady Lake Watershed

The diversion of the A watershed through the J watershed has slightly modified predicted flows and water levels presented in the 2011 EIS Update (De Beers 2011) for the outlet and waterbody of Lake A1 and A2 during operations. The updated analysis is presented below. Hydrological regimes of Lake J1b during baseline, construction and operations are also presented.

Table 8.I-5 Hydrological Effects on the Outflows from the A, B, D and E Watersheds during Operations

Lake	Condition	Local Lake Parameters			Watershed Parameters				
		Surface Area	Perimeter	Maximum Depth	Watershed Area	Lake Surface Area		Mean Annual Water Yield	
		(ha)	(m)	(m)	(km^2)	(km^2)	(%)	(mm)	(m^3)
A1[a]	Baseline	26.73[a]	3,894[a]	7.3[a]	2.236	0.639	28.6	161	361,000
	Diverted	54.2	3,842	9.0	2.236	0.806	36.0	144	323,000
B1	Baseline	8.21	2,340	4.1	1.269	0.174	13.7	198	251,000
	Diverted	8.21	2,340	4.1	1.269	0.174	13.7	198	251,000
D1	Baseline	1.88	780	[b]	4.497	1.027	22.8	175	788,000
	Diverted	1.88	780	[b]	0.349	0.019	5.4	210	73,300
D2	Baseline	12.53	2,320	1.0	4.148	1.008	24.3	172	713,000
	Diverted	103.00	6,460	3.8	4.148	1.447	34.9	155	645,000
D3	Baseline	38.37	4,070	3.0	2.957	0.839	28.4	163	481,000
	Diverted	[c]	[c]	4.6	[c]	[c]	[c]	[c]	[c]
E1	Baseline	20.24	2,780	3.9	1.225	0.244	19.9	182	223,000
	Diverted	26.98	3,150	4.7	1.225	0.311	25.4	173	212,000

(a) Diverted condition includes Lake A2

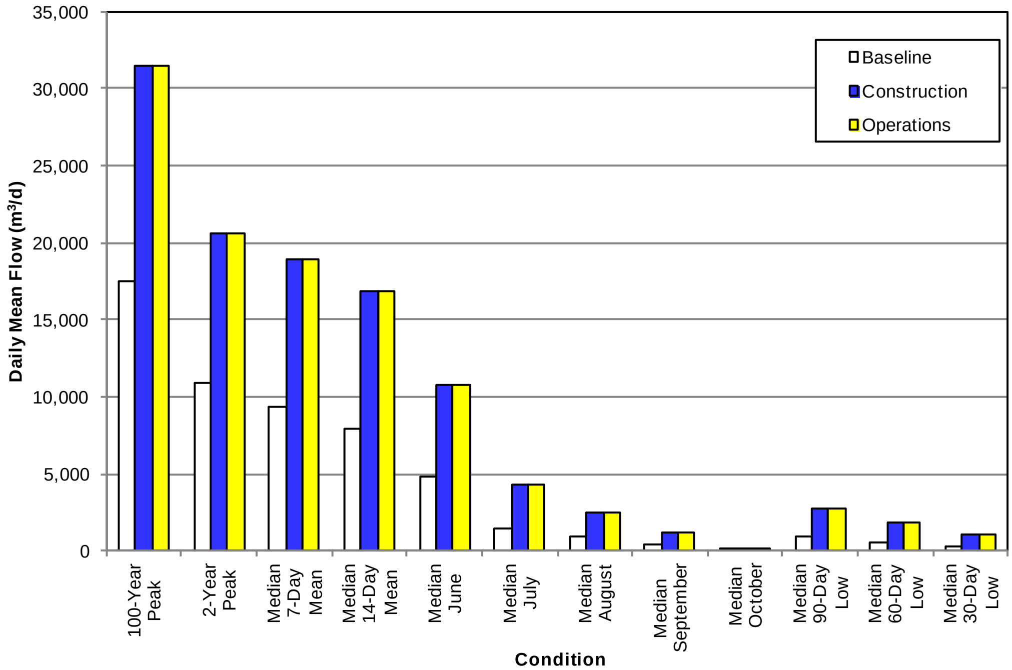
(b) Maximum depth unknown; no change anticipated due to Project.

(c) Included in values provided for raised Lake D2.

ha =- hectare; m = metre; km^2 = square kilometre; % = percent; mm = millimetre; m^3 = cubic metre.

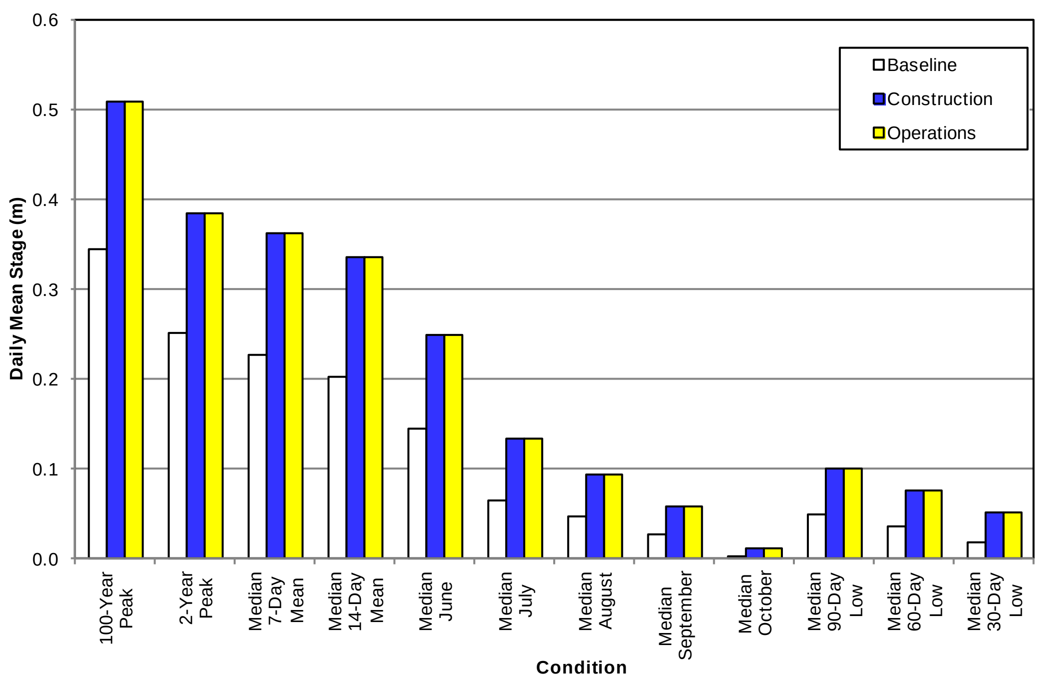
Construction and Operations: The water balance results for Lake J1b show that monthly mean flows and flood discharges will be greater than baseline throughout the open water season due to the constant augmentation in flow from Lake A1 during construction and operations. Effects on flow are expected to be identical during construction and operations.

Figure 8.I-3 Comparison of Effects on the Outlet of Lake J1b Discharges during Construction and Operations



m^3/d = cubic metres per day.

Figure 8.I-4 Comparison of Effects on the Outlet of Lake J1b Water Level during Construction and Operations



m = metres.

Table 8.I-6 Mean Daily Outflow Volumes at the Outlet of Lake J1b – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Daily Outflow Volume (m^3)				
			June	July	August	September	October
Wet	100	baseline	7,480	4,250	3,490	3,100	216
		construction	17,400	11,100	8,150	10,800	1,400
		operations	17,400	11,100	8,150	10,800	1,400
	10	baseline	6,420	2,710	1,930	1,430	91
		construction	14,600	7,430	4,830	4,100	441
		operations	14,600	7,430	4,830	4,100	441
Median	2	baseline	4,760	1,440	882	403	15
		construction	10,800	4,250	2,460	1,200	103
		operations	10,800	4,250	2,460	1,200	103
Dry	10	baseline	2,600	629	350	0	0
		construction	6,450	2,120	1,160	291	0
		operations	6,450	2,120	1,160	291	0
	100	baseline	358	189	117	0	0
		construction	2,530	903	549	36	0
		operations	2,530	903	549	36	0

m^3 = cubic metres.

Table 8.I-7 Representative Discharges at the Outlet of Lake J1b – Construction and Operations

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	0.20	14,000	11,400	3,530	3,150	2,910
		construction	0.36	28,600	24,700	6,460	7,860	8,090
		operations	0.36	28,600	24,700	6,460	7,860	8,090
	10	baseline	0.17	12,100	10,100	1,050	1,500	1,790
		construction	0.32	25,200	22,100	2,930	4,010	4,890
		operations	0.32	25,200	22,100	2,930	4,010	4,890
Median	2	baseline	0.13	9,300	7,910	224	604	953
		construction	0.24	18,900	16,800	1,040	1,810	2,730
		operations	0.24	18,900	16,800	1,040	1,810	2,730
Dry	10	baseline	0.08	5,860	4,860	0	247	463
		construction	0.14	11,600	10,500	288	871	1,530
		operations	0.14	11,600	10,500	288	871	1,530
	100	baseline	0.04	2,510	1,520	0	122	220
		construction	0.06	4,930	4,530	28	519	1,210
		operations	0.06	4,930	4,530	28	519	1,210

m^3/s = cubic metres per second; m^3/d = cubic metres per day; Q = discharge

Table 8.I-8 Mean Daily Water Levels at the Outlet of Lake J1b – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.195	0.134	0.118	0.109	0.018
		construction	0.343	0.255	0.207	0.249	0.064
		operations	0.343	0.255	0.207	0.249	0.064
	10	baseline	0.177	0.099	0.079	0.065	0.010
		construction	0.305	0.195	0.146	0.131	0.030
		operations	0.305	0.195	0.146	0.131	0.030
Median	2	baseline	0.145	0.065	0.047	0.028	0.003
		construction	0.249	0.134	0.093	0.058	0.011
		operations	0.249	0.134	0.093	0.058	0.011
Dry	10	baseline	0.097	0.038	0.025	-	-
		construction	0.177	0.084	0.056	0.022	-
		operations	0.177	0.084	0.056	0.022	-
	100	baseline	0.026	0.017	0.012	-	-
		construction	0.095	0.048	0.034	0.006	-
		operations	0.095	0.048	0.034	0.006	-

m = metre.

Table 8.I-9 Representative Water Levels at the Outlet of Lake J1b – Construction and Operations

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.345	0.298	0.259	0.119	0.110	0.104
		construction	0.510	0.478	0.434	0.177	0.202	0.206
		operations	0.510	0.478	0.434	0.177	0.202	0.206
	10	baseline	0.306	0.270	0.239	0.053	0.067	0.075
		construction	0.468	0.440	0.402	0.105	0.129	0.147
		operations	0.468	0.440	0.402	0.105	0.129	0.147
Median	2	baseline	0.252	0.226	0.203	0.019	0.037	0.050
		construction	0.383	0.362	0.335	0.052	0.076	0.100
		operations	0.383	0.362	0.335	0.052	0.076	0.100
Dry	10	baseline	0.186	0.166	0.147	-	0.020	0.031
		construction	0.273	0.262	0.245	0.022	0.047	0.068
		operations	0.273	0.262	0.245	0.022	0.047	0.068
	100	baseline	0.117	0.094	0.068	-	0.013	0.019
		construction	0.151	0.148	0.140	0.005	0.033	0.058
		operations	0.151	0.148	0.140	0.005	0.033	0.058

m = metre.

A summary of effects on flows, water levels and channel/bank stability is provided below:

- Effects on flows:
  - Annual outflows from raised lakes (i.e., D2/D3 and E1) will be reduced somewhat from baseline due to increased evaporation from

the lake water surfaces. The annual outflow from Lake D1 into Kennady Lake will be greatly reduced, because of the upstream diversion. The annual outflow from Lake B1 will be unchanged.

- Annual outflows of Lakes A1 and A2 will depend on the managed lake water surface elevation, with greater elevations resulting in greater surface area and greater evaporative losses.
- Annual outflows of Lake J1b will be increased due to augmentation of flow from Lake A1.
- Under the current mine plan, the construction of excavated diversion channels is not contemplated. However, new stream channels connecting Lake B1, and the raised Lakes D2 and D3, and E1 (created by the installation of Dykes E, F, and G) to the N watershed will be created once water surface elevations have increased to the spill elevation. These streams will be temporary, as Dykes E, F, and G will be removed at the end of the operations period, and flows returned to Kennady Lake through the original stream channels.

  The new channels will be evaluated to make sure that they allow the seasonal passage of fish between lakes that approximates natural conditions. Any enhancements required to improve the newly formed natural outlet channels will be designed during the detailed engineering design phase. The goal of the design enhancements will be to prevent erosion and maintain stability in permafrost, and to provide physical fish habitat features where they do not exist.

  The general shapes of the annual hydrographs in these diversion channels will be similar to that of the natural lake outflows to Kennady Lake, though peak and annual flows will be reduced due to increased evaporative losses.

- Effects on water levels:
  - The nominal water level of Lakes A1 and A2 will increase by 1.7 m, the nominal water level of Lake D2 will increase by 1.6 m, the nominal water level of Lake D3 will increase by 2.8 m, and the nominal water level of Lake E1 will increase by 0.8 m. The nominal water level of Lake B1 will not be affected.
  - Changes to water levels in Lake J1b will correspond to changes in flows. For median conditions, the greatest changes in June to October mean monthly stage are expected to occur in July during constructions and operations.
  - Annual variation in water levels in the raised lakes will be similar to pre-diversion values.

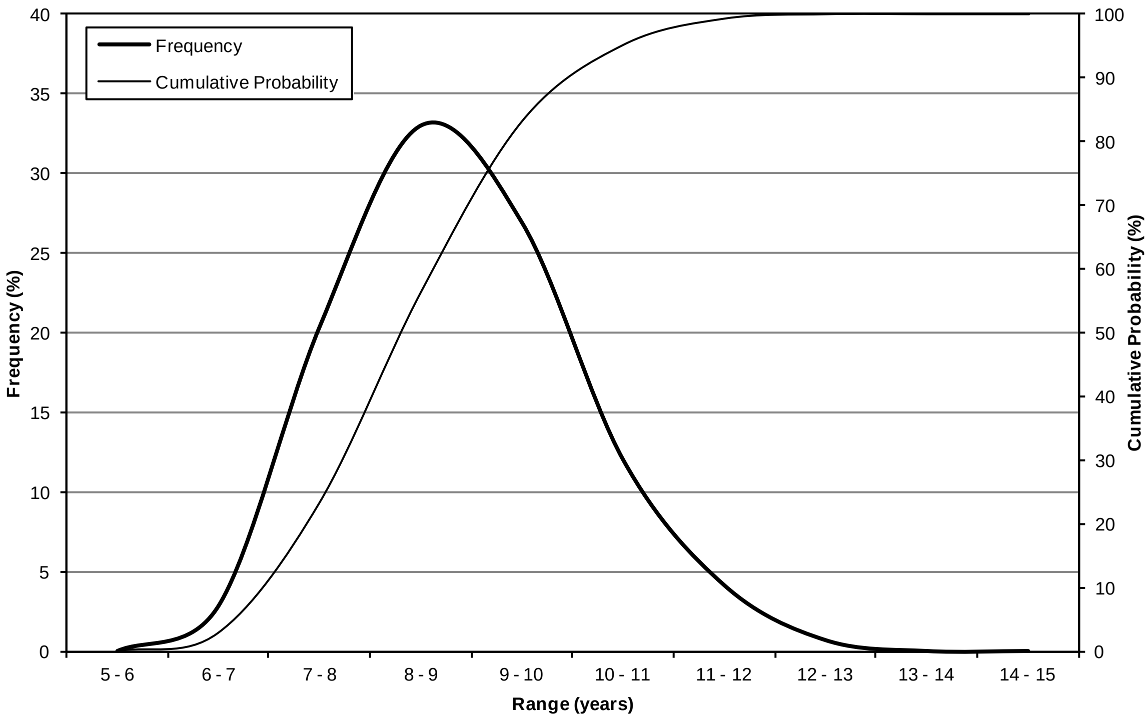
- Effects on channel/bank stability:
  - Diversions of the B, D and E watersheds will consist of channels that follow drainage paths to Lake N14; they will be evaluated and where required they will be enhanced to reduce the potential for erosion and to maintain stability in permafrost. Diversion of the B, D, and E watersheds will form new channels once water surface elevations have increased to the spill elevation and will be evaluated to make sure that they allow the seasonal passage of fish between lakes that approximates natural conditions. Any enhancements required to improve the newly formed natural outlet channels will be designed during the detailed engineering design phase. The goal of the design enhancements will be to prevent erosion and maintain stability in permafrost, and to provide physical fish habitat features where they do not exist.
  - Diversion of the A watershed will increase flows and water levels at Lake J1b, which may be subject to new shoreline formation and potential channel erosion. A monitoring and mitigation program will be incorporated in an adaptive management plan for shoreline and channel erosion, based on additional field data collection.
  - Raised lakes will be subject to erosion as new shorelines are established. Natural armoring of the 8.1 kilometres (km) of morainal soils is expected to limit erosion in these areas and persistent total suspended solids (TSS) generation is expected to be limited as coarse materials settle out on the lakebed near to where they are mobilized. Low slopes in new shoreline areas with organic (peat) soils are expected to minimize erosion and generation of TSS. A monitoring and mitigation program will be incorporated in an adaptive management plan for shoreline erosion Golder (2012).

8.I.2 Effects Analysis Results – Closure

8.I.2.1 Effect of Refilling Activities on Flows, Water Levels and Channel/Bank Stability in Areas 3, 4, 5, 6, and 7

The change in project footprint has slightly modified predicted flows and water levels presented in the 2011 EIS Update (De Beers 2011) for the refilling of Kennady Lake during closure. The updated analysis is presented below.

Figure 8.I-5 Kennady Lake Refilling Time Frequency and Cumulative Probability for the Option 2 Scenario



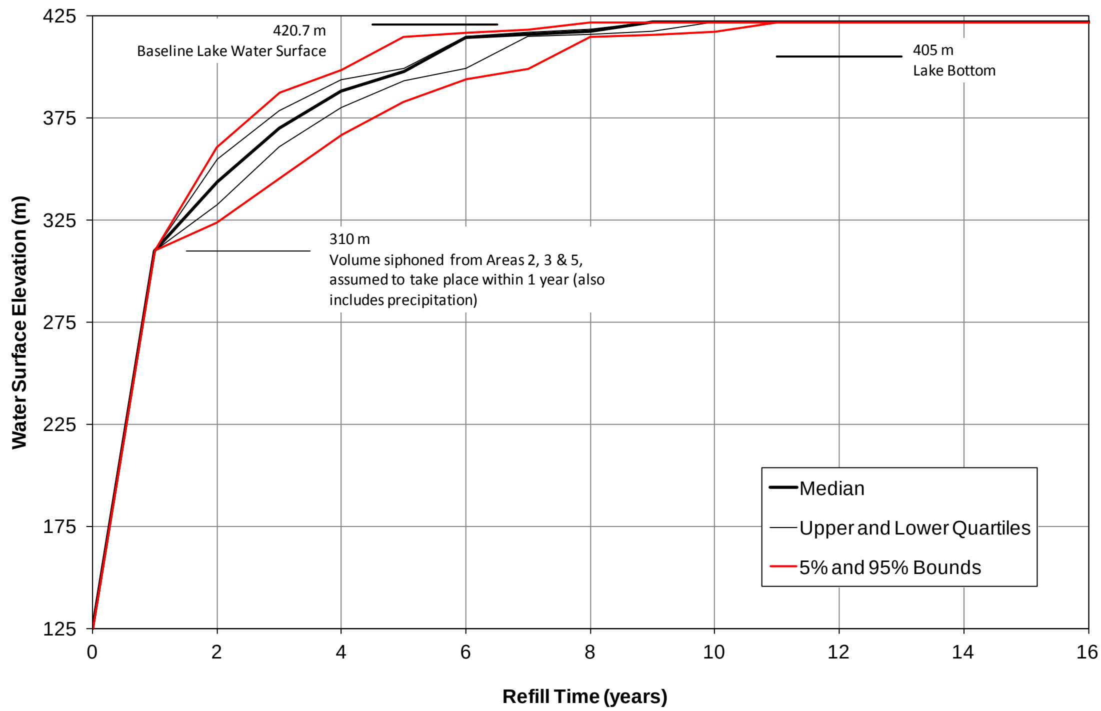
% = percent.

Table 8.I-10 Kennady Lake Refilling Time Frequency and Cumulative Probability for Mine Plan with Supplemental Mitigation (Option 2) Scenario

Range (years)	Option 2Scenario		Range (years)	Option 2 Scenario	
	Frequency (%)	Cumulative Probability (%)		Frequency (%)	Cumulative Probability (%)
5 to 6	0.00	0.00	10 to 11	12.00	95.20
6 to 7	2.84	2.84	11 to 12	4.12	99.32
7 to 8	20.40	23.24	12 to 13	0.68	100.00
8 to 9	33.04	56.28	13 to 14	0.00	100.00
9 to 10	26.92	83.20	14 to 15	0.00	100.00

% = percent.

Figure 8.I-6 Kennady Lake Water Levels with Time during Refilling – Supplemental Mitigation



m = metre; % = percent.

Table 8.I-11 Kennady Lake Water Levels with Time during Refilling – Supplemental Mitigation Scenario, Median Conditions

Lake Depth (m)	Water Level (m)	Refilling Time (Years)
0	405.00	5.5
5	410.00	5.8
10	415.00	6.6
15	420.00	8.6
15.7	420.70	9.0

m = metre.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - During closure, all flow from Kennady Lake Areas 3, 4, 5, 6 and 7 tributary watersheds will contribute to lake refilling. Diversion of water from Lake N11 to Kennady Lake during refilling will reduce the

median refilling time from approximately 16 to 17 years to approximately eight to nine years.

- Effects on water levels:
  - Water levels in Kennady Lake will rise during refilling as a function of the cumulative inflow, less lake evaporation.

- Effects on channel/bank stability:
  - The diversion pipeline outfall will be armoured to prevent erosion. No water will be released downstream from Kennady Lake Areas 3, 4, 5, 6 and 7 into Area 8 until the upstream water level is equal to that in Area 8 (and water quality in Area 7 meets specific water quality thresholds). Water levels in the upstream Areas will not exceed the naturally armoured shoreline elevation. Therefore, no effects on channel or bank stability are anticipated.

8.I.2.2 Long-term Effects of Mine Development on Hydrology of Kennady Lake

The change in project footprint has slightly modified lake to land proportions in the Kennady Lake watershed at post-closure presented in the 2011 EIS Update (De Beers 2011). The updated analysis is presented below.

Changes to the Kennady Lake watershed will have a negligible effect on the post-closure hydrological regime in the closure phase of the Project (i.e., after refilling of Kennady Lake and removal of Dyke A). Dyke A will be removed and all operational diversions within the watershed will be removed. Lakes A1 and A2 will remain permanently raised. Residual changes to the watershed will include:

- A net increase in the total land area (from 21.17 square kilometres (km^2) to 22.03 km^2) in the Kennady Lake watershed, due to the infilling of portions of Kennady Lake and some tributary lakes, partially offset by losses of land due to pit development.
- A net increase in the total water surface area of Kennady Lake tributaries (from 3.14 km^2 to 3.29 km^2), due to the net effects of permanent increase in water surface area of Lakes A1 and A2, and infilling of some smaller tributary lakes by mine rock piles and the Coarse Processed Kimberlite (PK) Pile. This will slightly decrease the water yield of the Kennady Lake watershed, due to increased lake evaporation.

- A net decrease in the water surface area of Kennady Lake (from 8.15 km^2 to 7.14 km^2), because the infill by the Fine PKC Facility, the Coarse PK Pile, and the South Mine Rock and the West Mine Rock Piles will be greater than the removal of land area during excavation of the 5034, Tuzo and Hearne mine pits. This will change the area-elevation-storage relationship of Kennady Lake and cause less attenuation of flood flows.

A summary of changes to the land and lake areas within the Kennady Lake watershed is shown in Table 8.7-15.

Table 8.I-12 Post-closure Changes to Kennady Lake Watershed Land and Lake Areas

Area Description	Total Watershed (km^2)	Total Land (km^2)	Total Lake (km^2)	Kennady Lake (km^2)	Tributary Lake (km^2)	Lake Proportion (%)
Baseline Kennady Lake Watershed	**32.463**	**21.170**	**11.293**	**8.149**	**3.144**	**34.8%**
Raised A1/A2 Lakes	-	-0.167	0.167	0.000	0.167	-
Infill - Mine Rock Covered	-	0.637	-0.637	-0.637	-	-
Infill - Mine Rock Covered Coarse PK	-	0.016	-0.016	-0.006	-0.009	-
Infill - West Mine Rock Pile	-	0.348	-0.348	-0.339	-0.009	-
Infill - South Mine Rock Pile	-	0.506	-0.506	-0.506	-	-
Land Cut - 5034 Pit and Benches	-	-0.266	0.266	0.266	-	-
Land Cut - Tuzo Pit and Benches	-	-0.173	0.173	0.173	-	-
Land Cut - Hearne	-	-0.037	0.037	0.037	-	-
Kennady Lake Post-Closure	**32.463**	**22.034**	**10.429**	**7.136**	**3.293**	**32.1%**
Change	0.000	0.864	-0.864	-1.013	0.149	-

km^2 = square kilometres; PK = processed kimberlite; % = percent; “-“ = not applicable.

The reduced lake area will affect lake evaporation and evapotranspiration within the watershed and the annual outflow from Kennady Lake, while the increased land area will increase runoff to the lake. A water balance was completed using results from the baseline model simulation at the outlet of Area 8 (K5 Outlet). These calculations show that the mean annual water yield will increase by 5.1 percent (%) at post-closure, from approximately 147 millimetres (mm) to 154 mm. Mean annual discharge from Kennady Lake will increase from 4,760 cubic decametres (dam^3) to 5,000 dam^3.

Due to the post-closure decrease in water surface area in Kennady Lake by 12.4%, the runoff of a given quantity of water into the lake will result in a proportionally greater increase in lake water level. This would be slightly offset by void spaces in the South and West Mine Rock piles, which will have a porosity of

23% and cover approximately 0.85 km^2. Changes to the Kennady Lake surface area will slightly increase post-closure flood peak discharges and water levels.

8.I.3 References

De Beers (De Beers Canada Inc.). 2011. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2.* Submitted to Mackenzie Valley Environmental Impact Review Board in response to the Environmental Impact Statement Conformity Review. July 2011.

Golder. (Golder Associates Ltd.). 2012. 2011 Shoreline and Channel Erosion Assessment Report. Report No. 11-1365-0001/DCN-048. Submitted to Mackenzie Valley Environmental Impact Review Board. March 2012.

8.I.4 Acronyms and Units

8.I.4.1 Acronyms

De Beers	De Beers Canada Inc.
EIS	Environmental Impact Statement
Golder	Golder Associates Ltd.
PK	processed kimberlite
PKC	processed kimberlite containment
TSS	total suspended solids

8.I.4.2 Units of Measure

%	percent
dam^3	cubic decametre
km	kilometre
km2	square kilometre
m	metre
m^3	cubic metre
mm	millimetre

APPENDIX 8.II

WATER QUALITY MODEL REPORT

Note: This appendix of the 2012 Environmental Impact Statement Supplemental Information Submission includes text highlighted in Yellow to identify revisions to the previous version of the appendix found in the 2011 EIS Update document**.**

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8.II.1 INTRODUCTION

De Beers Canada Inc. (De Beers) proposes to mine diamonds from three open pits (5034, Hearne, and Tuzo) at Kennady Lake, a headwater lake within the Lockhart River system, located approximately 280 kilometres (km) northeast of Yellowknife in the Northwest Territories (NWT), Canada. Mining from these three pits will require dewatering of Kennady Lake. Dewatering activities, mining, material placement and other site activities or water management strategies have the potential to impact the water quality in Kennady Lake and subsequently, in the downstream receiving environment during post-closure, when water will be released.

Water quality models are often used as a tool to provide an estimate of the direction and magnitude of impacts from proposed mining operations. A water quality model, to the extent practicable, should include the natural and anthropogenic processes that could affect the site water quality during operations and closure of mining facilities.

Four water quality models were developed for the Gahcho Kué Project (Project) to evaluate the magnitude and direction of impacts mining could have on Kennady Lake and in the downstream receiving environment. The water quality models were linked together at key times and nodes. The Kennady Lake model covered the portion of Kennady Lake that will be isolated from the receiving environment during mining (i.e., the controlled area). The downstream water quality model included Area 8, the Interlakes (i.e., the L and M watersheds), the N watershed, and Lake 410. These models were linked together during all periods of planned hydraulic connections, including pumping between systems, and at closure. The hydrodynamic model was used to estimate the amount of water in Tuzo and Hearne pits that will interact with Kennady Lake. These models are described individually in the following subsections. A nutrient and dissolved oxygen model was also developed for Kennady Lake to evaluate oxygen availability during winter in Kennady Lake. The approach, assumptions and results of this model are provided in Appendix 8.V.

The steps used to assess the Project effects on water quality are as follows:

- identify the spatial boundaries of the assessment;
- select time periods for the assessment;
- select the assessment locations on the watercourses where changes will be quantified;

- identify environmental design features and mitigation to reduce the effects to water quality; and
- develop models to quantify the changes in water quality.

This appendix presents the model approach, methods, inputs and assumptions related to the water quality predictions for the Project. Model results and interpretation are presented in Sections 8.2.5 and 9.2.5 of the Environmental Impact Statement (EIS) Supplement, and time series plots are provided in Appendix 8.IV (Kennady Lake) and Appendix 9.II (Downstream).

8.II.2 KENNADY LAKE WATER QUALITY MODEL

8.II.2.1 SITE OVERVIEW

Diamondiferous kimberlite pipes will be mined from three open pits (5034, Hearne and Tuzo) at the Project. All three kimberlite pipes are located beneath Kennady Lake. As such, segmentation and dewatering of Kennady Lake will be required to gain access to the open pits.

To facilitate the design of the Project, Kennady Lake will be divided into six principal areas whose limits are truncated by one or more filter dykes or impermeable, earth-filled dykes. Additional details of Kennady Lake water management are discussed in Section 3.9. Figure 8.II-1 presents the limits of each Kennady Lake area and Table 8.II-1 provides a brief description of each area. The water quality model inputs and assumptions presented in the subsequent sections are discussed with reference to these areas.

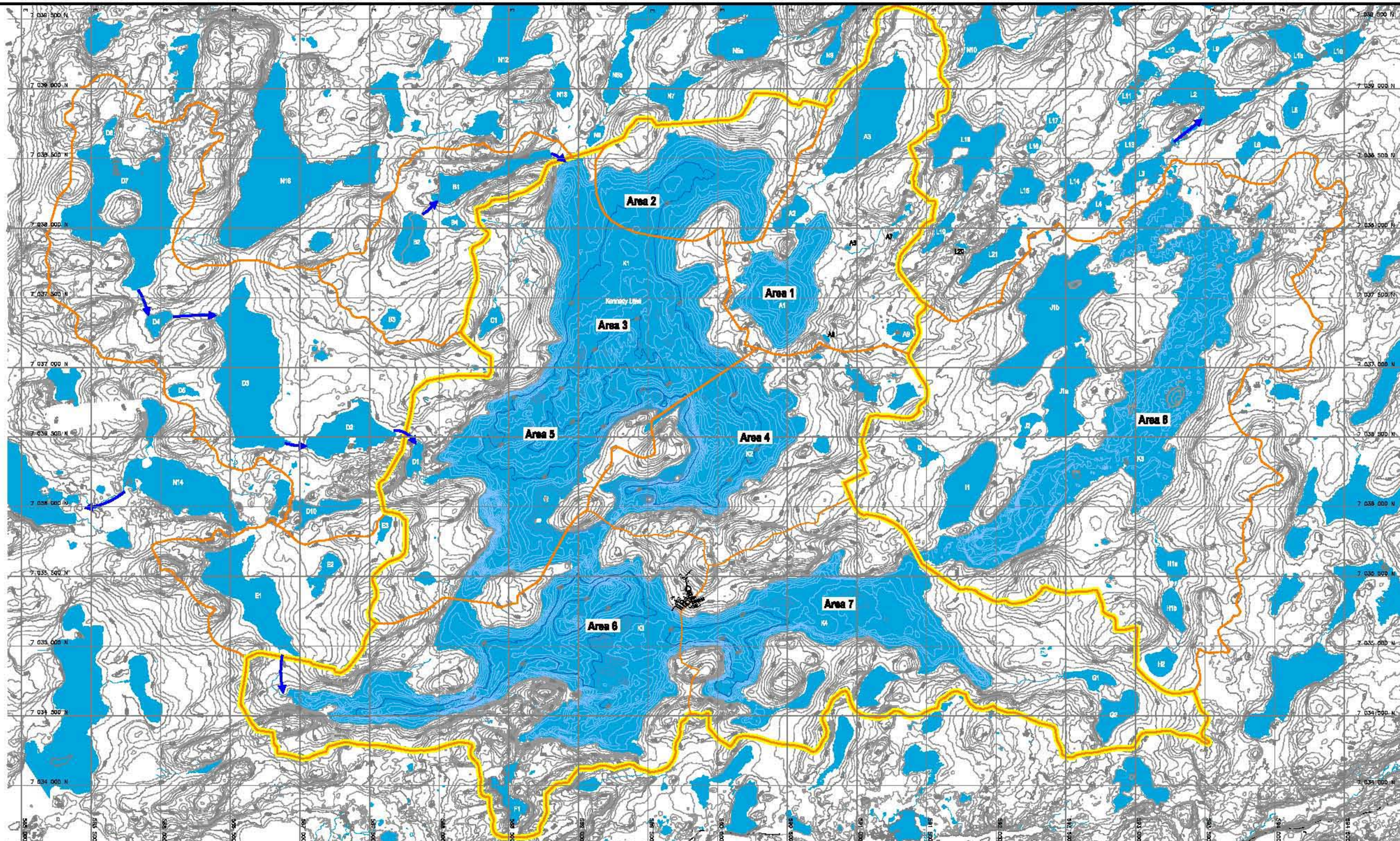
Table 8.II-1 Summary of Kennady Lake Areas

Area	Description
Area 1	Located in the northeast corner of Kennady Lake. Flows from this area will be diverted to Area 8 via the J watershed to minimize volumes of water in contact with processed kimberlite.
Area 2 (Fine Processed Kimberlite Containment Facility)	Located in the northeast corner of Kennady Lake and is designated for fine processed kimberlite deposition
Areas 3 and 5 (Water Management Pond)	This area will operate as the site water management pond and will provide the primary source of process reclaim water and is located in north of Kennady Lake.
Area 4	Located to the southeast of Areas 3 and 5. Location of the Tuzo kimberlite pipe,
Area 6	Located to the south of Areas 3 and 5. Location of the 5034 and Hearne kimberlite pipes.
Area 7	Truncates Area 6 to the east.
Area 8	East basin of Kennady Lake outside of project footprint.

Mining of the three open pits at the Project will require the construction of the following mine site facilities:

- Water Management Pond (WMP);
- Process Plant;
- West and South Mine Rock Piles;
- Coarse Processed Kimberlite (PK) Pile; and
- Fine Processed Kimberlite Containment (PKC) Facility.

Figure 8.II-2 presents the location of each of these facilities in relation to each Kennady Lake area.



LEGEND

- 430 — Existing Ground Contours 5m Index - 1m Intermediate
- 415 — Bathymetry Contours 5m Index - 1m Intermediate
- Controlled Area Boundary
- Marsh Area
- Scrub
- Sub-watershed Boundary
- Drainage Flow Direction
- Lake/Pond

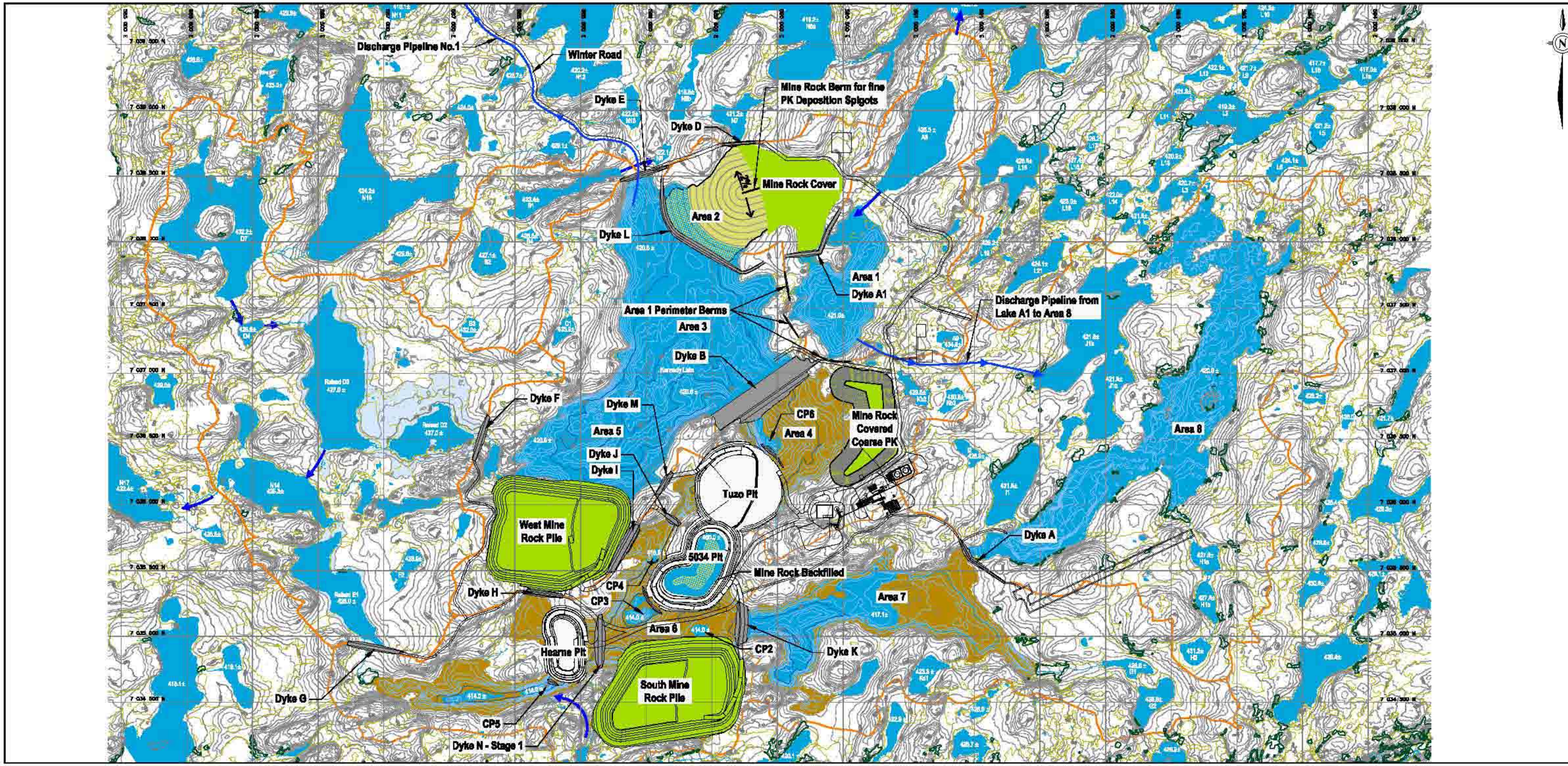
NOTES

Base data source: EBA Figure 4.5 - Stage 2 - Water Management During Mine Operation Years 1 to 3 (2015 to 2017)
Source: Adapted from Figure 3.2-2 of De Beers 2010.

GAHCHO KUÉ PROJECT

Kennady Lake Sub-watersheds and Controlled Area Boundary

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
SCALE 500 0 500 METRES		
FILE No: E-SWQ-006-CAD		DATE: April 23, 2012
JOB No: 11-1365-0001	REVISION No: 2	Figure 8.II-1
OFFICE: GOLD - SAS	DRAWN: BDS/TAH CHECK: JF	



LEGEND

430	Existing Ground Contours 5m Index - 1m Intermediate		Marsh Area		Drained Area
415	Bathymetry Contours 5m Index - 1m Intermediate		Scrub		Fine PK
			Sub-watershed Boundary		Flooded Areas
CP	Collection Pond		Drainage Flow Direction		Lake/Pond
	Winter Road		Discharge Pipeline		Mine Rock
					Submerged PK

NOTES

Base data source: EBA Figure 4.8 - Stage 5 - Water Management During Mine Operation Year 6 (2020)
Source: Adapted from Figure 3.5-3 of De Beers 2010.

GAHCHO KUÉ PROJECT

Mining Operations Year 6 (2020)

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
500 0 500 SCALE METRES		
FILE No: E-SWQ-006-CAD		DATE: April 23, 2012
JOB No: 11-1365-0001	REVISION No: 4	Figure 8.II-2
OFFICE: GOLD - SAS	DRAWN: AJL/TAH CHECK: JF	

G:\2011\1365\11-1365-0001 Gahcho Kue EIS Post-Submission\Mapping\MXD\Appendix 8\E-SWQ-006-CAD.dwg Apr 23, 2012 - 8:16am

8.II.2.2 KENNADY LAKE WATER BALANCE

A water management strategy for Kennady Lake is described in technical memoranda in Attachment 8.II.1 for the construction and operations phases and Attachment 8.II.2 for the closure phase. Respecting the constraints and considerations listed in Attachments 8.II.1 and 8.II.2, the key objectives of the Water Management Plan are to:

- dewater Kennady Lake to the maximum extent possible to safely access and mine the ore bodies;
- utilize passive treatment in the controlled area and discharge water when the water quality meets discharge criteria;
- utilize available containment volumes within the controlled area for water management as required, e.g., the mined-out pits for water storage;
- minimize environmental impacts to adjacent and downstream waters during construction, operations and closure phases of the Project; and
- re-establish a flow regime and self-sustaining ecosystem in the refilled Kennady Lake after closure.

The Water Management Plan described in these technical memoranda formed the basis for evaluating water quality in waterbodies that could be affected by the Project. Details of the Water Management Plan with emphasis on water quality considerations are provided in the Project Description (Section 3.9) of the EIS Supplement.

8.II.2.3 CONCEPTUAL MODEL

To facilitate mining of the kimberlite pipes, the upper watersheds will be temporarily diverted to an adjacent watershed, and Kennady Lake will be dewatered and divided into separate areas during the construction and operations phases of the Project. The remaining lake area will be closed-circuited, and will function as a WMP. At closure, the diverted upper watersheds will be restored, and the lake will be refilled by natural watershed inflows and by importing water from nearby Lake N11 to expedite refilling. Details regarding water management during all phases of the Project are included in Section 3.9 of the EIS Supplement.

The Kennady Lake water quality model was developed to simulate concentrations in Kennady Lake during the construction, operations, closure and post-closure phases. A deterministic water quality model was developed for Kennady Lake using GoldSim™ version 10.5. GoldSim™ is a graphical, object-oriented mathematical model where all input parameters and functions are defined by the user and are built as individual objects or elements linked together by mathematical expressions. The object-based nature of the model is designed to facilitate understanding of the various factors that influence an engineered or natural system and predict the future performance of the system.

In general, the Kennady Lake water quality model is a flow and mass-balance model that was set up to account for all inputs and processes described in Section 3.9. The spatial modelling domain includes the portion of Kennady Lake (i.e., Areas 2 to 7) that is planned to be hydraulically isolated from the surrounding environment during mining operations. Within the closed-circuited areas of Kennady Lake, the lake is planned to be divided by dykes into five basins (i.e., Area 2, Areas 3 and 5, Area 4, Area 6 and Area 7) during the operations phase. Each of these basins was treated as a distinct reservoir within the model.

Within each reservoir, volumes and concentrations were calculated on a monthly time step from Year -2, which corresponds to the start of construction, to Year 198, which is 200 years after the start of construction. Inflow volumes and concentrations were included as inputs to each reservoir to account for loadings from natural areas, disturbed areas, mine rock runoff, fine and coarse PK runoff and groundwater discharge.

The model assumed complete mixing within each basin at each timestep while the dykes are operational. At closure, when the dykes are planned to be breached, the model reports fully mixed conditions in Areas 3 to 7 (Area 2 will become incorporated into the Fine PKC Facility). Water that will be isolated under a pycnocline within the pits (as predicted by the hydrodynamic model in Section 8.II.4) was not included in the calculation of fully-mixed lake conditions. No chemical reactions or sinks were assumed to occur in the model, except where volumes of water are sequestered in mine rock pore space.

The water quality model predicted concentrations for a range of water quality parameters at the following key nodes, for specific Project phases:

- Kennady Lake (Areas 3 to 7):
  - For construction and operation the results reflect the water chemistry in Areas 3 and 5 (WMP), because this water will be discharged to Lake N11; and

– For closure (refilling and long-term closure), the results reflect the average water quality in Areas 3 to 7.

Model predictions were made on a monthly basis under average climate conditions (i.e., 1:2 year wet [median] conditions). Model predictions were based on average climate conditions for three reasons. First, as a lake-dominated system, water quality is less susceptible to inter-annual fluctuations in precipitation and temperature. Second, the majority of changes in water quality parameter concentration due to the Project are large in terms of relative change compared to baseline conditions (see Section 8.8.4.1 of the 2011 EIS Update [De Beers 2011]), so natural variability would be a relatively small contributor to overall change. Finally, using mean conditions allows for a straightforward assessment of incremental changes due to the Project.

Modelled changes in water quality resulting from the Project are the difference between the measured background concentrations and the modelled water concentrations at key nodes. The model used average background concentrations and conservative estimates of mass loadings from the Project to simulate changes in water quality. The model results are projections that are suitable for the assessment of effects; however, the model does not account for natural variability, and therefore, model results should not be viewed as predictions or forecasts of future conditions.

8.II.2.4 MODEL INPUTS

8.II.2.4.1 Kennady Lake and Receiving Environment Water Quality

Background water quality data in the Kennady Lake watershed were collected between 1995 and 2011. The data were collected by various consultants during open water and under-ice conditions (see Section 8.3 of the 2011 EIS Update [De Beers 2011]). For the purposes of the Kennady Lake and downstream lakes water quality assessments, data collected from the sources presented in Table 8.II-2 were used.

Table 8.II-2 Water Quality Studies Used in the Assessment of Kennady Lake and Downstream Lakes, 1995 to 2011

Report Author(s)	Publication Date	Report Title	Applied to	
			Kennady	Downstream
JWEL	1998	Water Quality Assessment of Kennady Lake, 1998 Final Report. Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT. July 1998.	✓	✓
JWEL	1999a	Results of Water Sampling Program for Kennady Lake July 1999 Survey. Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT. October 14, 1999	✓	✓
JWEL	1999b	Trip Report #1 and Data Assessment for Kennady Lake Water Quality - 1999 Survey Program. Submitted to Monopros Limited, Yellowknife, NWT	✓	
EBA & JWEL	2001	Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000) Submitted to De Beers Canada Exploration Ltd., Yellowknife, NWT	✓	✓
JWEL	2002a	Baseline Limnology Program (2001) Gahcho Kué (Kennady Lake). Project No. 50091. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. March 4, 2002	✓	
JWEL	2002b	Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake). Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. April 29, 2002.	✓	✓
EBA	2002	Gahcho Kué Winter 2001 Water Quality Sampling Program, Gahcho Kué, NWT. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	
EBA	2003	Kennady Lake Winter 2002 Water Quality Sampling Programme Kennady Lake, NWT. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	
JWEL	2003a	Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. June 4, 2003	✓	✓
JWEL	2003b	Baseline Limnology Program (2002) Gahcho Kue (Kennady Lake). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. June 4, 2003	✓	
JWEL	2004	Baseline Limnology Program (2003) Gahcho Kué (Kennady Lake). Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. January 20, 2004	✓	✓
EBA	2004a	Kennady Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	
EBA	2004b	Faraday Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	✓
EBA	2004c	Kelvin Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	✓
EBA	2004d	Kennady Lake (Winter 2004) Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT	✓	
AMEC	2004-2005	Unpublished water chemistry and field data collected in Kennady Lake and surrounding watersheds.	✓	✓
Sections 8.3 and 9.3	2010-2011	Additional baseline data collected in support of this application	✓	✓

JWEL = Jacques Whitford Environment Ltd.; EBA = EBA Environmental Consultants Ltd.; AMEC = AMEC Earth & Environmental.

Because the systems being modelled are lake-dominated, and therefore less prone to fluctuations, mean concentrations were chosen to represent baseline conditions. Long-term means were calculated by deriving long-term time series that fit probability distributions for each constituent. To do so, unique probability distributions were assigned to each water quality constituent modelled. Available water quality data were compiled and used to characterize the source waters. The following standardized screening process was used to develop a probability distribution for each constituent:

- Step 1 – remove outliers from the measured data;
- Step 2 – fit suitable probability distributions to the remaining data;
- Step 3 – assess the goodness of fit for all applicable distributions to determine the most appropriate distribution type;
- Step 4 – generate a long-term timeseries according to the chosen distribution; and
- Step 5 – calculate the mean from the timeseries.

Input concentrations for Kennady Lake and the downstream lakes are provided in Table 8.II-3.

8.II.2.4.2 Mine Rock Piles

Mine rock will be produced from mining of the three kimberlite pipes (5034, Hearne and Tuzo) at the Project. These materials will be placed in the West and South Mine Rock Piles (Figure 8.II-2) and in the mined-out 5034 pit. In addition at closure, mine rock will be used as cover materials in the Fine PKC Facility. The following mine rock units are expected to be mined at the Project:

- granite;
- altered granite;
- granodiorite;
- altered granodiorite;
- diorite; and
- diabase.

Table 8.II-3 Baseline Input Water Quality

Parameters	Units	Kennady Lake	Downstream Lakes
Conventional			
Total Dissolved Solids	mg/L	13	16
Total Suspended Solids		1.6	1.3
Major Ions			
Calcium	mg/L	1.2	1.1
Chloride	mg/L	0.55	0.49
Fluoride	mg/L	0.034	0.033
Magnesium	mg/L	0.52	0.43
Potassium	mg/L	0.48	0.39
Sodium	mg/L	0.71	0.78
Sulphate	mg/L	0.83	0.88
Nutrients			
Ammonia	mg/L	0.032	0.019
Nitrate	mg/L	0.032	0.019
Total Nitrogen	mg/L	0.347	0.12
Phosphorus, dissolved	mg/L	0.0033	0.0030
Phosphorus, total	mg/L	0.0057	0.0048
Dissolved Metals			
Aluminum	mg/L	0.0055	0.017
Antimony	mg/L	0.000081	0.000053
Arsenic	mg/L	0.00012	0.0001
Barium	mg/L	0.0027	0.002
Beryllium	mg/L	0.000038	0.000064
Boron	mg/L	0.002	0.0017
Cadmium	mg/L	0.0000006	0.000019
Chromium	mg/L	0.00016	0.00016
Cobalt	mg/L	0.00014	0.00019
Copper	mg/L	0.00069	0.00099
Iron	mg/L	0.021	0.045
Lead	mg/L	0.00003	0.000027
Manganese	mg/L	0.012	0.004
Mercury	mg/L	0.0000077	0.0000051
Molybdenum	mg/L	0.000058	0.000014
Nickel	mg/L	0.00032	0.00039
Selenium	mg/L	0.000043	0.000032
Silver	mg/L	0.000051	0.0000025
Strontium	mg/L	0.0082	0.0069
Thallium	mg/L	0.000017	0.0000012
Uranium	mg/L	0.000019	0.000011
Vanadium	mg/L	0.000134	0.000039
Zinc	mg/L	0.0023	0.0024
Total Metals			
Aluminum	mg/L	0.0043	0.019
Antimony	mg/L	0.000015	0.000062
Arsenic	mg/L	0.00017	0.00012
Barium	mg/L	0.0027	0.0027
Beryllium	mg/L	0.0000031	0.000064
Boron	mg/L	0.0008	0.0017

Table 8.II-3 Baseline Input Water Quality (continued)

Parameters	Units	Kennady Lake	Downstream Lakes
Cadmium	mg/L	0.00000063	0.000019
Chromium	mg/L	0.000044	0.00016
Cobalt	mg/L	0.00014	0.00019
Copper	mg/L	0.00052	0.0013
Iron	mg/L	0.044	0.059
Lead	mg/L	0.000018	0.000061
Manganese	mg/L	0.012	0.0057
Mercury	mg/L	0.000019	0.0000051
Molybdenum	mg/L	0.000016	0.00003
Nickel	mg/L	0.0000038	0.00047
Selenium	mg/L	0.00015	0.000032
Silver	mg/L	0.000029	0.0000081
Strontium	mg/L	0.0082	0.0069
Thallium	mg/L	0.0000041	0.000014
Uranium	mg/L	0.0000072	0.000016
Vanadium	mg/L	0.0001	0.000094
Zinc	mg/L	0.000513	0.0024

mg/L = milligrams per litre

Approximately 95 percent (%) of the mine rock to be produced at the Project is expected to be granite. Geochemical baseline testing indicates that a small fraction of the granitic mine rock will be acid generating (Appendix 8.III). When normalized to 100% of the total mine rock to be produced, 91% of the total granite was assumed to be non-potentially acid generating (PAG) and the remaining 4% was considered PAG granite. Relative proportions of the remaining mine rock lithologies were unknown and equal amounts of these units were assumed to represent the remaining 5% of the mine rock.

Mine rock will be stored at surface in the mine rock piles and in the Fine PKC Facility cover. In addition, mine rock will be used to backfill the ponded area in Area 2 and a portion of these materials are expected to remain saturated. Saturated and unsaturated mine rock are expected to exhibit different weathering rates, and individual source terms were developed for these materials and incorporated into the water quality model.

8.II.2.4.2.1 Unsaturated Mine Rock

The drainage quality from the mine rock piles is assumed to exhibit seasonality at the Project. During the freshet period in June, fresh oxidation products and readily soluble salts will be flushed from mine rock placed in the piles during the winter months. Following the initial flushing of these materials, the runoff is expected to obtain a more constant ("steady-state") water quality for the remaining runoff months.

In the De Beers (2010) EIS, concentrations observed during humidity cell testing were selected to represent the input water quality in the Kennady Lake water quality model. The maximum concentration observed in the first five weeks of the humidity cell tests of each lithology was selected to represent the freshet runoff water quality. The maximum concentration reported during the last five weeks of testing was considered to be representative of the expected steady-state water quality from each rock unit.

To supplement the geochemical dataset for the Project, additional geochemical testing began in 2010. This program included saturated column and humidity cell testing of granite mine rock, coarse PK and fine PK (Appendix 8.III). This information was incorporated into the source terms for each lithology as follows:

- A 75th percentile was calculated from each cell to represent the first-flush (first five weeks of testing) and steady-state (last five weeks of testing) water qualities. The 75th percentile was selected to omit anomalous values from the dataset;
- The 75th percentile values from individual humidity cell samples was averaged for each mine material (e.g. mine rock, coarse and fine PK); and
- The maximum of the De Beers (2010) EIS and the average of the humidity cell percentiles was carried forward into the model to represent the source term for each parameter.

It was identified during the 2010 EIS (De Beers 2010) that the above approach would produce artificially high total phosphorus concentrations. Total phosphorus source terms were therefore derived using the parameter-specific approach provided in Attachment 8.II.3.

In GoldSim™, the source term water chemistries were mixed in their relative proportions to simulate the drainage water quality from the mine rock piles at each month. The input water chemistry selected for each lithology is presented in Table 8.II-4. Detailed geochemical test results, forming the basis for the water quality inputs are provided in Appendix 8.III.

Table 8.II-4 Kennady Lake Model Geochemical Inputs

Parameter	Units	Process Water	Kimberlite		Coarse PK		Fine PK		Unsaturated Mine Rock														Saturated Mine Rock	
									Granite (non-PAG)		Granite (PAG)		Altered Granite		Granodiorite		Altered granodiorite		Diorite		Diabase			
			First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State	First Flush	Steady State
Conventional																								
Total Dissolved Solids	mg/L	117	191	42	449	116	1130	162	191	42	191	42	191	42	191	42	191	42	191	42	191	42	757	65
Major Ions																								
Calcium	mg/L	30	30	11	54.8	16	144	15	30	5.61	44	5.61	44	5.61	30	11	30.3	11	30.3	11	30.3	11	59	16
Chloride	mg/L	5.5	4.83	0.1	126	3.77	333	17	4.66	4.66	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	13	0.3
Fluoride, dissolved	mg/L	-	0.4	0.4	1.1	1.1	1.6	1.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Magnesium	mg/L	-	13	8.7	14.6	6.32	27	3.72	13	1.82	16	1.82	16	1.82	13	8.7	13	8.7	13	8.7	13	8.7	25	1.54
Potassium	mg/L	-	20.1	7.8	31.6	8.60	109	21	8.37	1.61	9.6	1.612	9.6	1.612	20.1	7.8	20.1	7.8	20.1	7.8	20.1	7.8	17	2.02
Sodium	mg/L	-	31.1	11.1	56.8	6.18	104	23	7.26	0.34	7.26	0.34	7.26	0.34	31.1	11.1	31.1	11.1	31.1	11.1	31.1	11.1	20	0.85
Sulphate	mg/L	23	119	26	44.5	2.5	347	15	119	26	195	26	195	26	119	26	119	26	119	26	119	26	231	7.33
Nutrients																								
Phosphorus, dissolved	mg/L	0.089	0.011	0.011	0.017	0.0171	0.06	0.06	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Dissolved Metals																								
Aluminum	mg/L	0.043	0.39	1.65	0.03	0.02	0.12	0.17	0.39	0.43	0.39	0.43	0.39	0.43	0.39	1.65	0.39	1.65	0.39	1.65	0.39	1.65	0.49	0.06
Antimony	mg/L	0.0095	0.003	0.0003	0.001	0.0003	0.003	0.0016	0.006	0.001	0.008	0.0003	0.008	0.0003	0.004	0.0005	0.004	0.0005	0.004	0.0005	0.004	0.0005	0.00067	0.00013
Arsenic	mg/L	0.0016	0.002	0.001	0.009	0.0015	0.21	0.056	0.003	0.003	0.0005	0.0002	0.0005	0.0002	0.002	0.0010	0.002	0.0010	0.002	0.0010	0.002	0.0010	0.0022	0.0018
Barium	mg/L	0.051	0.44	0.27	0.45	0.39	0.98	0.21	0.02	0.03	0.06	0.01	0.06	0.01	0.44	0.27	0.44	0.27	0.44	0.27	0.44	0.27	0.048	0.023
Beryllium	mg/L	0.00001	0.0009	0.00075	0.00001	0.00001	0.00001	0.00001	0.0009	0.00075	0.0009	0.00075	0.0009	0.00075	0.0009	0.00075	0.0009	0.00075	0.0009	0.00075	0.0009	0.00075	0.0012	0.00004
Boron	mg/L	0.082	2.68	0.85	1.57	0.22	2.83	2.63	0.14	0.03	0.05	0.01	0.05	0.01	2.68	0.85	2.68	0.85	2.68	0.85	2.68	0.85	0.12	0.015
Cadmium	mg/L	0.000002	0.00015	0.00005	0.00001	0.000002	0.00005	0.0000	0.00015	0.0001	0.0002	0.00005	0.0002	0.00005	0.00015	0.0001	0.00015	0.0001	0.00015	0.0001	0.00015	0.0001	0.00025	0.000002
Chromium	mg/L	0.0041	0.003	0.02	0.00089	0.0014	0.003	0.0025	0.0006	0.0015	0.0006	0.0015	0.0006	0.0015	0.003	0.02	0.003	0.02	0.003	0.02	0.003	0.02	0.0036	0.0025
Cobalt	mg/L	0.00011	0.012	0.0051	0.0003	0.00006	0.000	0.00007	0.012	0.0051	0.012	0.0051	0.012	0.0051	0.012	0.008	0.012	0.008	0.012	0.008	0.012	0.008	0.021	0.00044
Copper	mg/L	0.0024	0.0073	0.0055	0.005	0.0021	0.00385	0.0048	0.0073	0.0067	0.0073	0.0067	0.0073	0.0067	0.0073	0.0055	0.0073	0.0055	0.0073	0.0055	0.0073	0.0055	0.0078	0.00095
Iron	mg/L	0.012	0.41	2.12	0.03	0.03	0.15	0.10	0.41	0.44	1.60	0.08	1.60	0.08	0.41	2.12	0.41	2.12	0.41	2.12	0.41	2.12	1.83	0.27
Lead	mg/L	0.00008	0.0016	0.00072	0.0001	0.00012	0.0002	0.000205	0.0016	0.0023	0.011	0.00072	0.011	0.00072	0.0016	0.00072	0.0016	0.00072	0.0016	0.00072	0.0016	0.00072	0.0021	0.0002
Manganese	mg/L	0.0075	0.34	0.06	0.00	0.00	0.01	0.00	0.34	0.06	0.69	0.06	0.69	0.06	0.34	0.06	0.34	0.06	0.34	0.06	0.34	0.06	0.64	0.02
Mercury	mg/L	0.00003	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Molybdenum	mg/L	0.0038	0.073	0.00016	0.093	0.0039	0.57	0.026	0.029	0.0012	0.001	0.00016	0.001	0.00016	0.073	0.0011	0.073	0.0011	0.073	0.0011	0.073	0.0011	0.0053	0.0004
Nickel	mg/L	0.0021	0.032	0.078	0.008	0.0024	0.008	0.0035	0.032	0.0092	0.033	0.0092	0.033	0.0092	0.032	0.078	0.032	0.078	0.032	0.078	0.032	0.078	0.050	0.0015
Selenium	mg/L	0.00019	0.00028	0.00007	0.001	0.0001	0.003	0.0001	0.001	0.0005	0.001	0.0001	0.001	0.0001	0.003	0.0005	0.003	0.0005	0.003	0.0005	0.003	0.0005	0.00057	0.00021
Silver	mg/L	0.00014	0.00001	0.000005	0.00001	0.00001	0.00007	0.00001	0.00013	0.00013	0.00013	0.00003	0.00013	0.00003	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	0.00001	0.000005
Strontium	mg/L	0.16	0.21	0.08	0.98	0.27	2.50	0.30	0.29	0.05	0.29	0.05	0.29	0.05	0.21	0.08	0.21	0.08	0.21	0.08	0.21	0.08	0.61	0.13
Thallium	mg/L	0.0001	0.0001	0.00002	0.00008	0.00001	0.00008	0.00002	0.0001	0.00005	0.0001	0.00002	0.0001	0.00002	0.0001	0.00005	0.0001	0.00005	0.0001	0.00005	0.0001	0.00005	0.0001	0.00001
Uranium	mg/L	0.00023	0.026	0.0047	0.001	0.0002	0.001	0.0006	0.020	0.0008	0.001	0.0008	0.001	0.0008	0.026	0.0047	0.026	0.0047	0.026	0.0047	0.026	0.0047	0.0035	0.0013
Vanadium	mg/L	0.0096	0.031	0.029	0.074	0.044	0.039	0.036	0.004	0.001	0.001	0.001	0.001	0.001	0.031	0.029	0.031	0.029	0.031	0.029	0.031	0.029	0.0013	0.0003
Zinc	mg/L	0.0005	0.043	0.028	0.004	0.003	0.013	0.005	0.043	0.028	0.160	0.028	0.160	0.028	0.043	0.028	0.043	0.028	0.043	0.028	0.043	0.028	0.081	0.018

mg/L = milligrams per litre; PAG = potentially acid generating

Humidity cell testing was conducted on 17 mine rock samples collected from the Project (Appendix 8.III). One sample out of the 17 tests was considered not to be representative of granitic mine rock. The remaining 16 granite humidity cell samples were selected to represent the drainage quality from water in contact with granite in the mine rock piles. A small percentage of granite samples (approximately 5%) are expected to be acid generating. Granite mine rock samples with neutralization potential ratios (NPR) less than two were selected to represent these materials. Granite samples with NPRs greater than 2 were assumed to be non-acid generating. The PAG granite water quality was also selected to represent altered granite units. Additional detail regarding the static geochemical properties and results from each humidity cell sample in the kinetic test program at the Project are provided in Appendix 8.III.

Approximately 5% of the mine rock generated at the Project will be other minor lithologies (e.g., diorite, granodiorite). In addition, it is expected that some kimberlite will be deposited in the mine rock piles from mine rock extracted near the margins of the kimberlite pipe. The maximum observed concentrations in the first and last five weeks of the kimberlite and diorite humidity cell tests were compared to the average of the 75th percentile values calculated from the supplemental humidity cell tests. The maximum of these two values was selected to represent the drainage water quality from the following lithologies: granodiorite, altered granodiorite, diorite and diabase (Table 8.II-4).

8.II.2.4.2.2 Saturated Mine Rock

Once deposition of fine PK in the Fine PKC Facility is complete, the facility will be progressively covered with mine rock. At closure the ponded area located at the toe of the facility (Figure 8.II.1) will be backfilled with mine rock. A portion of this mine rock is expected to remain saturated and result in a different drainage chemistry compared to mine rock stored at surface. Drainage from the saturated mine rock was assigned a source term based on water qualities observed in the supplemental geochemistry program saturated mine rock column tests. The average of the 75th percentile water quality (Table 8.II-4) calculated for each humidity cell over the first and last five weeks was selected to represent the saturated mine rock first-flush and steady-state drainage chemistry, respectively. The first-flush water quality was only applied during the first year of closure when the mine rock is used to backfill the ponded area in the Fine PKC Facility because these materials will subsequently remain saturated.

It is important to note that although mine rock will be stored and submerged in the mined-out 5034 pit, advective fluxes from these materials were assumed to be negligible and not influence the surface water quality in Kennady Lake during post-closure.

8.II.2.4.3 Coarse Processed Kimberlite Pile

Coarse PK will be deposited in the Coarse PK Pile (Figure 8.II-2). Three coarse PK samples were submitted for humidity cell testing in 2008. In addition, as part of the current EIS, supplemental testing of coarse PK materials was conducted. Supplemental humidity cell testing and submerged column testing was used to represent coarse PK drainage water quality. Details of the geochemical test work and results are provided in Appendix 8.III.

Similar to the mine rock piles, it is expected that drainage from the Coarse PK Pile will result in a first flush during spring freshet and steady-state water quality for the remainder of the open water season. The maximum of either the highest concentration reported in the first five weeks of testing in the 2008 coarse PK testing programs or the average of the 75th percentile, calculated for each humidity cell in the supplemental geochemistry testing program (Appendix 8.III) was selected to represent the drainage water quality from coarse PK materials during freshet. The same approach was used to calculate the steady-state water quality over the last five weeks of humidity cell testing in each program. Coarse PK input concentrations are presented in Table 8.II-4.

8.II.2.4.4 Fine Processed Kimberlite Containment Facility

Fine PK will be deposited in the Fine PKC Facility located in Area 2 of Kennady Lake (Figure 8.II-2). Deposition of fine PK in Area 2 will result in water being displaced to Areas 3 and 5 as Area 2 becomes inundated.

The Fine PKC Facility will be separated from the WMP by Filter Dyke L. During operations, a pond will be consistently maintained between the toe of the Fine PKC Facility and Filter Dyke L (Figure 8.II-2). Water will be lost from the Fine PKC Facility to the WMP through the dyke. The quality of the water reporting to the WMP from the Fine PKC Facility will be a function of natural runoff, fine PK bleed water and fine PK runoff and seepage.

As part of early geochemical testing in 2008, three fine PK samples were submitted for humidity cell testing. In addition, as part of the current EIS, supplemental testing of fine PK materials was conducted. Details of the geochemical test work and results from both programs is provided in Appendix 8.III.

Runoff and seepage from the fine PK stored in the Fine PKC Facility is assumed to exhibit seasonality as described for the mine rock piles and the Coarse PK Pile. First-flush fine PK drainage water qualities were calculated as follows:

- The maximum concentration was determined over the first five weeks of testing from the 2008 humidity cell samples (i.e. this was the approach used in the De Beers (2010) EIS);
- The average of the 75th percentiles calculated over the first five weeks for each humidity cell test was calculated;
- The average of the 75th percentiles calculated over the first five weeks for each saturated column test was calculated; and
- The maximum of these three values was selected to represent the first-flush water quality from fine PK.

The same approach was used to calculate the steady state fine PK drainage water quality over the last five weeks of testing. Similar to the waste rock, total phosphorus detection limits used in the 2008 fine PK humidity cell tests resulted in artificially high source terms for this facility. Therefore, a separate approach was used to calculate the fine PK total phosphorus source term. This approach is detailed in Attachment 8.II.3.

There will also be a small amount of seepage from Lake A3 to the Fine PKC Facility through Dyke C (Figure 8.II-2). Natural runoff and seepage from Lake A3 was assigned the baseline water quality for Kennady Lake (Table 8.II-3).

Process water liberated from settled fine PK will also report to Area 2. The initial quality of the process water was assigned the process water quality based on the results of baseline geochemical test work (Table 8.II-4). The WMP is the primary source of the process plant reclaim, and the concentrations in the process plant effluent are expected to fluctuate as mining advances. To account for increases in chemical constituents in the WMP, the process water quality was assigned the maximum concentration of the geochemical process water testing and simulated concentrations in the WMP. When water is reclaimed from the Tuzo pit to the process plant, the process effluent water quality is assigned the maximum of the geochemical process water testing or a calculated mixture of reclaimed water from the WMP and the pit.

During operations, when water is maintained in Area 2 downstream of the Fine PKC Facility, it is expected that a component of fine PK will be submerged in Area 2. Supplemental geochemical testing indicated that diffusive fluxes from submerged PK materials could influence the quality of overlying water

(Appendix 8.III). To add an additional level of conservatism into the Kennady Lake model, the water quality in Area 2 was set to be the maximum of the simulated Area 2 water quality and simulated process water quality to account for diffusive fluxes into the pond.

8.II.2.4.4.1 Fine Processed Kimberlite Containment Facility Closure

Fine PK will begin to be deposited in the mined-out 5034 Pit and Hearne Pit following mining in these facilities, and the Fine PKC Facility will be progressively reclaimed. The Project Description (Section 3) indicates that fine PK will be covered with non-PAG mine rock. At closure, any impounded water remaining at the toe of the Fine PKC Facility footprint and Filter Dyke L (Figure 8.II-2) will be backfilled by mine rock and the water will be gradually displaced to the WMP. Following backfilling of this area, the water quality reporting to the WMP from the Fine PKC Facility will be a function of natural runoff, mine rock runoff, fine PK facility runoff and seepage. During this phase of mining, submerged fine PK will be covered with mine rock and diffusive fluxes were assumed to be negligible.

The Fine PKC cover has the potential to influence the water quality draining from the Fine PKC Facility during the closure period. Seepage analysis (EBA 2011), indicates approximately 19% of the flow from Area 2 will flow through fine PK and the remaining 81% will be in contact with mine rock before draining to Areas 3 and 5. Approximately 40% of the mine rock is expected to be saturated. The drainage water quality from the Fine PKC Facility during this period was simulated based on the relative proportions of natural runoff, mine rock backfill runoff and seepage, and fine PK runoff and seepage.

8.II.2.4.5 Open Pit Water Quality

Kimberlite will be mined from all three pits at the Project. As the pits are developed, the following water sources have the potential to influence the water quality in each of the pit sumps being dewatered to the WMP:

- pit wall rock runoff;
- groundwater inflow; and
- blasting residue.

Assumptions regarding each of these water sources are described in more detail in the following subsections.

8.II.2.4.5.1 Pit Wall Rock Runoff Water Quality

Lithological units in the exposed wall rocks of the open pits will influence the pit sump water quality. In the Kennady Lake water quality model, pit wall rock runoff in contact with these units was assigned the mine rock unit water quality (Table 8.II-4). Details regarding the relative proportions of each lithology in the exposed wall rock were not available for the current assessment. As such, the proportions of mine rock in the mine rock piles were selected to represent the relative proportion of the exposed lithologies. This is considered reasonable since 95% of the mine rock at the Project is granite.

8.II.2.4.5.2 Groundwater Quality

Groundwater reporting to the open pits during operations represents the greatest flow component, and will be the primary control on pit sump water quality. Groundwater reporting to the open pits will be a function of the following two sources:

- shallow groundwater from Kennady Lake Areas 3 and 5, 4, and 7, resulting from the dewatering cone of depression;
- and deeper saline connate water.

The results of groundwater quality monitoring presented in Section 11.6, Subject of Note: Permafrost, Groundwater, and Hydrogeology (De Beers 2011), were used to estimate the composition of groundwater that could passively flow into the open pits during operations. Depth profiles were developed to evaluate the variability of groundwater composition with depth. Total dissolved solids (TDS) is known to vary with depth in groundwater in the Canadian Shield. The purpose of the depth profiles was to identify parameters that correlate with TDS relative to depth. Metals that correlated with TDS, and which vary by depth, included major ions (e.g., calcium, chloride, potassium, magnesium, sodium and sulphate) and trace metals (e.g., arsenic, boron, copper, nickel and selenium). Slopes, intercepts and regression coefficients for each of these parameters are provided in Table 8.II-5. The slopes and intercepts were used to derive groundwater concentrations of these major ions and trace metals.

Groundwater modelling (Section 11.6, Appendices 11.6.I and 11.6.II [De Beers 2011]) provided a profile of the TDS concentrations reporting to each pit from deeper connate water with time. In addition, this modelling provided an estimate of the percentage of lake water contributing load to the groundwater. TDS will fluctuate in the lake as a result of mining activities and site water management. As such, the simulated TDS concentration in the WMP was mixed with the TDS concentration of expected connate water to determine a TDS concentration for groundwater reporting to each pit, according to the proportions indicated by hydrogeological model results. The relative percent of lake water from each area in Kennady Lake is provided in Table 8.II-6.

Table 8.II-5 Attributes of Correlated Parameters

Parameter	Slope	Intercept	r^2
Calcium (Ca)	0.2	11.7	0.97
Chloride (Cl)	0.59	-73.44	0.99
Magnesium (Mg)	0.021	17.28	0.74
Potassium (K)	0.0013	7.335	0.63
Sodium (Na)	0.133	-29.06	0.98
Sulphate (SO_4)	0.0657	9.97	0.78
Arsenic (As)	0.000006	0.0013	0.21
Boron (B)	0.0001	0.3736	0.77
Copper (Cu)	0.0000003	0.0021	0.78
Nickel (Ni)	0.000001	0.0024	0.52

r^2 = correlation of determination

Table 8.II-6 Groundwater and Lakewater Contributions

Year	Predicted Inflow (m^3/d)			Percent Contribution from Areas 3 and 5			Percent Contribution from Area 4			Percent Contribution from Area 7		
	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo
-2	0	0	0	-	-	-	-	-	-	-	-	-
-1	2100	0	0	0	-	-	59	-	-	8	-	-
1	2300	0	0	1	-	-	22	-	-	6	-	-
2	2100	0	0	3	-	-	12	-	-	9	-	-
3	2400	0	0	8	-	-	9	-	-	15	-	-
4	2600	400	0	12	2	-	8	64	-	19	17	-
5	2500	800	600	15	11	0	6	22	57	24	10	16
6	2200	1200	800	21	26	4	4	2	24	28	6	10
7	1200	1400	1100	27	38	12	9	1	15	34	3	6
8	1400	700	1800	28	66	20	5	2	6	36	2	4
9	1400	300	2100	29	87	29	3	0	4	40	2	2
10	1400	100	2200	31	90	35	2	0	3	41	0	2
11	1400	50	2400	31	90	39	2	0	3	42	0	1

m^3/d = cubic metres per day

Parameters that did not exhibit a relationship with TDS were estimated based on the range of results in the groundwater dataset. The groundwater quality dataset was used to develop input concentrations for groundwater inflows to the Hearne Pit and 5034 Pit. Input concentrations were set equal to the 75th percentile concentration measured in groundwater samples from each pit. Groundwater quality data were not available for the Tuzo Pit; therefore, groundwater reporting to this pit was assigned the 75th percentile concentration of all of the groundwater samples. Groundwater quality concentrations for parameters not correlated with TDS are presented in Table 8.II-7.

The approach of assigning groundwater concentrations to each pit was developed based on a detailed review of the groundwater quality dataset. This approach is considered somewhat conservative because of the high variability in metal concentrations with depth, and by location.

Table 8.II-7 Groundwater Quality Inputs (mg/L)

Parameter	Unit of Measure	5034	Hearne	Tuzo
Ammonia	mg/L	1.325	1.53	1
Total Kjeldahl Nitrogen	mg/L	1.325	1.53	1
Total Phosphorus	mg/L	0.03	0.02	0.03
Dissolved Phosphorus	mg/L	0.03	0.02	0.03
Aluminum	mg/L	0.02	0.011	0.02
Antimony	mg/L	0.002	0.0001	0.0006
Barium	mg/L	0.27	0.11	0.15
Beryllium	mg/L	0.00005	0.00005	0.00005
Cadmium	mg/L	0.0003	0.00005	0.0003
Chromium	mg/L	0.0012	0.0081	0.001
Cobalt	mg/L	0.001	0.0016	0.001
Iron	mg/L	0.86	3.50	1.56
Lead	mg/L	0.001	0.00065	0.001
Manganese	mg/L	0.18	0.26	0.20
Mercury	mg/L	0.00005	0.00001	0.00001
Molybdenum	mg/L	0.017	0.009	0.012
Selenium	mg/L	0.0002	0.0002	0.0002
Silver	mg/L	0.00005	0.00005	0.00005
Thallium	mg/L	0.002	0.00002	0.00004
Uranium	mg/L	0.01	0.005	0.01
Vanadium	mg/L	0.001	0.0022	0.001
Zinc	mg/L	0.025	0.11	0.03

mg/L = milligrams per litre

8.II.2.4.5.3 Explosives Usage

Open pit mining at the Project will require the use of both ammonium nitrate/fuel oil (ANFO) and emulsion explosives. Chemical loading of sodium and nitrogen species (e.g. nitrate and ammonium) are often associated with explosive usage at mine sites. Explosive usage assumptions for the mine site water quality model, used to estimate the chemical load release from explosives, are provided in Table 8.II-8.

Table 8.II-8 Summary of Assumptions for Explosives Usage

Assumption	ANFO	Emulsion
percent of total explosives	70%	30%
tonnage of explosives	94,196	40,470
fraction of residues	5%	5%
composition	94% ANFO, 6% Fuel Oil	63% ANFO, 18% $NaNO_3$, 9% water, 6% fuel oil, 4% microballoons

ANFO = ammonium nitrate/fuel oil; "%" = percent

The total life-of-mine explosives tonnages formed the basis for determining chemical loadings. The total mass of explosive was assumed to be released linearly over the mine life to develop estimates of nitrogen-species concentrations from blasting activities. Water reporting to active open pits is expected to mobilize the majority of explosives residues, and the mass of explosives released during each month was added to the WMP.

8.II.2.4.5.4 Other Open Pit Water Quality Influences

In addition to the above sources, the Water Management Plan for the Project (Section 3.9) includes the use of the mined-out pits for additional water and mine rock storage. As such, water pumped from other areas of Kennady Lake to the mined-out pits will influence the pit water quality during these periods. A chemical load to each pit from the various sources was calculated based on the simulated water quality for that area multiplied by the flow (EBA 2010, EBA 2012). The Water Management Plan details all of the flows that could influence the water quality in each pit.

Following the completion of mining in each of the three open pits, water will also be sequestered in void spaces in mine material backfill and isolated in deep pits due to water density differences. These water volumes are unique for each open pit and are discussed separately in the following subsections.

5034 Pit

Fine PK will be placed in the 5034 Pit from Year 5, when mining is complete in this facility, to Year 7. A total of 1.5 million tonnes (Mt) of Fine PK will be placed in the mined-out 5034 Pit (EBA 2012). The fine PK will be capped with approximately 38.5 million cubic metres (Mm^3) of waste rock with approximately 12 Mm^3 of this volume located below 300 metres above sea level (masl) (i.e., to the sill between the 5034 and Tuzo pits).

The total capacity of the mined-out open pit below 300 masl is 13.5 Mm^3 (EBA 2010). Backfilling to elevation 300 masl will be complete in Year 8 and diffusive fluxes from underlying fine PK are assumed to be negligible. The void space in the mine rock placed below 300 masl has a water storage capacity of 2.8 Mm^3.

By closure, an additional 27.5 Mm^3 of mine rock will have been placed over the mined-out 5034 Pit above elevation 300 masl. This will result an additional 6.8 Mm^3 of pore space available to sequester water in the pit. Following completion of the mine rock backfill in the 5034 Pit, approximately 8.9 Mm^3 of water will be sequestered in the mine rock pore space.

Hearne Pit

Following the cessation of mining in the Hearne Pit, fine PK slurry will be deposited in the mined-out open pit.

Approximately 15.7 Mm^3 of void space will be available in the Hearne Pit and Area 6 west of Dyke N following completion of mining. Between Year 8 and Year 11, approximately 8.3 Mm^3 of fine PK slurry will be placed in Hearne Pit. Once the fine PK settles, the pore volume in the fine PK will be approximately 3.1 Mm^3.

A pit lake, approximately 100 metres (m) deep, will form above the fine PK stored at the bottom of the Hearne Pit. Hydrodynamic modelling (Section 8.II.4) of the pit lake indicated that a pycnocline would form, isolating deeper saline water from the lower density, overlying water that would mix with the lake surface water. As such, diffusive fluxes from the fine PK are assumed not to influence the surface water quality in Kennady Lake.

Following refilling of the Hearne Pit, it is expected that the monimolimnion will isolate 4.7 Mm^3 of water from Kennady Lake. Over a 100-year modelled timeframe, it was predicted that the pycnocline will migrate downwards, ultimately isolating approximately 3.7 Mm^3 of deeper water in the Hearne Pit.

In the GoldSim™ model, the deeper water was tracked and released to the surface according to these volumes. Excess water was allowed to migrate into the upper portion of the pit where it was considered to be fully mixed with Kennady Lake. Any water volume and chemical load stored in the deeper portion of the Hearne Pit at the end of the 100 year timeframe was treated as a loss from the system.

Tuzo Pit

The Tuzo Pit will not be backfilled with mine rock. Instead, a pit lake will form during the closure phase of the Project. Hydrodynamic modelling (Section 8.II.4) of the pit lake predicted that a pycnocline will form, isolating deeper saline water from the lower density, overlying water that will mix with the lake surface water. Following refilling of the Tuzo Pit, it was predicted that the monimolimnion will isolate 22.8 million cubic metres (Mm^3) of water from Kennady Lake. Over a 100-year modelled timeframe, it was predicted that the pycnocline will migrate downwards, ultimately isolating approximately 20.4 Mm^3 of deeper water in the Tuzo Pit.

Similar to the Hearne pit, in the GoldSim™ model, the deeper water was tracked and released to the surface according to these volumes, and excess water was allowed to migrate into the upper portion of the pit where it was considered to be fully mixed with Kennady Lake. Water volume and chemical load stored in the deeper portion of the Tuzo Pit at the end of the 100-year timeframe was also treated as a loss from the system.

8.II.2.4.6 Treated Sewage Water Input

Treated sewage water will be discharged with the fine PK slurry. Advetic fluxes associated with this flow were directed to the WMP to provide a conservative estimate of the quality in Areas 3 and 5. The chemistry of the treated sewage water was based on observed treated sewage effluent from the Snap Lake Mine. It is expected that the treated effluent at the Project will be similar to the concentrations measured at Snap Lake.

8.II.2.4.7 Particulate Matter

The Kennady Lake water quality model tracked the concentrations of dissolved and particulate species separately, then summed the two fractions to arrive at total concentrations. In general, loadings from geochemical sources and groundwater contributed only dissolved parameter species. The sources of particulate loading were existing (background) waters and dust.

Background particulate parameter concentrations were calculated as the difference between total and dissolved parameter concentrations in Table 8.II-3. The particulate fraction of metals in the background water was assumed to remain in the water column and never settle out.

The principal source of aerially-deposited material to Kennady Lake during operations was expected to be fugitive dust from fleet and milling activities.

Because this dust will be composed of finely-ground rock, it is anticipated that some, or all, of it will settle out during the eight to nine year closure period while Kennady Lake is being refilled. The settling of dust was modelled using the hydrodynamic model (Section 8.II.4), and it was predicted that less than 1 milligram per litre (mg/L) of these solids would remain in suspension. Therefore, 1 mg/L of particulate matter was added to the water column. The dust was not allowed to settle in the model, but it was advectively transported into the pits during pit refilling and downstream after lake refilling. The parameter concentrations of this particulate matter were based on the average analytical data collected as part of the baseline geochemical assessment (Appendix 8.III). The solid composition of fine PK was selected to represent the aerially-deposited particulate matter in Kennady Lake.

8.II.2.4.8 Kennady Lake Refilling Inputs

At the end of operations, Tuzo Pit and Kennady Lake will be refilled using passive and active inflows. Several water management strategies will be employed to expedite the filling of Kennady Lake back to its natural elevation of 420.7 metres above sea level (masl). These include:

- pumping supplemental freshwater from Lake N11 to Areas 3 and 5;
- breaching Dyke E to allow watershed B to recharge Kennady Lake in Areas 3 and 5;
- ceasing the diversion of D2 to N14 to reconnect the D watershed to Kennady Lake in Areas 3 and 5;
- breaching Dyke G to re-establish E watershed recharge to Kennady Lake Area 6; and
- re-establishing flow from Area 1 into Areas 3 and 5.

During construction and the first four years of operations, water will be pumped from the WMP to Lake N11. As such, the quality of Lake N11 will deviate from background concentrations (Table 8.II-3) as a function of the chemical loading from the WMP. During the refilling period, water from Lake N11 will be pumped to Kennady Lake to expedite the refilling period. This water was assigned the simulated Lake N11 water quality from the downstream water quality model (Section 8.II.3). Water flowing to Kennady Lake from the B, D, and E watersheds was assigned the Kennady Lake baseline water quality (Table 8.II-3).

8.II.3 DOWNSTREAM WATER QUALITY MODEL

8.II.3.1 CONCEPTUAL MODEL

A downstream (receiving environment) water quality model was developed in GoldSim™ to assess the effects the Project would have on the downstream lakes during the construction, operation and closure phases. The downstream water quality simulated concentrations for a range of water quality parameters at the following key nodes, for each of the Project phases:

- Lake N11; and
- Lake 410.

During the dewatering phase, water will be pumped from Kennady Lake to Area 8 and to Lake N11. In addition, while the water quality in Areas 3 and 5 is suitable for discharge, water will be pumped to Lake N11 to provide additional storage capacity in Kennady Lake during operations. In the post-closure period (after 2035), the original flow path of Kennady Lake will be re-established, and Area 8 will receive flows from the refilled portion of Kennady Lake. Therefore, Area 8 was included in the downstream water quality model.

Although presently part of Kennady Lake, Area 8 is proposed to be hydraulically isolated from the rest of the lake during the construction, operations and closure phases of the Project. During these phases, runoff from natural areas within the Area 8 sub-watershed is expected to be sufficient for maintaining water quality within this basin, as described in Section 8.2.5. Therefore, water quality was not assessed in Area 8 during these phases of the Project.

The downstream water quality model was developed to predict concentrations in Area 8, the Interlakes (i.e., the L and M watersheds), the N watershed, and Lake 410. At each location, average simulated Kennady Lake outflow concentrations were mixed with background concentrations in their relative proportions based on downstream flows provided in the hydrological assessment (Section 9.2.4).

At each location, concentrations were calculated on a daily time step from Year -2, which corresponds to the start of construction, to Year 86, which is 88 years after the start of construction. Inflow volumes and concentrations were included as inputs to each reservoir to account for loadings from natural areas and site water reporting to the downstream watershed.

8.II.3.2 MODEL INPUTS

Water quality was simulated in several lakes in Area 8, in the L and M watersheds, Lake N11, and in Lake 410, downstream of Kennady Lake. The downstream water quality model predicted concentrations during the construction, operations and closure phases. The model assumed fully-mixed conditions within each lake at each timestep.

Within each watershed, water quality profiles were assigned to natural inflows as baseline chemistry (Table 8.II-3). Throughout the construction, operations and closure phases of the Project, the downstream watershed was assumed to behave according to baseline conditions, with the following exceptions:

- water will be discharged from the WMP to Lake N11 during the construction and operations phases;
- water will be drawn from Lake N11 to refill Kennady Lake during the closure phase;
- the flow path from Area 7 to Area 8 will be disconnected during the operations and closure phases; and
- the flow path from Area 7 to Area 8 will be reconnected after Kennady Lake has refilled (i.e., the post-closure period).

Based on these flows, the only inputs to the downstream water quality model were the baseline concentrations and dynamic inputs from the Kennady Lake water quality model (Section 8.II.2).

It is expected that downstream of the mine site, settling of particulates may occur in the receiving environment; however, the model did not include a sink term for settling. This approach provides a conservative estimate of downstream concentrations.

8.II.4 HYDRODYNAMIC MODEL

8.II.4.1 CONCEPTUAL MODEL

The water quality in the Hearne Pit basin (Hearne Pit), Tuzo Pit basin (Tuzo Pit) and in the restored Kennady Lake will be influenced by several input sources. During the initial phase of refilling, water quality will be primarily influenced by groundwater inflows and the sources used to fill the pits, namely, deposits of fine PK slurry, water from the WMP and Lake N11 (Section 3.9). After Kennady Lake is filled, water quality in Hearne and Tuzo pits will be influenced by surface runoff to Kennady Lake, fine PK slurry deposits, surface – groundwater interaction, and lake hydrodynamics.

The stability of stratification in Hearne and Tuzo pits was analyzed using two methods:

- hydrodynamic modelling of the first 100 years after refilling, using CE-QUAL-W2; and
- mass balance calculations over 15,000 years using a vertical slice spreadsheet model.

The CE-QUAL-W2 (W2) model (Cole and Wells 2008) was used to compute TDS, temperature and density at 1 m intervals in Kennady Lake including the pits. The W2 model is a two-dimensional, laterally averaged, hydrodynamic and water quality model. The model is public domain software maintained and supported by the United States Army Corp. of Engineers Waterways Experiment Station. The model has established a well-recognized reputation as an effective and practical modelling tool for lake and reservoir hydrodynamics and water quality.

The hydrodynamic, temperature and water quality modules of the model simulate interactions of physical and chemical processes, including flow, thermal and substance mass loading regimes, meteorological forcing conditions (e.g., air temperature, wind, solar radiation, precipitation, evaporation, etc.) and lake-bottom interactions. The W2 model also includes a module to simulate ice-cover in the winter. The formation of a complete ice-cover prevents re-aeration, provides complete wind sheltering and results in reduced thermal inputs via solar radiation. The model has been used extensively to simulate the potential performance of natural and constructed lakes, including mine pit lakes (Cole and Wells 2008, Castendyk and Eary 2009).

8.II.4.1.1 W2 Model Inputs

The W2 model includes several hydrodynamic coefficients that may be used to calibrate the model to observed conditions. Because Hearne and Tuzo pits have not been constructed, this model cannot be calibrated to this system. However, to obtain estimates of hydrodynamic coefficients, a W2 model was constructed for Kennady Lake under pre-development conditions. A hydrodynamic calibration was carried out for the pre-development W2 model to match the vertical profiles of simulated and observed temperature. Hydrodynamic coefficients were also adjusted to produce a reasonable match of ice cover periods in the range of observations in similar climate conditions. The calibrated hydrodynamic coefficients obtained from the predevelopment model were then applied to the closure model.

The spatial extent of the hydrodynamic model under the closure scenario was Kennady Lake, including Hearne and Tuzo pits, and excluding Area 8. A model bathymetry grid was developed based on Geographic Information System (GIS) shapefile contours of bottom elevations of these connected waterbodies. The waterbody boundary and contour data were processed to generate a complete bathymetric grid for the lake and pits with 1 m vertical layers within each segment.

The model requires meteorological forcing data to drive currents and thermal behaviour in the lake. Meteorological data were obtained from weather stations at Snap Lake and the Yellowknife Airport. Data were selected preferentially from the Snap Lake Mine station because this station is closer to the Project, and data gaps were filled in using data from Yellowknife Airport. The required meteorological data were air temperature, dew point, wind speed and direction and cloud cover. Additional details regarding construction of the meteorological record are available in the Snap Lake Water Quality Model report (Golder 2011).

Surface and subsurface inflow and outflow volumes and corresponding concentration inputs to the model were consistent with those in the GoldSim™ Water Quality Model (Section 8.II.2). Initial concentrations in the pits were set at concentrations determined by the Kennady Lake water quality model, accounting for water transfers throughout the refilling period. Consequently, each pit was assumed to initially contain a lower layer (monimolimnion) with higher total dissolved solids (TDS) and density, overlain by an upper layer (mixolimnion) with lower TDS, as calculated by the GoldSim™ model (Section 8.II.2). The upper portions of the pits and remaining part of Kennady Lake were assumed to have a TDS concentration that was constant over the mixolimnion of the refilled Kennady Lake.

Over time, the model predicted some transfer of constituents from the monimolimnion to the mixolimnion. To estimate the rates of constituents released from the monimolimnion, a tracer constituent was included in the hydrodynamic model. The initial tracer concentration was set to 1 mg/L in the monimolimnion of both pits and 0 mg/L in the mixolimnion. Based on the simulated vertical profiles of tracer concentrations, equivalent replacement volumes in the monimolimnion were calculated. The calculated replacement volumes were then transferred to the Kennady Lake water quality model, and these volumes were used as time series of water movement from each pit into the closure Kennady Lake. Associated mass of constituents from each pit were also transferred upwards in the Goldsim™ model.

It is recognized that these layers will not form a sharp boundary, and that some mixing at the interface may occur due to turbulence caused by refilling and other factors. This was reflected in the hydrodynamic simulations, which indicated that transport and mixing in the first simulation year would be rapid across the boundary between the upper and lower compartments. A 20 m transition zone was predicted to form in the first year, which would slowly expand in thickness thereafter and approach a relatively stable stratification. Therefore, the assumption of a sharp boundary of initial concentration produced reasonable results, since all mass transferred by the initial mixing was accounted for within the first year.

It is not known exactly which months of the year the pit will be filled. Therefore, an average temperature of Kennady Lake was calculated based on samples that were skewed toward summer sampling events. The resulting average temperature (4 degrees Celsius [ºC]) is anticipated to be reasonable, because refilling activities are also expected to be most intense during open water periods. The uniform temperature of 4ºC was used to initialize the pit water column. It should be noted that the temperature profiles in the refilled pits can be manipulated somewhat by preferentially filling during different times of the year to take advantage of natural variations in Kennady Lake surface temperatures.

Once the model was initialized, it was run for 100 years to predict the change in elevation of the pycnocline, and therefore the volume of water that will essentially be isolated from Kennady Lake. Inputs during the simulation included natural inflows, which were the same as those for the Kennady Lake water quality model (Section 8.II.2) and groundwater inputs. Groundwater inflows from the hydrogeological model was an input to the hydrodynamic model at several vertical points according to time-varying volumes and concentrations throughout the modelled time frame. Groundwater modelling is presented in Section 11.6, Appendix 11.6.II of the 2011 EIS Update (De Beers 2011).

The W2 model includes an inorganic suspended solids compartment to model the settling and resuspension of particulate matter. This compartment was used to model the deposition of dust from fleet traffic on the lake. The model was run such that 5 mg/L of particulate matter measuring 2.5 microns or less ($PM_{2.5}$) dust composed of fine PK was instantaneously deposited on the lake at the end of mining operations. During the refilling period, the particulate matter was allowed to settle in the model, and maximum concentrations were tracked during periods of wind-driven turbulence. The model predicted that nearly all particulate matter would settle within the first winter, and suspended sediment would not exceed 1 mg/L thereafter. A value of 1 mg/L was conservatively assumed to represent dust at the end of the refilling period for the Kennady Lake model (Section 8.II.2).

8.II.4.2 LONG-TERM VERTICAL SLICE SPREADSHEET MODEL

To estimate the long-term stability of Tuzo Pit, long-term TDS profiles were calculated using a vertical slice spreadsheet model. A spreadsheet model was used because it was not feasible to run a hydrodynamic model for this length of time due to computational limitations. The vertical slice spreadsheet model incorporated long-term inflows that were predicted by the hydrogeological model (Section 11.6 Subject of Note: Permafrost, Hydrogeology and Groundwater of the 2011 EIS Update [De Beers 2011]) to simulate TDS profiles over 15,000 years at 25 m vertical intervals in Tuzo Pit.

The main inputs used in the mass balance calculation were initial conditions in Tuzo Pit, which were the same as those used for the Hydrodynamic model, and long-term groundwater inflows and outflows. Groundwater inflow volumes and concentrations and outflow volumes were predicted for the first 1,000 years after Tuzo Pit is filled. After 1,000 years, the inflows were assumed to continue at constant volumes and concentrations.

To complete the calculations, inflow volumes and concentrations were directed to the appropriate 25 m interval within the pit. Within each interval, a mass-balance calculation was performed, and excess water (difference between inflow and outflow) was directed upwards to the next segment.

The vertical slice spreadsheet model generated annual time series at 25 m intervals over a 15,000 year timeframe. Vertical TDS profiles for select time snapshots are shown in Section 8.8.4.2 of the 2011 EIS Update (De Beers 2011).

8.II.5 MODEL ASSUMPTIONS AND LIMITATIONS

Water quality modelling requires many assumptions due to the uncertainty related to determining the future physical and geochemical characteristics of a complex system. The prediction of water quality is based on several inputs (i.e., surface flows, groundwater flows and seepage, background water quality and geochemical characterization), all of which have inherent variability and uncertainty. The water quality model has attempted to incorporate natural processes and mineral weathering of mine materials, and combine them with flows to develop predictions for water quality, all for a mine that has not yet been developed. Water quality results predicted herein are based on current understanding of the Project Water Management Plan and provide a reasonable estimate of the expected conditions in Kennady Lake. Given all of the inherent uncertainties, the results of the water quality modelling should be viewed as a tool to aid in mine planning and design, to develop mitigation and monitoring strategies, and to outline potential risks. The absolute concentrations predicted by the water quality model were produced as a means to meet these objectives.

The following key assumptions have been made in the water quality modelling:

- there is complete mixing of masses in simulated site concentrations in the various areas of Kennady Lake;
- there are no seepage losses from the site to the downstream receptors;
- development of permafrost conditions in the mine rock and PK storage facilities were not considered in the assessment scenario;
- measured water quality parameters that were less than the analytical detection limit have been assumed to be equal to the detection limit for geochemical sources and half the detection limit for background water quality; and
- expected long-term water quality estimates are based only on laboratory data as no site data of mine materials (i.e., fine PK) currently exist. It is assumed that laboratory data are representative of the material that will be generated. This issue can be addressed through on-site monitoring programs of expected mining materials and periodic re-evaluation of predictions.

Care was taken to incorporate known processes as understood during the model development. However, in natural systems and complex man-made systems, observed conditions, particularly on a daily basis, will almost certainly vary with respect to estimated conditions.

The data and approach used to estimate future water quality are currently believed to provide a reasonable approximation of the system as currently understood, within the context of the assumptions used in the model. Changes in Project site conditions, input data, or assumptions regarding Project site conditions will necessarily result in changes to water quality predictions.

Due to the factors listed above, even the best of models cannot be expected to match operational monitoring data. It is the goal of modelling to conservatively predict concentrations, so monitored data are anticipated to be less than predicted concentrations. Once the Project is operational, monitoring of water quality and periodic re-assessment of effects predictions and/or remedial measures will be required.

8.II.6 REFERENCES

8.II.6.1 LITERATURE CITED

Castendyk, D.N. and L.E. Eary. 2009. Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability. Society for Mining, Metallurgy and Exploration Inc. Littleton, Colorado. 304 pp.

Cole, T.M. and Wells, S.A. 2008. *CE-QUAL-W2: A Two-dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.6 User Manual.* August 2008.

De Beers (De Beers Canada Inc.). 2010. Environmental Impact Statement for the Gahcho Kué Project. *Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N.* Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.

De Beers. 2011. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2.* Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.

EBA & JWEL (EBA Engineering Consultants Ltd. and Jacques Whitford Environment Ltd.). 2001. *Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000)* Submitted to De Beers Canada Exploration Ltd., Yellowknife, NWT.

EBA. (EBA Engineering Consultants Ltd.). 2002. Gahcho Kué Winter 2001 Water Quality Sampling Program, Gahcho Kué, NWT. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT.

EBA. 2003. Kennady Lake Winter 2002 Water Quality Sampling Programme Kennady Lake, NWT. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT.

EBA. 2004a. Kennady Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT

EBA. 2004b. Faraday Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT

EBA. 2004c. Kelvin Lake Winter 2003 Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT.

EBA. 2004d. Kennady Lake (Winter 2004) Water Quality Sampling Program. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT

EBA. 2010. *Updated summary of preliminary water and waste management closure plan for feasibility study of Gahcho Kué Project.* Technical Memo from Gordon Zhang to Wayne Corso, JDS Energy and Mining Inc. May 14, 2010.

EBA. 2011. *Preliminary Seepage Volume Estimates for 4 Options for MAA Purpose.* June 24, 2011.

EBA. 2012. *Updated summary of water management and balance during mine operation, Gahcho Kue, NT (for Updated fine PK disposal plan – Option 2).* Technical Memo from Hongwei Xia to Bill Horne and Gordon Zhang, EBA. October 6, 2011.

Golder (Golder Associates Ltd.). 2011. *Snap Lake Water Quality Model.* Attachment 7 of Water License Renewal Application. Submitted to Mackenzie Valley Land and Water Board. June 2011.

JWEL (Jacques Whitford Environment Ltd.). 1998. Water Quality Assessment of Kennady Lake, 1998 Final Report. Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT.

JWEL. 1999a. *Results of Water Sampling Program for Kennady Lake July 1999 Survey.* Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT. October 14, 1999.

JWEL. 1999b. *Trip Report #1 and Data Assessment for Kennady Lake Water Quality - 1999 Survey Program*. Submitted to Monopros Limited, Yellowknife, NWT

JWEL. 2002a. *Baseline Limnology Program (2001) Gahcho Kué (Kennady Lake).* Project No. 50091. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. March 4, 2002.

JWEL. 2002b. *Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake).* Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. April 29, 2002.

JWEL. 2003a. *Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002).* Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. June 4, 2003.

JWEL. 2003b. *Baseline Limnology Program (2002) Gahcho Kue (Kennady Lake).* Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. June 4, 2003.

JWEL. 2004. *Baseline Limnology Program (2003) Gahcho Kué (Kennady Lake).* Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT. January 20, 2004.

8.II.7 ACRONYMS AND UNITS

8.II.7.1 ACRONYMS

AMEC	AMEC Earth & Environmental
ANFO	ammonium nitrate/fuel oil
De Beers	De Beers Canada Inc.
EBA	EBA Environmental Consultants Ltd.
EIS	environmental impact statement
GIS	Geographic Information System
Golder	Golder Associates Ltd.
JWEL	Jacques Whitford Environment Ltd.
NPR	neutralization potential ratios
NWT	Northwest Territories
PAG	potentially acid generating
PK	processed kimberlite
PKC	processed kimberlite containment
$PM_{2.5}$	particulate matter measuring 2.5 microns or less
Project	Gahcho Kué Project
TDS	total dissolved solids
WMP	Water Management Pond

8.II.7.2 UNITS OF MEASURE

%	percent
km	kilometre
m	metre
masl	metres above sea level
mg/L	milligrams per litre
Mm^3	million cubic metres
ºC	degrees Celsius

ATTACHMENT 8.II.1

UPDATED SUMMARY OF WATER MANAGEMENT AND BALANCE DURING MINE OPERATION FOR FEASIBILITY STUDY OF GAHCHO KUÉ PROJECT

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TECHNICAL MEMO

ISSUED FOR USE

TO:	Andrew Williams, De Beers Veronica Chisholm, De Beers	**DATE:**	April 17, 2012
C:	Wayne Corso, JDS, Dan Johnson, JDS John Faithful, Golder		
FROM:	Bill Horne, EBA Guangwen (Gordon) Zhang, EBA, Hongwei Xia, EBA	**EBA FILE:**	E14101143
SUBJECT:	2012 Gahcho Kué EIS Supplement - Updated Summary of Water Management Plan during Mine Operation for Gahcho Kué Diamond Project, NWT, Canada		

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company (EBA) was retained by JDS Energy and Mining Inc. (JDS) to develop a water and waste management plan as a part of the project feasibility study for the Gahcho Kué Diamond Project. EBA completed the original water and waste management plan and submitted the report to JDS in September 2010. An assessment on the Gahcho Kué fine PK disposal alternatives was carried out through a Multiple Accounts Analysis (MAA) approach by Gahcho Kué project work teams in July 2011. Based on the MAA a modification was made to the fine PK disposal plan in that the fine PK disposal will be deposited in Area 2 (as opposed to Area 1 and Area 2) and then be placed in mined out pits.

The water management plan during mine operation has been updated accordingly to facilitate the selected fine PK disposal alternative. This memo summarizes the updated water management plan during mine operation. This memo should supersede EBA's previous memo dated May 14, 2010, entitled "Updated Summary of Water Management and Balance during Mine Operation for Feasibility Study of Gahcho Kué Project, Memo 006 (Updated)" (EBA 2010), and also supersede's an EBA internal memo on the same subject, dated October 6, 2011.

The key objectives of this water management plan are to:

- dewater Kennady Lake to the maximum extent possible to safely access and mine the ore bodies;
- utilize passive treatment in the controlled area and discharge water when the water quality meets discharge criteria;
- utilize available containment volumes within the controlled area for water management as required, e.g., the mined-out pits for water storage;
- minimize environmental impacts to adjacent and downstream waters during construction, operations and closure phases of the Project; and

- re-establish a flow regime and self-sustaining ecosystem in the refilled Kennady Lake after closure.
-

2.0 DESIGN BASIS

2.1 Mine Production Plan

Table 1 summarizes the mine production plan used in this study, which was provided by JDS in an email to EBA on December 11, 2009. A uniform monthly production rate of 250,000 tonnes of dry ore was assumed for the water management plan in this study, which resulted in a mine production period of 11 years (March 2015 to August 2025).

Table 1: Summary of Mine Production Plan

Year	Pit	Production (tonnes of dry ore)
-3		Pre-disturbance
-2	5034	Initial Lake Dewatering
-1	5034	Pre-stripping 5034
1	5034	2,500,000
2	5034	3,000,000
3	5034	3,000,000
4	5034/Hearne	3,000,000
5	5034/Hearne/Tuzo	3,000,000
6	Hearne/Tuzo	3,000,000
7	Hearne/Tuzo	3,000,000
8	Tuzo	3,000,000
9	Tuzo	3,000,000
10	Tuzo	3,000,000
11	Tuzo	1,800,000
Total		31,300,000

2.2 Pit Development Plan

Table 2 summarizes the yearly pit development plan that was received from the JDS team on December 13, 2009. The pit bottom depths with time were obtained from a set of yearly pit development drawings received from SRK. No data for the pit start and completion months were provided, so the pit start and completion months for each of the three pits were roughly estimated and listed in Table 3.

Table 2: Yearly Pit Development Plan

Year	Bottom Elevation of 5034 Pit (m)	Mine Waste and Ore from 5034 Pit (M tonnes)			Bottom Elevation of Hearne Pit (m)	Mine Waste and Ore from Hearne Pit (M tonnes)			Bottom Elevation of Tuzo Pit (m)	Mine Waste and Ore from Tuzo Pit (M tonnes)		
		Overburden	Waste Rock	Ore		Overburden	Waste Rock	Ore		Overburden	Waste Rock	Ore
-2	421	0.46	1.56									
-1	373	0.26	15.95									
1	349	2.21	27.19	2.5								
2	301		24.71	3.0								
3	253		17.74	3.0								
4	181		10.51	3.0	409	1.24	1.89					
5	121		2.92	1.7	361	0.74	10.01	1.2	397	1.86	11.63	0.1
6					301		11.85	2.5	361	0.36	13.30	0.5
7					217		3.56	1.8	325	0.21	27.16	1.2
8									253		31.49	3.0
9									193		9.89	3.0
10									157		4.03	3.0
11									121		0.96	1.8
Total		**2.93**	**100.58**	**13.2**		**1.98**	**27.31**	**5.5**		**2.43**	**98.46**	**12.6**

Table 3: Summary of Assumed Pit Start and Completion Months

Pit	Start	Completion
5034	October Year -2 *	June Year 5
Hearne	September Year 4	June Year 7
Tuzo	September Year 5	August Year 11
* Quarrying materials in the on-land portion of the 5034 Pit footprint may begin in early Year -2 for dyke construction.		

2.3 Precipitation, Surface Runoff, and Lake Surface Evaporation

Inconsistent values for precipitation, surface runoff, and lake surface evaporation parameters have been reported in various documents for the previous studies (AMEC 2005; Golder EIS 2010) for the Gahcho Kué project. The values adopted in this study are generally based on those reported in the draft Environmental Impact Statement (Golder EIS 2010). These values are slightly conservative when compared to those in the 2005 site water balance study (AMEC 2005). Table 4 summarizes the key parameters used for the water balance and management in this study.

Table 4: Precipitation, Runoff and Lake Surface Evaporation Parameters

Parameter	Value
Annual total precipitation for a mean year (1/2 return period)	328 mm
Net annual unit runoff for open water surface for a mean year	- 8 mm
Net annual unit runoff for vegetated natural land surfaces for a mean year	210 mm
Net annual unit runoff for disturbed land surfaces for a mean year	249 mm
Net annual unit runoff for waste rock dump surface during active waste rock placement period for a mean year	105 mm
Net annual unit runoff for inactive waste rock dump surface after completion of final waste rock placement for a mean year	210 mm
Monthly runoff distribution	7.7% in May 55.6% in June 19.6% in July 7.4% in August 7.2% in September 2.5% in October
Annual total lake surface evaporation for a mean year	285 mm
Monthly distribution of lake surface evaporation	13% in June 38% in July 29% in August 20% in September
Annual total precipitation for a wet year with a 1/10 return period	428 mm
Annual total precipitation for a wet year with a 1/100 return period	553 mm
1-hour extreme rainfall with a 1/100 return period	28 mm
1-day extreme rainfall with a 1/100 return period	56 mm
30-day extreme rainfall with a 1/100 return period	152 mm
Spring snowpack snow water equivalent for a mean year (1/2 return period)	120 mm
Extreme spring snowpack snow water equivalent in wet condition with a 1/100 return period	162 mm

2.4 Fine PK Parameters and Management Plan

The following parameters were adopted in the water management and balance for this study.

- Natural moisture content of ore: 6% (from JDS/Hatch);

- Specific gravity of ore and PK: 2.7 (AMEC 2005);
- Average ratio of dry fine PK over total PK by weight: 25% (assumed based on the discussions with JDS on August 25, 2009);
- Cut-off (maximum) size of fine PK: 0.3 (mm) (JDS/Hatch);
- Moisture content of coarse PK: 18% (from EKATI Mine);
- Solid content of slurry fine PK at discharge points: 30% (assumed based on the discussions with JDS on August 25, 2009);
- Dry density of settled fine PK (no entrained ice): 1.0 tonnes/m^3 (assumed based on experience at EKATI and Jericho);
- Average dry density of in-place fine PK (with entrained ice): 0.77 tonnes/m^3 (assumed based on experience at EKATI and Jericho);
- Beach slope of fine PK surface: 2% (assumed).

Area 2, the mined-out 5034 pit, and the mined-out Hearne pit have been identified as feasible locations for fine PK deposition based on the updated fine PK management plan. Fine PK slurry will be discharged into Area 2 first and then discharged into the mined-out 5034 pit. Once the Hearne pit is mined out, the fine PK slurry will be discharged into the mined-out Hearne pit. Table 5 summarizes the overall fine PK management plan.

Table 5: Fine PK Management Plan

Planned Fine PK Deposition Location	Area 2	Mined-out 5034 Pit	Mined-out Hearne Pit
Deposition Schedule	March of Year 1 to July of Year 5	August of Year 5 to July of Year 7	August of Year 7 to August of Year 11
Total Dry Fine PK Placed (M tonnes)	3.32	1.50	3.01
Fine PK Slurry Deposition Method	Discharge at spigot locations above water elevations	Underwater discharge	Underwater discharge
Estimated Total Volume of In-place Settled Fine PK (Including entrained Ice when applicable) (Mm^3)	4.31	1.50	3.01
Maximum Elevation of Settled Fine PK (m)	429	185	320

2.5 Passive Inflow to Pit

Golder (2010) conducted a detailed hydrological study using both conceptual hydrogeological and numerical models to predict the potential pit inflows for the Gahcho Kué project. The model assumed that there are three enhanced permeability zones at Gahcho Kué site, which are influence the pit inflow quality and quantity. Similar zones have been found at Diavik, Ekati and Snap Lake mine sites. The study also assumed that water reporting to pits will originate both from the Kennady Lake basin (i.e. Areas 3&5, Area

4, and Area7) and from deep bedrock (Golder EIS 2010). The potential pit inflow and percentage of lake water contribution from Areas 3&5, Area 4, and Area 7 to pit inflow were provided by Golder to EBA via emails on August 15, 2011 and September 27, 2011. Table 6 summarizes the pit inflow information provided by Golder and the estimated net pit inflow from deep bedrock.

Table 6: Summary of Estimated Rates of Passive Inflow to Pits during Mine Operation

Year	Total Predicted Inflow (m^3/day)[a]			Lakewater Contribution from Areas 3&5 (%)[a]			Lakewater Contribution from Area 4 (%)[a]			Lakewater Contribution from Area 7 (%)[a]			Estimated Net Pit Inflow from Deep Bedrock (excluding lake water contribution) (m^3/day)[b]		
	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo
-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-1	2100	-	-	-	-	-	59	-	-	8	-	-	684	-	-
1	2300	-	-	1	-	-	22	-	-	6	-	-	1643	-	-
2	2100	-	-	3	-	-	12	-	-	9	-	-	1588	-	-
3	2400	-	-	8	-	-	9	-	-	15	-	-	1623	-	-
4	2600	400	-	12	2	-	8	64	-	19	17	-	1576	67	-
5	2500	800	600	15	11	0	6	22	57	24	10	16	1362	452	156
6	2200	1200	800	21	26	4	4	2	24	28	6	10	1041	793	499
7	1200	1400	1100	27	38	12	9	1	15	34	3	6	353	817	743
8	1400	700	1800	28	66	20	5	2	6	36	2	4	425	210	1272
9	1400	300	2100	29	87	29	3	0	4	40	2	2	395	33	1359
10	1400	100	2200	31	90	35	2	0	3	41	0	2	365	10	1312
11	1400	50	2400	31	90	39	2	0	3	42	0	1	343	5	1372

[a]: value provided by Golder via emails.

[b]: value calculated by EBA.

3.0 MAJOR ASSUMPTIONS AND CONSIDERATIONS

The following assumptions have been adopted in developing the water management plan.

- The basin in Areas 3 to 5 will become a water management pond during the early years of mine operation.
- Based on the preliminary results of the water quality assessment by Golder (Golder EIS 2010), it is assumed that water in Area 3 will meet direct discharge criteria during the first four years (Year -1 to Year 3) of mine operation; therefore, it is planned to discharge water from the Area 3 to Lake N11 during that period for the current water management plan. The actual discharge period can be extended beyond Year 3 if the water quality in the basin meets the discharge criteria after Year 3. It is understood that Golder will use this updated water balance model to reassess the previous water quality model and verify the above water discharge assumption. This water balance model should be updated based on the result of Golder's water quality reassessment.
- It has been assumed for the purpose of this memo that the lake level drawdown in the basin is limited to 2.0 m from the original lake level during the first three years. The planned maximum lake level has assumed to increase to 2.5 m for the fourth year to increase the water storage capacity in the basin, which will accommodate more water during the following no-discharge period. It may be possible to further draw down the water level in the basin based on the empirical approach of discharging 50% of lake volume without treatment. Nevertheless, the assumed drawdowns leave some conservatism and flexibility in the water management plan. Site performance observations and monitoring are required to determine the final value of the maximum drawdown during mine operation.
- Mine waste (mine rock, coarse PK, and fine PK slurry) will not be directly placed in the water management pond during the first four years of mine operation so that the clean water in the polishing pond can be discharged annually during the period.
- A filter dyke will be constructed between Area 2 and Area 3 to retain the excess suspended solids in the water within Area 2, where the fine PK slurry will be deposited during early mine operation before 5034 pit is mined out. Past experience with filter dykes at several northern mines suggests that the filter dyke will sufficiently remove the excess suspended solids in the water released from the settled fine PK slurry. The filter dyke will be constructed before any fine PK slurry is placed in Area 2.
- An in-line treatment system will be used for both the contact runoff water collected in water collection ponds (CP) and pit water pumped into the polishing pond to lower the suspended solid concentration in the water.
- Fine PK slurry will be deposited into the mined-out 5034 pit after it is available and the deposited fine PK volume reaches the design capacity of Area 2. Fine PK slurry will be deposited into the mined-out Hearne pit after it is available. Mine rock will be also placed into the mined-out 5034 pit. It is assumed in this water balance that placement of mine rock in the mined-out 5034 pit will start after fine PK slurry is discharged into the mined-out Hearne pit. The maximum water elevation in the mined-out 5034 pit will be limited to the elevation of the sill between the 5034 and Tuzo pits (i.e. 300 m elevation) while active mining in Tuzo pit takes place.

- Only fine PK slurry is planned to discharge into the mined-out Hearne pit. No mine rock or coarse PK is planned to be placed in the mined-out Hearne pit in the current water balance. This could be reassessed latter in the mine life if there is excess capacity in the mined out Hearne Pit.
- Prior to discharging fine PK slurry to Area 2, the treated sewage water will be pumped to the water management pond. After starting discharge fine PK slurry, the treated sewage water will be pumped to the same locations as fine PK slurry discharged.
- Water required for processing ore will be reclaimed solely from the pond in Area 3 during the early stage of mine operation before fine PK slurry is deposited into the mined-out Hearne pit. Pit water from the active Tuzo pit will be used as a portion of reclaim water for the process plant after the fine PK is directed into the mined-out Hearne pit. The balance of reclaim water for ore processing will come from the water management pond.

4.0 WATER MANAGEMENT PLAN DURING MINE OPERATION

The updated water management plan during the mine operation period under mean precipitation years (Year -1 to Year 11) can be divided into the following seven stages. A total of 14 dykes are required for the updated water management plan. The conceptual design of the required dykes is summarized in a separate EBA memo dated March 27, 2012 (EBA 2012). The overall project timeline for water management during the mine operation is presented in Table 7.

Table 7 Overall Project Timeline for Water and Fine PK Slurry Management during Mine Operation

Items	Water and Fine PK Slurry Management			Project Timeline (Year)											
	From	To	Method	-1	1	2	3	4	5	6	7	8	9	10	11
Water Diversion	Watershed A	Area 8	Dyke/Pipeline												
	Watershed B	Lake N8	Dyke/Natural Flow												
	Watershed D	Lake N14													
	Watershed E	Lake N14													
Area 2	Fine PK Facility	Area 3	Seepage												
Area 3&5	Area 3	Lake N11	Pipeline												
		Process Plant													
Area 4	Area 4 Pond	Mined-out 5034 Pit													
	CP6	Area 3													
Area 6	CP2 to CP5	Area 5													
	CP2 to CP4	Area 5													
Area 7	CP1	Area 5													
5034 Pit	Active 5034 Pit	Area 5													
	Mined-out 5034 Pit	Mined-out Hearne Pit													
		Area 5													
Hearne Pit	Active Hearne Pit	Area 5													
Tuzo Pit	Active Tuzo Pit	Area 5													
		Process Plant													
Fine PK Slurry	Process Plant	Area 2													
		Mined-out 5034 Pit													
		Mined-out Hearne Pit													

Note: Fresh Water Contact Water Fine PK Slurry

Figures 1 to 8 present the updated water management site plan for each of stages. Detailed activities of water management for each stage were described as follows:

Stage 1: Year -1 (Figure 1)

- Pump water from the 5034 pit through an in-line treatment system to Area 5;
- Pump runoff water collected in various collection ponds in Areas 6 and 7 through an in-line treatment system to Area 5;
- Discharge treated sewage water from sewage treatment plant into Area 3;
- Divert excess runoff water from the watershed D by constructing Dyke F (the water level in Lakes D2 and D3 will rise to about 426.5 m by the end of Year -1);
- Divert excess runoff water from the watershed E by constructing Dyke G (the water level in Lake E1 will rise to about 426.0 m by the end of 2014 and extra runoff will flow into Lake N14 and then Lake N17);
- Complete Dyke A1 before the Year -1 spring freshet and pump the excess runoff water from the watershed A to Area 8 through Lake J1b;
- Allow excess runoff water from the watershed B flowing into Area 3 by deferring the construction of Dyke E to alleviate the dyke construction requirements before the freshet of Year -1;
- Discharge water from Area 3 to Lake N11 during June to November to lower the water elevation in the Areas 3 to 5 to a minimum of about 418.7 m by end of November; and
- Complete the Stage 1 construction of Dyke L before placing fine PK in Area 2.

Stage 2: Years 1 to 3 (Figure 2)

- Same as Stage 1 except for the following additions and changes;
- Discharge fine PK slurry together with treated sewage water into Area 2;
- Reclaim water from the Area 3 to process plant for ore processing;
- Divert excess runoff water from the watershed B by constructing Dyke E (the runoff water will flow to Lake N8 and then Lake N6);

Stage 3: Year 4 (Figure 3)

- Same as Stage 2 except for the following additions and changes;
- Pump pit water from both 5034 pit and Hearne pit to Area 5;
- Water replaced by mine rock placed below the water in the south portion of the basin in Area 5 (or Area 5B);
- Assume no discharge from Area 3 to Lake N11 for the current management plan; annual discharge may continue depending on the water quality in Area 3.

Stage 4: Year 5 (Figure 4)

- Same as Stage 3 except for the following additions and changes;
- Keep discharging fine PK slurry together with treated sewage water into Area 2 until July of Year 5;
- Start discharging fine PK slurry with treated sewage water into mined-out 5034 pit from August of Year 5;
- Stop pumping pit water from the 5034 pit to Area 5 after July of Year 5;
- Dyke B completed by July of Year 5 to separate Area 4 from Area 5;
- Siphon water from Area 4 to the mined-out 5034 pit to drain Area 4 in August and September of Year 5;
- Pump runoff water collected in collection pond CP6 in Area 4 to Area 3 after September of Year 5;
- Pump pit water from Tuzo pit to the Area 5 after September of Year 5;

Stage 5: Year 6 (Figure 5)

- Same as Stage 4 except for the following additions and changes;
- Stop pumping runoff water collected in Area 7 into Area 5 from Year 6; and
- Start raising water level in Area 7 with the completion of Dyke K before April of Year 6.

Stage 6: Year 7 (Figure 6)

- Same as Stage 5 except for the following changes;
- Stop discharging fine PK slurry together with the treated sewage water into the mined-out 5034 pit after July of Year 7;
- Start discharging fine PK slurry together with the treated sewage water into the mined-out Hearne pit from August of Year 7;
- Stop pumping pit water from the Hearne pit to Area 5 after June of Year 7 when the Hearne pit is mined-out;
- Surface runoff water from the west portion of Area 6 naturally flows into the mined-out Hearne pit;
- Continue pumping the surface runoff from the east portion of Area 6 to Area 5; and
- Start pumping extra water cumulated in the mined-out 5034 pit into the mined-out Hearne pit after September of Year 7.

Stage 7: Years 8 to 11 (Figures 7 and 8)

- Same as Stage 6 except for the following additions and changes;
- Stop pumping pit water from the Tuzo pit to Area 5 after June of Year 8;

- Stop pumping water cumulated in the mined-out 5034 pit to the mined-out Hearne pit after May of Year 8;
- Start pumping water cumulated in the mined-out 5034 pit to Area 5 from June of Year 8;
- Pump pit water from the Tuzo pit to the process plant as a portion of the reclaim water after June of Year 8 to promote locking the chloride/TDS in the Tuzo pit water in the fine PK slurry placed in the bottom portion of Hearne pit;
- Pump the remaining reclaim water required for ore processing from Area 3; and
- Complete construction of Dyke N to increase water storage capacity in the west portion of Area 6 containing the mined-out Hearne pit before September of Year 9.

5.0 WATER STORAGE CURVES AND CATCHMENT AREAS

The water storage capacities with depths for various additional areas used in water management and balance during the mine operation are summarized in Table 8.

Table 8: Water Stage-Storage Capacity During Mine Operation for Various Areas

Water Elevation (m)	Area 2 after Final Deposition of Fine PK (Mm^3)	Areas 3 and 5 after Construction of Dykes L and B and Final Placement of Mine Rock in Area 5B * (Mm^3)	Area 4 after Construction of Dyke B (Mm^3)	Mined-out 5034 Pit below the Sill between 5034 pit and Tuzo pit (Mm^3)	West of Dyke N in Area 6 Including Mined-out Hearne Pit (Mm^3)
200				2.06	
225				3.83	
250				6.28	
275				9.57	1.00
300				13.53	
350					5.47
410		0.44	0.14		12.42
411		0.72	0.22		12.58
412		1.38	0.37		12.74
413		2.04	0.52		12.92
414		3.14	0.75		13.09
415		4.24	1.01		13.32
416		5.75	1.36		13.56
417		7.26	1.71		13.85
418	0.00	9.09	2.14		14.14
419	0.03	10.93	2.64		14.52

Table 8: Water Stage-Storage Capacity During Mine Operation for Various Areas

Water Elevation	Area 2 after Final Deposition of Fine PK	Areas 3 and 5 after Construction of Dykes L and B and Final Placement of Mine Rock in Area 5B *	Area 4 after Construction of Dyke B	Mined-out 5034 Pit below the Sill between 5034 pit and Tuzo pit	West of Dyke N in Area 6 Including Mined-out Hearne Pit
420	0.09	13.01	3.23		14.91
421	0.22	15.08	3.89		15.50
422	0.41	17.42	4.65		16.08
423	0.67	19.76	5.41		
424	1.08				
*The volume includes the voids within the submerged portion of the mine rock placed in south portion of Area 5. An average porosity of 0.23 was used for the submerged mine rock.					

The total catchment areas for various areas used in water management and balance during the mine operation are summarized in Table 9.

Table 9: Summary of Catchment Areas for Various Areas During Mine Operation

Area	Total Catchment Area Including Water Surface (km^2)
Area 2	1.25
Area 3&5	4.65
Area 4	2.17
Area 6	3.94
Area 7	3.82
5034 pit including surrounding areas where runoff water directly flows into 5034 pit after surface water diversion and collection	0.50
Hearne pit including surrounding areas where runoff water directly flows into Hearne pit after surface water diversion and collection	0.53
Tuzo pit including surrounding areas where runoff water directly flows into Tuzo pit after surface water diversion and collection	0.80
West portion of Area 6 after construction of Dyke N	1.63
Final mine rock pile surface in Area 6	0.78
Final mine rock pile surface in Area 5	0.74
Final coarse PK pile surface in Area 4	0.32
Final settled fine PK surface in Area 2	0.71

6.0 WATER BALANCE DURING MINE OPERATION

A monthly water balance was conducted for the basins in Areas 1 to 7, the mined-out 5034, and the mined-out Hearne pits during the mine operation under mean precipitation years. Table 10 summarizes the major sources of water inputs and outputs for each of the basins and pits for the water balance.

Table 10: Summary of Sources of Water Inputs and Outputs for Water Balance

Items	Water Inputs	Water Outputs
Area 1	Net runoff into the watershed A	Water discharged from Lake A1 to Area 8 through Lake J1b
Area 2	Net runoff into catchment area of Area 2; Free water released from settled fine PK deposited in Area 2; Treated sewage water.	Water flowing from Area 2 to Area 3 before Dyke L is constructed or seepage water through the filter dyke (Dyke L) from Area 2 to Area 3.
Areas 3&5	Net runoff into catchment area of Areas 3&5; Treated sewage water (during Year -1 only); Inflow from the watershed B into Area 3 before Dyke E is constructed or seepage through Dyke E into the Area 3 after Dyke E is constructed; Inflow from the watershed D into Area 5 before Dyke F is constructed or seepage through Dyke F into Area 5 after Dyke F is constructed; Water flowing from Area 2 to Area 3 before Dyke L is constructed or seepage water through the filter dyke (Dyke L) from Area 2 to Area 3; Pit water in active pits pumped to Area 5; Water flowing from Area 4 to Area 3 before Dyke B is constructed or water pumped from collection ponds in Area 4 to Area 3 after Dyke B is constructed; Water pumped from collection ponds in Area 6 to Area 5; Water pumped from collection ponds in Area 7 to Area 5; Water pumped from the mined-out 5034 pit to Area 5.	Water discharged from Area 3 to Lake N11; Water reclaimed from Area 3 to process plant; Seepage water through internal Dykes B and M into Area 4; Seepage water through internal Dykes H and I into Area 6; Pit inflow contributed by Area 3&5 through seepage water.
Area 4	Net runoff into catchment area of Area 4; Seepage water through internal Dykes B and M into Area 4.	Water pumped from water collection pond in Area 4 to Area 3; Seepage water through internal Dyke J into Area 6; Water pumped from Area 4 to mined-out 5034 pit. Pit inflow contributed by Area 4 through seepage water.

Table 10: Summary of Sources of Water Inputs and Outputs for Water Balance

Items	Water Inputs	Water Outputs
Area 6	Net runoff into catchment area of Area 6; Inflow from the watershed E into Area 6 before Dyke G is constructed or seepage through Dyke G into Area 6 after Dyke G is constructed; Seepage water through internal Dykes H, I, J, K, and N into Area 6.	Water flowing from Area 6 to Area 7 during initial lake dewatering; Water pumped from collection ponds in Area 6 to Area 5; Water flowing from Area 6 into mined-out 5034 pit.
Area 7	Net runoff into catchment area of Area 7; Water flowing from Area 6 to Area 7 during initial lake dewatering before construction of Dyke K; Seepage water through Dyke A in Area 7.	Water discharged from Area 7 to Area 8 during initial dewatering; Water pumped from Area 7 to Area 5; Pit inflow contributed by Area 7 through seepage water.
Mined-out 5034 pit	Net runoff into catchment area of mined-out 5034 pit; Water pumped from Area 4 to mined-out 5034 pit; Treated sewage water into the pit Underground seepage through bottom and walls of inactive mined-out 5034 pit into the pit; Water released from settled fine PK deposited in 5034 pit	Water pumped from mined-out 5034 pit to mined-out Hearne pit; Water pumped from mined-out 5034 pit to Area 5.
West Portion (Area 6A) of Area 6 including mined-out Hearne pit	Net runoff into catchment area of Area 6A; Seepage through Dyke G and drained lakebed into Area 6A; Treated sewage water into the pit; Underground seepage through bottom and walls of inactive mined-out Hearne pit into Hearne pit; Water released from settled fine PK deposited in Hearne pit; Water pumped from mined-out 5034 pit to mined-out Hearne pit.	Seepage water through internal Dyke N from Area 6A to Area 6B (east portion of Area 6)

The volume of net runoff water in a given catchment area was calculated based on sub-areas of various surface types including vegetated land surface, open water surface, disturbed land surface, active waste rock surface, and inactive waste rock surface. The net unit runoff value for each of the surface types is summarized in Table 4.

The seepage volume through the filter dyke (Dyke L) was calculated using a macro built into the spreadsheets for the water balance. The seepage values calculated from these macros were compared to the values determined using a finite element method, SEEP/W. Good agreement between these values was obtained, which provides a solid basis for using the macro in this study.

Filter dykes similar to Dyke L have been successfully constructed and operated in several mines in northern Canada. The performance of the filter dykes was monitored. The hydraulic conductivity of the unblocked filter material was back-calculated based on actual operational data for a mine and estimated to be 9.7E-05 m/s. This value was used for the filter material in Dyke L for seepage evaluations in this study. Seepage paths could be blocked in the upper filter zone due to ice formation in winter periods and in the lower filter zone below the potential fluffy fine PK zone due to infiltration of the silty particles into the filter material. These factors were considered in the macro for estimating seepage volumes through the filter dyke.

Seepage volumes through the perimeter dykes (Dykes A, D, E, F, and G) around Areas 2 to 7 were explicitly considered in the water balance model. The monthly seepage volumes through Dyke A were estimated in seepage analyses using SEEP/W. The seepage volumes though the other perimeter dykes are expected to be 0 or minor because these dykes will have a liner system keyed into the top of saturated permafrost or bedrock. Nominal values of the seepage volumes through the dykes were assumed in the water balance model.

Seepage through internal water retention dykes (Dykes B, H, I, J, K, M, and N) will be collected in water collection ponds and pumped back to the source reservoirs. Therefore, the monthly seepage values through these dykes were not included in the water balance spreadsheets.

Figure 9 presents the projected water elevations with time during mine operation for Areas 2 and 7 and the mined-out Hearne pit. The projected total monthly rates of water discharge to the outside receiving environmental is also shown in Figure 9.

Figure 10 presents the excess storage capacity with time in the water management system including both the water storages basins and the mined-out pits.

7.0 PUMPING REQUIREMENTS DURING MINE OPERATION

Table 11 summarizes yearly volumes of water to be pumped for various water sources during the mine operation period for a mean precipitation year. These values were based on the monthly values in the water balance model and the estimated volumes of seepage water through internal dykes. Extra pumping capacity or longer pumping periods are required to handle additional volumes of runoff water during a wet precipitation year.

Table 11: Yearly Volumes of Water to be Pumped during Mine Operation under Mean Precipitation Years

Water Source		Yearly Volume of Water to be Pumped during Mine Operation (Mm^3)											
From	To	-1	1	2	3	4	5	6	7	8	9	10	11
Lake A1	Area 8 (through Lake J1b)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Area 3 pond	Lake N11	4.31	2.64	2.93	3.81	-	-	-	-	-	-	-	-
	Process plant	-	1.67	1.98	1.99	1.98	1.98	1.98	1.99	1.51	1.07	1.04	0.65
Area 4 pond	Mined-out 5034 pit	-	-	-	-	-	3.67	-	-	-	-	-	-
Water collection pond CP6 (in Area 4)	Area 3 pond	-	-	-	-	-	-	0.42	0.43	0.44	0.46	0.46	0.42
Water collection ponds CP2 to CP5 (in Area 6)	Area 5 pond	0.65	0.70	0.74	0.74	0.82	0.83	0.84	0.50				
Water collection ponds CP2 to CP4 (in Area 6)	Area 5 pond								0.20	0.46	0.46	0.46	0.48
Water collection pond CP1 (in Area 7)	Area 5 pond	0.77	0.77	0.77	0.77	0.72	0.57	-	-	-	-	-	-
Active 5034 pit	Area 5 pond	0.92	1.00	0.92	1.00	1.06	0.55	-	-	-	-	-	-
Mined-out 5034 pit	Mined-out Hearne pit	-	-	-	-	-	-	-	2.04	2.78	-	-	-
	Area 5 pond	-	-	-	-	-	-	-	-	1.20	0.65	0.63	0.62
Active Hearne pit	Area 5 pond	-	-	-	-	0.06	0.46	0.65	0.44	-	-	-	-
Active Tuzo pit	Area 5 pond	-	-	-	-	-	0.08	0.59	0.71	0.54	-	-	-
	Process plant	-	-	-	-	-	-	-	-	0.47	0.91	0.95	0.67

REFERENCES

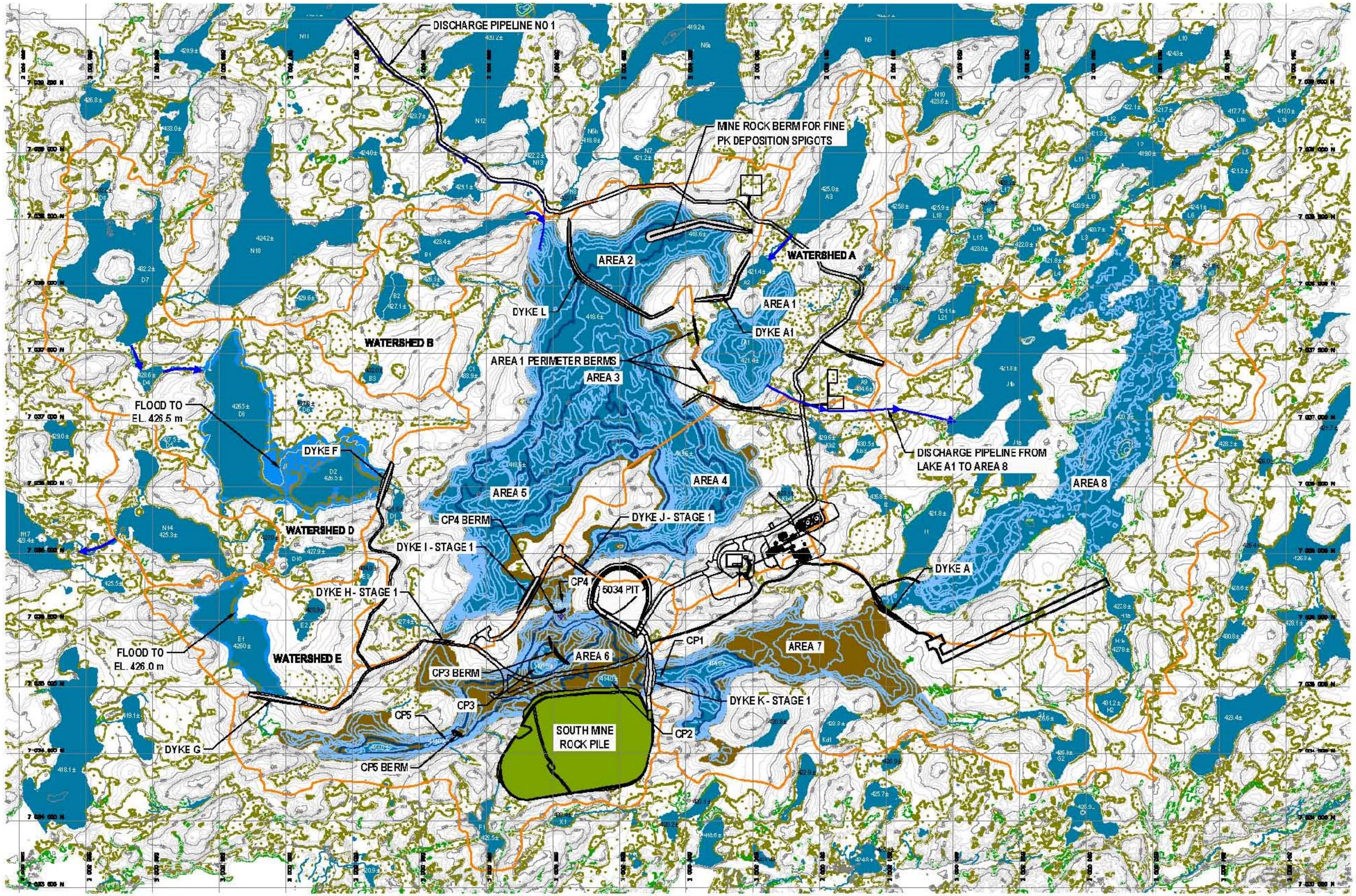
AMEC, 2005. Gahcho Kué Diamond Project 2005 Study Report. Submitted to De Beers Canada by AMEC, June 2005.

AMEC, 2008. Gahcho Kué Project 2006 Conceptual Study Update Report. Submitted to De Beers Canada by AMEC, June 2008.

EBA, 2010. Updated Summary of Water Management and Balance during Mine Operation for Feasibility Study of Gahcho Kué Project. A Memo submitted to JDS by EBA, May 2010.

EBA, 2012. 2012 Gahcho Kué EIS Supplement – Summary of Dyke Conceptual Design and Construction Material for Gahcho Kué Diamond Project, NWT, Canada. A Memo submitted to De Beers and JDS by EBA, March 27, 2012.

De Beers (De Beers Canada Inc.). 2010. Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N. Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010



LEGEND:

430 EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE

415 BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE

0 1 000 m

Scale: 1: 30 000

MARSH AREA

SCRUB

CATCHMENT BOUNDARY

DRAINAGE FLOW DIRECTION

LAKE/POND

DRAINED AREA

MINE ROCK

NOTES
- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
ISSUED FOR USE

CLIENT

DE BEERS CANADA

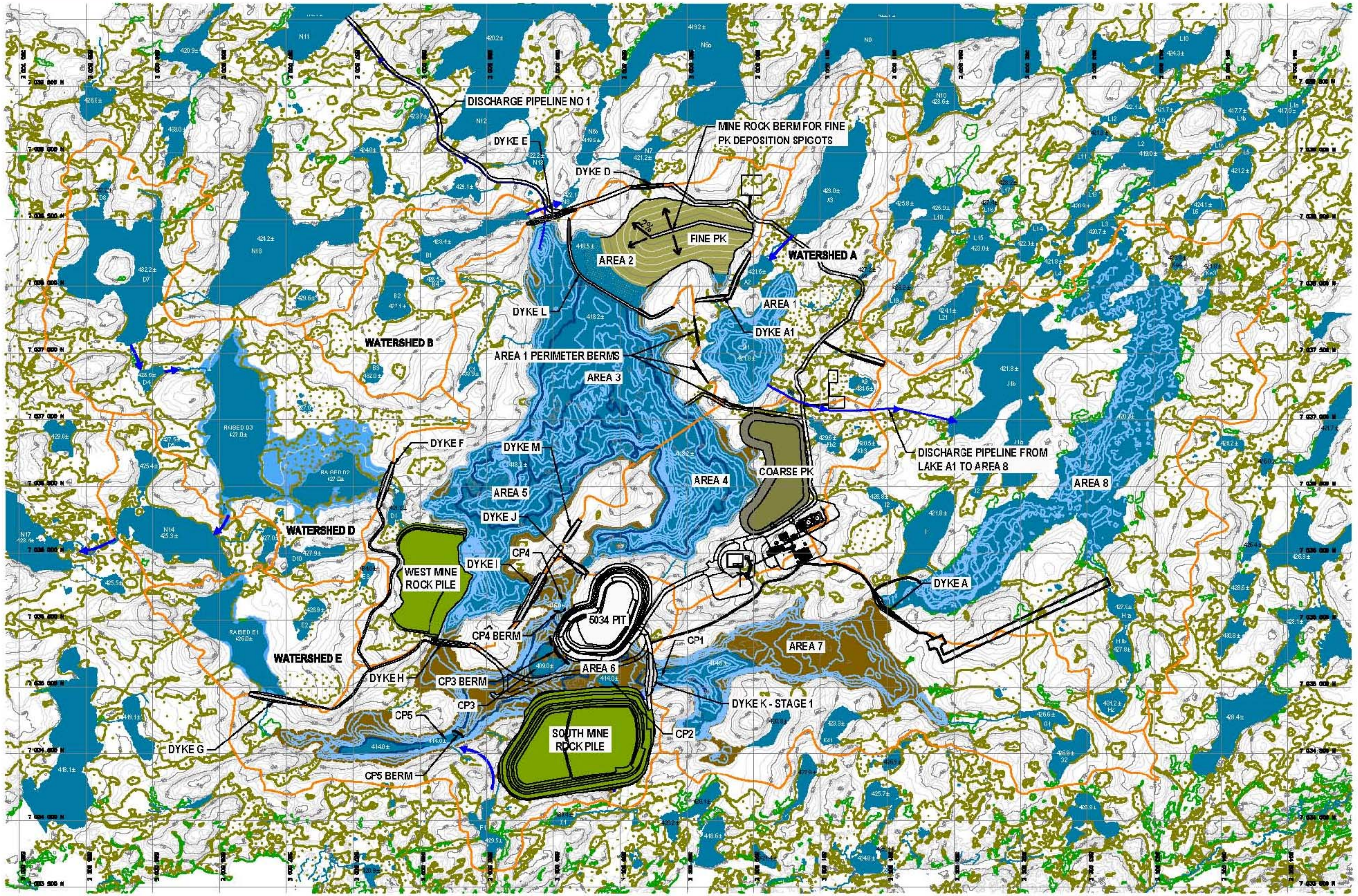
MOUNTAIN PROVINCE DIAMONDS INC.

eba A TETRA TECH COMPANY

2012 GAHCHO KUÉ EIS SUPPLEMENT
NWT, CANADA

STAGE 1 - WATER MANAGEMENT DURING MINE OPERATION (YEAR -1)

PROJECT NO.	DWN	CKD	REV	
E14101143	DBD/EL	GZ	0	Figure 1
OFFICE	DATE			
EDM	March 28, 2012			



LEGEND:

EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE

BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE

0 1 000 m

Scale: 1: 20 000

MARSH AREA

SCRUB

CATCHMENT BOUNDARY

DRAINAGE FLOW DIRECTION

LAKE/POND

DRAINED AREA

MINE ROCK

NOTES
• ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
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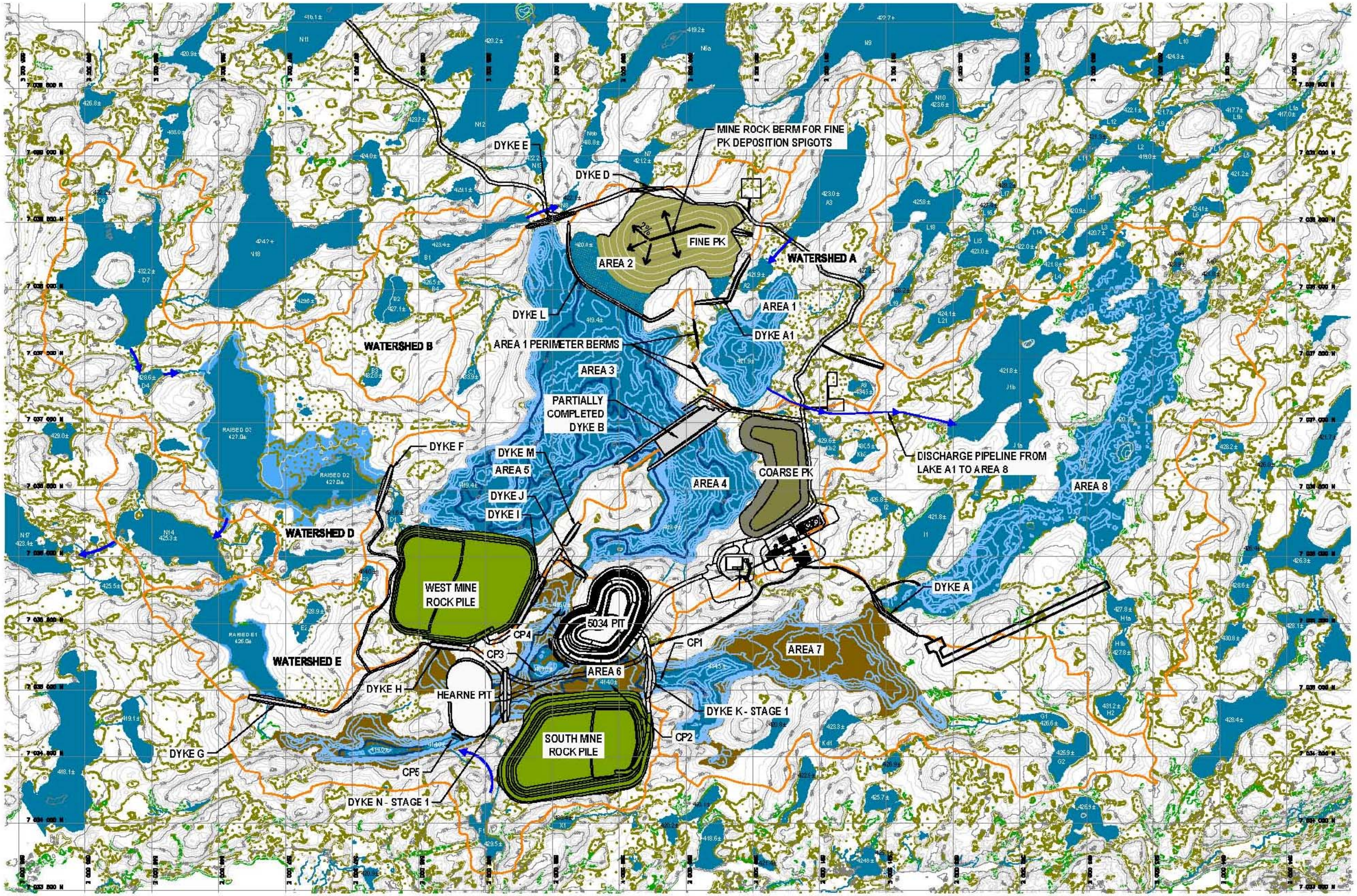
STAGE 2 - WATER MANAGEMENT DURING MINE OPERATION YEARS 1 TO 3

PROJECT NO.	DWN	CKD	REV
E14101143	DBD/EL	GZ	0
OFFICE	DATE		
EDM	March 28, 2012		

Figure 2



LEGEND:

EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE	MARSH AREA	LAKE/POND
BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE	SCRUB	DRAINED AREA
	CATCHMENT BOUNDARY	MINE ROCK
	DRAINAGE FLOW DIRECTION	

0 — 1 000 m

Scale: 1: 30 000

NOTES
- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
ISSUED FOR USE

CLIENT

DE BEERS CANADA

MOUNTAIN PROVINCE DIAMONDS INC.

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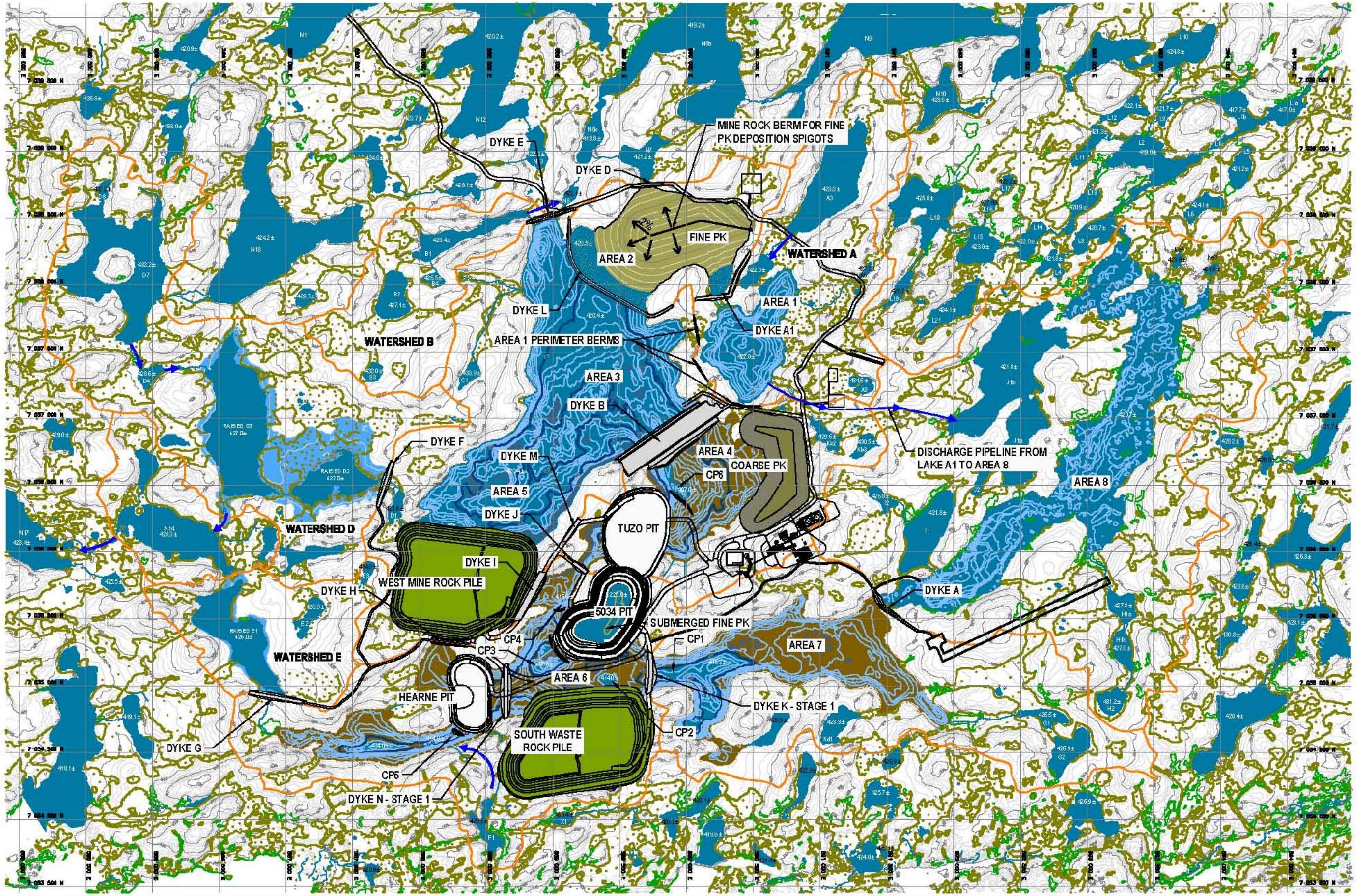
NWT, CANADA

STAGE 3 - WATER MANAGEMENT DURING MINE OPERATION YEAR 4

PROJECT NO.	DWN	CKD	REV	
E14101143	DBD/EL	GZ	0	Figure 3
OFFICE	DATE			
EDM	March 28, 2012			

Q:\Edmonton\Data\0101\Users\Hoa\To Bill (Gahcho Kue)\Water and Waste Operation Memo\Figures 1-8_R0\E14101143_FIG 4.6_R0 - AutoCAD 2007 Drawing Format\E14101143_FIG 4.6_R0.dwg [FIGURE 3] April 02, 2012 - 11:33:26 am (BY: XA, HONGWEI)



LEGEND:

- EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- MARSH AREA
- SCRUB
- CATCHMENT BOUNDARY
- DRAINAGE FLOW DIRECTION
- LAKE/POND
- DRAINED AREA
- MINE ROCK

0 1 000 m

Scale: 1: 30 000

NOTES

- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
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CLIENT

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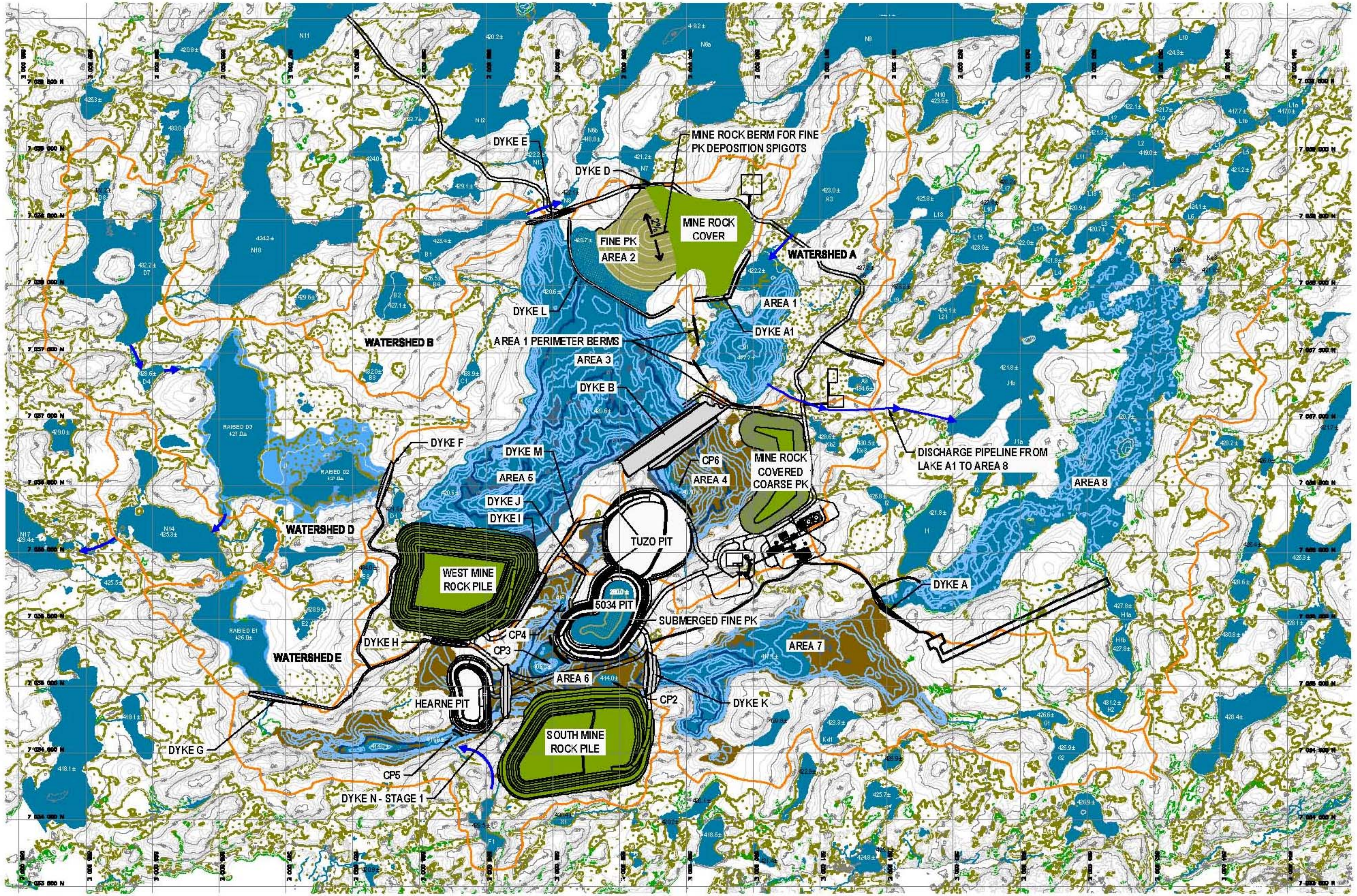
STAGE 4 - WATER MANAGEMENT DURING MINE OPERATION YEAR 5

PROJECT NO.	DWN	CKD	REV	
E14101143	DBD/EL	GZ	0	Figure 4
OFFICE	DATE			
EDM	March 28, 2012			



LEGEND:

- 430 EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- 415 BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- MARSH AREA
- SCRUB
- CATCHMENT BOUNDARY
- DRAINAGE FLOW DIRECTION
- LAKE/POND
- DRAINED AREA
- MINE ROCK

0 1 000 m

Scale: 1: 30 000

NOTES

- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS

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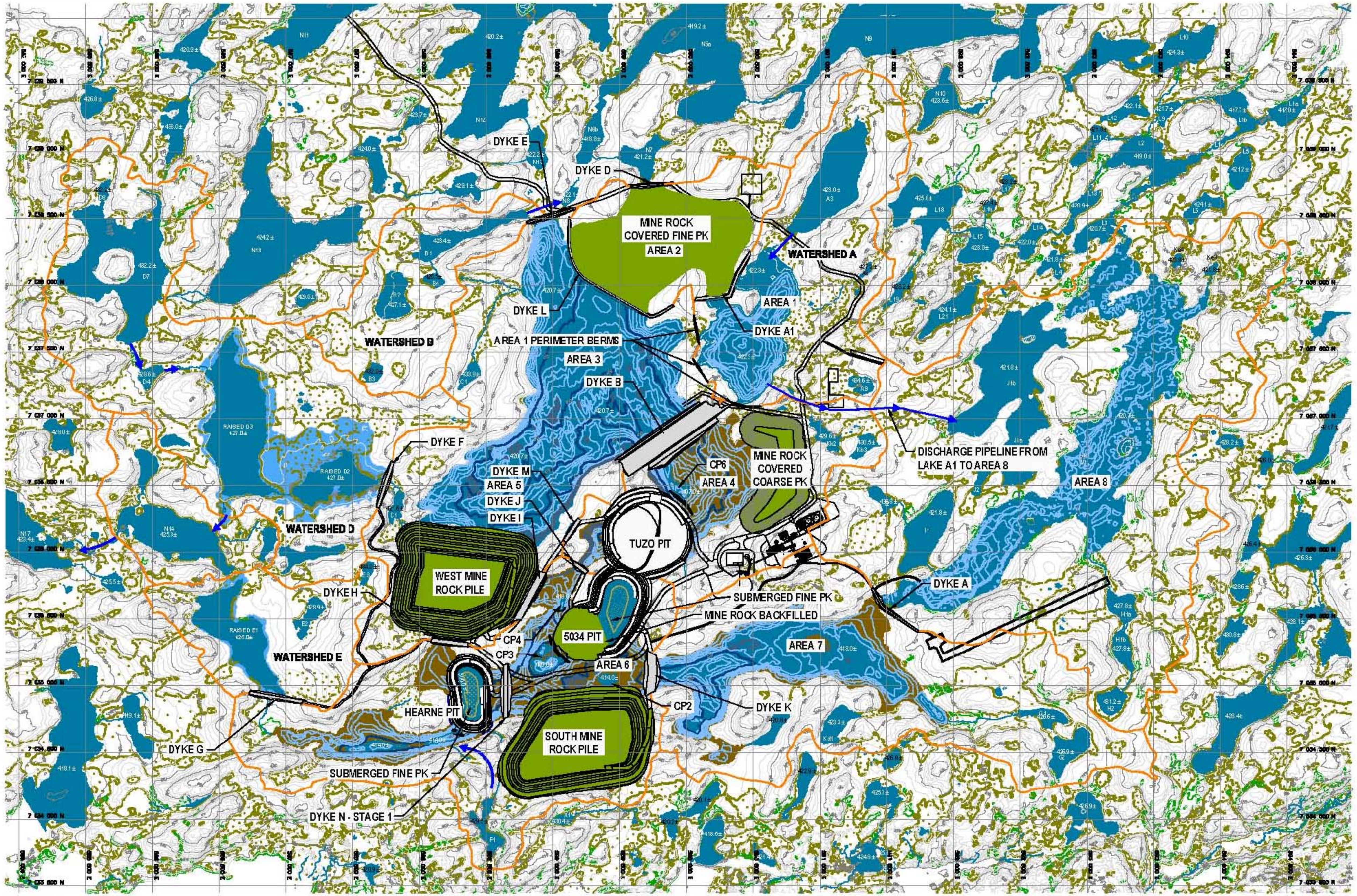
STAGE 5 - WATER MANAGEMENT DURING MINE OPERATION YEAR 6

PROJECT NO.	DWN	CKD	REV	
E14101143	DBD/EL	GZ	0	Figure 5
OFFICE	DATE			
EDM	March 29, 2012			



LEGEND:

430	EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE
415	BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE
	CATCHMENT BOUNDARY
	DRAINAGE FLOW DIRECTION
	MARSH AREA
	SCRUB
	LAKE/POND
	DRAINED AREA
	MINE ROCK

0 1 000 m

Scale: 1: 30 000

NOTES
- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
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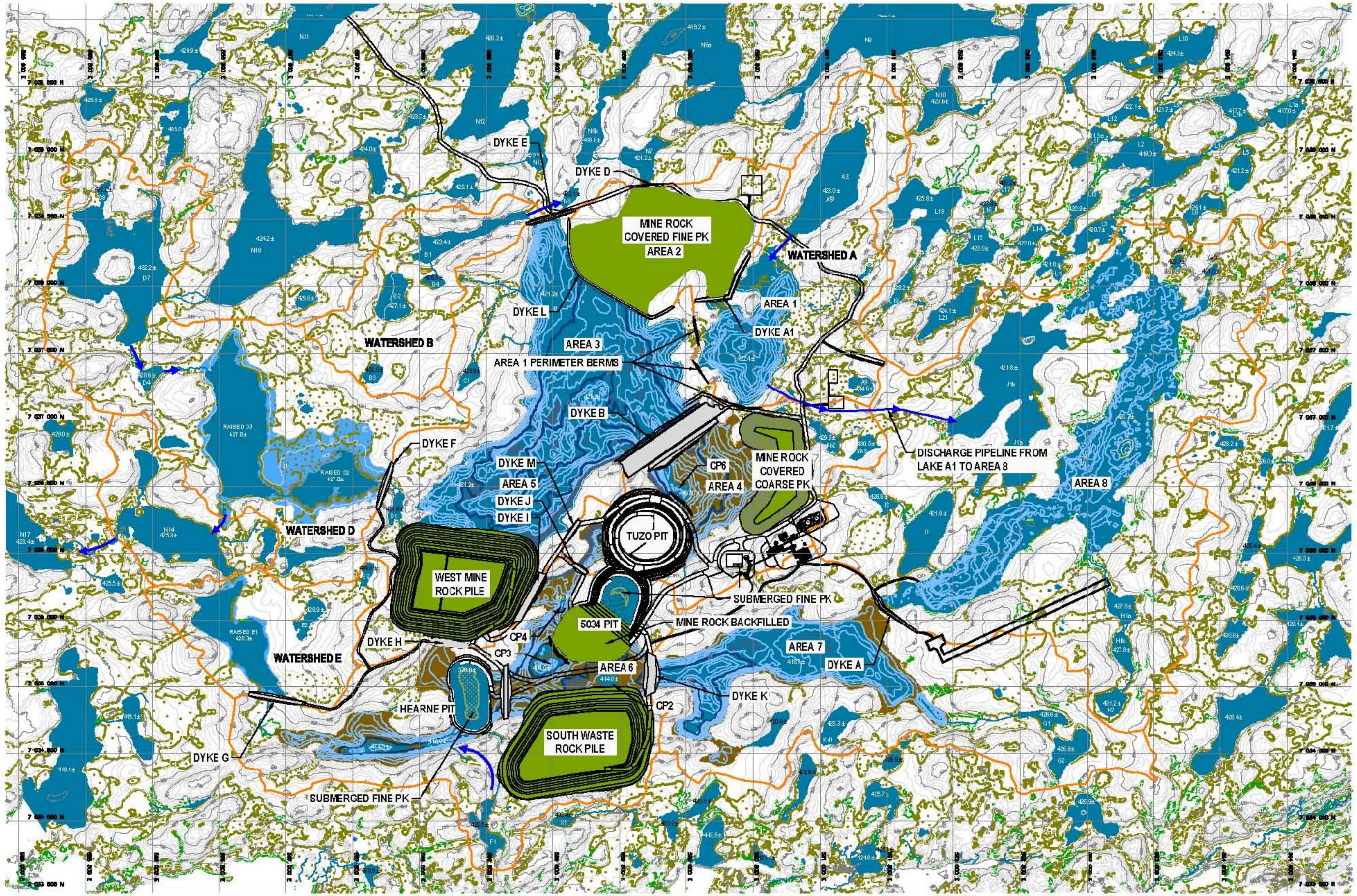
STAGE 6 - WATER MANAGEMENT DURING MINE OPERATION YEAR 7

PROJECT NO.	DWN	CKD	REV	
E14101143	DBD/EL	GZ	0	Figure 6
OFFICE	DATE			
EDM	March 29, 2012			



LEGEND:

- EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE
- MARSH AREA
- SCRUB
- CATCHMENT BOUNDARY
- DRAINAGE FLOW DIRECTION
- LAKE/POND
- DRAINED AREA
- MINE ROCK

0 1 000 m

Scale: 1: 30 000

NOTES
- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

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2012 GAHCHO KUÉ EIS SUPPLEMENT
NWT, CANADA

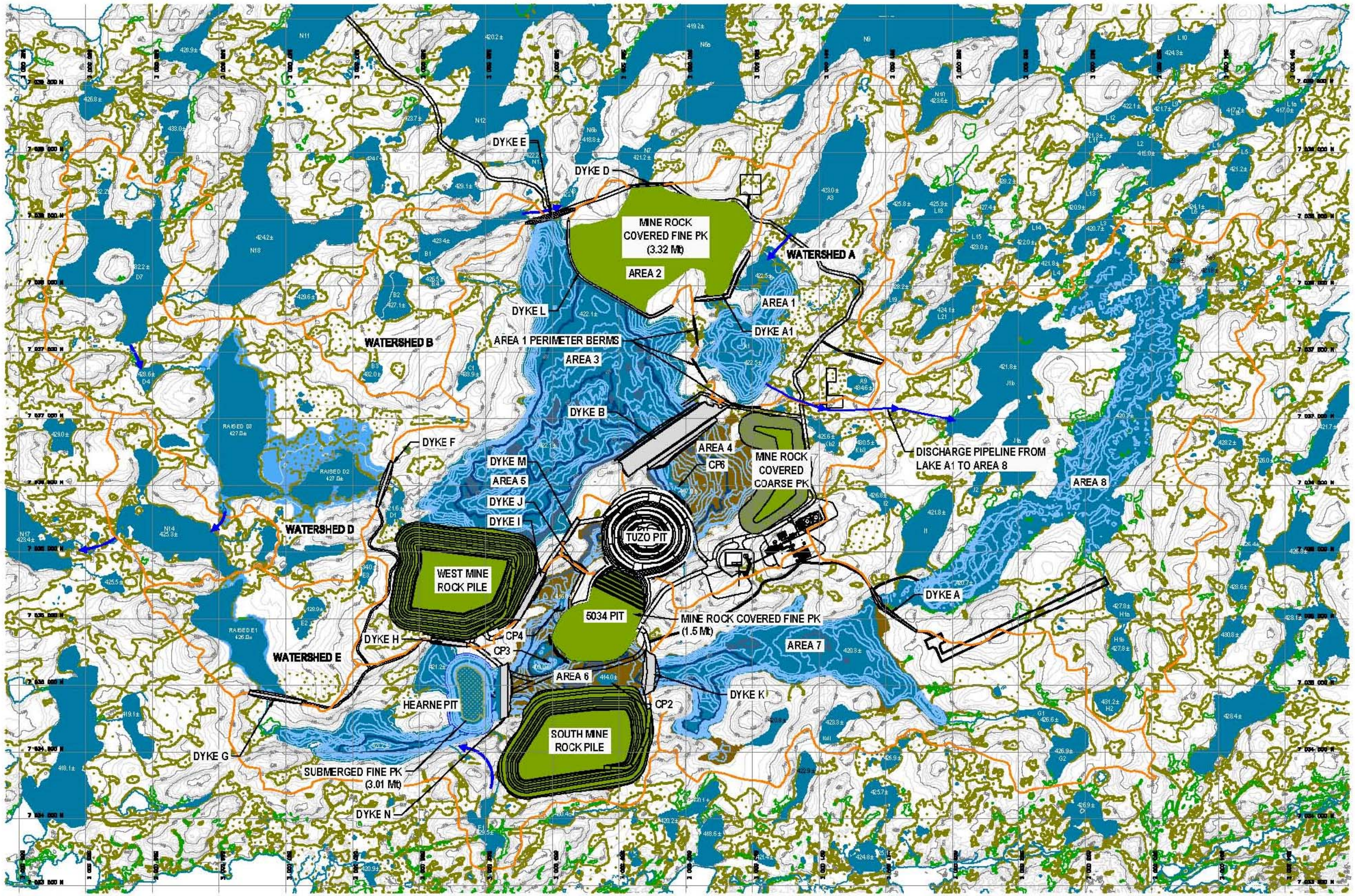
STAGE 7 - WATER MANAGEMENT DURING MINE OPERATION YEAR 8

PROJECT NO.	DWN	CKD	REV
E14101143	DBD/EL	GZ	0

OFFICE	DATE
EDM	March 29, 2012

Figure 7

O:\Edmonton\Data\0101\Users\Helz\To Bill (Gahcho Kue)\Water and Waste Operation Memo\Figures 1-8_ROI\E14101143_FIG 4.10_R0 - AutoCAD 2007 Drawing Format\E14101143_FIG 4.11_R0.dwg [FIGURE 7] April 09, 2012 - 10:31:17 am (BY: XIA, HONGWEI)



LEGEND:

430 EXISTING GROUND CONTOURS 5 m INDEX - 1 m INTERMEDIATE

415 BATHYMETRY CONTOURS 5 m INDEX - 1 m INTERMEDIATE

0 1 000 m

Scale: 1: 30 000

MARSH AREA

SCRUB

CATCHMENT BOUNDARY

DRAINAGE FLOW DIRECTION

LAKE/POND

DRAINED AREA

MINE ROCK

NOTES

- ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS

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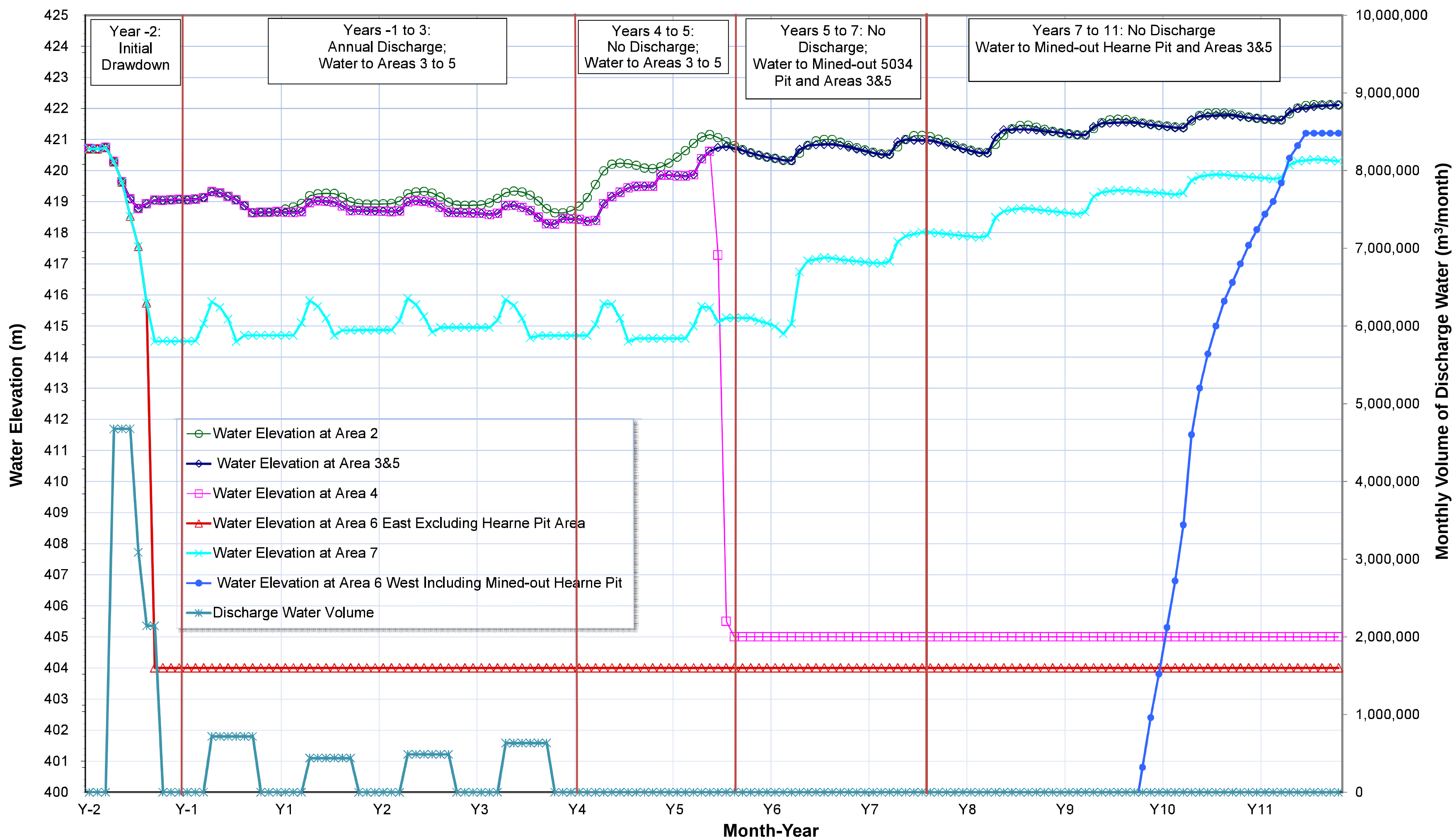
2012 GAHCHO KUÉ EIS SUPPLEMENT
NWT, CANADA

STAGE 7 - WATER MANAGEMENT DURING MINE OPERATION YEARS 9 TO 11

PROJECT NO.	DWN	CKD	REV
E14101143	DBD/EL	GZ	0

OFFICE	DATE
EDM	March 29, 2012

Figure 8



CLIENT	2012 GAHCHO KUE EIS SUPPLEMENT NWT, CANADA	
	Projected Water Elevations and Discharge Rates with Time during Mine Operation	
A TETRATECH COMPANY	PROJECT NO. E14101143 · DWN GZ · CKD GZ · APVD BH · REV HX	Figure 9
	OFFICE EBA-EDM · DATE March 29, 2012	

STATUS
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