Table 5.5-15 Summary of Characteristics of Stream Crossings Along the Proposed Kiggavik Haul Road, Winter Access Road, and Alternate Option All-Season Road Alignments, 2008 to 2010

Access Road	Crossing Identification[a]	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
Kiggavik Site – Sissons Site Haul Road	Km 2.0 (Mushroom/ End Grid Stream)	1,313	-	-	-	1,313	-	-	-	-	-	-	0.3	5.2 - 18.6	1.0 - 6.2	silt/cobble	Arctic grayling; lake trout[b]
	Km 2.9[c]	77	-	-	-	-	-	-	2	75	-	no visible channel	0.5	30 - 45	30 - 95	silt/sand	no fish sampling
	Km 6.7 (West Inflow of Boulder Lake)	124	-	-	8	94	22	-	-	-	-	-	1.1	0.5 - 7.0	1.0 - 8.0	gravel/cobble	Arctic grayling
	Km 11.3(Sleek/ Caribou Stream)	600	-	-	174	55	256	-	-	-	115	-	0.3	7.0 - 23	7.0 - 23	gravel/cobble	Arctic grayling; slimy sculpin
	Km 14.1[c]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 15.6 (Rhyolite/Fox Stream)	588	-	-	31	-	529	28	-	-	-	-	0.5	0.3 - 15	0.3 - 15	boulder/cobble	ninespine stickleback
	Km 17.2 (Crash/Fox Stream)	989	-	-	654	170	-	-	113	-	52	-	> 1	0.8 - 4	1.0 - 10	gravel/cobble	Arctic grayling; ninespine stickleback; slimy sculpin
	Km 19.6[c]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
–Kiggavik Site – Siamese Lake	Km 100.2 (Northeast Inflow of Pointer Lake)	475	-	-	-	-	130	139	-	-	-	206 m dry	0.3	0 - 3.0	0 - 3.0	organic material/ gravel	ninespine stickleback near mouth[d]
	alternate W1 (Meadow/Jaegar Stream)	320	-	-	-	-	-	-	120	-	-	no visible channel present and 200 m dry	-	0	2.0	organic material/silt	ninespine stickleback
	alternate W2 (Escarpment/Jaegar Stream)	595	-	-	15	245	335	-	-	-	-	-	0.5	0.4 - 1.2	0.4 - 1.2	cobble/gravel	ninespine stickleback; slimy sculpin
	alternate W3 (North Inflow of Drum Lake)	630	-	-	30	305	135	-	160	-	-	-	0.4	0.7 - 75	0.7 - 75	cobble/boulder	ninespine stickleback
Winter Road	alternate W4	670	-	-	30	75	345	-	135	-	-	85 m dry	0.1	0.2 - 0.5	0.2 - 0.5	cobble/boulder	no fish sampling
	alternate W5	275	-	-	-	20	255	-	-	-	-	-	0.7	0.3 - 7.0	0.3 - 7.0	organic material/cobble	no fish observed or captured
	alternate W6	885	-	-	15	610	260	-	-	-	-	-	0.3	0.2 - 10	0.2 - 6.0	organic material/ gravel	no fish observed or captured
	S14	247	-	-	-	35	113	60	-	-	-	39 m no defined channel	0.65	0.3 - 30	0.3 - 20	organic material/silt	Arctic grayling; ninespine stickleback; slimy sculpin(e)

Table 5.5-15 Summary of Characteristics of Stream Crossings Along the Proposed Kiggavik Winter Access and Alternate Option All-Season Access Road Alignments, 2008 to 2010

Access Road	Crossing Identification[a]	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
Alternate Option All-Season Road	Km 109.8 (South Inflow of Skinny Lake)	578	-	-	-	135	93	-	350	-	-	-	0.4	0.5 - 75	1.0 - 75	gravel/cobble	Arctic grayling; ninespine stickleback; slimy sculpin
	Km 112.9[c]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 127.5	957	-	-	-	477	478	-	-	2	-	-	1.0	0.5 - 20	1.0 - 21	gravel/silt	Arctic grayling; ninespine stickleback; slimy sculpin
	Km 129.2	1,141	-	-	511	624	-	4	-	2	-	-	1.1	8.0 - 26	15 - 40	cobble/boulder	Arctic grayling; burbot; slimy sculpin; lake trout[f]
	Km 130.1	700	-	-	-	-	-	210	-	-	-	400 m no visible channel and 90 m dry	0.75	35 - 140	35 - 140	organic material/sand	no fish sampling
	Km 131.3	122	-	-	-	-	122	-	-	-	-	-	0.1	0.25	0.25	organic material/sand	no fish sampling
	Km 145.3	541	-	-	61	347	133	-	-	-	-	-	0.6	2.0 - 6	2.0 - 6.5	sand/gravel	Arctic grayling; ninespine stickleback; round whitefish; slimy sculpin
	Km 147.1	1,045	-	-	-	983	60	2	-	-	-	-	1.0	0.5 - 8	0.5 - 8	sand/gravel	ninespine stickleback; slimy sculpin
	Km 147.6	861	-	-	-	-	614	243	4	-	-	-	~ 1.0	1.0 - 120	3.0 - 125	organic material/sand	no fish observed or captured
	Km 154.8[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 157.3 (North Inflow of Qikittalik Lake)	300	-	-	-	300	-	-	-	-	-	-	0.75	100	105	sand/gravel	ninespine stickleback; lake trout[g]
	Km 157.7 (Northeast Inflow of Qikittalik Lake)	351	-	-	-	-	32	142	6	96	-	75 m dry	0.5	0.5 - 12	1.0 - 40	cobble/gravel	Arctic grayling; longnose sucker; ninespine stickleback
	Km 159.5[c]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling
	Km 161.5[c]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling
	Km 163.2[c]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling
	Km 168.0[c]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 171.2[c]	-	-	-	-	-	-	-	-	-	-	dry	-	-	200	-	no fish sampling
	Km 172.2	700	-	-	-	-	640	60	-	-	-	-	1.0	1.0 - 5.0	1.0 - 5.0	organic material/cobble	no fish observed or captured
	KM 174.3	364	-	-	-	-	-	-	-	-	-	364 m dry	-	-	0.3 - 4.0	cobble/boulder	no fish sampling

Table 5.5-15 Summary of Characteristics of Stream Crossings Along the Proposed Kiggavik Winter Access and Alternate Option All-Season Access Road Alignments, 2008 to 2010

Access Road	Crossing Identification[(a)]	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
Alternate Option All-Season Road	Km 174.8 (Thelon River around proposed bridge/ferry locations)	3,205	-	85	-	3,205	-	-	-	-	-	-	7.5	300 - 520	330 - 550	cobble/boulder and gravel	Arctic grayling; lake trout; slimy sculpin
	Km 203.0	266	-	-	-	134	-	-	132	-	-	-	0.5	1.5 - 20	1.5 - 15	organic material/cobble	ninespine stickleback
	Km 209.4	313	-	-	-	172	5	55	70	-	-	11 m no defined channel	0.25	0.20 - 10	0.2 - 37	gravel/boulder	no fish observed
	Km 212.2	357	75	-	-	77	-	71	-	-	22	112 m dry	0.3	0.15 - 20	0.15 - 20	boulder garden/cobble	no fish observed
	Km 213.1	426	360	-	34	32	-	-	-	-	-	-	0.5	0.5 - 9.0	0.5 - 20	boulder garden/cobble	Arctic grayling

NOTES:

(a) Habitat assessment was not conducted for crossings Km 140.0, alternate EC30, Km 193.3, Km 195.1, Km 197.5, and Km 207.6.

(b) Arctic grayling was observed in spring 2009 near the proposed road location; lake trout was captured and Arctic grayling was observed during 2008 Arctic grayling spring spawning survey.

(c) No habitat map produced because section of stream had no visible channel or stream was dry at the time of survey.

(d) No fish were captured or observed during the summer 2009 field sampling at the proposed road crossing located in the upper section of this stream, but ninespine sticklebacks were captured near the mouth of this stream during 2008 and 2009 Arctic grayling spring spawning surveys.

(e) Slimy sculpin was observed or captured about 1 km east of alternate S14 crossing on Long/Audra Stream.

(f) Lake trout was observed or captured 4 km downstream of Km 129.2.

(g) Lake trout was observed or captured 0.5 km upstream of Km 157.3.

m =metres; Km = kilometres; > = greater than; - = not available or not applicable; Arctic grayling = *Thymallus arcticus*; lake trout = *Salvelinus namaycush*; slimy sculpin = *Cottus cognatus*; ninespine stickleback = *Pungitius pungitius*; burbot = *Lota lota*; round whitefish = *Prosopium cylindraceum*; longnose sucker = *Catostomus catostomus*.

Table 5.5-16 Summary of Road Crossings for the Proposed Kiggavik Mine Site Road Alignments and the Alternate Option All-Season Access Road Alignment, 2008 to 2010

Access Road	Crossing Identification from EBA (Golder Equivalent Identification)	Drainage Area (km^2)	Flood Frequency Prediction (m^3/s)				Morphology (Habitat Condition)						Crossing Design					Fish/Fish Habitat				
			3Q10	1 in 20	1 in 50	1 in 100	Stream Type[a] (distance in metres)	Upstream Connections	Downstream Connections	Maximum Depth[a] (m)	Bankfull Width[b] (m)	Substrate[b]	Design Discharge (m^3/s)	Number of Culverts	Shape	Diameter (mm)	Embedment Depth (mm)	Fish Bearing[a]	Habitat Suitability[a] Overwintering	Spawning	Rearing	Passage for LBF
Kiggavik Site - SissonsSite Haul	Km 2.0 (Mushroom/End Grid Stream, NC31 Stream)[c]	4.23	1.63	2.17	2.42	2.57	-	Mushroom Lake	End Grid Lake	-	-	cobble/boulder	1.63 (3Q10)	1	circular	2,600	1,300	Arctic grayling lake trout	- -	- -	- -	suitable
	Km 2.9 (NC30.5 Stream)[d]	NA	NA	NA	NA	NA	NVC (254), backwater (75), pond (2)	-	-	0.5	NVC[e]	-	NA	NA	NA	NA	NA	no fish expected based on ground visit	-	-	-	-
	Km 6.7 (NC30 Stream)	17.87	5.23	6.98	7.77	8.27	run (94), flat (22), riffle (8)	several small ponds	Boulder Lake	1.1	~1.5[e]	gravel/cobble	5.23 (3Q10)	bridge	-	-	-	Arctic grayling (young-of-year found)	unsuitable	suitable	suitable	suitable
	Km 11.3 (NC29 Stream)	32.76	8.54	11.4	12.7	13.52	flat (256), riffle (174), boulder garden (115), run (55)	Sleek Lake	Caribou Lake	0.3	~15[e]	cobble/boulder/gravel	8.54 (3Q10)	bridge	-	-	-	Arctic grayling slimy sculpin	unsuitable	suitable suitable	suitable suitable	suitable
	Km 14.1 (NC28 Stream)	1.04	0.52	0.69	0.77	0.82	NDC	-	-	-	-	-	0.82 (1:100yr)	1	circular	900	0	no fish expected based on aerial observation	-	-	-	-
	Km 15.6 (NC27 Stream)	4.66	1.76	2.35	2.62	2.79	flat (529), riffle (31), pool (28)	Rhyolite Lake	Fox Lake	0.5	1.5[e]	organic material	1.76 (3Q10)	2	circular	3,000	1,500	ninespine stickleback	unsuitable	suitable	suitable	unsuitable
	Km 17.2 (NC26 Stream)	12.26	3.85	5.14	5.73	6.1	riffle (654), run (170), pond (113), boulder garden (52)	Crash Lake	Fox Lake	>1	7.0[e]	cobble/boulder	3.85 (3Q10)	3	circular	3,000	1,500	Arctic grayling (young-of-year found) ninespine stickleback slimy sculpin	unsuitable	suitable suitable suitable	suitable suitable suitable	suitable
	Km 19.6 (NC25 Stream)	0.35	0.22	0.29	0.33	0.35	NVC	-	-	-	-	-	0.35 (1:100yr)	1	circular	600	0	no fish expected based on ground visit	-	-	-	-
Site	Km 100.2 (NC24 Stream)	2.57	1.09	1.45	1.62	1.72	dry (206), pool (139), flat (130)	-	Pointer Lake	0.3	-[e]	-	1.72 (1:100yr)	1	circular	1,000	0	no fish captured or observed	-	-	-	-
Kiggavik Site - Siamese Lake	alternate W1[d]	NA	NA	NA	NA	NA	dry (200), pond (120), NVC (320)	Meadow Lake	Jaeger Lake	-	2.0[f]	organic material	NA	NA	NA	NA	NA	ninespine stickleback (in pond upstream of crossing)	unsuitable	unsuitable	suitable	unsuitable
	alternate W2[d]	NA	NA	NA	NA	NA	flat (335), run (245), riffle (15)	Felsenmeer and Escarpment lakes	Jaeger Lake	0.5	0.5[f]	organic material/boulder	NA	NA	NA	NA	NA	ninespine stickleback slimy sculpin	unsuitable	suitable suitable	suitable suitable	unsuitable
	alternate W3[d]	NA	NA	NA	NA	NA	run (305), pond (160), flat (135), riffle (30)	-	Drum Lake	0.4	1.0[f]	cobble/gravel/boulder	NA	NA	NA	NA	NA	ninespine stickleback	unsuitable	suitable	suitable	unsuitable
Sissons Site – Mushroom Lake	S-M1 (Pond 1/Mushroom Stream)[d]	NA	NA	NA	NA	NA	NVC	Pond 1	Mushroom Lake	-	0.2[g]	-	NA	NA	NA	NA	NA	no fish expected based on ground visit	-	-	-	-
Kiggavik Site- Judge Sissons Lake	K-JS1 (tributary to the Northwest inflow of Pointer Lake)[d,h]	NA	NA	NA	NA	NA	NA	-	Pointer Lake	NA	0.2[g]	NA	NA	NA	NA	NA	NA	not sampled, assumed fish bearing based on LIDAR image	unsuitable	possibly[i]	possibly[i]	possibly[i]
Sissons Site – Judge Sissons Lake	S-JS1 (End Grid/Shack Stream)[d]	NA	NA	NA	NA	NA	flat (736), pool (585), run (110)	End Grid Lake	Shack Lake	>1.0	140[g]	organic material/silt	NA	NA	NA	NA	NA	Arctic grayling	unsuitable	unsuitable	suitable	suitable
	S-JS2 (Boulder/Judge Sissons Stream)[d,h]	NA	NA	NA	NA	NA	NA	Boulder Lake	Judge Sissons Lake	NA	13.3[g]	NA	NA	NA	NA	NA	NA	not sampled, assumed fish bearing based on LIDAR image and connectivity between Boulder Lake and Judge Sissons Lake	unsuitable	possibly[i]	suitable	suitable
All-Season	Km 109.8 (NC22.5/NC32 Stream)	2.4	1.03	1.37	1.53	1.63	lake (350), run (135), flat (93)	several small ponds	Skinny Lake	0.4	~2.0 at flat or ~75 at lake[e]	gravel/cobble/sand at flat or gravel/cobble/organic material at lake[e]	1.03 (3Q10)	2	circular	2,000	1,000	Arctic grayling (young-of-year found) ninespine stickleback slimy sculpin	unsuitable	suitable suitable suitable	suitable suitable suitable	suitable
	Km 112.9 (NC19 Stream)	0.15	0.11	0.15	0.16	0.17	NDC	-	-	-	-	-	0.17 (1:100yr)	1	circular	600	0	no fish expected based on ground visit	-	-	-	-
	Km 127.5 (NC16 Stream)	16.53	4.91	6.55	7.3	7.77	flat (478), run (477), snye (2)	several small ponds	medium size lake between L2 and Long Lake	1.0	6.1[e]	silt/organic material	4.91 (3Q10)	4	circular	3,000	1,500	Arctic grayling ninespine stickleback slimy sculpin	unsuitable	suitable suitable suitable	suitable suitable suitable	suitable
	Km 129.2 (NC15 Stream)	305.01	52.02	69.47	77.39	82.37	run (624), riffle (511), pool (4), backwater (2)	several large lakes including Kavisilik and Skinny lakes	medium size lake upstream of Long Lake	1.1	~33[e]	cobble/boulder/gravel	52.02 (3Q10)	bridge	-	-	-	Arctic grayling burbot slimy sculpin	unsuitable	suitable unsuitable suitable	suitable suitable suitable	suitable
	Km 130.1 (NC14.5 Stream)[d]	NA	NA	NA	NA	NA	NVC (400), pool (210), dry (90)	-	-	0.75	-[e]	-	NA	NA	NA	NA	NA	no fish expected based on ground visit	-	-	-	-
	Km 131.3 (NC14 Stream)	4.34	1.66	2.22	2.47	2.63	NVC (421), flat (122)	-	-	0.1	-	-	2.63 (1:100yr)	1	circular	1,400	0	no fish expected based on ground visit	-	-	-	-

Table 5.5-16 Summary of Road Crossings for the Proposed Kiggavik Mine Site Road Alignments and the Alternate Option All-Season Access Road Alignment, 2008 to 2010

Access Road	Crossing Identification from EBA (Golder Equivalent Identification)	Drainage Area (km^2)	Flood Frequency Prediction (m^3/s)				Morphology (Habitat Condition)						Crossing Design					Fish/Fish Habitat				
			3Q10	1 in 20	1 in 50	1 in 100	Stream Type[a] (distance in metres)	Upstream Connections	Downstream Connections	Maximum Depth[a] (m)	Bankfull Width[b] (m)	Substrate[b]	Design Discharge (m^3/s)	Number of Culverts	Shape	Diameter (mm)	Embedment Depth (mm)	Fish Bearing[a]	Habitat Suitability[a]: Overwintering	Spawning	Rearing	Passage for LBF
All-Season	Km 140.0	2.84	1.18	1.57	1.75	1.86	NDC	-	-	NA	1.2[e]	NA	1.86 (1:100yr)	1	circular	1,000	0	no fish expected based on ground visit	-	-	-	-
	Km 145.3 (NC13 Stream)	43.17	10.67	14.26	15.88	16.9	run (347), flat (133), riffle (61)	several small and medium size lakes	large lake upstream of Long Lake	0.6	~2.5[e]	sand/gravel/cobble	10.67 (3Q10)	bridge	-	-	-	Arctic grayling	unsuitable	suitable	suitable	suitable
																		lake trout (in lake upstream)		unsuitable	suitable	
																		ninespine stickleback		suitable	suitable	
																		round whitefish		unsuitable	suitable	
																		slimy sculpin		suitable	suitable	
	Km 147.1 (NC12 Stream)	5.29	1.95	2.6	2.9	3.09	run (983), flat (60), pool (2)	a small lake	large lake upstream of Long Lake	1.0	0.8[e]	sand/gravel	1.95 (3Q10)	3	circular	2,400	1,200	ninespine stickleback	unsuitable	suitable	suitable	unsuitable
																		slimy sculpin		suitable	suitable	
	KM 147.6 (NC11.5 Stream)[d]	NA	NA	NA	NA	NA	flat (614), pool (243), pond (4)	-	large lake upstream of Long Lake	~ 1.0	12[f]	organic material/sand	NA	NA	NA	NA	NA	no fish captured or observed	-	-	-	-
	Km 154.8 (NC11 Stream)	10.4	3.37	4.5	5.01	5.34	NVC	several small ponds	Qikittalik Lake	-	-	-	5.34 (1:100yr)	1	circular	1,800	0	no fish expected based on aerial observation	-	-	-	-
	Km 157.3 (NC10 Stream)	56.67	13.31	17.77	19.8	21.07	run (300)	several small lakes and ponds	Qikittalik Lake	0.75	~43[e]	sand/gravel	13.31 (3Q10)	bridge	-	-	-	lake trout (further upstream)	unsuitable	unsuitable	suitable	suitable
																		ninespine stickleback		suitable	suitable	
	Km 157.7 (NC09 Stream)	3.9	1.52	2.03	2.26	2.41	pool (142), snye (96), dry (75), flat (32), pond (6)	a small pond	Qikittalik Lake	0.5	1.0[e]	cobble/boulder/gravel	1.52 (3Q10)	3	circular	3,000	600	Arctic grayling	unsuitable	suitable	suitable	suitable
																		lake trout (in lake downstream)		unsuitable	suitable	
																		longnose sucker		suitable	suitable	
																		ninespine stickleback		suitable	suitable	
	Km 159.5 (NC08 Stream)	0.96	0.49	0.65	0.73	0.78	NDC, dry, pond (2)	a small pond	Qikittalik Lake	-	-	-	0.78 (1:100yr)	1	circular	800	0	no fish expected based on ground visit	-	-	-	-
	Km 161.5 (NC07 Stream)	2.79	1.16	1.55	1.73	1.84	NVC, dry, pond (2)	several small ponds	Qikittalik Lake	-	1.3[e]	-	1.84 (1:100yr)	1	circular	1,000	0	no fish expected based on ground visit	-	-	-	-
	Km 163.2 (NC06 Stream)	1.07	0.53	0.71	0.79	0.84	NDC, dry, pond (2)	a small pond	medium size lake upstream of Tunuhuk Lake	-	-	-	0.84 (1:100yr)	1	circular	800	0	no fish expected based on ground visit	-	-	-	-
	Km 168.0 (NC05 Stream)	3	1.23	1.64	1.83	1.95	NDC	a small pond	Thelon River	-	-	-	1.95 (1:100yr)	1	circular	1,200	0	no fish expected based on ground visit	-	-	-	-
	Km 171.2 (NC04 Stream)	0.53	0.3	0.4	0.45	0.48	NDC	a small pond	Thelon River	-	-	-	0.48 (1:100yr)	1	circular	600	0	no fish expected based on ground visit	-	-	-	-
	Km 172.2 (NC03 Stream)	3.78	1.48	1.98	2.21	2.35	flat (640), pool (60)	several small ponds	Thelon River	1.0	3.3[e]	organic material	2.35 (1:100yr)	1	circular	1,200	0	no fish captured or observed	-	-	-	-
	Km 174.3 (NC02 Stream)	1.14	0.56	0.75	0.84	0.89	dry pool (364), NVC (40)	-	Thelon River	-	-[e]	-	0.89 (1:100yr)	1	circular	800	0	no fish expected based on ground visit	-	-	-	-
	Km 174.8 (NC01/X18 Stream)[d]	NA	NA	NA	NA	NA	run (3,205), rapid (85)	Thelon River		7.5	~330[e]	cobble/boulder and gravel	NA	ferry	-	-	-	Arctic char*	suitable	suitable	suitable	suitable
																		Arctic grayling		suitable	suitable	
																		cisco*		suitable	suitable	
																		lake trout		suitable	suitable	
																		longnose sucker*		suitable	suitable	
																		ninespine stickleback*		suitable	suitable	
																		round whitefish*		suitable	suitable	
																		slimy sculpin		suitable	suitable	
	alternate EC30[h]	5.66	2.06	2.75	3.06	3.26	NA	medium size lake	Swimming Lake	NA	3.3[e]	NA	2.06 (3Q10)	2	circular	3,000	1,500	not sampled, fish expected based on ground visit and connectivity	unsuitable	possibly[i]	suitable	suitable
	Km 193.3 (EC21 Stream)[h]	8.16	2.77	3.7	4.12	4.39	NA	several small lakes	Swimming Lake	NA	2.7[e]	NA	2.77 (3Q10)	3	circular	3,200	1,600	not sampled, lake trout (in downstream lake)	unsuitable	unsuitable	suitable	suitable

Table 5.5-16 Summary of Road Crossings for the Proposed Kiggavik Mine Site Road Alignments and the Alternate Option All-Season Access Road Alignment, 2008 to 2010

Access Road	Crossing Identification from EBA (Golder Equivalent Identification)	Drainage Area (km^2)	Flood Frequency Prediction (m^3/s)				Morphology (Habitat Condition)						Crossing Design					Fish/Fish Habitat				
			3Q10	1 in 20	1 in 50	1 in 100	Stream Type[a] (distance in metres)	Upstream Connections	Downstream Connections	Maximum Depth[a] (m)	Bankfull Width[b] (m)	Substrate[b]	Design Discharge (m^3/s)	Number of Culverts	Shape	Diameter (mm)	Embedment Depth (mm)	Fish Bearing[a]	Habitat Suitability[a]: Overwintering	Habitat Suitability[a]: Spawning	Habitat Suitability[a]: Rearing	Habitat Suitability[a]: Passage for LBF
All-Season	Km 195.1 (EC20 Stream)[h]	2.6	1.1	1.46	1.63	1.74	NA	small lake	Swimming Lake	NA	1.2[e]	NA	1.10 (3Q10)	2	circular	1,800	900	not sampled, fish expected based on ground visit and connectivity	unsuitable	possibly(i)	suitable	suitable
	Km 197.5 (EC19 Stream)[h]	5.44	1.99	2.66	2.96	3.16	NA	small lake	Swimming Lake	NA	1.1[e]	NA	1.99 (3Q10)	2	circular	3,000	1,500	not sampled, lake trout (in upstream and downstream lakes)	unsuitable	unsuitable	suitable	suitable
	Km 203.0 (EC10/EC08 Stream)	4.59	1.74	2.32	2.59	2.75	run (134), pond (132)	several small ponds	small lake upstream of Airplane Lake	0.5	8.7[e]	silt/organic material	1.74 (3Q10)	2	circular	2,200	1,100	ninespine stickleback	unsuitable	suitable	suitable	unsuitable
	Km 207.6 (EC5 Stream)[h]	0.82	0.43	0.57	0.64	0.68	NA	a small pond	Airplane Lake	NA	NA	NA	0.68 (1:100yr)	1	circular	800	0	not sampled, no fish expected based on aerial observation	-	-	-	-
	Km 209.4 (EC4 Stream)	2.74	1.14	1.53	1.7	1.81	run (172), wetland (70), pool (55), NDC (11), flat (5)	several small ponds	Baker Lake	0.25	0.6[e]	gravel/silt/sand	1.14 (3Q10)	2	circular	2,200	660	fish expected based on ground visit and connectivity	unsuitable	possibly[i]	suitable	suitable
	Km 212.2 (EC3 Stream)	1.43	0.68	0.9	1.01	1.07	dry (112), run (77), cascade (75), pool (71), exposed boulder (22)	a small pond	Baker Lake	0.3	1.9[e]	boulder/cobble	1.07 (1:100yr)	1	circular	900	0	no fish observed; access limited due to elevation	-	-	-	-
	Km 213.1 (EC2 Stream)	4.7	1.77	2.37	2.63	2.8	cascade (360), riffle (34), run (32)	a small pond	Baker Lake	0.5	12.3[e]	boulder/cobble/gravel	1.77 (3Q10)	2	circular	3,000	1,500	Arctic grayling (observed near mouth)	unsuitable	suitable	suitable	suitable

Note: When "NA" is present under columns "drainage area", "flood frequency prediction", and "crossing design", it means that the hydrology data was not available for these crossings. When "-" is present under columns "crossing design", it means that the information was not required because a bridge, not a culvert is proposed.

When "NA" is present under column "morphology" and fish/fish habitat", it means that fish habitat data was not available. When "-" is present under column "substrate", it means that substrate information was not required because "no fish were expected based on aerial observation".

If fish were expected, or appeared to potentially be present at the crossing location based on aerial observation (helicopter site inspection), "NA" was used to specify that substrate information was not available.

*Historical information.

[a]Stream type, maximum depth, fish bearing, and habitat suitability refer to the entire reach assessed.

[b]Bankfull width, and substrate refer to the stream crossing site only.

[c]Proposed road crossing is not on Mushroom/End Grid Stream (1313 m of run habitat), but over Fresh Water Diversion Channel S1 at the Sissons Site.

[d]Hydrology assessement was not conducted at the time of the baseline studies because the road alignment was not known yet (i.e., alternat W1 to W3, S-M1, K-JS1, S-JS1, S-JS2), it was a none visible channel (i.e., Km 2.9 and Km 130.1), the stream was found afterward during the fish habitat assessment (i.e., Km 147.6), and the stream was assessed by somebody else (Km 174.8 - Thelon River).

[e]Average stream channel width at crossing location. When habitat assessment was not conducted, the information was determined based on the hydrology assessment.

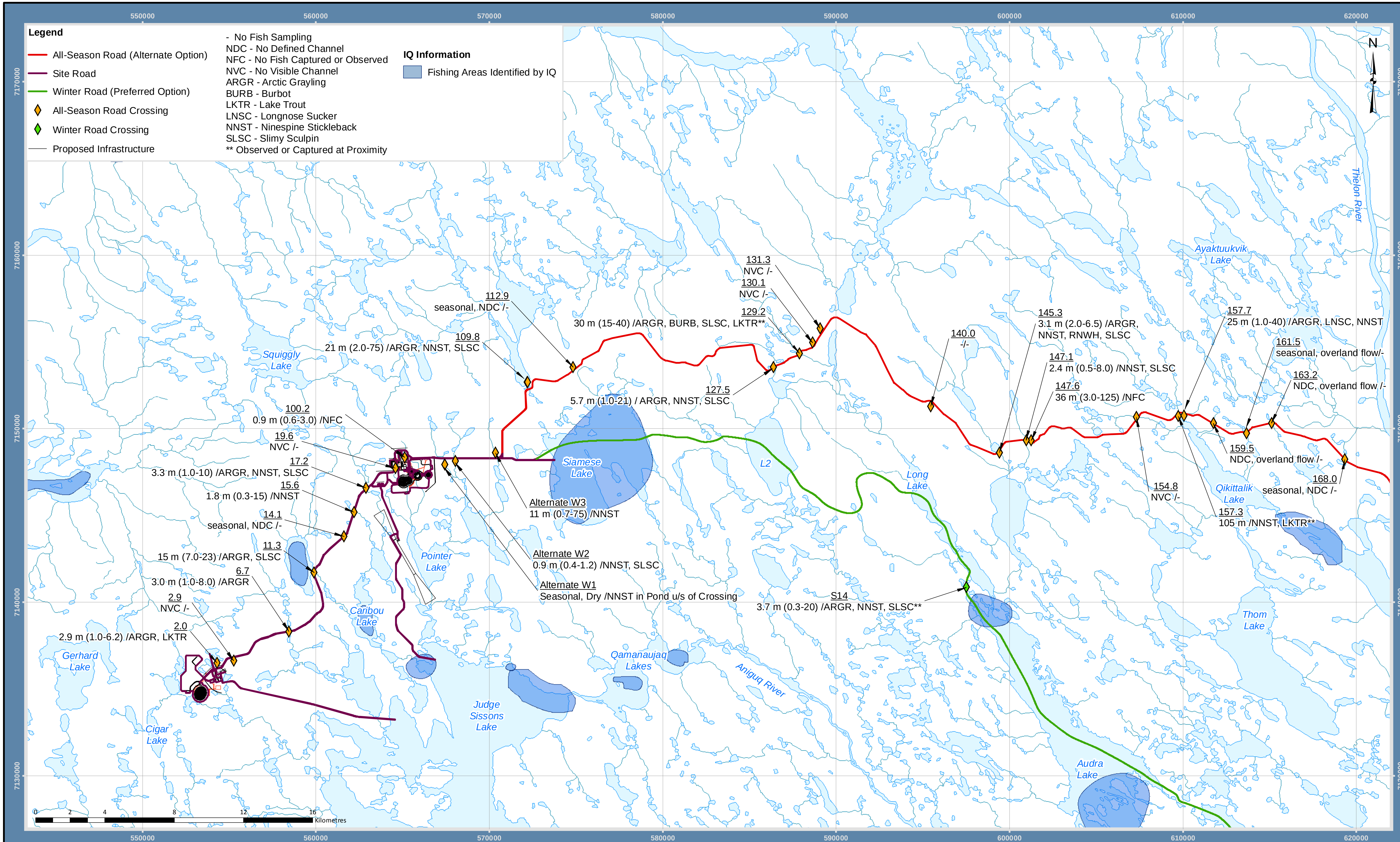
[f]Average stream channel width estimated from habitat map.

[g]Average stream channel width estimated from LIDAR image.

[h]Habitat assessment was not conducted at the time of the baseline studies because the road alignment was not known yet (i.e., K-JS1, S-JS2), the stream was found afterward during the hydrology assessment (i.e., alternate EC30), the road alignments were too numerous to get all crossings done (i.e., Km 193.3, Km 195.1, Km 197.5, Km 207.6).

[i]Habitat suitability is identified as "possibly" because there is no habitat and fish species information available for the crossing (i.e., K-JS1, S-JS2, alternate EC30 and Km 195.1), and the suitability is variable depending on the fish species present (i.e., Km 209.4).

EBA = EBA Engineering Consultants Ltd.; km^2 = square kilometres; m = metres; m^3/s = cubic metres per second; mm = millimetres; LBF = large-bodied fish; HADD = harmful alteration, disruption or destruction; NA = not available, - = not applicable; NVC = no visible channel; NDC = no defined channel.



Projection: NAD 1983 UTM Zone 14N
Creator: JRC/LMR
Date: 30/06/2014 Scale: 1:200,000
File: KIO8C347
Data Sources: *NTS Mapsheet 56D, 66A, 66B; AREVA Resources Canada Inc. Hattie Mannik and the Baker Lake Elder's Focus Group Baker Lake HTO, Baker Lake Hunter Focus Group*

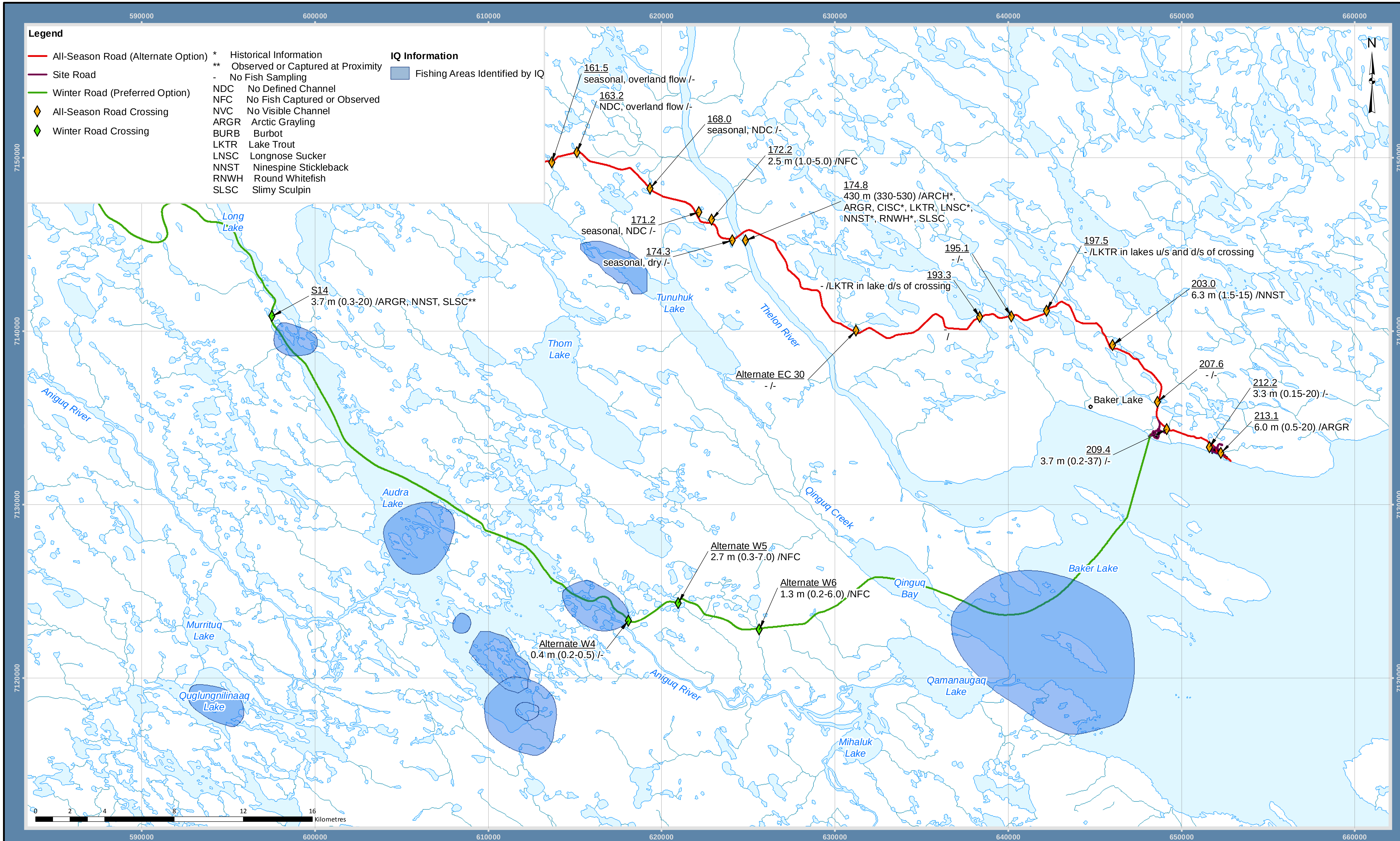
FIGURE 5.5-1A
SUMMARY OF AQUATIC HABITAT AND FISH DISTRIBUTION AT PROPOSED ROAD CROSSINGS

KIGGAVIK PROJECT - EIS

Stream Crossing ID (Kilometre Marker): 120.0
Bankfull Width: 2.5m(1.0 - 5.0)/NFC — Fish Species

Golder Associates
AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5



Projection: NAD 1983 UTM Zone 14N
Creator: JRC/LMR
Date: 30/06/2014 Scale: 1:200,000
File: KIO8C348
Data Sources: *NTS Mapsheet 56D, 66A, 66B. AREVA Resources Canada Inc. Hattie Mannik and the Baker Lake Elder's Focus Group Baker Lake HTO, Baker Lake Hunter Focus Group*

FIGURE 5.5-1B
SUMMARY OF AQUATIC HABITAT AND FISH DISTRIBUTION AT PROPOSED ROAD CROSSINGS

KIGGAVIK PROJECT - EIS

Proposed Water Intake - Sissons Road (Sissons Site – Mushroom Lake)

The proposed road for the water intake pipeline at the Sissons site may cross one stream (S-M1) that is likely classified as having a no defined or visible channel. Although NTS (National Topographic System) coverage shows a stream at this location, Light Detection and Ranging (LiDAR) imagery indicates that this stream does not exist.

Summary Table 5.5-16 includes the available information for the S-M1 stream. Hydrological information is not available, and habitat and fish information are limited for this site because it was not originally identified as a location of interest.

Proposed Treated Effluent Discharge - Kiggavik Road and Road to Airstrip (Kiggavik Site – Judge Sissons Lake)

The proposed road along the treated effluent discharge pipeline at the Kiggavik site also provides access to the airstrip. This road appears to cross one potential stream (K-JS1) that is likely small to intermediate in size with channel widths less than 5 m. The road does not appear to cross any other streams, however, since it is located on the divide between the Willow and Caribou lake sub-basins.

Summary Table 5.5-16 includes the stream type, maximum depth, habitat condition, habitat suitability, and fish-bearing potential for the entire reach assessed. The bankfull width and substrate as close as possible to the proposed crossing locations, as well as the upstream and downstream connections for the assessed stream are included (Figure 5.5-2 part A). Hydrological information is not available and habitat and fish information are limited for this site since it was not originally identified as a location of interest.

Proposed Treated Effluent Discharge - Sissons Road (Sissons Site – Judge Sissons Lake)

The proposed road for the treated effluent discharge at the Sissons site crosses two streams (S-JS1 and S-JS2); these are classified as large streams (i.e., channel width greater than 5 m).

A habitat assessment for one stream crossing (i.e., S-JS1 [End Grid/Shack Stream]) located on the proposed road for the water intake pipeline at the Sissons site was completed in 2008 (Table 5.5-11). The second stream crossing (i.e., S-JS2 [Boulder/Judge Sissons Stream]) was not assessed in the field. The stream length assessed in 2008 for S-JS1 (End Grid/Shack Stream) was 1,431 m. The maximum depth recorded was greater than 1 m. Wetted width ranged from 30 m to 500 m in an area of unconfined flow during high water conditions in S-JS1 (End Grid/Shack Stream). Bankfull width ranged from 1.9 m to 25 m (Table 5.5-14).

Dominant habitat types recorded for S-JS1 (End Grid/Shack Stream) were flats (736 m) and pools (585 m) (Table 5.5-14). Run (110 m) habitat was observed less frequently.

Organic material was observed as the dominant substrate in S-JS1 (End Grid/Shack Stream) (Table 5.5-15). The shoreline slope was predominantly flat. Shoreline vegetation consisted primarily of grasses. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrate; some areas of emergent and submergent vegetation were also observed (Tier 3, Technical Appendix 5C, Table 10A-1).

Summary Table 5.5-16 includes the stream type, maximum depth, habitat condition, habitat suitability, and fish-bearing potential for the entire reach assessed. The bankfull width and substrate as close as possible to the proposed crossing location, as well as the upstream and downstream connections for the stream are included (Figure 5.5-2a). Hydrological information is not available and habitat and fish information are limited for S-JS1 and S-JS2 because they were not originally identified as locations of interest.

5.5.5.2 Site Access Local Study Area

A brief summary of the stream and lake habitat characteristics is provided in the following sections for the site access Local Study Area. Several site access road options were evaluated during the Project design phase; however, only the information pertaining to the final options are presented here. Information pertaining to the other options considered is presented in the baseline report (Tier 3, Techncial Appendix 5C).

Proposed Winter Access Road

Four potential stream crossing locations were assessed along the route of the proposed winter access road in 2009. All of the assessed watercourses (i.e., S14, alternate W4, alternate W5, and alternate W6) were small to intermediate in size with channel widths less than 5 m (Figures 5.5-1, parts A and B). One of the streams (i.e., alternate W4) had localized ponding where the channel width in the area sampled was substantially wider that the channel width of the majority of the stream (Table 5.5-15; Figures 5.5-1 parts A and B).

Habitat assessments at the four stream crossings were also completed in 2009 (Tables 5.5-12 and 5.5-15). The stream lengths assessed ranged from 247 m for S14 to 885 m for alternate W6. Maximum depths recorded ranged from 0.1 m in alternate W4 to 0.7 m in alternate W5. Wetted width ranged from 0.2 m in alternate W4 and alternate W6 to 30 m in S14. Bankfull widths ranged from 0.2 m in alternate W4 and alternate W6 to 20 m in S14 (Table 5.5-15).

Dominant habitat types recorded were flats (n = 4, for a total of 973 m) and runs (n = 4, for a total of 740 m) (Table 5.5-15). Riffles (n = 2, for a total of 45 m), ponds (n = 1, for a total of 135 m), and pools (n = 1, for a total of 60 m) were observed less frequently. Several no visible channel/dry channel (n = 2, for a total of 124 m) habitat types were also observed.

Organic material was observed as the dominant substrate in three streams. Cobble was observed as the dominant substrate in one stream (Table 5.5-15). Overhead cover was limited and consisted of undercut banks and overhanging vegetation. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrates, with some streams containing areas of emergent and/or submergent vegetation and areas of deeper water and concealing turbulence (Tier 3, Technical Appendix 5C, Table 10A-2).

Several lakes were also present along the proposed winter access road. From west to east, the proposed road crosses the following large waterbodies: Siamese Lake, an unnamed lake (Lake 2), Long Lake, Audra Lake, and Quinguq Bay of Baker Lake. No habitat assessments were completed in these lakes because they were ice-covered during the 2009 (winter) assessment (Table 5.3-1). Surface areas of lakes along the proposed winter access road range from 614.4 ha for Long Lake to 9,520 ha for Audra Lake. Maximum depths range from 2.5 m in Long Lake to 8.0 m in Lake 2. The shoreline development index ranges from 1.3 for Lake 2 to 2.7 for Long Lake, which has an elongated shape (Table 5.3-1).

Alternate Option All-Season Access Road

The portion of the Thelon River (i.e., Km 174.8) in the site access LSA is generally comprised of fast-flowing run sections, with a rapid section further upstream. The Thelon River is a fish-bearing stream with suitable overwintering habitat, and year-round cover and spawning habitats in the assessed river section. Interstitial spaces in the coarse substrate, depth, and water turbulence provide suitable cover for all sizes of fish.

The majority of the watercourses located west of the Thelon River that will be crossed along the proposed alternate option all-season access road were identified as having no defined or visible channels. Six were classified as large streams or rivers (i.e., crossings Km 109.8 [South Inflow of Skinny Lake], Km 127.5, Km 129.2, Km 147.6, Km 157.3 [North Inflow of Qikittalik Lake], and Km 157.7 [Northeast Inflow of Qikittalik Lake]). Four streams (i.e., Km131.3, Km 145.3, Km 147.1, and Km 172.2) were small to intermediate in size with channel widths less than 5 m (Tables 5.5-12 and 5.5-15; Figures 5.5-1 parts A and B).

A majority of the watercourses that would be crossed by the section of the alternate option all-season access road located east of the Thelon River were classed as having no defined or visible channel, or were not assessed for habitat and fish presence (i.e., crossings alternate EC30, Km 193.3, Km 195.1, Km 197.5, Km 207.6). Two streams were small to intermediate in size with channel widths less than 5 m (i.e., crossings Km 209.4, and Km 212.2). Three of the streams that were not assessed are expected to be fish bearing due to their proximity to fish bearing lakes (i.e., crossings Km 193.3, Km 195.1, and Km 197.5). Two large watercourses had average channel widths ranging from 6.0 m (crossing Km 213.1) to 6.3 m (crossing Km 203.0) (Tables 5.5-12 and 5.5-15; Figure 5.5-1b). Detailed habitat assessments were completed only on specific streams between the Thelon River and Baker Lake. At crossing locations where fish habitat assessments and fishing efforts were not completed, passage for large-bodied fish was generally assessed based on fish species observed or captured at upstream or downstream locations, as well as connectivity between these upstream and downstream locations.Assessments of connectivity were based on ground surveys and aerial survey data. When the presence of fish, or the use of a stream by fish, was uncertain, crossings were designed to facilitate fish passage.

Habitat assessments at 24 stream crossings located along the alternate option all-season access road were completed between 2008 and 2009 (Tables 5.5-12 and 5.5-15). The stream lengths assessed ranged from 122 m for Km 131.3 to 3,205 m for Km 174.8 (Thelon River around the proposed ferry crossing location). Maximum depths recorded ranged from 0.1 m at Km 131.3 to 7.5 m at Km 174.8 (Thelon River around the proposed ferry crossing location). Wetted widths ranged from 0.15 m at Km 212.2 to 520 m at Km 174.8 (Thelon River around the proposed ferry crossing location). Bankfull widths ranged from 0.15 m at Km 212.2 to 550 m at Km 174.8 (Thelon River around the proposed ferry crossing location) (Table 5.5-15; Figures 5.5-1 parts A and B).

Dominant habitat types recorded were runs (n = 11, for a total of 6,486 m), flats (n = 9, for a total of 2,177 m), no visible channel/dry channel/underground channel (n = 12, for a total of more than 1,052 m), pools (n = 8, for a total of 787 m), and riffles (n = 3, for a total of 606 m) (Table 5.5-15). Pond/lake/wetland (n = 8, for a total of 568 m) and backwater/snye (n = 3, for a total of 100 m) habitat types were observed less frequently. Some sections of boulder garden (n = 1, for a total of 22 m) were also observed.

Organic material was the dominant substrate type observed in five streams. Cobble was the dominant substrate in four streams. Gravel and sand were the dominant substrate type in three streams each. Boulder was the dominant substrate type in two streams (Table 5.5-15). Overhead cover was limited and consisted of undercut banks, overhanging vegetation, and ledges. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrates. Some streams contained areas of emergent and/or submergent vegetation, and areas of deeper flows and concealing water turbulence (Tier 3, Technical Appendix 5C, Table 10A-2).

Summary Table 5.5-16 includes the stream types, maximum depths, habitat condition, habitat suitabilities, and fish-bearing potential for the entire reach assessed within each stream. The bankfull width and substrate as near as possible to the proposed crossing locations, as well as the upstream and downstream connections for the assessed streams are included (Figures 5.5-2a and 5.5-2b). Hydrological information was not collected from the Thelon River as part of the baseline investigations. Habitat and fish information are limited for most sites east of the Thelon River (i.e., alternate EC30 to Km 207.6) since the alignment was not decided at the time of the field survey.

Aniguq River (Proposed Treated Effluent Path to Baker Lake)

The Aniguq River is classified as a large river (i.e., S5). A flight overview of the entire river was completed in 2008. A habitat assessment for a 290 m long section of the river was completed in 2009. The maximum depth recorded was greater than 2 m. The recorded wetted width was 98 m; the bankfull width was 100 m (Table 5.5-15).

Dominant habitat types recorded in the surveyed section consisted of run (for a total of 203 m) and a backwater/snye (for a total of 87 m). Silt was the dominant substrate observed; cobble was a sub-dominant substrate. Overhead cover was limited and consisted of overhanging vegetation. In-stream cover consisted of interstitial spaces between the coarse substrates, with some areas of emergent and/or submergent vegetation, and areas of deeper flows and concealing water turbulence (Tier 3, Technical Appendix 5C, Table 10A-2).

Baker Lake (Proposed Baker Lake Facility)

Fish habitat was assessed at five sites in Baker Lake between 2008 and 2009. Three were located on the north shore and two on the south shore. The two sites on the south shore were eliminated as options for the proposed Baker Lake dock site, and a new site on the north shore was added as an optional location. Four sites in Baker Lake were re-assessed for fish habitat during winter 2011. Based on the 2011 assessment, Site 1 was identified as the preferred location of the dock facility; the existing Agnico Eagle dock site and Site 2 are the alternate options moving forward (Tier 2, Volume 2, Sections 4.4.4 and 10.3.5).

Of the potential dock sites assessed, the preferred location (Site 1) was the site with the steepest underwater slope. An under-ice depth of 9 m was present within about 30 m to 60 m from the shoreline, depending on the location. The adjacent shore had two steep exposed bedrock areas. The best quality fish habitat (i.e., boulder substrate) identified in less than 5 m of water was concentrated at the north-west end of the assessed area (Tier 3, Technical Appendix 5P, Baker Lake Potential Barge Dock Site Bathymetry and Fish Habitat Survey Technical Memorandum).At the “Site 2” alternate site, water reached under-ice depths of 3 m in areas between 53 m and 62 m away from the shoreline. The water reached 9 m deep at around 105 m to 114 m from the shoreline, depending on the location. The best quality fish habitats identified in less than 5 m of water were concentrated at the west end (i.e., boulder and cobble) and the middle (i.e., submergent vegetation) of the assessed area.

Ice formation on Baker Lake occurs during September or October (EN-CI HTO 2013[111]).

5.6 Fish

5.6.1 Fish Distribution

This section presents the current information available on fish distribution within the LSAs, as well as information collected for selected streams along the potential alternate option all-season access road. The discussion is based on historical records and Inuit Qaujimajatuqangit (IQ), as well as recent baseline surveys. Detailed methods and results of the historical data review and recent baseline surveys can be found in Tier 3, Technical Appendix 5C (Section 11.0).

Previous studies by McLeod et al. (1976) and BEAK (1987, 1990, 1992a,b), as well as the most recent studies by Golder and Nunami Stantec that are presented in Tier 3, Technical Appendix 5C (Section 11.0), indicate the following seven fish species are present in lakes within the mine site LSA:

- Arctic grayling;
- burbot;
- cisco;
- lake trout;
- ninespine stickleback;
- round whitefish; and
- slimy sculpin.

The species listed above also occur in Baker Lake. Four additional species of fish have been documented as occurring in Baker Lake; these are:

- Arctic char;
- fourhorn sculpin (*Myoxocephalus quadricornis*);
- lake whitefish; and
- longnose sucker.

Arctic grayling were the most widely distributed species in lakes and streams in the LSA, followed by lake trout (Tables 5.6-1 and 5.6-2).

[111] EN-CI HTO 2013: *The fish are feeding in July/Aug so if you have monitors this is FYI for them. Ice forming Sept/Oct.*

Fishing areas identified by IQ are presented in Figure 4.1-1A and Figure 4.1-1B. *The west shore of Baker Lake and Judge Sissons Lake were identified as fishing areas, as well as numerous fishing lakes in the Baker Lake region including areas close the Project lease area, such as Siamese Lake and the east shore of Aberdeen Lake* (IQ-BL16 2008). *Elders also said that all of the little lakes in the region were fishing lakes* (IQ-BL16 2008). Fish species caught included whitefish, trout, and Arctic char, which corresponds to the fish species caught during the baseline surveys in the area.

The majority of the lakes examined (37 of 39 lakes) are situated within the Aniguq River watershed. Squiggly Lake (Thelon Lake watershed) and Baker Lake (Baker Lake watershed) are outside the Aniguq River watershed (Figures 5.3-1, 5.3-2, and 5.3-3).

Twenty-four rivers and stream segments associated with the assessed lakes in the LSA (referred to as "streams"), were assessed by Golder between 2008 and 2010. The Aniguq River was assessed in 1975 by McLeod et al. (1976). Twenty-three of the assessed streams are situated in the Aniguq River watershed, with one (Thelon River) in the Thelon River watershed. Two fish species reported in Baker Lake were not reported in streams sampled between 1975 and 2010 (i.e., fourhorn sculpin and lake whitefish).

5.6.1.1 Mine Site Local Study Area

Willow Lake Sub-Basin (Surrounding the Proposed Kiggavik Mine Site)

Twelve lakes and eight stream segments (streams) in the Willow Lake sub-basin of the Aniguq River watershed were assessed for fish species distribution. Arctic grayling were most widely distributed species and were present in all lakes except Meadow Lake, Scotch Lake, Pointer Pond, and Sik Sik Lake. Meadow Lake was the only lake with no fish documented. Inuit Qaujimajatuqangit (IQ) indicates that fish are no longer found in Pointer Lake (IQ-BL02 2008[112]), or were perhaps absent from the lake for some time; Arctic grayling, cisco, lake trout and ninespine stickleback were captured from Pointer Lake during the baseline surveys. Slimy sculpin were the only species reported in Pointer Pond; ninespine stickleback were the only species reported from Sik Sik Lake (Table 5.6-1).

Fish were not found in the upper tributary to the northeast Inflow of Pointer Lake, and low to negilible flows observed during baseline sampling may have been a barrier to fish access; however, this tributary was only surveyed in one season. The remaining seven streams in the sub-basin contained fish, with ninespine stickleback being most widely distributed (found in five streams), followed by Arctic grayling (found in four streams; Table 5.6-2).

[112] IQ-BL02 2008: One of the Elders said that the rivers flowing into Pointer Lake have caused the fish there to die, and that the same will happen to Judge Sissons Lake when mining operations start to get close to the lake.

Table 5.6-1 Summary of Fish Species Distribution in Lakes of the Kiggavik Project Area, 1975 to 2010

Watershed	Sub-Basin	Waterbody	Fish Species										
			Arctic Char (*Salvelinus alpinus*)	**Arctic Grayling (*Thymallus arcticus*)**	**Burbot (*Lota lota*)**	**Cisco (*Coregonus artedi*)**	**Fourhorn Sculpin (*Myoxocephalus quadricornis*)**	**Lake Trout (*Salvelinus namaycush*)**	**Lake Whitefish (*Coregonus clupeafomis*)**	**Longnose Sucker (*Catostomus catostomus*)**	**Ninespine Stickleback (*Pungitius pungitius*)**	**Round Whitefish (*Prosopium cylindraceum*)**	**Slimy Sculpin (*Cottus cognatus*)**
Aniguq River	Willow Lake	Meadow Lake[(a)]	-	-	-	-	-	-	-	-	-	-	-
		Felsenmeer Lake	-	X	-	-	-	X	-	-	-	X	-
		Escarpment Lake	-	X	-	-	-	X	-	-	-	X	-
		Drum Lake	-	X	-	-	-	-	-	-	-	-	-
		Lin Lake	-	X	-	-	-	-	-	-	-	-	-
		Scotch Lake	-	-	-	-	-	X	-	-	X	X	X
		Jaegar Lake	-	X	-	-	-	-	-	-	-	-	-
		Pointer Pond	-	-	-	-	-	-	-	-	-	-	X
		Pointer Lake	-	X	-	X	-	X	-	-	X	-	-
		Sik Sik Lake	-	-	-	-	-	-	-	-	X	-	-
		Rock Lake	-	X	-	-	-	X	-	-	-	-	-
		Willow Lake	-	X	-	-	-	X	-	-	X	-	-
	Lower Lake	Mushroom Lake	-	X	-	X	-	X	-	-	-	X	-
		Ponds 1 to 8[(b)]	-	-	-	-	-	-	-	-	-	-	-
		End Grid Lake	-	X	-	-	-	-	-	-	-	-	-
		Smoke Lake	-	X	-	X	-	-	-	-	-	-	-
		Cigar Lake	-	X	X	X	-	X	-	-	-	X	-
		Knee Lake	-	X	-	-	-	-	-	-	-	-	-
		Lunch Lake	-	X	-	-	-	X	-	-	-	X	-
		Andrew Lake	-	X	X	X	-	-	-	-	-	X	-
		Shack Lake	-	X	-	-	-	-	-	-	-	-	-
		Bear Island Lake	-	X	-	-	-	-	-	-	-	-	-
		Lower Lake	-	X	X	X	-	-	-	-	X	X	-
	Caribou Lake	Ridge Lake	-	-	-	-	-	X	-	-	-	-	-
		Cirque Lake	-	X	-	-	-	-	-	-	X	-	-
		Crash Lake	-	X	-	-	-	-	-	-	-	-	-
		Fox Lake	-	X	-	X	-	X	-	-	X	-	-
		Caribou Lake	-	X	X	X	-	X	-	-	X	X	-
		Calf Lake	-	-	X	X	-	-	-	-	X	-	-

Table 5.6-1 Summary of Fish Species Distribution in Lakes of the Kiggavik Project Area, 1975 to 2010

Watershed	Sub-Basin	Waterbody	Fish Species										
			Arctic Char (*Salvelinus alpinus*)	**Arctic Grayling (*Thymallus arcticus*)**	**Burbot (*Lota lota*)**	**Cisco (*Coregonus artedi*)**	**Fourhorn Sculpin (*Myoxocephalus quadricornis*)**	**Lake Trout (*Salvelinus namaycush*)**	**Lake Whitefish (*Coregonus clupeafomis*)**	**Longnose Sucker (*Catostomus catostomus*)**	**Ninespine Stickleback (*Pungitius pungitius*)**	**Round Whitefish (*Prosopium cylindraceum*)**	**Slimy Sculpin (*Cottus cognatus*)**
Aniguq River	Judge Sissons Lake	Judge Sissons Lake	-	X	X	X	-	X	-	-	X	X	X
	Siamese Lake	Siamese Lake	-	-	-	-	-	X	-	-	-	-	-
	Skinny Lake	Skinny Lake	-	X	-	X	-	X	-	-	-	X	-
	Kavisilik Lake	Kavisilik Lake	-	X	-	X	-	X	-	-	-	X	-
Thelon River	Squiggly Lake	Squiggly Lake	X	X	X	-	-	X	-	-	-	X	-
Baker Lake	Baker Lake	Baker Lake	X	X	X	X	X	X	X	X	X	X	X

SOURCE: Modified from Tier 3, Technical Appendix 5C, Table 11A-1.

NOTES:

[a] No fish captured as per BEAK 1987; 1990; 1992b.

[b] No fish captured during spring 2010.

X = fish captured; - = no fish captured.

Table 5.6-2 Summary of Fish Species Distribution in Streams of the Kiggavik Project Area, 1975 to 2010

Watershed	Sub-Basin	Watercourse	Fish Species								
			Arctic Char (*Salvelinus alpinus*)	**Arctic Grayling (*Thymallus arcticus*)**	**Burbot (*Lota lota*)**	**Cisco (*Coregonus artedi*)**	**Lake Trout (*Salvelinus namaycush*)**	**Longnose Sucker (*Catostomus catostomus*)**	**Ninespine Stickleback (*Pungitius pungitius*)**	**Round Whitefish (*Prosopium cylindraceum*)**	**Slimy Sculpin (*Cottus cognatus*)**
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	-	-	-	-	-	-	X	-	-
		Upper Tributary to the Northeast Inflow of Pointer Lake[a]	-	-	-	-	-	-	-	-	-
		Upper Northwest Inflow of Pointer Lake	-	-	-	-	-	-	-	-	X
		Northwest Inflow of Pointer Lake	-	X	-	-	X	-	-	-	-
		Pointer/Rock Stream	-	X	X	-	-	-	X	X	-
		Sik Sik/Rock Stream	-	-	-	-	-	-	X	-	-
		Rock/Willow Stream	-	X	-	X	X	-	X	X	-
		Willow/Judge Sissons Stream	-	X	-	-	X	-	X	-	X
	Lower Lake	Mushroom/End Grid Stream	-	X	-	-	X	-	-	-	-
		End Grid/Shack Stream	-	X	-	-	-	-	-	-	-
		Cigar/Lunch Stream[b]	-	-	-	-	-	-	-	-	-
		Knee/Lunch Stream	-	-	-	-	X	-	-	-	-
		Lunch/Andrew Stream	-	X	-	-	-	-	-	-	-
		Andrew/Shack Stream	-	X	-	-	-	-	-	-	-
		Shack/Lower Stream	-	-	-	-	X	-	-	-	-
		Lower/Judge Sissons Stream	-	-	-	-	X	-	X	-	-
	Caribou Lake	Fox/Caribou Stream[b]	-	-	-	-	-	-	-	-	-
		Caribou/Calf Stream[b]	-	-	-	-	-	-	-	-	-
		Calf/Judge Sissons Stream	-	X	-	-	X	-	-	-	-
	Aniguq River	Aniguq River[c]	-	X	X	-	X	-	X	-	X
Thelon River		Thelon River	X	X	-	X	X	X	X	X	X

SOURCE: Modified from Tier 3, Technical Appendix 5C, Table 11A-2.

NOTES:

[a] No fish captured during the spring 2010 field sampling.

[b] No fish captured during the Arctic grayling spring spawning survey in 2008.

[c] Data came from the "Bunker River" between Audra Lake and Baker Lake (Mcleod et al. 1976), which is a section of the Aniguq River and the former alternate S5 road crossing.

X = fish captured; - = no fish captured.

Lower Lake Sub-basin (Surrounding the Proposed Sissons Mine Site)

Ten lakes, eight ponds, and eight stream segments (streams) in the Lower Lake sub-basin were assessed for fish species distribution. Arctic grayling were present in all ten lakes with cisco and round whitefish documented in five lakes each. No fish were found in the eight shallow (less than or equal to 1.5 m deep) ponds; these were not connected by visible outflow watercourses to nearby fish-bearing streams or lakes (Table 5.6-1).

Of the eight streams assessed for fish in the Lower Lake sub-basin, Cigar/Lunch Stream was the only stream in which no fish were captured or observed. Only three fish species were found in streams in the Lower Lake sub-basin (Arctic grayling, lake trout, and ninespine stickleback; Table 5.6-2).

Caribou Lake Sub-basin (Traversed by the Proposed Mine Haul Road)

Six lakes were assessed for fish distribution in the Caribou Lake sub-basin. Arctic grayling and ninespine stickleback were most widely distributed species (four lakes each), followed by cisco and lake trout (three lakes each). Fish were found in every lake assessed (Table 5.6-1) with the exception of Sleek Lake (Figure X.IX-1a in Tier 3, Technical Appendix 5C), although arctic grayling were caught in Sleek/Caribou Stream (Table 5.6-3). Caribou and Sleek lakes were identified by IQ as fishing areas (Figure 4.1-1).

Three streams of interest in the Caribou Lake sub-basin were not surveyed for the presence of fish (Ridge/Crash Stream, Cirque/Crash Stream, and Crash/Fox Stream); however, these stream segments connect lakes known to contain Arctic grayling, lake trout or ninespine stickleback (Table 5.6-1). Three streams were assessed for fish distribution in the Caribou Lake sub-basin. Fox/Caribou Stream and Caribou/Calf Stream were visited in one field season and no fish were captured. However, these streams connect lakes known to contain Arctic grayling, cisco, lake trout, and ninespine stickleback, with the addition of burbot and round whitefish in Caribou Lake (Table 5.6-2). Arctic grayling and lake trout were found in Calf/Judge Sissons Stream (Table 5.6-2).

Judge Sissons Lake (Proposed Treated Effluent Discharge)

Seven fish species were documented in Judge Sissons Lake (Arctic grayling, burbot, cisco, lake trout, ninespine stickleback, round whitefish, and slimy sculpin; Table 5.6-1). Judge Sissons Lake was identified as a fishing area by the elders (Figure 4.1-1A; IQ-BL16 2008[113]). Domestic and recreational fishing also occur occasionally on the lake.

Siamese Lake (Proposed Water Supply Lake, Traversed by Proposed Winter Access Road, and Near Proposed Alternate Option All-Weather Access Road)

Only lake trout have been documented in Siamese Lake (Table 5.6-1), although a number of other species are also expected to inhabit the lake. Siamese Lake was identified as a fishing area by the elders (Figure 4.1-1A; IQ-BL16 2008[114]).

Skinny Lake and Kavisilik Lake

Arctic grayling, cisco, lake trout, and round whitefish have been documented in both Skinny and Kavisilik lakes (Table 5.6-1).

Proposed Kiggavik-Sissons Haul Road (Kiggavik Site – Sissons Site Haul)

Fish are widely distributed in the streams that will be crossed by the proposed haul road. Ninespine stickleback and slimy sculpin were present in streams greater than 2 m wide. Large-bodied fish species including Arctic grayling and lake trout were found in streams with bankfull widths of approximately 3 m or more.

Proposed Water Intake – Kiggavik Road (Kiggavik Site – Siamese Lake)

Fish are widely distributed in the streams that will be crossed by the proposed road for the water intake pipeline at the Kiggavik site. Ninespine stickleback and/or slimy sculpin were present in all four streams (Table 5.6-3).

Proposed Water Intake – Sissons Road (Sissons Site – Mushroom Lake)

The proposed road for the water intake pipeline at the Sissons site will cross one potential stream; this stream is classified as having no defined or visible channel. Although NTS coverage shows a stream at this location, LiDAR imagery indicates that this stream does not exist.

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[113] IQ-BL16 2008: The west shore of Baker Lake and Judge Sissons Lake were identified as fishing areas, as well as numerous fishing lakes in the Baker Lake region including areas close the Project lease area, such as Siamese Lake and the east shore of Aberdeen Lake.
[114] IQ-BL16 2008: The west shore of Baker Lake and Judge Sissons Lake were identified as fishing areas, as well as numerous fishing lakes in the Baker Lake region including areas close the Project lease area, such as Siamese Lake and the east shore of Aberdeen Lake.

Proposed Treated Effluent Discharge - Kiggavik Road and Road to Airstrip (Kiggavik Site – Judge Sissons Lake)

The proposed road from the Kiggavik site to the treated effluent discharge point in Judge Sissons Lake will also provide airstrip access. This road alignment may cross one potential stream (K-JS1) that may be fish bearing.

Proposed Treated Effluent Discharge – Sissons Road (Sissons Site – Judge Sissons Lake)

Fish are widely distributed in the two streams that will be crossed by the proposed road for the treated effluent discharge at the Sissons site. Arctic grayling are present in End Grid/Shack Stream (Table 5.6-2), and most local fish species are expected to be present in Boulder/Judge Sissons Stream due to its proximity to Judge Sissons Lake, its width, and the expected potential for fish to overwinter in Boulder Lake.

5.6.1.2 Site Access Local Study Area

Nine species of fish are present in the streams of the site access LSA; two additional species of fish are found in Baker Lake only (Table 5.6-3). None of these fish species are considered regionally or locally rare. Fish communities in the site access LSA streams are dominated by ninespine stickleback, Arctic grayling, and slimy sculpin. Lake trout, round whitefish, burbot, and longnose sucker were present in larger streams and rivers of the site access LSA. Arctic char and cisco were only present in the Thelon River and in Baker Lake. All fish species present in the site access LSA were also present in Baker Lake. Fourhorn sculpin and lake whitefish were only present in Baker Lake (Table 5.6-3).

Proposed Winter Access Road

Three stream crossing locations were checked for fish presence along the proposed winter access road. Fish species present were limited to Arctic grayling and ninespine stickleback at S14, and slimy sculpin at a location 1 km east of S14 on Long/Audra Stream) (Table 5.6-3; Figure 5.5-1 part A). Fish were not observed or captured at the two stream crossing locations near the downstream section of the Aniguq River watershed (Figure 5.5-1 part B).

Several lakes were also present along the proposed winter access road. From west to east, the proposed road will cross the following large waterbodies: Siamese Lake, an unnamed lake (Lake 2), Long Lake, Audra Lake, and Quinguq Bay of Baker Lake. No fishing was completed in any of these lakes, except for Siamese Lake which had lake trout (Table 5.6-1). Siamese and Audra lakes were identified as a fishing area by IQ (Figure 4.1-1A and 4.1-1B; IQ-BL16 2008[115]).

Proposed Alternate Option All-Weather Access Road

Fish are widely distributed in the streams crossed by the proposed alternate option all-season access road (Table 5.6-3, Figures 5.5-1 parts A and B). In general, fish appeared to be present if the stream was flowing in late July and there was a large pond or lake upstream of the sampling location. Channel width also appeared to influence fish presence. Ninespine stickleback and slimy sculpin were usually present if the stream was greater that 2 m wide (e.g., crossing Km 147.1). Large-bodied fish species, such as Arctic grayling and longnose sucker, were found in streams with bankfull widths of about 3 m or more (e.g., crossing Km 157.7). Eight fish species were historically and/or more recently captured in the Thelon River (crossing Km 174.8), included Arctic char, Arctic grayling, cisco, lake trout, longnose sucker, ninespine stickleback, round whitefish, and slimy sculpin (Table 5.6-3; Figures 5.5-1 part B).

Aniguq River (Proposed Treated Effluent Path to Baker Lake)

Arctic grayling, burbot, lake trout, ninespine stickleback, and slimy sculpin were all found in the Aniguq River (Table 5.6-2). The mouth of the Aniguq River was identified as a fishing area by IQ (Figure 4.1-1B).

Baker Lake (Proposed Baker Lake Facility)

Baker Lake had the most diverse fish community of all the lakes assessed. Eleven species including Arctic char, Arctic grayling, burbot, cisco, fourhorn sculpin, lake trout, lake whitefish, longnose sucker, ninespine stickleback, round whitefish and slimy sculpin are reported in Baker Lake (Tables 5.6-1 and 5.6-3; EN-BL CLC 2008[116]).

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[115] IQ-BL16 2008: The west shore of Baker Lake and Judge Sissons Lake were identified as fishing areas, as well as numerous fishing lakes in the Baker Lake region including areas close the Project lease area, such as Siamese Lake and the east shore of Aberdeen Lake.
[116]EN-BL CLC 2008 ….*In Baker Lake we have white fish, graylings, lake Trout, char, and others (sucker fish)…..*

Table 5.6-3 Summary of Fish Species Distribution in Stream Crossings Along the Proposed Kiggavik Winter Access Road, Alternate Option All-Season Access Road and the Baker Lake Facility, 1979 to 2010

Access Road	Crossing Identification[a]	No Fish Captured / Observed	Fish Species										
			Arctic Char *Salvelinus alpinus*)	Arctic Grayling (Thymallus arcticus)	Burbot (*Lota lota*)	Cisco (*Coregonus artedi*)	Fourhorn Sculpin (*Myoxocephalus quadricornis*)	Lake Trout (*Salvelinus namaycush*)	Lake Whitefish (*Coregonus clupeaformis*)	Longnose Sucker (*Catostomus catostomus*)	Ninespine Stickleback (*Pungitius pungitius*)	Round Whitefish (*Prosopium cylindraceum*)	Slimy Sculpin (*Cottus cognatus*)
Kiggavik Site – Sissons Site Haul	Km 2.0 (Mushroom/End Grid Stream)	-	-	X	-	-	-	X	-	-	-	-	-
	Km 6.7 (West Inflow of Boulder Lake)	-	-	X	-	-	-	-	-	-	-	-	-
	Km 11.3 (Sleek/Caribou Stream)	-	-	X	-	-	-	-	-	-	-	-	X
	Km 15.6 (Rhyolite/Fox Stream)	-	-	-	-	-	-	-	-	-	X	-	-
	Km 17.2 (Crash/Fox Stream)	-	-	X	-	-	-	-	-	-	X	-	X
–Kiggavik Site – Siamese Lake	Km 100.2 (Northeast Inflow of Pointer Lake)	X[b]	-	-	-	-	-	-	-	-	X[b]	-	-
	alternate W1 (Meadow/Jaegar Stream)	-	-	-	-	-	-	-	-	-	X	-	-
	alternate W2 (Escarpment/Jaegar Stream)	-	-	-	-	-	-	-	-	-	X	-	X
	alternate W3 (North Inflow of Drum Lake)	-	-	-	-	-	-	-	-	-	X	-	-
Winter	alternates W5 and W6	X	-	-	-	-	-	-	-	-	-	-	-
	S14	-	-	X	-	-	-	-	-	-	X	-	X[c]
Alternate Option All-Season	Km 109.8 (South Inflow of Skinny Lake)	-	-	X	-	-	-	-	-	-	X	-	X
	Km 127.5	-	-	X	-	-	-	-	-	-	X	-	X
	Km 129.2	-	-	X	X	-	-	X[d]	-	-	-	-	X
	Km 145.3	-	-	X	-	-	-	-	-	-	X	X	X
	Km 147.1	-	-	-	-	-	-	-	-	-	X	-	X
	Km 147.6	X	-	-	-	-	-	-	-	-	-	-	-
	Km 157.3 (North Inflow of Qikittalik Lake)	-	-	-	-	-	-	X[e]	-	-	X	-	-
	Km 157.7 (Northeast Inflow of Qikittalik Lake)	-	-	X	-	-	-	-	-	X	X	-	-
	Km 172.2	X	-	-	-	-	-	-	-	-	-	-	-
	Km 174.8 (Thelon River)	-	X	X	-	X	-	X	-	X	X	X	X
	alternate EC30	X	-	-	-	-	-	-	-	-	-	-	-

Table 5.6-3 Summary of Fish Species Distribution in Stream Crossings Along the Proposed Kiggavik Kiggavik Winter Access Road, Alternate All-Season Access Road and the Baker Lake Facility, 1979 to 2010

Access Road	Crossing Identification[a]	No Fish Captured / Observed	Fish Species										
			Arctic Char (*Salvelinus alpinus*)	Arctic Grayling (*Thymallus arcticus*)	Burbot (*Lota lota*)	Cisco (*Coregonus artedi*)	Fourhorn Sculpin (*Myoxocephalus quadricornis*)	Lake Trout (*Salvelinus namaycush*)	Lake Whitefish (*Coregonus clupeaformis*)	Longnose Sucker (*Catostomus catostomus*)	Ninespine Stickleback (*Pungitius pungitius*)	Round Whitefish (*Prosopium cylindraceum*)	Slimy Sculpin (*Cottus cognatus*)
Alternate Option All-Season	Km 193.3	X[f]	-	-	-	-	-	X[f]	-	-	-	-	-
	Km 195.1	X[g]	-	-	-	-	-	-	-	-	-	-	-
	Km 197.5	X[h]	-	-	-	-	-	X[h]	-	-	-	-	-
	Km 203.0	-	-	-	-	-	-	-	-	-	X	-	-
	Km 209.4	X	-	-	-	-	-	-	-	-	-	-	-
	Km 212.2	X	-	-	-	-	-	-	-	-	-	-	-
	Km 213.1	-	-	X	-	-	-	-	-	-	-	-	-
Baker Lake Facility	Baker Lake	-	X	X	X	X	X	X	X	X	X	X	X

SOURCE: Modified from March 18, 2011 Golder Associates Ltd. (Golder) Technical Memo to Nicola Banton, AREVA titled "Summary of Aquatics Studies for the Kiggavik Uranium Project" (Golder 2011).

NOTES:

(a) Fish sampling was not conducted for crossings Km 2.9, Km 14.1, Km 19.6, alternate W4, Km 112.9, Km 130.1, Km 131.3, Km 140.0, Km 154.8, Km 159.5, Km 161.5, Km 163.2, Km 168.0, Km 171.2, Km 174.3, and Km 207.6. Most of these crossings were either dry or with no visible channel.

(b) No fish were captured or observed during the summer 2009 field sampling at the proposed road crossing located in the upper section of this stream, but ninespine stickleback were captured near the mouth of this stream during 2008 and 2009 Arctic grayling spring spawning surveys.

(c) Slimy sculpin was observed or captured about 1 km east of alternate S14 on Long/Audra Stream.

(d) Lake trout were observed or captured 4 km downstream of Km 129.2.

(e) Lake trout were observed or captured 0.5 Km upstream of Km 157.3

(f) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes and lake trout captured in the downstream lake.

gc) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes.

(h) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes and lake trout captured in both lakes.

X = fish captured or observed;- = no data; Km = kilometre.

5.6.2 Fish Habitat Requirements and Uses

This section presents information for all fish species known to occur in the mine site and site access LSAs. The habitat requirements for each species were obtained from a review of fish habitat literature describing rearing, feeding, overwintering, spawning, and other habitat requirements for each species. A short summary of observed fish habitat use is also included for each species. More detailed life history and a habitat requirement summary can be found in Tier 3, Technical Appendix 5C (Section 11.2.1).

5.6.2.1 Arctic Char

Arctic char may be anadromous (living in salt water, but spawning in fresh water) or freshwater residents. Depending on their life history type (anadromous or strictly freshwater), they may be found in rivers, lakes, estuaries and marine environments at different stages of their lifecycle (Johnson 1989; Lee et al. 1980; Scott and Crossman 1973). In lakes, adult Arctic char migrate seasonally between the open water zone in summer and the shoreline areas in the fall and winter. Arctic char are most commonly found in less than 5 m of water and over boulder, rubble and cobble substrates (Bjoru and Sandlund 1995; Jamet 1995). Diet is variable, depending on fish size and availablility of prey items. In freshwater habitats, the diet may include a variety of algae, insects, invertebrates, fish, and plankton (Hunter 1970; McPhail and Lindsey 1970; Scott and Crossman 1973). Resident (i.e., strictly freshwater) Arctic char overwinter in deeper lakes, or sometimes in deep rivers that don't freeze to the bottom during winter (Scott and Crossman 1973; Stewart and Watkinson 2004).

For both anadromous and fresh water resident forms of Arctic char, spawning occurs in rivers or deep lakes in areas where water depth is less than 6 m and over gravel and cobble substrates; spawning occurs from September through October (Gyselman 1984; Johnson 1980, 1989; Scott and Crossman 1973). Fry hatch in late March to April, emerge around the time of ice breakup, and remain on the spawning grounds (Johnson 1980; Scott and Crossman 1973). Later in the summer, YOY Arctic char move to the shallow, near shore zone, and reside in rocky or cobble areas for protection from predators (Johnson 1980; Scott and Crossman 1973). Dwarf forms of Arctic char have been documented to spawn and reside in deeper water than normal forms, and also to mature earlier (Parker and Johnson 1991).

Arctic char were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA. However, they have been caught in Squiggly Lake, which is part of the Thelon River watershed, as well as in the Thelon River, and Baker Lake (Tables 5.6-1 and 5.6-2). It appears that Arctic char may not be able to access the upper Aniguq River watershed and the sub-basins of the mine site LSA. Movements upstream from Baker Lake appear to be blocked by two sets of cascades in the Aniguq River. The first barrier is a single cascade that may be passable under some flow conditions. However, the second barrier is a double cascade that appears to completely obstruct upstream fish migration (Photo 5.6-1). As a result, Judge Sissons Lake and its contributing watersheds are not used by Arctic char for spawning or rearing.

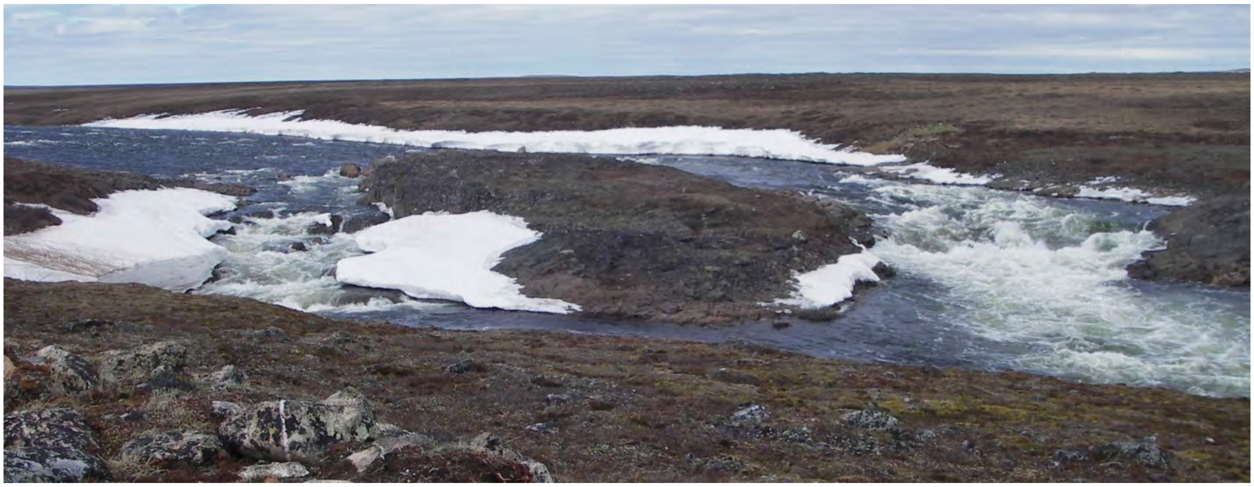

Photo 5.6-1 Second set of cascades in the Aniguq River

5.6.2.2 Arctic Grayling

Arctic grayling occur in clear, cold rivers, streams and lakes and generally avoid turbid areas (Scott and Crossman 1973). The diet of young Arctic grayling consists of zooplankton, but shifts to immature and mature insects, various invertebrates, and fish as they attain adult size (Schmidt and O'Brien 1982; Scott and Crossman 1973). Arctic grayling are assumed to overwinter in deep pools of rivers, and in deeper portions of lakes (Ford et al. 1995).

As the ice begins to break up, adult Arctic grayling migrate from lakes and larger rivers to smaller streams or tributaries with areas of small gravel and rock to spawn before returning to the lakes or rivers from which they came (Scott and Crossman 1973). The timing of spawning may vary from April to June depending on the particular Arctic habitat (Scott and Crossman 1973). Eggs hatch after about 13 to 18 days and alevin absorb their egg sacs over a period of approximately eight days post-hatch before they begin feeding externally (Scott and Crossman 1973). Lakes tend to provide warmer summer water temperatures, and YOY Arctic grayling from watersheds with more lakes tend to exhibit increased growth rates (Luecke and MacKinnon 2008).

Arctic grayling were present in most lakes and streams throughout all sub-basins sampled (Tables 5.6-1 and 5.6-2). After overwintering in the deeper lakes (i.e., Pointer, Mushroom, Cigar, Cirque, Fox, Caribou, and Judge Sissons lakes), Arctic grayling migrate to tributaries in the early spring to spawn. Spawning was confirmed in four streams of the Willow Lake and Lower Lake sub-basins. Rearing and feeding activities may occur throughout all the sub-basins, in both shallow and deep lakes. Shallow lakes freeze to the bottom in winter and thus do not support overwintering fish. However, the presence of larger inlet and outlet streams allows re-colonization of the shallow lakes from nearby overwintering lakes each spring. Deeper lakes like Cirque Lake near the head waters of the Caribou Lake sub-basin may support an isolated Arctic grayling population. Its outlet stream channel contains obstructions that would prevent upstream fish movement from the downstream lakes.

In 2009, spawning was confirmed in Pointer/Rock Stream and Rock/Willow Stream in the Willow Lake sub-basin, and in Lunch/Andrew Stream and Andrew/Shack Stream in the Lower Lake sub-basin. The eggs were collected in 0.1 to 0.7 m water depth, with velocities between 0.2 and 1.0 m/s. The spawning substrate consisted of primarily gravel or cobble, with some sand in the Willow Lake sub-basin; in the Lower Lake sub-basin, spawning substrates varied greatly, but generally consisted of cobble, with some sand, gravel, or boulder (Tier 3, Technical Appendix 5C, Section 11.2.5.5).

Eggs were more abundant in the streams of the Lower Lake sub-basin compared to the streams of the Willow Lake sub-basin. By comparing fish habitat, limnology, daily stream temperature, and stream hydrology at the time of sampling, Arctic grayling eggs appeared to be most abundant in streams characterized by the following:

- the smallest drainage area;
- the smallest number of lakes deeper than 2 m located upstream;
- the smallest volume ratio between deep lakes and shallow lakes;
- the lowest stream discharge;
- the quickest flushing rate; and
- the largest number of Arctic grayling captured.

The scarcity of lakes deeper than 2 m and the abundance of large lakes shallower than 2 m in depth in the Lower Lake sub-basin appears to promote more rapid warming of streams in spring. This may favour earlier spawning and faster embryonic development of Arctic grayling.

5.6.2.3 Burbot

Burbot may complete their life history as residents of lakes or rivers, or both; burbot spawning has been documented in lakes, rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1973). Burbot are nocturnal predators; young feed on aquatic insects, crayfish, molluscs and invertebrates, and adults feed on fish eggs, invertebrates, and fish (Scott and Crossman 1973). Juvenile habitat includes rock and gravel substrate along rocky shorelines with the presence of daytime shelter (i.e., boulders, cobbles, logs, or within submergent vegetation). Adults prefer cooler deeper waters in the summer and move in to shallower water to feed. Both juvenile and adult burbot are found over boulders, cobble, and sand substrates or in turbid water (Ford et al. 1995; Scott and Crossman 1973).

Burbot spawn under the ice in winter (January to April) when water temperatures are between 0.6 and 1.7°C. Spawning typically occurs over gravel or rubble in 0.5 to 3.0 m of water (Ford et al. 1995; Scott and Crossman 1973). Eggs hatch after three weeks to three months, depending on water temperature (Goodyear et al. 1982; Scott and Crossman 1973). Sac-fry are most active at twilight, and are found in the open water zone over sand and rubble; ; YOY and juvenile burbot are primarily nocturnal bottom feeders found in the shoreline zone (Ford et al. 1995; McPhail 1997; Ryder and Pisendorfer 1992).

Burbot were found in eight lakes throughout the Lower (Cigar, Andrew, and Lower lakes), Caribou (Caribou and Calf lakes), Judge Sissons, Squiggly, and Baker lakes sub-basins, and in two streams in the Willow Lake (Pointer/Rock Stream) and Aniguq River sub-basins (Tables 5.6-1 and 5.6-2). It is expected that burbot are able to migrate freely between Pointer and Judge Sissons lakes, Cigar and Judge Sissons lakes, and Caribou and Judge Sissons lakes. Spawning and overwintering habitat may be limited to Pointer, Cigar, Caribou, and Judge Sissons lakes; rearing and foraging habitats are abundant in lakes and streams accessible to burbot.

5.6.2.4 Cisco

Cisco are primarily a lake species but may be found in larger rivers in the Northwest Territories and Nunavut. A dwarf form of cisco also exists in the same habitat as the normal form. The diet of cisco is varied, with the young reported to feed on algae, copepods and cladocera (Pritchard 1930). As adults they feed on copepods, small minnows, crustaceans, aquatic insects (mayflies and caddisflies), water mites, zooplankton, as well as their own eggs and those of other fish species (Scott and Crossman 1973). Cisco are a significant part of the diet of many fish species, and are a preferred food source of lake trout (Scott and Crossman 1973).

Spawning in lakes occurs in the fall over a variety of substrates (Scott and Crossman 1973; Stewart and Watkinson 2004). In small inland lakes, spawning is usually underway when ice begins to form around the shores (Scott and Crossman 1973). Although cisco are primarily a lake species, large numbers have been reported at the mouth of the Thelon River during mid-November, where suitable spawning habitat (i.e., coarser sand, gravel, and cobble) exists, as well as in a pooled area of the same river above a section of rapids (McLeod et al. 1976). River spawning runs have also been reported in the Hudson Bay region; however, rivers are not normally considered as cisco habitat (Scott and Crossman 1973). Hatching of eggs does not occur until after the spring breakup (Scott and Crossman 1973).

Cisco were found in 13 lakes throughout the Willow (Pointer Lake), Lower (Mushroom, Smoke, Cigar, Andrew, and Lower lakes), Caribou (Fox, Caribou and Calf lakes), Judge Sissons, Skinny, Kavisilik, and Baker lakes sub-basins, and in two streams in the Willow Lake (Rock/Willow Stream) and Thelon River sub-basins (Tables 5.6-1 and 5.6-2). It is expected that cisco can migrate freely between Pointer and Judge Sissons lakes, Cigar and Judge Sissons lakes, and Fox and Judge Sissons lakes. Spawning and overwintering habitats may be limited to Pointer, Cigar, Mushroom (cisco were present in this lake according to historical data), Fox, Caribou, and Judge Sissons lakes. Rearing and feeding habitat are present in all lakes and streams accessible to cisco.

5.6.2.5 Fourhorn Sculpin

The fourhorn sculpin (freshwater form) is a land locked relic, found in cold, deep freshwater lakes. Preference for cold water (less than 10°C) seems to influence depth distribution in summer (Hammar et al. 1996). Fourhorn sculpin are usually found near the lake bottom at temperatures below 5°C; however, the freshwater form may have a higher tolerance for warmer temperatures, with some specimens being caught near the surface at 17°C (Hammar et al. 1996). Fourhorn sculpin are largely nocturnal but may also be diurnal through the winter, consuming invertebrates, small fish and fish eggs (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2003). Little is known about reproductive habits and requirements of the fourhorn sculpin, especially the freshwater form (COSEWIC 2003).

In 1975, fourhorn sculpin were found in Baker Lake (Table 5.6-1). No fourhorn sculpin were captured during recent fish sampling of Baker Lake. Spawning, overwintering, rearing, and feeding habitats are expected to occur in Baker Lake.

5.6.2.6 Lake Trout

Lake trout are mainly found in deeper lakes, but may also be found in large, clear rivers (Ford et al. 1995; Scott and Crossman 1973). Cobble, boulder, rubble and woody debris provide juvenile lake trout with cover (Ford et al. 1995). Adult lake trout are commonly found at depths of 10 m or greater and in cooler (about 10°C) waters. Juveniles move to shallower waters at night for foraging (Scott and Crossman 1973). Lake trout are predatory fish with a varied diet consisting of plankton, aquatic and terrestrial insects, crustaceans, small mammals and fish (Scott and Crossman 1973).

In lakes, spawning occurs in late summer or early fall over the shallow, inshore areas and on cobble, rubble and large gravel substrates that are interspersed with boulders (Ford et al. 1995; McPhail and Lindsey 1970). Spawning areas in lakes are often associated with currents or wave action and may occur at a variety of depths (Ford et al. 1995; McPhail and Lindsey 1970; Scott and Crossman 1973; Stewart and Watkinson 2004). Spawning may also occur over similar substrate in slower moving sections of streams and rivers (Evans et al. 2002). The eggs usually hatch from March to April, and even June in northern lakes such as Great Bear Lake (Scott and Crossman 1973). The YOY may remain at the spawning area for several weeks or several months before moving to deeper cooler waters (Goodyear et al. 1982; Martin and Oliver 1980; Morrow 1980; Peck 1982; Scott and Crossman 1973).

Lake trout were found in 18 lakes throughout the Willow (Felsenmeer, Escarpment, Scotch, Pointer, Rock, and Willow lakes), Lower (Mushroom, Cigar, and Lunch lakes), Caribou (Ridge, Fox, and Caribou lakes), Judge Sissons, Siamese, Skinny, Kavisilik, Squiggly, and Baker lakes sub-basins, and in ten streams throughout the Willow Lake (Northwest Inflow of Pointer Lake, Rock/Willow Stream, and Willow/Judge Sissons Stream), Lower Lake (Mushroom/End Grid Stream, Knee/Lunch Stream, Shack/Lower Stream, and Lower/Judge Sissons Stream), Caribou Lake (Calf/Judge Sissons Stream), Aniguq River, and Thelon River sub-basins (Tables 5.6-1 and 5.6-2).

In the Willow Lake, Lower Lake and Caribou Lake sub-basins, there is potential for migration of lake trout throughout the sub-basin and towards Judge Sissons Lake, as evidenced by their relatively widespread distribution. Sik Sik Lake is the only lake considered inaccessible to lake trout. Lake trout overwintering habitat may be limited to Mushroom, Cigar, Ridge, Judge Sissons, Siamese, Skinny, Kavisilik, Squiggly, and Baker lakes (Table 5.3-1). Potential overwintering habitat maybe available in the deeper portions of Pointer, Fox, and Caribou lakes, but the absence of lake trout during the fall spawning surveys suggests that aggregations of lake trout in these lakes are transient. The maximum depth of these three lakes ranged from 2.7 to 3.0 m; therefore, use by spawning lake trout is unlikely. After overwintering, lake trout may remain in the same lake for rearing, feeding and spawning. However, based on observations and fish captured in the spring surveys, it is thought that some lake trout may migrate into nearby shallow lakes and tributaries to feed. As these shallow lakes likely freeze to the bottom during winter, the lake trout sampled in them appear to be transient, using the lakes during the open water period as foraging areas, before returning to larger, deeper lakes for overwintering.

Lake trout spawning was confirmed in Mushroom, Cigar, Ridge, Judge Sissons, and Siamese lakes. The habitats and site characteristics where lake trout in spawning condition were captured included:

- depths between 1.5 and 3.9 m;
- substrate containing a majority of cobble with either boulder, gravel, or sand; and
- surface water temperatures ranging between 6.6ºC and 10.7ºC.

5.6.2.7 Lake Whitefish

Lake whitefish are usually found in lakes and large rivers (McPhail and Lindsey 1970; Richardson et al. 2001). Lake whitefish prefer deep water habitat (depths greater than 10 m) for most of the year (i.e., rearing and overwintering; McPhail and Lindsey 1970). Despite being primarily bottom dwelling, they may be found in the open water zone of lakes (Ford et al. 1995). Lake whitefish move into shallow water habitats at night to feed (McPhail and Lindsey 1970). Their diet includes snails, clams, terrestrial insects, aquatic insects, plankton, and small fishes (Scott and Crossman 1973). Lake whitefish are preyed upon by lake trout, burbot and other lake whitefish, in both the egg and adult life-stages (Scott and Crossman 1973). Lake whitefish are a valuable commercial freshwater fish species in Canada (Scott and Crossman 1973); however, in the Project area, harvests of this species are limited to subsistence fishing (Tier3, Volume 3).

Lake whitefish in northern regions usually spawn in lakes and rivers from mid-September to mid-October (Richardson et al. 2001). Individual fish may only spawn every two or three years (Scott and Crossman 1973). Spawning usually takes place in shallow water areas at depths less than 8 m (Scott and Crossman 1973). Eggs are broadcast over substrates that range from large boulders to gravel and occasionally sand (Richardson et al. 2001; Scott and Crossman 1973). The eggs settle into crevices, incubate, and hatch between March and May (Richardson et al. 2001). Juveniles are often found close to spawning areas in association with boulder, cobble or sand substrate and emergent vegetation and woody debris (Ford et al. 1995).

Lake whitefish were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA, however they are reported to occur in Baker Lake (Table 5.6-1). Spawning, overwintering, rearing, and feeding habitats are also expected to exist in Baker Lake.

5.6.2.8 Longnose Sucker

Longnose sucker are found in lakes, rivers and streams. The diet of longnose sucker consists mostly of amphipods, chironomids, midge larvae, caddisfly larvae and sphaeriid clams (Richardson et al. 2001). Their ventral mouths and large lips aid in suction as they feed on invertebrates from stream and lake beds (Mecklenburg et al. 2002). Juveniles occupy shallow areas of lakes, in association with vegetation and sandy substrates, as well as shallow weedy areas (Richardson et al. 2001).

Longnose sucker spawn in the spring, between April and June, shortly after ice breakup. Spawning occurs in streams and rivers but may also occur in shallow lakes over gravel and sand substrates. Eggs hatch after 11 to 15 days of incubation and YOY remain in the gravel substrate for an additional 7 to 14 days (depending upon water temperature). Emergent young occupy shallow areas in association with vegetation and sandy substrate (Richardson et al. 2001).

Longnose suckers were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA. However, they have been caught in the Thelon River and Baker Lake (Tables 5.6-1 and 5.6-2). Spawning, overwintering, rearing, and feeding habitats are expected to occur in both the Thelon River and Baker Lake.

5.6.2.9 Ninespine Stickleback

In fresh water, ninespine stickleback are found in densely vegetated areas, as well as sand and gravel beaches with sparse vegetation, in shallow bays of lakes, tundra ponds and slow streams (Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1973). Ninespine stickleback become mature in their first year, and live for up to three and a half years (Scott and Crossman 1973; Wootton 1984). Diet consists of aquatic insects, chironomid larvae, small crustaceans, molluscs, and cladocerans and other zooplankton (McPhail and Lindsey 1970; Scott and Crossman 1973). Ninespine stickleback are part of the diet of larger fish species (Scott and Crossman 1973). Ninespine stickleback are tolerant of low dissolved oxygen levels (Morrow 1980).

Spawning occurs in shallow, weedy areas between May and July (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976). Spawning males build nests amongst weeds in densely vegetated areas. Eggs hatch after four to seven days and the YOY are then moved into a nursery area that is constructed by the male from nest building material immediately above the nest (McPhail and Lindsey 1970; Morrow 1980; Wootton 1976). Once they become free swimming, the emergent young disperse into shallow weedy areas, before dispersing again into deeper waters in the fall to overwinter (Goodyear et al. 1982; McPhail and Lindsey 1970).

Ninespine stickleback were found during the open water season in 11 lakes distributed throughout the Willow (Scotch, Pointer, Sik Sik, and Willow lakes), Lower (Lower Lake), Caribou (Cirque, Fox, Caribou and Calf lakes), Judge Sissons, and Baker lakes sub-basins, and in eight streams in the Willow Lake (Northeast Inflow of Pointer Lake, Pointer/Rock Stream, SikSik/Rock Stream, Rock/Willow Stream, and Willow/Judge Sissons Stream), Lower Lake (Lower/Judge Sissons Stream), the Aniguq River, and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). Ninespine stickleback are thought to return to Pointer, Cirque, Fox, Caribou, Judge Sissons, and Baker lakes, and into the Aniguq and Thelon rivers, to overwinter.

5.6.2.10 Round Whitefish

Adult round whitefish are commonly found in areas with rocky and boulder substrates, often in the shallows of lakes or slow flowing rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1973). Round whitefish feed on benthic invertebrates; mayfly, caddisfly and chironomids larvae; small crustaceans; fishes and fish eggs; and molluscs (Scott and Crossman 1973; Stewart and Watkinson 2004). Round whitefish are preyed upon by lake trout and round whitefish eggs are preyed on by lake trout, burbot, and round whitefish (Scott and Crossman 1973).

Round whitefish spawn from fall to early winter, usually in lakes and occasionally in streams and rivers; they prefer gravel and cobble substrate for spawning (Normandeau 1969; Richardson et al. 2001). Round whitefish broadcast spawn their eggs over the chosen substrate, in 15 to 200 cm of water (Normandeau 1969). Hatching generally occurs between March and May (Goodyear et al.

1982). After emerging from the eggs, the young are generally found near the bottom, in association with rock, sand and gravel substrates (Goodyear et al. 1982).

During the open water season round whitefish were found in 14 lakes distributed throughout the Willow (Felsenmeer, Escarpment, and Scotch lakes), Lower (Mushroom, Cigar, Lunch, Andrew, and Lower lakes), Caribou (Caribou Lake), Judge Sissons, Skinny, Kavisilik, Squiggly, and Baker lakes sub-basins, and in three streams in the Willow Lake (Pointer/Rock Stream and Rock/Willow Stream) and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). It is expected that round whitefish return to deeper lakes during the winter. After overwintering in these large lakes and rivers, round whitefish may rear, feed, and spawn in these lakes and rivers, or they may migrate to the tributaries.

5.6.2.11 Slimy Sculpin

Slimy sculpin may live in either lakes or rivers; they are found in cool, clear or muddy waters of rivers, in streams with rocky or gravelly bottoms, as well as in lacustrine habitats (Craig and Wells 1976; Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1973). In lakes, adult slimy sculpin can be found on gravel and rocky substrates at depths from 0.5 m to 210 m (Mohr 1984, 1985; Scott and Crossman 1973). In the Northwest Territories, slimy sculpin are reported in areas with both current and wind action, as well as in depths less than 10 m (McPhail and Lindsey 1970). When living in small and shallow lakes, slimy sculpin show seasonal and diurnal changes in behavior that are likely due to variation in water temperature and/or oxygen concentrations (Mohr 1984, 1985). Diet of the slimy sculpin consists of aquatic insects, crustaceans, juvenile fish and aquatic vegetation (McPhail and Lindsey 1970; Mohr 1984).

Slimy sculpin spawn in May over sand, gravel or rock substrate in shallow water (McPhail and Lindsey 1970; Scott and Crossman 1973). Emergent young are found over shallow gravel and sand and move to deeper water as they mature (Mohr 1984). As they mature, the young slimy sculpin gradually move to deepwater habitat (Mohr 1985).

During the open water season slimy sculpin were found in four lakes distributed throughout the Willow (Scotch Lake and Pointer Pond), Lower (Lower Lake), Judge Sissons, and Baker lakes sub-basins, and in four streams in the Willow Lake (Upper Northwest Inflow of Pointer Lake and Willow/Judge Sissons Stream), the Aniguq River, and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). After overwintering in these large lakes and river, slimy sculpin may rear, feed, and spawn in these lakes and river, or they may migrate short distances up their small tributaries.

5.6.3 Fish Health and Fish Tissue Chemistry

During fish sampling completed between 2007 and 2010, a total of 995 fish from eight species were processed (Table 5.6-4). Fish health assessments (external only, or full) were completed on 28 fish in 2007, 336 fish in 2008, 366 fish in 2009, and eight fish in 2010.

Table 5.6-4 Summary of the Fish Processed and the Fish Health Assessment Conducted Between 2007 and 2010

Fish Species	2007			2008			2009			2010	Total
	None	External	Full[(a)]	None	External	Full[(a)]	None	External	Full[(a)]	External	
Arctic grayling (*Thymallus arcticus*)	0	9	1	0	40	52	5	102	10	0	**219**
Burbot (*Lota lota*)	0	1	0	1	2	2	2	1	0	0	**9**
Cisco (*Coregonus artedi*)	0	1	0	5	3	67	20	17	0	0	**113**
Lake trout (*Salvelinus namaycush*)	0	1	0	10	66	54	1	15	5	0	**152**
Longnose sucker (*Catostomus catostomus*)	0	0	0	0	0	0	4	0	0	0	**4**
Ninespine stickleback (*Pungitius pungitius*)	0	15	0	2	6	0	199	120	0	0	**342**
Round whitefish (*Prosopium cylindraceum*)	0	0	0	4	1	43	0	7	0	0	**55**
Slimy sculpin (*Cottus cognatus*)	0	0	0	0	0	0	4	89	0	8	**101**
Total	**0**	**27**	**1**	**22**	**118**	**218**	**235**	**351**	**15**	**8**	**995**

NOTES:
(a) Full assessment includes external and internal health assessment.

Based on the fish health assessments, all species sampled appeared to be in good health. Observations of external or internal abnormalities, or parasites, were generally low. However, IQ indicates that the flesh of fish captured from the Kiggavik area, and particularly from Judge Sissons Lake, has become softer in recent years (EN-BL CLC 2007[117]; IQ-BL02 2008[118];

Flesh and bone from Arctic char, Arctic grayling, cisco, lake trout, and round whitefish captured between 1980 and 2009 were analyzed for trace metals and radionuclides (Table 5.6-5). Historical chemistry data (1980 to 1990) came from composite flesh samples and the recent analyses (2008 to 2009) were completed using individual fish that were separated into flesh and bone. Liver tissue was analyzed for Arctic char and lake trout captured in Baker Lake. In recent sampling, one to 12 fish were analyzed per fish species per lake for Pointer, Mushroom, Lower, Caribou, Judge Sissons, and Baker lakes (Table 5.6-5).

Fish tissue chemistry results indicate that most metals and radionuclides were at or below detection limits. There were a small number of individual exceedances of consumption guidelines for arsenic, cadmium, mercury, and lead. Selenium appeared to be present at higher concentrations in fish captured in Mushroom Lake.

Table 5.6-5 Summary of Waterbodies and Fish Species Sampled for Tissue Chemistry, Between 1980 and 2009

Sub-Basin	Waterbody	Arctic Char (*Salvelinus alpinus*)	Arctic Grayling (*Thymallus arcticus*)	Cisco (*Coregonus artedi*)	Lake Trout (*Salvelinus namaycush*)	Round Whitefish (*Prosopium cylindraceum*)
Willow Lake	Felsenmeer Lake	-	1986 (C)	-	1986 (C)	-
	Escarpment Lake	-	-	-	1986 (C)	-
	Lin Lake	-	1986 (C)	-	-	-
	Pointer Lake	-	1988 (10); 2008 (5)	2009 (5)	1989 (3); 2008 (4)	
	Willow Lake	-	1986 (C)		1986 (C)	-
Lower Lake	Mushroom Lake		2008 (5)	-	1990 (C); 2008 (5)	2008 (5)
	Cigar Lake	-	-	-	1990 (C)	-
	Andrew Lake	-	1990 (C)	-	-	-
	Lower Lake	-	1990 (C)	-	-	2008 (1)

117 EN-BL CLC 2007: *Someone said that at the Sissons Lake the fish meats are now way too soft when you even just pull the out.*
118 IQ-BL02 2008: *One of the Elders said that the rivers flowing into Pointer Lake have caused the fish there to die, and that the same will happen to Judge Sissons Lake when mining operations start to get close to the lake.*

Sub-Basin	Waterbody	Arctic Char (*Salvelinus alpinus*)	Arctic Grayling (*Thymallus arcticus*)	Cisco (*Coregonus artedi*)	Lake Trout (*Salvelinus namaycush*)	Round Whitefish (*Prosopium cylindraceum*)
Caribou Lake	Ridge Lake	-	-	-	1986 (C)	-
	Caribou Lake	-	1986 (C); 2008 (3)	-	1986 (C); 2008 (1)	2008 (4)
Judge Sissons Lake	Judge Sissons Lake	-	2008 (2), 2009 (5)	-	1980 (?); 2008 (5), 2009 (5)	2008 (1)
Baker Lake	Baker Lake	1989 (C), 2009 (3)	-	-	2009 (12)	-
SOURCE: Modified from Tier 3, Technical Appendix 5C, Table 11.2-21.						
NOTES:						
(number) = number of samples; (C) = composite sample, number of samples in the composite sample is not available; (?) = number of samples not available.						

5.6.3.1 Arctic Char

Three Arctic char were captured in Baker Lake in 2009. The fork lengths of these fish ranged from 445 to 490 millimetres (mm); the total body weight ranged from 875 to 1,200 g. The age of Arctic char sampled ranged from seven to eight years.

Historical concentrations of trace metals in Arctic char from Baker Lake were low, with the exceptions of arsenic, mercury and selenium in 1989.

Flesh and liver samples from three Arctic char captured from Baker Lake were analyzed in 2009. Some of the concentrations of iron, zinc, selenium, and molybdenum in Arctic char liver tissue exceeded the corresponding guidelines (i.e., Rieberger average for uncontaminated lakes [Rieberger 1992], British Columbia [BC] tissue quality guidelines, and Environmental Residue Effects Database [ERED] toxicity values specified for sockeye salmon [*Oncorhynchus nerka*]). Mean concentrations of aluminum, copper, iron, and zinc were highest for Arctic char liver samples collected at Site 1. Mean mercury concentrations in Arctic char muscle tissue at Station 1 did not exceed Rieberger averages (Rieberger 1992) and were below BC Ministry of Environment (MoE) recommended levels for human consumption (0.1 to 0.5 milligrams per kilogram [mg/kg]) (BC MoE 2006). Radionuclide values of flesh and bone samples from Baker Lake Arctic char were near or below detection limits.

5.6.3.2 Arctic Grayling

External (n = 214) and internal (n = 63) fish health assessments were conducted on Arctic grayling captured in 2007, 2008 and 2009, excluding Arctic grayling captured in Baker Lake (Table 5.6-4). The fork lengths of Arctic grayling ranged from 57 to 362 mm; the total body weights ranged from 2.5 to 680 g. The age of Arctic grayling sampled ranged from one to 10 years. Younger fish (i.e., ages one to three) were captured in lakes 3 m deep or less, suggesting that smaller fish were rearing in the shallow lakes in the ILSA. The older fish (i.e., ages nine and 10) were captured in the deeper lakes in the LSA. The Arctic grayling captured in Baker Lake in 2009 had a fork length of 315 mm and a total body weight of 400 g.

Overall, the majority of the Arctic grayling processed were in good health and abnormalities or incidents of parasites were low. However, there were nine fish with minor to severe fin erosion, one fish with moderate skin aberrations, and eight fish with minor to severe parasite infestations. All parasitic infestations consisted of copepods on gills. Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low; one fish was identified as having hemorrhaged gonads, another fish had a fatty liver, and another had a pale, discoloured liver.

Historical concentrations of trace metals in Arctic grayling were low and close to the detection limit or below the consumption guideline, with the exception of arsenic in Arctic grayling from Felsenmeer, Lin, Willow, and Caribou lakes in 1986; cadmium and lead in Arctic grayling from Pointer Lake in 1988; and mercury in Arctic grayling from Andrew and Lower lakes in 1990. Historical concentrations of radionuclides were below detection limits for all parameters with the exception of Po-210 in Arctic grayling flesh from Andrew and Lower lakes in 1990, and Ra-226 in Arctic grayling bone from Pointer Lake in 1988.

In general, concentrations of trace metals in flesh and bone samples of Arctic grayling in 2008 were similar between lakes. Many of the chemistry parameters were near or below detection limits. In 2009, chemistry analyses were completed on Arctic grayling flesh and bone samples from Judge Sissons Lake only. The concentration of arsenic, cadmium, and lead in flesh samples of Arctic grayling were below guidelines. Variation between flesh and bone samples was limited. Many of the chemistry parameters were near or below detection limits.

Concentrations of radionuclides were near or below detection limits in flesh and bone samples from Arctic grayling captured in 2008 and 2009 for all parameters, with the exception of Pb-210 in flesh samples from Pointer Lake (2008), bone samples from Judge Sissons Lake (2008 and 2009), and Po-210 and Ra-226 in flesh and bone samples from at least one fish from Pointer (2008), Mushroom (2008), Caribou (2008), and Judge Sissons (2008 and 2009) lakes.

5.6.3.3 Burbot

External (n = 6) and internal (n = 2) fish health assessments were conducted on burbot captured in 2007, 2008, and 2009 (Table 5.6-4). Total lengths of burbot ranged from 70 to 219 mm; total body weights ranged from 4 to 70 g.

Overall, all burbot processed were in good health with no abnormalities or incidents of parasites observed. Internal health assessments were conducted in 2008; no internal abnormalities were observed.

5.6.3.4 Cisco

External (n = 88) and internal (n = 67) fish health assessments were conducted on cisco captured in 2007, 2008, and 2009, excluding cisco captured in Baker Lake (Table 5.6-4). Cisco ranged from 80 to 342 mm fork length and from 30 to 600 g total body weight. Fish with total body weights less than 100 g were captured in Pointer, Cigar, Caribou, and Calf lakes, suggesting that these are rearing lakes for juvenile cisco. Larger fish, with total body weights greater than 500 g, were captured in Pointer and Caribou lakes. Five cisco were captured in Baker Lake in 2009. The fork lengths of cisco ranged from 223 to 295 mm. The ages of cisco sampled ranged from five to 10 years.

Overall, the majority of the cisco processed were in good physical health and abnormalities or incidents of parasites were low. However, nine fish had minor to severe fin erosion and one fish had evidence of hemorrhage on its fins. Internal health assessments were conducted in 2008. The incidents of internal abnormalities were low, with the exception of one fish with a fatty liver and two fish with discoloured livers.

In 2009, chemistry analyses were completed on cisco flesh and bone samples from Pointer Lake only. Many of the chemistry parameters were near or below detection limits. The concentrations of arsenic, cadmium, and lead in flesh samples of cisco were below guidelines. Variation between flesh and bone samples was limited, with the exception of nickel detected in bone samples and higher concentrations of aluminum, arsenic, barium, iron, manganese, strontium, titanium, and zinc in bone samples. Concentrations of all radionuclides were near or below detection limits in flesh and bone samples from cisco, except for Pb-210 (lower in flesh samples than bone samples) and Po-210.

5.6.3.5 Lake Trout

External (n = 141) and internal (n = 59) fish health assessments were conducted on lake trout captured in 2007, 2008, and 2009, excluding lake trout captured in Baker Lake (Table 5.6-4). The fork lengths of lake trout ranged from 174 to 810 mm; total body weights ranged from 60 to 5,450 g. The ages of lake trout sampled ranged from six to 35 years.

Twenty-four lake trout were captured in Baker Lake in 2009; fork lengths ranged from 340 to 685 mm, and total body weights ranged from 500 to 2,250 g. The ages of lake trout sampled ranged from seven to 17 years. The absence of young age classes and small fish lengths for lake trout captured in Baker Lake in 2009 is likely a product of the selected sampling method and location.

Overall, the majority of the lake trout processed were in relatively good physical health and abnormalities or incidents of parasites were moderate. There were three fish with body deformities, such as clubbed dorsal fin, bump on caudal fin, or lump on jaw; eleven fish were blind in one or both eyes; four fish had eroded gills, gill raker detached, or frayed gills; thirty-seven fish had minor to severe fin erosion or hemorrhaged fins; three fish had minor to moderate shortening of the opercle, or the top of the opercle was cut; nine fish had minor skin aberrations, pale skin, or scars on the body; two fish had minor hindgut inflammation or reddening; and thirty-six fish had minor to moderate parasite infestation (e.g., copepods on gills, leaches on gills, and leaches on the skin). Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low. Twofish had minor to moderate parasite infestations consisting of either segmented worms or nematodes; two fish had hemorrhaged or atretic gonads; one fish had a cyst on the kidney; one fish had an enlarged gall bladder; four fish had fatty livers; and four fish had discoloured livers.

In general, historical concentrations of trace metals in lake trout were low and close to the detection limit or below the consumption guideline, with the exception of arsenic in lake trout from Escarpment Lake (1986); cadmium in lake trout from Judge Sissons Lake (1980); and mercury in lake trout from Pointer Lake in 1989, Mushroom and Cigar lakes in 1990, Caribou Lake in 1986, and Judge Sissons Lake in 1980. Concentrations of radionuclides were below detection limits in most of the lake trout sampled between 1980 and 1990 with the exception of Pb-210 in lake trout flesh from Judge Sissons Lake (1980) and from Mushroom and Cigar lakes (1990), as well as Th-230 in lake trout flesh from Cigar Lake (1990).

In general, concentrations of trace metals in flesh and bone samples of lake trout in 2008 were similar between lakes, with the exception of barium, selenium, and uranium in flesh and aluminum and boron in bone. Many of the trace metals were near or below detection limits, or below guidelines concentrations. Higher concentrations were found in Pointer Lake (barium, selenium, and uranium in flesh samples), Mushroom Lake (selenium in flesh sample), Caribou Lake (selenium in flesh sample), and Judge Sissons Lake (barium and selenium in flesh sample). In 2009, chemistry analyses were completed on lake trout flesh and bone samples from Judge Sissons Lake only. Many of the trace metals were near or below detection limits or below guidelines, with the exception of mercury in the flesh samples of lake trout. Concentrations of all metals for lake trout captured in Baker Lake in 2009 were below Rieberger averages plus one standard deviation for uncontaminated lakes (Rieberger 1992). Mean concentrations of aluminum, copper, iron, and zinc were highest for lake trout liver samples. Mean mercury concentrations in lake trout muscle tissue at Station 1 did not exceed Rieberger averages (Rieberger 1992) and were below maximum BC MoE recommended levels for human consumption (0.1 to 0.5 mg/kg) (BC MoE 2006).

Concentrations of radionuclides were near or below detection limits in flesh and bone samples from lake trout captured in 2008 and 2009 for all parameters, with the exception of Po-210 in bone samples from Mushroom Lake (2008) and Judge Sissons Lake (2008 and 2009), as well as Ra-226 in bone samples from Pointer Lake (2008) and in flesh and bone samples from Judge Sissons Lake (2009). Concentrations of radionuclides were near or below detection limits in flesh and bone samples from lake trout captured in Baker Lake in 2009 for a few parameters (i.e., Th-228 and Th-230). However, Pb-210, Po-210, and Ra-226 were detected in flesh and bone samples from several lake trout captured in Baker Lake.

5.6.3.6 Lake Whitefish

Twenty-three lake whitefish were captured in Baker Lake in 2009. The fork lengths of lake whitefish ranged from 115 to 359 mm. The ages of lake whitefish ranged from zero (i.e., YOY) to eight years, with all fish captured between zero and three years, except for one eight-year-old fish.

5.6.3.7 Ninespine Stickleback

External (n = 141) fish health assessments were conducted on ninespine stickleback captured in 2007, 2008, and 2009 (Table 5.6-4). The fork lengths of ninespine stickleback ranged from 27 to 67 mm; total body weights ranged from 1 to 4 g.

Overall, the majority of the ninespine sticklebacks processed were in good physical health and no abnormalities or incidents of parasites were observed.

5.6.3.8 Round Whitefish

External (n = 51) and internal (n = 43) fish health assessments were conducted on round whitefish captured in 2008 and 2009 (Table 5.6-4). The fork lengths of round whitefish ranged from 95 to 387 mm; the total body weights ranged from 6.75 to 640 g. The ages of round whitefish ranged from two to 17 years.

Overall, the majority of the round whitefish processed were in good physical health and abnormalities or incidents of parasites were low. Two fish had cataracts in both eyes; two fish had a section of the gill missing; fourteen fish had minor to moderate fin erosion or fin haemorrhaging; one fish had minor skin aberrations; and eight fish had minor to moderate parasite infestations. Parasitic infestations consisted ofcopepods on gills. Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low, and included three fish with shrunken or incomplete gonads, two fish with granular kidneys or discoloured kidneys, one fish with a fatty liver, and two fish with discoloured livers.

In general, concentrations of trace metals in flesh and bone samples of round whitefish captured in 2008 were similar between lakes. Many of the trace metals were near or below detection limits or below guidelines concentrations. Higher concentrations were found in Caribou Lake (aluminum, barium, copper, lead, silver, strontium, uranium, and zinc in flesh samples, and uranium in bone samples), Mushroom Lake (selenium in flesh and bone samples and manganese, strontium, and uranium in bone samples), and Lower Lake (boron and zinc in bone samples).

Concentrations of radionuclides were near or below detection limits in flesh and bone samples from round whitefish captured in 2008 for all parameters, with the exception of Po-210, which was detected in flesh and bone samples from at least one fish from all four lakes sampled in 2008.

5.6.3.9 Slimy Sculpin

External (n = 97) fish health assessments were conducted on slimy sculpins captured in 2009 and 2010. The total lengths of slimy sculpins ranged from 34 to 110 mm; the total body weights ranged from 0.5 to 13 g.

Overall, the majority of the slimy sculpins processed were in good physical health and no abnormalities or incidents of parasites were observed.

5.7 Species at Risk

The freshwater form of the fourhorn sculpin is the only listed fish species occuring in the freshwater or marine environments that has the potential to interact with the Project. Freshwater fourhorn sculpin were designated as a species of Special Concern by COSEWIC in April 1989. The COSEWIC status of of this species was reconsidered in November 2003, and was changed to “Data Deficient”, based on a lack of necessary data to evaluate the status of the species, as well as uncertainty regarding the taxonomic status (COSEWIC 2003). The *Species at Risk Act* (SARA) (Government of Canada 2002) lists the fourhorn sculpin as a species of Special Concern under Schedule 3, thereby providing legislated protection under SARA. Although this species is identified as occurring in Nunavut, no historic records occur within the mine site LSA (COSEWIC 2003; Scott and Crossman 1973) and no specimens were captured there during recent fish surveys. The only documented occurrence of fourhorn sculpin within the site access LSA was in Baker Lake in 1975 (McLeod et al. 1976).

6 Effects Assessment for Surface Hydrology

6.1 Surface Hydrology

The scope of the assessment for surface hydrology focuses on the water quantity aspect of the aquatic environment. As outlined in Section 4, surface hydrology has been identified as a valued environmental component (VEC), which is a component of the environment that is considered to be important by society. While measureable parameter(s) have been identified to quantify changes in surface hydrology, no defined thresholds exist for determining the significance of effects to surface hydrology. Instead, through stakeholder and public consultations, regulatory requirements, and professional scientific judgement, effects on surface hydrology are of relevance and regulated as a pathway to other valued components, such as water quality, fish, and fish habitat. For example, while the collection, storage, treatment, and disposal methods of contaminated snow, ice, and surface runoff may result in changes in hydrological measurable parameters, the significance of these changes in baseline conditions is ultimately determined in the context of environmental effects to water quality and fish. Therefore, the assessment for surface hydrology identifies key environment-project interactions and quantifies their respective effects, but does not classify residual effects or determine the significance of effects. The hydrological assessments provide an appropriate hydrological context that can be linked to other VECs and assessment endpoints for which thresholds and significance are directly defined (e.g., fish and fish habitat).

6.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement and by the Nunavut Impact Review Board (NIRB) to identify project activities that have potential to interact with surface hydrology by affecting its spatial and/or temporal distribution. Public engagement identified a number of potential Project-Environmental interactions and effects, including sourcing potable water (EN-KIV OH 2009[119]), site water management (EN-BL OH 2010[120], EN-RI OH 2010[121], EN-RB KIA 2007[122]), dewatering Andrew Lake (EN-WC NIRB 2010[123], EN-WC OH 2012[124]), waste rock pile construction (EN-WC OH 2012[125]), and establishing

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119 EN-KIV OH 2009: *Potable water, where do you get it?*
120 EN-BL OH 2010: *Will you divert water? Are you going to treat all of the water and manage all that waste?*
121 EN-RI OH 2010: *What will you do with all the water during the high spring melt? Rock piles and tailings pit. North is different from south and there will be more snow piling up and spring runoff will create more contamination.*
122 EN-RB KIA 2007: *Would water flow through the tailings?*
123 EN-WC NIRB 2010: *the dewatering of Andrew Lake would occur if Kiggavik were to go ahead.*
124 EN-WC OH 2012: *What would happen if a lake goes into the pit?*
125 EN-WC OH 2012: *Are there lakes under the waste rock?*

site access roads (EN-CI KIA 2010[126]). The relevant project activities and the associated environmental interactions for each Project phase are presented in Table 6.1-1.

Table 6.1-1 Project-Environmental Interactions and Effects – Surface Hydrology

	Project Activities/Physical Works	Change in Water Quantity
Construction:		
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, and collection ponds)	1
	Construct in-water/shoreline structures	1
	Freshwater withdrawal	2
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	2
Operation:		
Mining	Mine dewatering	2
Water Management	Freshwater withdrawal	2
	Collection of site and stockpile drainage	2
	Discharge of treated effluents (including greywater)	2
Ongoing exploration	Drilling	1
Final Closure:		
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	1
	Remove in-water/shoreline structures	1

NOTES:

Category 1 activities are those having an interaction with the aquatic environment that is likely to result in a minor environmental change, but a negligible residual effect on a VC relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects of other existing or reasonably foreseeable projects. As noted in the following section, screening of these project interactions indicates that project effects will be minimal and no further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

[126] EN-CI KIA 2010: *There are calving areas, rivers, migratory birds along the proposed access road. Make sure you understand the Elder's point of view when you get to Baker Lake.*

The construction and decommissioning of in-water/shoreline structures, freshwater diversions, and site drainage containment systems includes the installation of water crossing structures, and the construction of dykes, berms, collection ponds, and diversion channels. These Project activities have been ranked as “1” with respect to surface hydrology. The installation and removal of structures may interrupt or constrict local and/or downstream water quantity. However, effects will be mitigated by following standard construction practices that will help to maintain the spatial and temporal distribution of water. For example, in-water works will take place “in the dry”, with a temporary channel or pumping system to maintain downstream flow. If this is not possible, work will be restricted to low flow periods and flow constriction will be minimized. As mitigation and best management practices are expected to effectively reduce effects of in-water works on water quantity, no important effects are likely and no further assessment is warranted.

Ongoing exploration in the vicinity of the site may require additional water sources. A drill rig typically requires intermittent water withdrawal at a rate of less than 10 m^3/day, for a period of several days. As this small volume of water is likely to be withdrawn from a proximal waterbody of a sufficient size such that effects to surface hydrology are not measureable, no important effects are likely and no further assessment is warranted. Additional mitigation measures associated with ongoing exploration activities are described in Tier 2, Volume 2, Project Description, Section 3.3 Future Exploration Activities.

6.1.2 Indicators and Measurable Parameters

In the Guidelines for the Preparation of an Environmental Impact Statement issued in May 2011, NIRB identified hydrology as a VEC. A number of Project activities have the potential to affect surface water quantity and therefore other environmental receptors; surface water quantity is a key pathway to other components of the natural ecosystem due to its fundamental role in sustaining life, including that of fish, vegetation, wildlife, and people.

In assessing Project effects on surface water quantity, four measureable parameters were selected: water level, waterbody volume, stream flow rates, and effective drainage areas (Table 6.1-2). Water level, waterbody volume, and stream flow rates directly capture the spatial and temporal characteristics of surface water and provide a means of quantifying changes. Effective drainage area is an indirect measure of water quantity as it largely controls the amount of runoff generated from a watershed. Sufficient water level, volume, stream flow, and geospatial data are available to confidently estimate potential effects through these measurable parameters.

Table 6.1-2 Measurable Parameters for Surface Water Quantity

Environmental Effect	Measurable Parameter(s)	Notes or Rationale for Selection of the Measureable Parameter
Change in water quantity	• Water level • Waterbody volumes • Stream flow rates • Effective drainage area	• Stream flow rates, water levels, and waterbody volumes allow quantification of changes in the spatial and temporal distribution of water and provide information on water availability and storage capacities. • Effective drainage areas affect the quantity of water in a watershed and the respective drainage characteristics • Community, government, stakeholder engagement and professional judgment

6.2 Effects Assessment for Surface Hydrology

6.2.1 Assessment for Changes in Surface Hydrology

Stream flow rate, water level, water body volume, and effective drainage areas typically capture changes in water quantity which in turn can be associated with changes in fish, aquatic organisms and fish habitat, sediment quality, and water quality.

Project activities that are expected to have a substantive effect on surface hydrology are:

- Construction – In-Water Construction: Freshwater withdrawal; On-Land Construction: Site clearing and pad construction;
- Operation - Mining: Mine dewatering;
- Operation - Water Management: Freshwater withdrawal;
- Operation - Water Management: Collection of site and stockpile drainage;
- Operation - Water Management: Discharge of treated effluents (including greywater); and
- Final Closure – General: Ongoing withdrawal, treatment and release of water, including domestic wastewater.

6.2.1.1 Analytical Methods for Changes in Surface Hydrology

Flow Rate

Extreme high and low flow rates are calculated for sites potentially affected by Project activities. Many factors can influence the magnitude of extreme (flood or low flow) events, including the number of lakes within a drainage basin, lake outlet geometry, topography of the basin, and vegetation. Flood frequencies for the monitoring locations near the Kiggavik Project are estimated using the flood frequency data for Qinguq Creek. Qinguq Creek was selected for flood frequency estimates due to the length of its period of record and size of its drainage basin. Streams associated with smaller drainage areas commonly have higher peak runoff values on a unit-area basis, due to reduced storage within the basin. For streams smaller than the Qinguq Creek, a relationship with Akkutuak Creek (drainage are of 15 km^2) was developed. Over eight years of coincident peak flow data, an average correlation coefficient of 0.81 was observed with a standard deviation of 0.13, a minimum of 0.62 and a maximum of 1.05. Plots to show the variability in one-in-ten year, seven-day low flow (7Q10), one-in-ten year, peak three-day delay (3Q10) flow are included in Technical Appendix 5A, Figure II-1. The flood and low flow estimates are also compared to measured peak flows. All values were within acceptable ranges. Therefore, uncertainty in flood flow rates was addressed by calculating flood flow rates by various methods, i.e., exceedance probabilities and 3Q10, measured data, and flow duration analysis.

Mean natural flow conditions are calculated by averaging the 3 to 4 year record for streamflow at each site of concern (Andrew Lake Outflow, Judge Sissons Lake Outflow, and Siamese Lake Outflow) and the peak flow is compared to estimated flood flow values as reported in the baseline report. In cases where measured streamflow records are not available (i.e., Mushroom Lake Outflow), a hypothetical hydrograph is created using regional hydrological characteristics and estimated flood flows (1 in 2 year flood flow) and annual basin yields. Conservative assumptions are incorporated when creating hypothetical hydrographs such that effects are overestimated rather than underestimated (Technical Appendix 5N).

To estimate the effects of water withdrawal or discharge to/from source waterbodies and their outflow channels, withdrawal or discharge rates are superimposed on baseline flow conditions to determine relative change.

Water Level

Lake water levels respond to inflow and outflow characteristics, which are active during the open water season and inactive during the winter. Therefore, water levels during ‘open-system’ conditions (i.e., the active flow season) and ‘closed-system’ (i.e., the inactive flow season) are analyzed separately.

Open-system conditions are applied to lakes when the outflow channel is actively flowing according to the baseline hydrograph; this ranges from mid-June through mid-July for Mushroom Lake to mid-June through mid-September for Judge Sissons Lake. Changes in lake water level during open-system conditions is estimated by using the outflow stage-discharge curve developed during baseline studies (Technical Appendix 5A) and baseline flow rates (Section 6.3.1.2). These data are also used to estimate the intra-annual fluctuation in lake level.

Closed-system conditions are applied to lakes when the outflow channel is inactive according to the baseline hydrograph; this ranges from mid-July for Mushroom Lake or mid-September for Judge

Sissons Lake until the following spring freshet. During this period, when inflows and outflow effectively cease, the lake is considered to be a close system, and thus effects from withdrawal or discharge are isolated to the lake. This is a conservative approach because if the system remains open, effects to water levels will be attenuated by the inflow and outflow conditions.

Changes in lake levels during closed-system conditions are estimated using bathymetric data and resultant stage-storage curves. For instances where water levels must be estimated beyond the observed water level, the slope of the upper-most contour is extrapolated. For lakes in which bathymetric data are not available, changes in lake volumes are estimated by applying the observed basin slopes from ground penetrating radar (GPR) transects to the entire lake. If bathymetric data and estimated ice thicknesses (Technical Appendix 5A) suggest that specific basins of the lake become hydrologically separated for a portion of the winter season, effects are examined in the affected basin exclusively for the period of separation.

Waterbody Volume

Natural waterbody volumes are calculated from bathymetric surveys. For lakes in which detailed bathymetry is not available, lake volumes are estimated using GPR transects that were completed along lake crossing segments of the proposed winter road. From these data, bathymetric information is synthesized for each lake by applying the observed basin slopes to the entire lake.

When appropriate, a range of lake volumes are calculated for the open water season; the high value is associated with spring freshet and the low value is associated with low water levels prior to freeze-up in the fall. As lake ice thickness near Kiggavik is estimated to reach approximately 2 m to 2.5 m near the end of the winter (Technical Appendix 5A), minimum under-ice volumes were calculated as the volume under the 2 m or 2.5 m contour.

Effective Drainage Area

Effective drainage areas are delineated using ArcHydro™ software and a digital elevation model using LiDAR topographic data.

6.2.1.2 Baseline Conditions for Changes in Surface Hydrology

Streams

Streams in the LAA and RAA are typically characterized by an arctic nival regime. Their hydrographs reflect a steep rising limb, peaking in approximately mid-June due to the onset of spring snowmelt, followed by receding flows for the remainder of the open water period. Rainfall events throughout the summer may temporarily reactivate the channels or cause secondary peaks. Streamflow typically ceases during winter months.

Flood magnitude and frequency predictions for Andrew Lake Outflow, Judge Sissons Lake Outflow, Mushroom Lake, and Siamese Lake Outflow (Technical Appendix 5A) and mean baseline hydrographs are presented in Figure 6.2-1 to 6.2-4. Sharp fluctuations observed in the average hydrographs at the beginning and end of the open water period are due to differences in the time period associated with the datasets. For example, the flow on August 24 according to the Judge Sissons outlfow hydrograph is derived from all four years of data, while flow on September 2 is derived from 2007 data exclusively.

The magnitude of each baseline hydrograph peak can be compared to the flood magnitude and frequency values (Table 6.2-1) to confirm that conservatism is incorporated into the specific assessments.

Table 6.2-1 Flood Magnitude (m^3/s) and Frequency Predictions for Streams Potentially Affected By the Project

Stream Name	Return Interval (year)						
	1.01	**2**	**5**	**10**	**20**	**50**	**100**
Outflow of Andrew Lake	1.19	6.12	8.91	10.4	11.7	13.0	13.8
Outflow of Mushroom Lake	0.21	1.10	1.60	1.87	2.09	2.33	2.48
Outflow of Siamese Lake	2.54	13.1	19.0	22.3	24.9	27.8	29.5
Outflow of Judge Sissons Lake	13.2	67.7	98.5	115	129	144	153

NOTES:
m^3/s = cubic metres per second

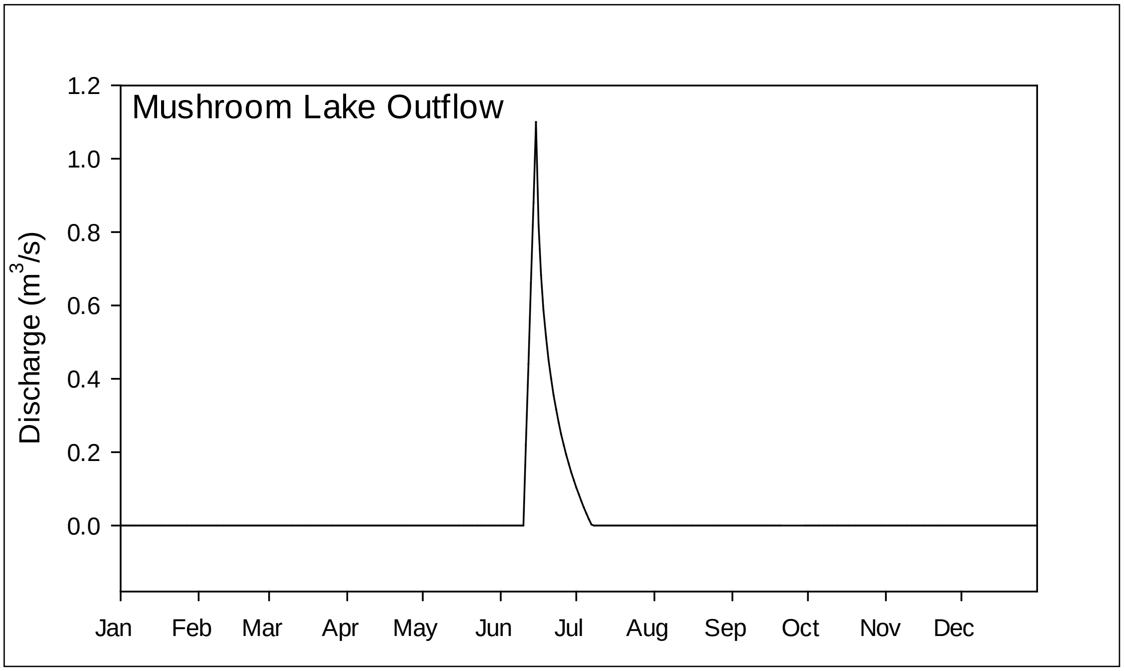


Figure 6.2-1 Baseline Hydrograph for Mushroom Lake Outflow

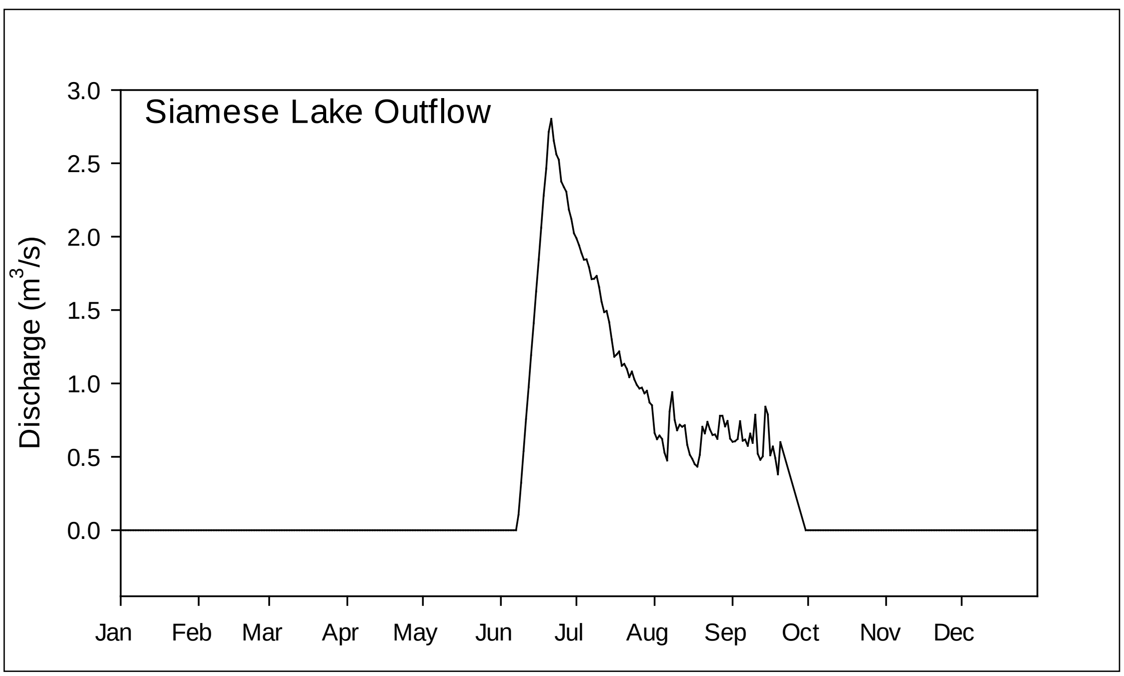


Figure 6.2-2 Baseline Hydrograph for Siamese Lake Outflow

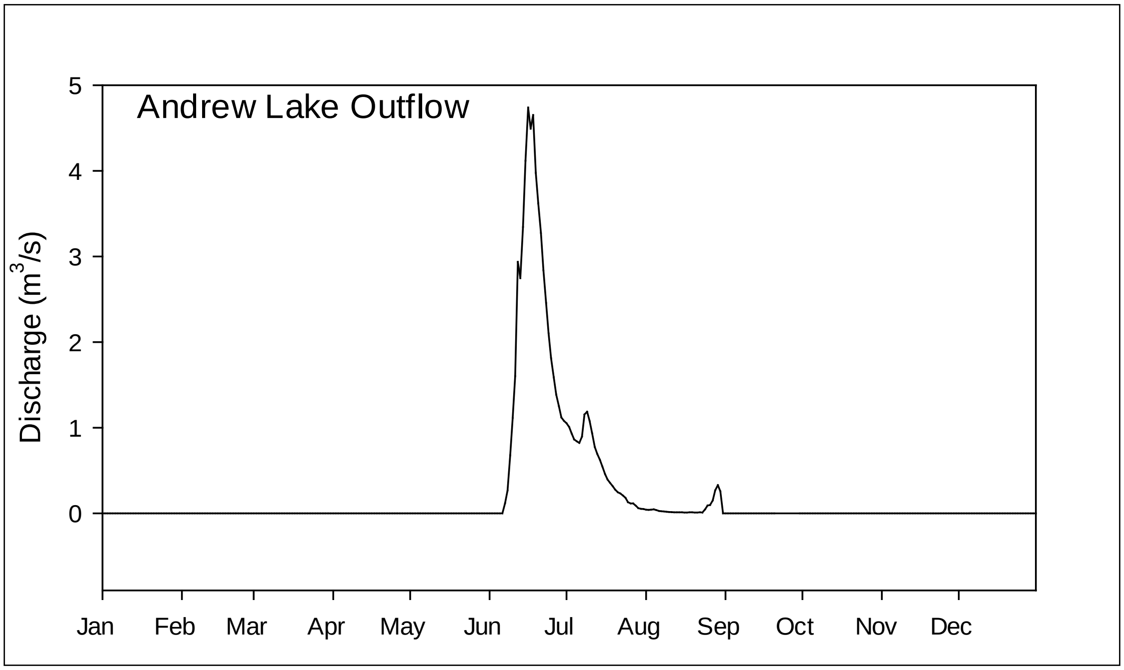


Figure 6.2-3 Baseline Hydrograph for Andrew Lake Outflow

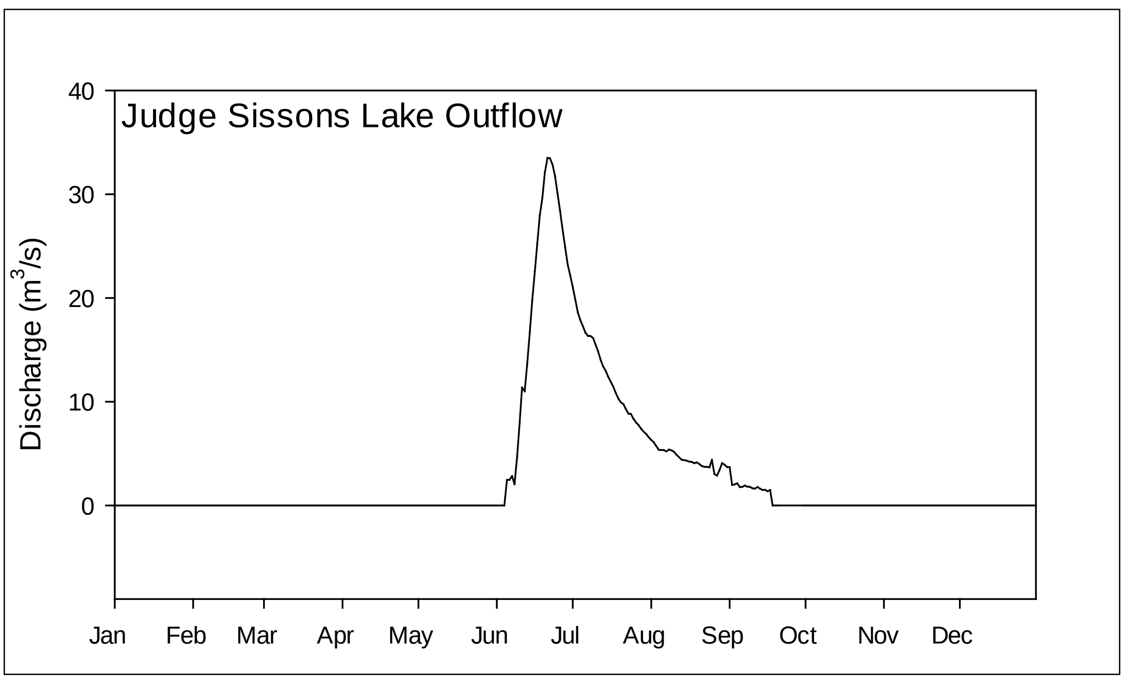


Figure 6.2-4 Baseline Hydrograph for Judge Sissons Lake Outflow

Lakes

Lakes in the LSA and RSA are typically ice covered from approximately October through June, with mean maximum thickness near 2 m. Lake levels and volumes reflect inflow and outflow characteristics and thus reach their peaks during the spring freshet in mid-June with levels and volumes typically decreasing throughout the remainder of the open-water season. Lake volumes and changes in levels for Andrew Lake, Pointer Lake, Judge Sissons Lake, Mushroom Lake, Siamese Lake, 20 km Lake, Long Lake, Audra Lake, Unnamed Ponds, and Qinguq Bay are presented in Table 6.2-2.

Table 6.2-2 Depths and Volumes for Lakes Potentially Affected by the Project

Lake		Volume (m^3)	Under-Ice Volume (m^3)[b]	Change in Water Level During the Open Water Period (cm)
Andrew Lake	Pit Area	41,000-91,000[a]	NA[c]	60
	Remaining Area	54,800	NA[c]	
	Total	95,800	NA[c]	
Pointer Lake		5,470,000	118,000	NA
Mushroom Lake		587,000	284,000	20
Siamese Lake	East	NA	38,000,000	30
	West	NA	27,800,000	
	Total	115,000,000	65,800,000	
Judge Sissons Lake	East Basin	NA	271,469,000	30
	Northwest Basin	NA	771,000	
	Southwest Basin	NA	9,579,000	
	Total	439,000,000	281,819,000	
"20 km Lake"	NA	NA	21,215,910	NA
Long Lake	NA	NA	1,573,164	NA
Audra Lake	NA	NA	30,409,439	NA
Unnamed Ponds	NA	NA	1,990,323	NA
Qinguq Bay	NA	NA	1,389,562	NA

NOTE:
[a] Peak volume associated with the spring freshet.
[b] Assumed ice thickness = 2 m
[c] n/a = not applicable (lake depth is less than 2 m)
m^3 = cubic metres; cm = centimetres; NA: not applicable.

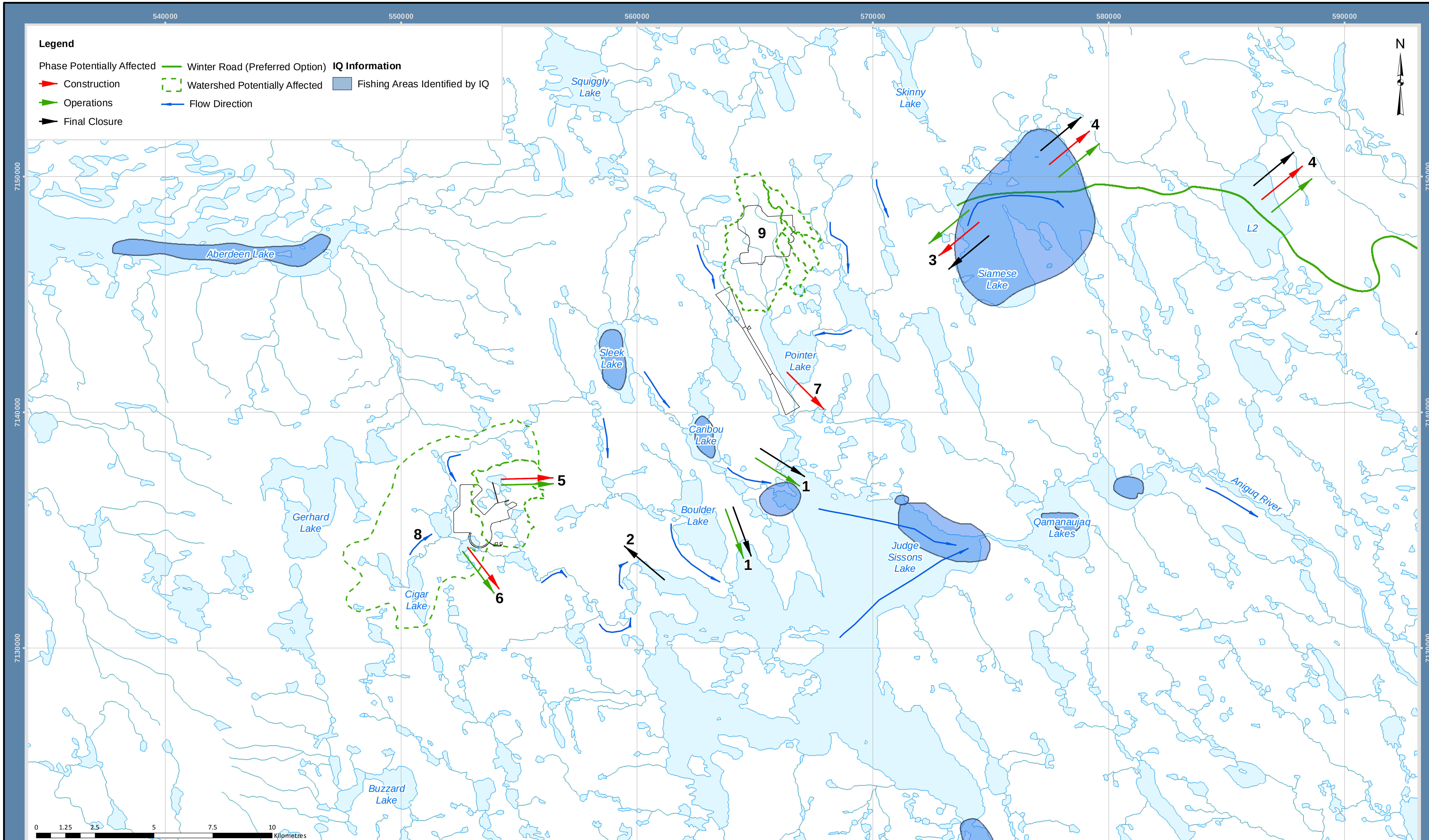
Effective Drainage Areas

Effective drainage areas potentially affected by the project are included in Table 6.2-3 and Figure 6.2-5.

Table 6.2-3 Effective Drainage Areas Potentially Affected by the Project

Site	Watershed	Baseline Effective Drainage Area (km^2)
Kiggavik Site	Watershed 1	10.9
	Watershed 2	1.6
	Watershed 3	1.2
	Watershed 4	1.5
	Pointer Lake Outflow	79.1
Sissons Site	Watershed 1	8.2
	Andrew Lake Outflow	33.7

NOTES:
km^2 = square kilometres.



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Date: 30/06/2014 Scale: 1:150,000
File: KI09C345
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Areva Resources Canada Inc. Hattie Mannik and the Baker Lake Elder's Focus Group Baker Lake HTO, Baker Lake Hunter Focus Group*

FIGURE 6.2-5A
POTENTIAL PROJECT EFFECTS ON SURFACE HYDROLOGY NEAR THE KIGGAVIK AND SISSONS SITES

KIGGAVIK PROJECT - EIS

Note:
1. Treated effluent and greywater discharge
2. Withdrawal for flooding the Andrew Lake Pit
3. Freshwater withdrawal for Kiggavik Site
4. Freshwater withdrawal for ice road flooding
5. Freshwater withdrawal for Sissons Site
6. Discharge from dewatering the Andrew Lake Pit Area
7. Withdrawal for flooding temporary airstrip
8. Sissons Site watersheds
9. Kiggavik Site watersheds

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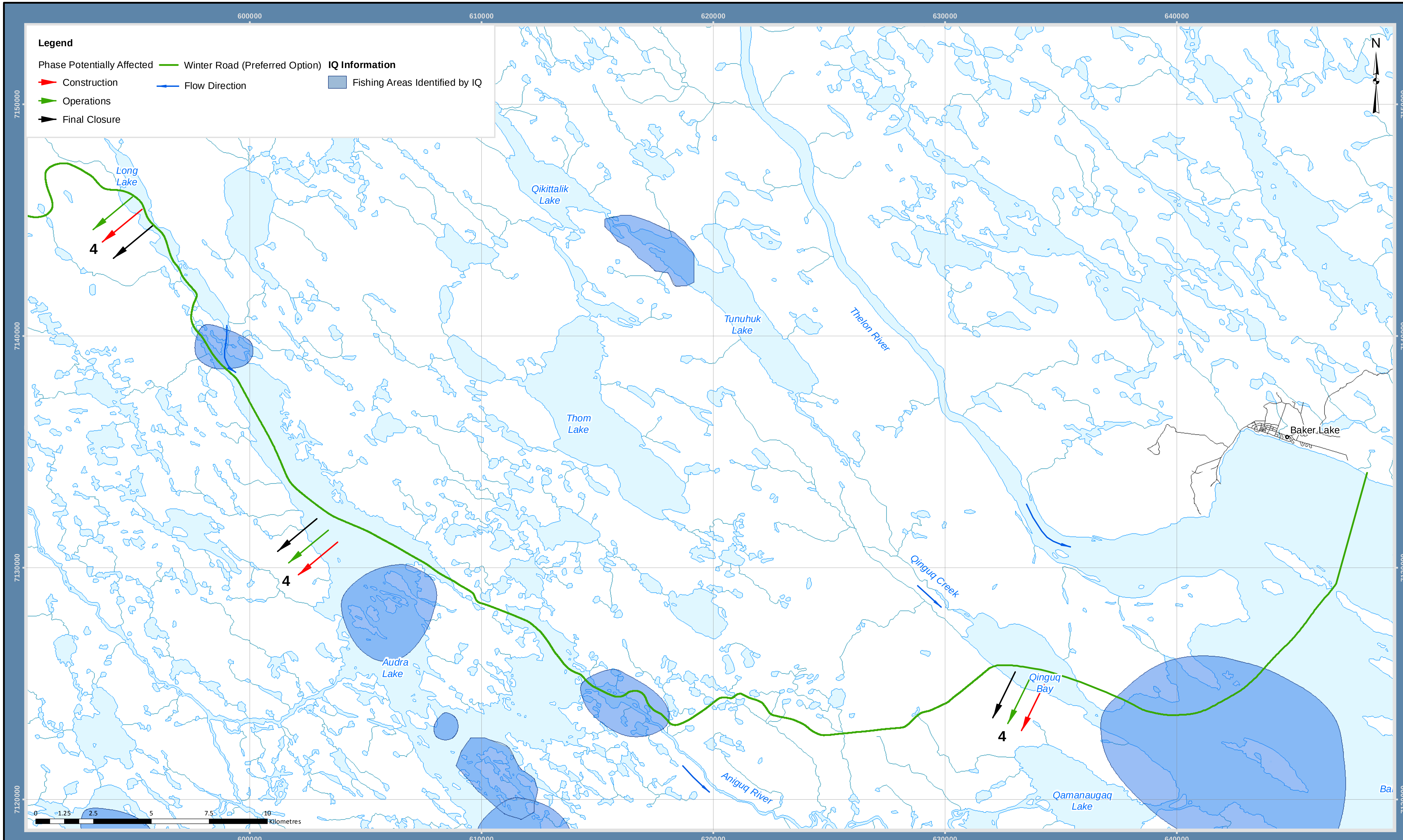

Projection: NAD 1983 UTM Zone 14N
Creator: JRC/LMR
Date: 30/06/2014 Scale: 1:150,000
File: KI08C346
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Areva Resources Canada Inc., Hattie Mannik and the Baker Lake Elder's Focus Group Baker Lake HTO, Baker Lake Hunter Focus Group*

FIGURE 6.2-5B

POTENTIAL PROJECT EFFECTS ON SURFACE HYDROLOGY ALONG THE SITE ACCESS ROAD

KIGGAVIK PROJECT - EIS

Note:
4. Freshwater withdrawal for ice road flooding

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6.2.1.3 Effect Mechanism and Linkages for Changes in Surface Hydrology

The effect mechanisms and linkages for changes in surface hydrology include site clearing and pad construction, mine dewatering, freshwater withdrawal, the collection of site and stockpile drainage, the discharge of treated effluents, and the ongoing withdrawal, treatment and release of water (Table 6.1-1). These activities have potential to affect a number of waterbodies, both at the location of the activity, and in the downstream environment. Figure 6.2-5 indicates the location for each activity and the corresponding waterbodies directly affected. The following describe the effect mechanisms and linkages associated with each activity.

Construction - On-Land Construction: Site clearing and pad construction: General construction activities at the Kiggavik and Sissons Sites will require the dewatering of minor ponds and standing water, which can affect surface hydrology (including water volumes, levels, and flow rates) locally and downstream. A total of about 25,000 m^3 of ponded water will require dewatering at the Kiggavik Site while about 15,000 m^3 of ponded water will require dewatering at the Sissons site.

Operation - Mining: Mine dewatering: The construction of the Andrew Lake Pit requires that a dyke be constructed and a section of Andrew Lake dewatered. The water will be pumped out of the future pit area into the main body of Andrew Lake. The additional water to the main body of Andrew Lake may increase water quantities in the lake and the downstream environment and therefore water volumes, levels, and flow rates.

Operation - Water Management: Freshwater withdrawal and Construction – In-Water Construction Freshwater Withdrawl: Water withdrawal is required during the construction and operational phases to support activities at the Sissons and Kiggavik sites, as well as for flooding of the winter roads and temporary airstrip. Water will be sourced from local waterbodies, which, depending on the flow-through characteristics and size, may reduce water levels, volumes, and flow rates in the lake and downstream environment.

Operation - Water Management: Collection of site and stockpile drainage: To avoid effects to water quality, runoff from site during operation, including that from the core facilities, the ore, permanent and temporary mine rock piles and the Andrew Lake Pit, will require treatment or passage through sedimentation ponds prior to release. As water is treated or passed through sedimentation ponds and released at a controlled rate, there is potential for effects to the temporal distribution of water quantity and therefore water levels, volumes, and flow rates. Effective drainage boundaries may also be altered as the runoff requiring treatment will ultimately be discharged with effluent and wastewater at Judge Sissons Outflow. In effect, some site runoff will bypass its natural drainage pathway between the Kiggavik or Sissons sites and Judge Sissons Lake Outflow and will therefore no longer contribute runoff to waterbodies between the two locations. As a consequence, water quantity will be reduced in the connecting waterbodies.

Operation - Water Management: Discharge of treated effluents (including greywater): Discharge of wastewater and treated effluent will occur during the construction, operation and decommissioning phases of the Project. The additional source of water to the receiving environment may increase local and downstream water levels, volumes, and flow rates.

Final Closure – General: Ongoing withdrawal, treatment and release of water, including domestic wastewater: Water withdrawal is required during the final closure phase of the Project, for industrial and domestic purposes, including the flooding of winter roads and the temporary airstrip and the flooding of the Andrew Lake Pit. Water will be sourced from local waterbodies for these activities, which, depending on the flow-through characteristics and size, may reduce water levels, volumes and flow rates in the lake and downstream environment. Final closure activities will also result in the discharge of treated effluent and greywater into a local waterbody, which also has potential to affect water levels, volumes, and flow rates.

6.2.1.4 Mitigation Measures and Project Design for Changes in Surface Hydrology

A number of mitigation measures and project designs will be implemented to limit changes to surface hydrology:

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained;
- The site water management system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities;
- Diversion channels will be designed to intercept freshwater from upslope, divert it around development areas, and reintroduce it to natural stream channels downstream (Technical Appendix 5O);
- Sedimentation ponds will be designed with a control structure so that evaporative losses can be minimized;
- In-water construction will follow standard protocols and best management practices (Technical Appendix 5O);
- Snow fences will be constructed to limit snow drifting on site;
- Andrew Lake pit will be pumped and refilled at a rate such that effects to surface hydrology are minimized.
- DFO procedures for water withdrawal from ice-covered waterbodies in the Northwest Territories and Nunavut will be followed. Specifically, no more than 10% of the under-ice volume will be withdrawn from a lake during one ice covered season.
- Water will be sourced and discharged into large waterbodies to reduce effects to surface hydrology;

- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored; and
- Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).

6.2.1.5 Residual Effects for Changes in Surface Hydrology

Residual effects for changes in surface hydrology have potential to occur at the waterbodies and drainage areas directly affected by Project activities as well as their downstream environments. Project activities are predicted to occur at Judge Sissons Lake, Siamese Lake, Andrew Lake, Mushroom Lake, waterbodies along the site access road, and watersheds associated with the Project Footprint.

Judge Sissons Lake and Outflow

Hydrological effects at Judge Sissons Lake and its outflow are largely a result of the discharge of treated effluent and greywater during operations and potentially final closure, and water withdrawal during final closure. AREVA proposes to release treated effluent and greywater at either one or two locations in the east basin of Judge Sissons Lake. Although Judge Sissons Lake and its outflow will additionally be affected by upstream activities, such as pit dewatering, site runoff, and water withdrawal at Mushroom Lake, these activities are expected to be sufficiently attenuated downstream such that incremental effects at Judge Sissons Lake and its outflow are not measureable (Section 6.3.1.5.7). Therefore, potential effects at Judge Sissons Lake and its outflow during operations is exclusively associated with the discharge of treated effluent and greywater in Judge Sissons Lake. During final closure, Judge Sissons may continue to be affected by the discharge of treated effluent and greywater, as well as water withdrawal from Judge Sissons Lake to augment flooding of the Andrew Lake Pit.

Operations

AREVA has estimated treated effluent and greywater discharge at a base case of 4,407 m^3/day for Sissons and Kiggavik sites combined; however, to incorporate environmental conservatism and potential variability in discharge, 0.054 m^3/s (4,700 m^3/day) has been assessed; 0.035 m^3/s (3,000 m^3/day) from the Kiggavik Site and 0.012 m^3/s (1,700 m^3/day) from the Sissons Site.

Currently, Judge Sissons Lake is the preferred location for treated effluent and greywater discharge from both the Kiggavik and Sissons sites. Treated effluent and greywater from both sites may be discharged into the Judge Sissons Lake at one location in the east basin, or at two separate locations in the east basin. As both discharge locations remain hydraulically connected throughout the year, resultant effects to flow rates, water levels, and water volumes will be equivalent under both scenarios.

During the open water period, the discharge of treated effluent and greywater may cause an increase in streamflow from Judge Sissons Lake by up to 0.054 m^3/s, which is indistinguishable from baseline conditions (Figure 6.2-6). This increase in discharge consistently accounts for less than 4% of natural discharge from Judge Sissons Lake and is therefore unlikely to be measureable, particularly during spring freshet when treated effluent and greywater consists of less than 0.5% of the natural discharge. Treated effluent and greywater discharge results in a predicted increase in stream level of less than 3 mm at Judge Sissons Outflow. As natural inter and intra-annual stream level fluctuations are of the magnitude of 10s of centimeters, this increase is well within natural variability, and not likely measurable.

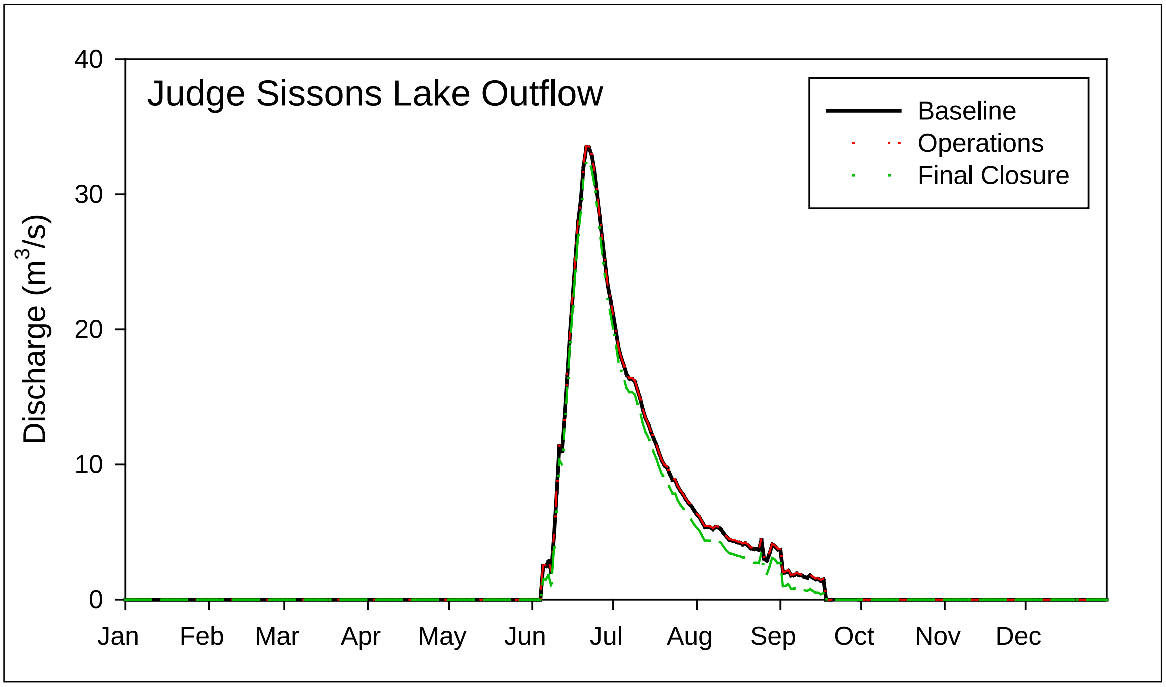

Figure 6.2-6 Discharge at Judge Sissons Lake Outflow During Operations and Final Closure

During natural conditions and mean discharge under conditions of treated effluent and greywater release, Judge Sissons lake level is predicted to increase 0.5 mm due to effluent and greywater discharge during open system conditions. The predicted increase in lake level is considerably lower than the approximately 30 cm mean natural intra-annual fluctuation, and is not likely to be measurable.

During winter, the under ice water level increase due to treated effluent and greywater discharge is estimated at 2.18 cm; this is considerably lower than the approximately 30 cm intra-annual natural fluctuations in lake level. The cumulative discharge over the nine winter months accounts for an increase in under ice volume of approximate 0.46% in the east basin.

Further details regarding the hydrological assessment of effluent discharge into Judge Sissons Lake are included in Technical Appendix 5N.

Final Closure

During final closure, Judge Sissons Lake and its outflow may be potentially affected by continued discharge of treated effluent and greywater and the withdrawal of water to fill the Andrew Lake Pit. If treated effluent and greywater are discharged into Judge Sissons Lake during Final Closure, they are not predicted to exceed effects observed during operations (i.e. increase in discharge of 0.054 m^3/s). If water withdrawal from Judge Sissons Lake is required to augment water diverted from Andrew Lake during flooding of the Andrew Pit Lake, the withdrawal rate will be maintained at less than 1 m^3/s. Therefore, the greatest effects on Judge Sissons Lake will occur if no water is discharged, but water is withdrawn at a rate of 1 m^3/s. Therefore, potential hydrological effects to Judge Sissons Lake will be less than those due to withdrawal exclusively.

If water withdrawal occurs from Judge Sissons Lake from mid June through mid September (122 days), at a rate of 1 m^3/s (86,400 m^3/day), 10,540,800 m^3 of the pit can be filled annually and withdrawal will occur for approximately 4 seasons. During this period, effects to flow rates at Judge Sissons Outflow will be a maximum of 1 m^3/s; 1 m^3/s is less than 3% of the average peak flow. Water levels at Judge Sissons Lake are predicted to decrease approximately 8 cm during the period of water withdrawal.

The effects predicted for Judge Sissons Lake and outlflow are predicted to diminish downstream as drainage areas and basin yields increase.

Siamese Lake and Outflow

No Project activities will occur upstream of Siamese Lake and thus Project activities with potential to affect hydrological conditions at Siamese Lake and its outflow include freshwater water withdrawal for industrial and domestic purposes, and water withdrawal for flooding the ice road. These activities have potential to occur throughout construction, operations, and final closure phases of the Project, with peak effects occurring during operations when withdrawal requirements are greatest.

AREVA has estimated water withdrawal rates for the Kiggavik site at 0.0926 m^3/s (8,000 m^3/day). Withdrawal at this rate is predicted to cause a maximum decrease in discharge of 0.0926 m^3/s (Figure 6.2-7). During the period June through September, withdrawal rates may result in a decrease of approximately 3% in peak discharge rates and approximately 20% during low discharge rates in the fall.

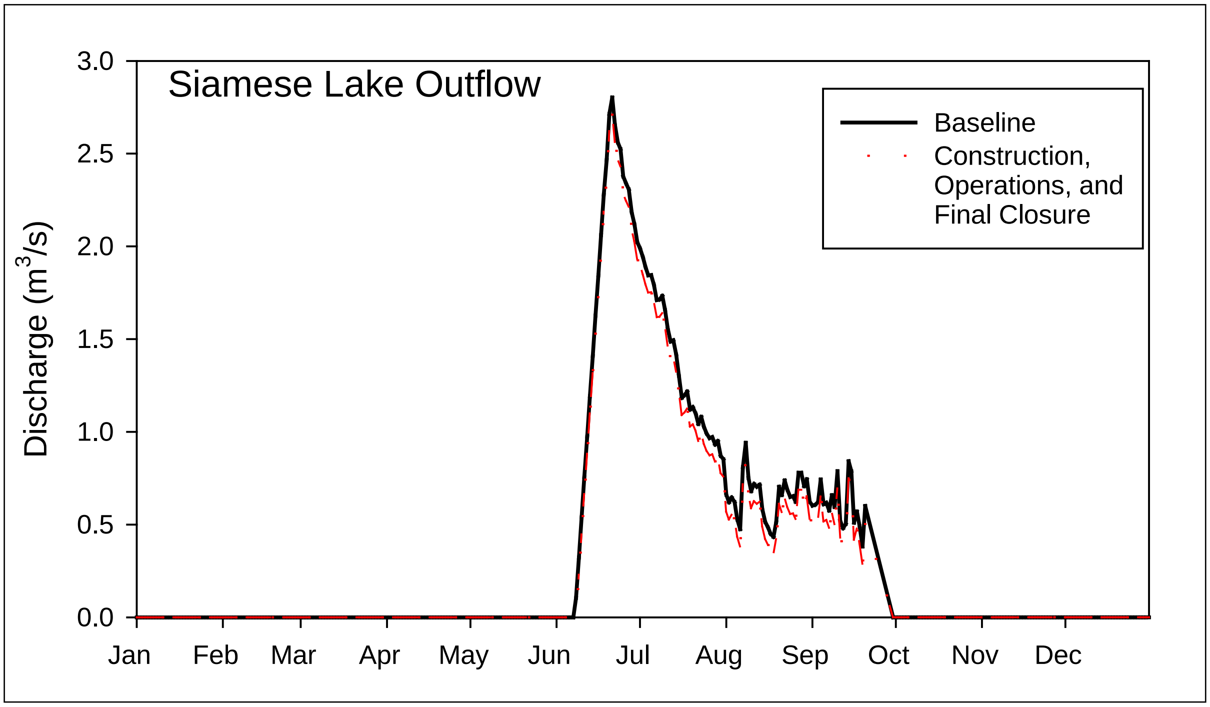

Figure 6.2-7 Discharge at Siamese Lake Outflow During Construction, Operations, and Final Closure

During summer while Siamese Lake inflows and outflow are active, lake levels will be moderated by through-flow. During this time, changes in lake level due to water withdrawal are estimated to reach 2 cm. During winter, when Siamese Lake is effectively a closed system, cumulative water withdrawal is predicted to reach a maximum of 4% of the under ice volume over the entire lake immediately prior to spring melt. If the east and west basins of Siamese Lake become disconnected during the winter and withdrawal occurs from the west basin exclusively during April and May, withdrawal reaches a maximum of 5% of the under ice volume in the west basin (Tier 3, Technical Appendix 5N).

Water withdrawal during winter is typically permitted to be 10% of under-ice volume for lakes that have a depth of at least 1.5 m during maximum ice thickness (DFO 2010). Therefore, for winter conditions, cumulative water withdrawal from Siamese Lake is limited to 10% of the under-ice volume. Water withdrawal requirements for the winter road are predicted to be 75,000 m^3 annually. Although other waterbodies suitable for freshwater withdrawal are available along the road alignment (Section 6.3.1.5.6), if all the required water is withdrawn from Siamese Lake, this would account for 0.1% of its under-ice volume. As up to 1,960,000 m^3 (4% to 5% of the under-ice volume) is required for domestic and industrial purposes, cumulative withdrawal at Siamese Lake should remain below 4.1 to 5.1% of the under ice volume; corresponding to a decrease in lake level in the west basin of approximately 15 cm to 20 cm

The effects predicted for Siamese Lake and its outflow are predicted to diminish downstream as drainage areas and basin yields increase. Further details regarding the hydrological assessment of water withdrawal at Siamese Lake, including assumptions used to incorporate conservatism into the assessment, are included in Technical Appendix 5N.

Mushroom Lake and Outflow

No Project activities will occur upstream of Mushroom Lake and thus hydrological effects at Mushroom Lake and its outflow stream will result from water withdrawal for industrial and domestic purposes at the Sissons Site exclusively. Water withdrawal requirements are estimated to be 0.000694 m^3/s (60 m^3/day) for the Sissons Site; therefore, water will be withdrawn from Mushroom Lake at a continuous rate of 0.000694 m^3/s throughout construction, operations, and final closure phases of the Project, with peak effects occurring during operations when withdrawal requirements are greatest.

If steady state conditions are reached in Mushroom Lake, natural discharge will decrease by a maximum of 0.000694 m^3/s, which is indistinguishable from baseline conditions (Figure 6.2-8). A withdrawal rate of 0.00694 m^3/s is approximately 0.06% of the peak discharge at Mushroom Lake Outflow. While inflows and outflows are active, withdrawal is predicted to result in a 2 mm change in lake level from natural levels.

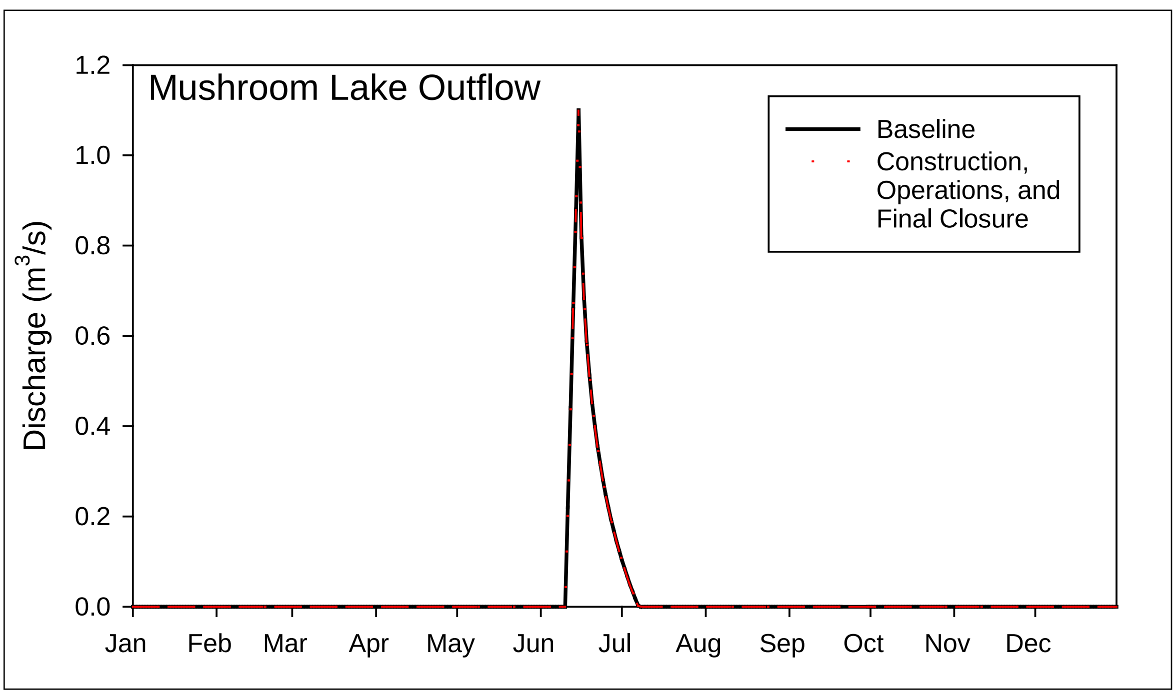

Figure 6.2-8 Discharge at Mushroom Lake During Construction, Operations, and Final Closure

For July though May, Mushroom Lake is effectively a closed system as little outflow occurs after the spring freshet. Cumulative water withdrawal is 20,100 m^3, which is 3.4% of the total volume and 8% of the approximate late-winter under-ice volume. The decrease in water level during closed system conditions is predicted to be 10.4 cm.

The effects predicted for Mushroom Lake and its outflow are expected to diminish downstream as drainage areas and basin yields increase. Further details regarding the hydrological assessment of water withdrawal at Mushroom Lake, including assumptions used to incorporate conservatism into the assessment, are included in Technical Appendix 5N.

Andrew Lake and Outflow

Construction

During construction, no Project activities will occur upstream of Andrew Lake and thus hydrological effects at Andrew Lake and its outflow will result from the dewatering of the Andrew Lake pit exclusively. The dewatering area of Andrew Lake has an estimated volume of 41,000 m^3 during late summer when water levels are low. During the spring freshet, when water levels are at their maximum, the volume of this area increases to approximately 91,000 m^3. At a continuous pumping rate of 0.15 m^3/s, the dewatering process would occur over a period of 3-7 days, depending on lake water levels when dewatering is initiated.

To avoid potential erosion and inundation of shoreline, Andrew Lake Pit area will not be dewatered during the spring freshet. The elevated discharge resulting from dewatering at 0.15 m^3/s for 3-7 days in July or August will not cause flows to reach spring flood rates or levels (Figure 6.2-9). If the area is dewatered during this time, lake water levels would recede more slowly than usual until pumping is completed. Lake level may reach 24 cm higher than normal, though both lake elevation and stream discharge would be well below early summer levels and the effect would be limited to seven days.

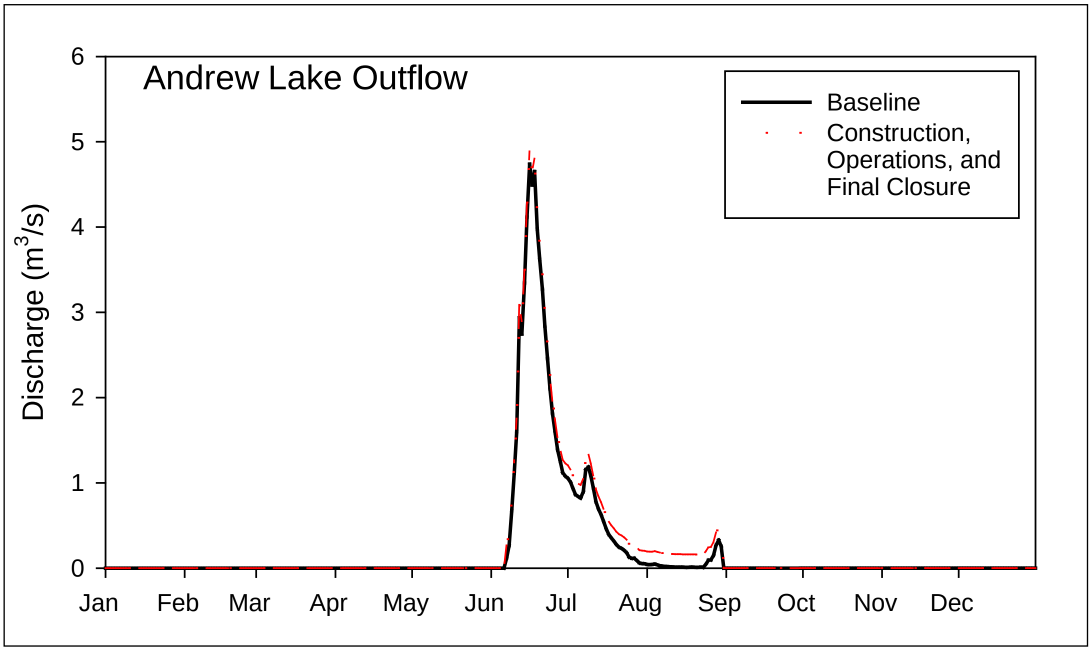

Figure 6.2-9 Discharge at Andrew Lake During Construction

Operations

During operations, when diversion channels, sedimentation ponds, and water treatment plant processes are active at the Sissons Site, the effective drainage area of Andrew Lake Outflow is predicted to decrease by 3% (Technical Appendix 5N). This 3% change in effective drainage area may result in a 3% change in the annual basin yield at Andrew Lake Outflow. Peak infiltration of 1050 m^3/day (Technical Appendix 5E) into the Andrew Lake pit are predicted to be less than 0.2% of peak discharge from Andrew Lake and is therefore considered negligible.

The effects for Andrew Lake and its outlflow are predicted to diminish downstream as drainage areas and basin yields increase.

Final Closure

Water will be diverted from Andrew Lake during spring freshet, to flood the Andrew Pit Lake over an estimated time of six seasons. Details are provided in Tier 3, Technical Appendix 2R, Preliminary Decommissioning Plan, Attachment A. The diversion system is designed to maintain water elevations in Andrew Lake within the natural range during periods of flow diversion.

When surface water quality guidelines are met in the flooded pit, the berm which allowed the pit to remain dewatered will be removed from Andrew Lake. This will re-establish Andrew Lake hydrology to the original conditions.

Pointer Lake

During construction, until the airstrip is built, a temporary airstrip will be maintained west of Pointer Lake. This temporary airstrip will be flooded, requiring 450 m^3 of water annually. Due to its proximity, this water will be withdrawn from Pointer Lake, which has a total volume of 5,470,000 m^3, and an under-ice volume of 118,000 m^3. Therefore, the water requirements from Pointer Lake consist of 0.4% of the under-ice volume.

During operations, when diversion channels, sedimentation ponds, and water treatment plant processes are active at the Kiggavik Site, the effective drainage area of Pointer Lake Outflow is predicted to decrease by 1% (Technical Appendix 5N). This 1% change in effective drainage area may result in a 1% change in the annual basin yield at Pointer Lake outflow. In addition, peak infiltration of 745 m^3/day (Technical Appendix 5E) into the Main Zone pit are predicted to be less than 0.1% of peak discharge from Pointer Lake and is therefore considered negligible.

Site Access Road Waterbodies

AREVA has proposed options for a site access road from Baker Lake: one winter road option and an all-season road option (Figure 6.2-5b). The Winter Road is currently the preferred option for early stages of the project. In the event that traffic requirements, climatic conditions, or surface conditions become unmanageable for a winter road, an all-season road option may be explored further.

The proposed Winter Road crosses 6 major waterbodies. It is recommended that over-land portions of the winter road be flooded to maintain sufficient bearing capacity and estimate that 75,000 m^3 of water will be required annually (see Technical Appendix 2K).

DFO protocol indicates that, for the protection of aquatic species, water withdrawal from lakes in Nunavut during one ice covered season should not exceed 10% of the under ice volume (DFO 2010). Ten percent of the estimated under-ice volume is calculated for each lake crossing and is presented as the maximum withdrawal volume (Table 6.2-4).

Table 6.2-4 Maximum Water Withdrawal Volumes for the Kiggavik Winter Road

Waterbody	Under-ice volume (m^3)	Maximum available withdrawal volume (m^3)
Siamese Lake	65,800,000	4,620,000[a]
“20 km Lake”	21,200,000	2,120,000
Long Lake	1,600,000	160,000
Audra Lake	30,400,000	3,040,000
Unnamed Ponds	2,000,000	200,000
Qinguq Bay	1,400,000	140,000
Total	*160,400,000*	*10,280,000*

NOTES:
[a] 1,960,000 m^3 of water may be withdrawn from Siamese Lake for freshwater at the Kiggavik Site leaving 4,620,000 m^3 available for withdrawal for the winter road.

According to Table 6.2-4, approximately 10,280,000 m^3 of water is available from the proposed winter road lake crossings. It is estimated that 75,000 m^3 will be required during the winter and therefore sufficient supply from any of the listed sources in Table 6.2-4. In practice, water would be withdrawn from the nearest source to where water is needed for the ice road, thus the required volume would be pumped from multiple sources over the length of the winter road. Therefore, hydrological effects due to the Winter Road are predicted to remain far below a reduction of 10% in under ice volume Bathymetric data will be collected such that 10% of the under-ice volume will not be exceeded during one winter season of water withdrawal.

The all-season road option is not predicted to pose effects to surface hydrology; mitigation measures will be applied such as the installation of cross drainage structures and implementation of best management practices (see Technical Appendix 5O) such that natural drainage pathway will be maintained, and flow rates, water levels, and water body volumes will not be affected. Additionally, the construction and maintenance of the all-season road, including any structures on the Thelon River, will not create or consume water and will therefore not affect water quantity.

Footprint Waterbodies

Waterbodies associated with the project footprint and immediately downstream have potential to be affected by site clearing and pad construction, and the collection of stockpile and site drainage. During construction, ponds and standing water will be dewatered and diversion channels be built, thereby potentially affecting the hydrology of receiving waterbodies. However, the ponds directly under the Project footprint are the only wetlands in the RAA with potential to be directly affected by the Project. Additionally, the presence of diversion channels and the collection of stockpile and site drainage have potential to alter effective drainage areas.

During site clearing and pad construction activities, ponds and standing water will be dewatered according to the Pond Dewatering Plan for the Kiggavik and Sissons Sites (Technical Appendix 5N). If ponds are dewatered at 0.15 m^3/s in sequence at the Kiggavik and Sissons sites, and this occurs outside the period associated with the spring freshet, effects to streamflows and lake levels and volumes should remain within their intra-annual variation. All receiving waterbodies identified in the Pond Dewatering Plan for the Kiggavik and Sissons Sites experience natural inflows greater than 0.15 m^3/s.

The waterbodies potentially affected by the collection of stockpile and site drainage are indicated in Figure 6.2-5. The Hydrological Assessment on the Downstream Effects of Site Runoff and Diversions (Technical Appendix 5N) estimate changes in basin yields as indicated in Table 6.2-5. For example, the basin yield in Watershed 1 at the Kiggavik site is predicted to decrease by 2%, while 14% of the basin yield in this watershed may either be attenuated or subject to small increases in evaporative losses as it passes through the sedimentation ponds.

Table 6.2-5 Changes in Watersheds Associated with the Kiggavik and Sissons Sites

		Potential change in basin yield (%)	Percent of modified basin yield subject to attenuation or small increases in evaporative losses
Kiggavik Site	Watershed 1	-2	14
	Watershed 2	-44	0
	Watershed 3	-33	0
	Watershed 4	-27	0
Sissons Site	Watershed 1	-10	0

NOTES:
% = percent.

6.2.1.6 Compliance and Environmental Monitoring for Changes in Surface Hydrology

Monitoring of hydrological effects can be completed through the collection of specific data at the waterbodies potentially affected by project activities. These data are sufficient for measuring or estimating flow rates, water levels, and waterbody volumes and can be obtained by the following methods.

- **Water levels:** Staff gauges can be installed on Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels and levels can be manually recorded on a regular basis during periods in which effects may occur. Continuous water levels sensors can also be installed in these lakes and streams during the open water season to obtain detailed water level data.
- **Flow rates:** Instantaneous discharge measurements can be measured at Andrew Lake Outflow, Siamese Lake Outflow, Mushroom Lake Outflow, and Judge Sissons Lake Outflow while effects are predicted to occur. These flow rates can be used to develop and maintain stage-discharge rating curves so that water level data can be used to estimate continuous discharge. In addition, water withdrawal and treated effluent and greywater discharge rates can be continually documented;
- **Waterbody volumes:** Lake level data can be applied to bathymetric data to estimate waterbody volumes at waterbodies potentially affected by the project. Under-ice volumes can be confirmed by annual ice thickness measurements at Siamese Lake, Mushroom Lake, and ice road lakes.

6.3 Cumulative Effects Analysis for Surface Hydrology

6.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to surface hydrology occur within the LAA and are expected to diminish to immeasurable levels downstream at the Anigaq River. Should monitoring results identify any remaining residual effects to surface hydrology outside the LAA, these effects would have potential to overlap with other projects and activities that occur or may occur in the future, and may therefore act cumulatively on surface water hydrology.

The screening for cumulative effects to surface hydrology was conducted to determine if cumulative environmental effects are likely to occur. Potential cumulative effects exist if Project-related effects to surface hydrology overlap spatially and temporally with those of other past, present and future projects, and activities. Projects considered for cumulative environmental effects are described in Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect surface hydrology within the spatial (i.e., Judge Sissons Lake) and temporal (i.e., throughout the duration of hydrology effects associated with the Project) boundaries. Therefore, no cumulative effects to surface hydrology are predicted for the Project.

6.4 Summary of Residual Effects on Surface Hydrology

6.4.1 Project Effects

Project activities have potential to directly affect Judge Sissons Lake, Siamese Lake, Mushroom Lake, Andrew Lake, Pointer Lake and their outflow streams, site access lakes (20 km Lake, Long Lake, Audra Lake, Unnamed Ponds, and Qinguq Bay), and watersheds associated with the project footprint. A summary of potential effects is included in Table 6.4-1 as well as a reference to the sections of this document for which significance is determined.

6.4.2 Effects of Climate Change on Project and Cumulative Effects on Surface Hydrology

To estimate the effects of climate change on the Project and cumulative effects on surface hydrology, climate change data were used to estimate five components of the water balance at Pointer Lake Outflow and Judge Sissons Lake Outflow: precipitation, evaporation, evapotranspiration, sublimation, and runoff, as discussed in Technical Appendix 5K.

Twenty three climate change ensembles, which reflect different combinations of models and emission scenarios, were explored. Twenty of these twenty three ensembes predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. However, under nine ensembles lake evaporation is predicted to decrease and under seven ensembles, evapotranspiration is predicted to decrease. Fifteen ensembles result in a predicted decrease in sublimation, while eight result in a predicted increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively. The maximum increase in runoff is observed at 177% and 200% of historical discharge for the two watersheds. The hydrological effects resulting from climatic changes are orders of magnitude greater than those generated from Project activities.

Although runoff volumes are predicted to increase by 2071-2099, potential changes in the intensity of precipitation events is unknown. Most site designs, particularly those of high hydrological importance such as diversion channels, are designed based on a probable maximum precipitation (PMP) event. This design criterion is not sensitive to annual runoff rates, but rather the intensity of specific rainfall events. Therefore, if the intensity of rainfall events remains consistent with historical conditions, climate change will not affect the effectiveness of Project designs based on a PMP event.

Table 6.4-1 Summary of Project Effects on Surface Hydrology

	Phase			Magnitude of Effects to Surface Hydrology					
					Lake Level (cm)				
	Construction	Operations	Final Closure	Outflow Flow Rate (m^3/s)	During the active flow season	During the inactive flow season	Under-ice Volume (%)	Effective Drainage Area (%)	Duration/Frequency of Effect to Surface Hydrology
Judge Sissons Lake		X		0.054	0.05	2.18	0.46	-	Continuously
			X	-1.000	-8	-	-	-	Occurs continuously during June through September for 4 seasons
Siamese Lake	X	X	X	-0.0926	-2	-15 or 20	-4.1 or -5.1	-	Continuously
Mushroom Lake	X	X	X	-0.000694	-0.2	-10.4	-8	-	Continuously
Andrew Lake	X			0.15	24	-	-	-	Continuously for 3-7 days after the spring freshet
		X		-	-	-	-	3	Continuously
Pointer Lake	X			-	-	-	-0.4	-	Seasonally until airstrip is built
		x		-	-	-	-	1	Continuously
20 km Lake	X	X	X	-	-	-	<-10	-	Seasonally
Long Lake	X	X	X	-	-	-	<-10	-	Seasonally
Audra Lake	X	X	X	-	-	-	<-10	-	Seasonally
Unnamed Ponds	X	X	X	-	-	-	<-10	-	Seasonally
Qinguq Bay	X	X	X	-	-	-	<-10	-	Seasonally
Kiggavik site – watershed 1		X		-	-	-	-	5	Continuously
Kiggavik site – watershed 2		X		-	-	-	-	-44	Continuously
Kiggavik site – watershed 3		X		-	-	-	-	-39	Continuously
Kiggavik site – watershed 4		X		-	-	-	-	-30	Continuously
Sissons site – watershed 1		X		-	-	-	-	-10	Continuously

NOTES:
m^3/s = cubic metres per second; cm = centimetres; % = percent; X = phase applicable; - = not available.

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6.5 Compliance and Environmental Monitoring for Surface Hydrology

Monitoring of hydrological effects can be completed through the collection of specific data at the waterbodies potentially affected by project activities, as recommended through IQ and engagement (EN-BL CLC 2010[127], EN-BL CLC 2010[128],EN-AR NIRB 2010[129], EN-BL CLC 2009[130], EN-BL CLC 2010[131], EN-RB NIRB2010[132]). These data are sufficient for measuring or estimating flow rates, water levels, and waterbody volumes and can be obtained by the following methods.

- **Water levels:** Staff gauges and continuous water level sensors will be installed on Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels and levels will be manually recorded during periods in which effects may occur;
- **Flow rates:** Instantaneous discharge measurements will be taken at Andrew Lake Outflow, Siamese Lake Outflow, Mushroom Lake Outflow, and Judge Sissons Lake Outflow while effects are predicted to occur. These flow rates can be used to develop and maintain stage-discharge rating curves so that water level data can be used to estimate continuous discharge. In addition, water withdrawal and treated effluent discharge rates will be continually documented;
- **Waterbody volumes:** Under-ice volumes will be confirmed by annual ice thickness measurements at Siamese Lake, Mushroom Lake, and ice road lakes.

[127]EN-BL CLC 2010*: it would be a good idea to also monitor the ice break up at the river to see how high or how strong it is, to take note of the ice flow, ice melts, water levels etc.*
[128] EN-BL CLC 2010*: Is the chopper going to monitor the shallow part of the river?*
[129] EN-AR NIRB 2010: *Long term monitoring should be in place for caribou, fish, rivers and reservoirs (lakes?).*
[130] EN-BL CLC 2009: *Community Liaison Committee has to request for full monitoring of river, not talk about it.*
[131] EN-BL CLC 2010: *the river monitoring that we saw are just monitoring current of river and Lakes so that they will know how it will have affect or changes.*
[132] EN-RB NIRB2010: *Concerned over who will be conducting the studies and environmental monitoring during the review at the proposed mine site. It is important that studies be done before the mine is in operation*

7 Effects Assessment for Hydrogeology

7.1 Scope of the Assessment for hydrogeology

In the context of the proposed Kiggavik Project (the Project), the scope of the assessment for groundwater and hydrogeology focuses on the groundwater quantity and groundwater quality aspects of the aquatic environment. However as there is no current and foreseeable usage of groundwater in the Project area, groundwater is primarily valued as a pathway to other valued components, such as surface water quality and aquatics organisms. For example, while the mining, mine rock and tailings management activities may result in changes in hydrogeological measurable parameters, the significance of these changes on baseline conditions is ultimately determined in the context of environmental effects to surface water quality and, as described for hydrology, the importance of these changes to biological components and human use.

Refer to Section 4.1 for a discussion of issues and concerns raised during Inuit Qaujimajatuqangit (IQ) interviews and engagement initiatives.

Refer to Section 4.1.1 for a description of the influence of IQ and engagement data on the hydrogeology assessment.

7.1.1 Project–Environment Interactions and Effects

The environmental effects of the Project on hydrogeology are changes to groundwater quantity and surface water receptor quality. The relevant project activities and the associated environmental interactions for each Project phase are presented in Table 7.1-1.

Table 7.1-1 Project-Environmental Interactions and Effects – Groundwater

	Project Activities/Physical Works	Change in groundwater quantity	Change in surface water receptor quality
On-Land Construction	Construct foundations	1	0
Mining	Mine dewatering	2	0
Mine rock management	Stockpiling activities	0	2
Tailings Management	Pumping and placement of tailings slurry	0	2

Table 7.1-1 Project-Environmental Interactions and Effects – Groundwater

	Project Activities/Physical Works	Change in groundwater quantity	Change in surface water receptor quality
Water Management	Freshwater withdrawal	1	0
	Discharge of treated effluents (including greywater)	0	1
Ongoing exploration	Drilling	1	1

NOTES:

Category 1 activities are those having an interaction with the aquatic environment that is likely to result in a minor environmental change, but a negligible residual effect on a VC relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects of other existing or reasonably foreseeable projects. As noted in the following section, screening of these project interactions indicates that project effects will be minimal and no further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

7.1.2 Indicators and Measurable Parameters

In assessing Project effects on groundwater, two measureable parameters were selected.

- The first indicator is the elevation of lakes potentially affected by the dewatering of mines extending beneath the permafrost. This is considered to be an indicator of groundwater quantity because dewatering activities of open pit and underground mines commonly result in depressed groundwater levels in the vicinity of the mines and have the potential to affect lake levels in the study area.
- The second indicator is the quality of the receiving surface water bodies potentially connected hydraulically to the deep groundwater system. Groundwater represents a pathway for potential interactions between dissolved constituents in water originating from the mining activities and the surface water where the groundwater discharges. Because groundwater is not used for potable water in the Kiggavik Project area, this indicator is considered to be the main measurable parameter of the potential long-term effects of the Project on the aquatic environment.

It is considered that sufficient geological, hydrogeological and hydrological data, as well as modelling results, are available to confidently estimate potential effects through these measurable parameters.

Table 7.1-2 Measurable Parameters for Groundwater

Environmental Effect	Measurable Parameter(s)	Notes or Rationale for Selection of the Measureable Parameter
Change in groundwater quantity	• Hydraulic head • Lake water level	• Hydraulic heads measured from piezometers and lake water levels measurements allow quantification of potential changes in the spatial and temporal distribution of groundwater as a result of Project activities
Change in surface water receptor quality	• Major ions, trace metals and radionuclides in groundwater and surface water samples	• The chemical composition of groundwater and surface water allow quantification of potential migration of constituents of concern in groundwater as a result of Project activities

7.1.3 Residual Environmental Effects Criteria

Residual environmental effects criteria specific to hydrogeology and groundwater that differ from the description in Tier 2 Volume 5, Section 4.6 are:

- The magnitude of residual environmental effects for groundwater describes the overall effect of project activities on the surface water where groundwater discharges. For hydrogeology, magnitude is defined as:
  - Negligible: Very minor changes to groundwater quantity or surface water receptor quality that are imperceptible in their effect in the local assessment area (LAA) or regional assessment area (RAA)
  - Low: Minor changes to groundwater quantity or surface water receptor quality that can be detected in the LAA or RAA but do not exceed surface water quality standards or affect water users
  - High: Large changes to groundwater quantity or surface water receptor quality that exceed water quality standards or affect water users in the LAA or RAA.
- The geographic extent of environmental effects to hydrogeology refers to the area within which the environmental effect occurs and is described either as the number of square kilometres affected or the number of kilometres affected downstream of the activity location. The geographic extent is described as local if the predicted effect does not extend beyond the local study area and Regional if it extends into the regional study area.
- The frequency of an environmental effect to hydrogeology refers to the number of times the effect occurs during the project or during a specific phase of the project. Frequency is described as isolated, periodic, or continuous. An environmental effect has an isolated frequency if the effect is confined to a specific discrete period; an environmental effect has a periodic frequency if the effect occurs intermittently or may repeat over the assessment period, while an environmental effect is continuous if the effect occurs continually over the assessment period.

7.1.4 Standards or Thresholds for Determining Significance

The significance of Project environmental effects on hydrogeology is determined by the extent of change in lake levels and the quality of the surface water where groundwater discharges in comparison to Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (1999 with updates to 2014c) and Health Canada guidelines for drinking water (2012). A significant environmental effect on hydrogeology occurs if there is a greater than 10-cm change in a lake level as a result of mine dewatering or if the CCME and Health Canada guidelines, as presented in Table 7.1-3 are exceeded. The effects are not significant if these conditions do not occur.

Table 7.1-3 CCME and Health Canada Guidelines for Determination of Significance on Surface Water Receptor Quality

Analyte	Units	CCME Aquatic Life Guidelines	Health Canada Drinking water Guidelines	
pH (laboratory)	pH units	6.5 to 9.0	6.5 - 8.5	OG
Aluminum	mg/L	0.005-0.1	0.1 / 0.2	OG
Antimony	mg/L	-	0.006	MAC
Arsenic	µg/L	5	10	MAC
Barium	mg/L	-	1.0	MAC
Boron	mg/L	-	5	MAC
Cadmium	mg/L	0.00004-0.00037[(a)]	0.005	MAC
Chromium	mg/L	0.001 (Cr(VI)) 0.0089 (Cr(III))	0.05	MAC
Copper	mg/L	0.002-0.004[(b)]	≤1.0	AO
Iron	mg/L	0.3	≤0.3	AO
Lead	mg/L	0.001-0.007[(c)]	0.010	MAC
Manganese	mg/L	-	≤0.05	AO
Molybdenum	mg/L	0.073	-	-
Nickel	mg/L	0.025-0.150[(d)]	-	-
Selenium	mg/L	0.001	0.01	MAC
Silver	mg/L	0.0001	-	-

Table 7.1-3 CCME and Health Canada Guidelines for Determination of Significance on Surface Water Receptor Quality

Analyte	Units	CCME Aquatic Life Guidelines	Health Canada Drinking water Guidelines	
Thallium	mg/L	0.0008	-	-
Uranium	µg/L	15 (long-term)	20	MAC
Vanadium	mg/L	-	-	-
Zinc	mg/L	0.03	≤5	AO
Lead-210	Bq/L	-	0.2	MAC
Radium-226	Bq/L	-	0.5	MAC
Chloride	mg/L	120 (long term)	≤250	AO or OG
Sodium	mg/L	-	≤200	AO or OG
Sulphate	mg/L	-	≤500	AO or OG
Nitrate	mg/L	13	45	MAC

NOTES:

(a) The CCME cadmium guideline is hardness dependent, the value provided is the guideline for hardness (0 to 17 mg/L and > 280 mg/L as $CaCO_3$).

(b) The CCME copper guideline is hardness dependent, the value provided is the guideline for hardness 0 to 82 mg/L and > 180 mg/L as $CaCO_3$.

(c) The CCME lead guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180 mg/L as $CaCO_3$.

(d) The CCME nickel guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180mg/L as $CaCO_3$.

CCME – Canadian Water Quality Guidelines for the Protection of Aquatic Life (1999c with updates to 2014)

Health Canada – Guidelines for Canadian Drinking Water Quality (December 2012)

MAC – Maximum Acceptable Concentration

AO – Aesthetic Objectives or Operational Guidance Values (OG)

mg/L = milligrams per litre; µg/L = micrograms per litre; Bq/L = Becquerels per litre; - = not applicable.

7.2 Effects Assessment for Hydrogeology

7.2.1 Assessment of Changes in Groundwater Quantity

7.2.1.1 Analytical Methods for Changes in Groundwater Quantity

A three-dimensional regional groundwater flow model of the LAA was developed in support of the effects assessment for hydrogeology. This regional flow model encompasses a large area, including the Kiggavik and Sissons Mine Sites, considering as far as practical natural boundary conditions with limited artificial control of the calculated flow regime. The groundwater flow model was based on historical and recent geological and hydrogeological information, including ground temperature measurements, hydraulic conductivity test results and water levels.

Details of the conceptual and numerical models can be found in Technical Appendix 5D. The groundwater flow model was used to simulate progressive mining of the open pit and underground workings below the permafrost zone (see Technical Appendix 5E). Steady state and transient mine dewatering rates were predicted and natural reflooding rates were estimated for the End Grid underground mine and the Andrew Lake open pit. The flow model was also used as part of the assessment of the long-terms effects related to tailings management (see Technical Appendix 5J).

7.2.1.2 Baseline Conditions for Changes in Groundwater Quantity

Baseline conditions for changes in groundwater quality are summarized by the current hydraulic distribution in the sub-permafrost aquifer. Figure 5.2-6 (Tier 2 Volume 5, Section 5) shows the simulated steady-state hydraulic head distribution in the sub-permafrost aquifer under pre-mining conditions. The figure also shows the areas where groundwater is predicted to be flowing artesian.

7.2.1.3 Effect Mechanism and Linkages for Changes in Groundwater Quantity

Dewatering activities of the Kiggavik open pits, Andrew Lake open pit and End Grid will result in depressed groundwater levels in the vicinity of the mine and have the potential to affect waterbodies by decreasing water quantities in the lakes in the vicinity of the mines.

7.2.1.4 Residual Effects for Changes in Groundwater Quantity

Mine dewatering activities are predicted to result in depressed groundwater levels beyond the upper limits of natural variation in the immediate vicinity of the Kiggavik open pits, Andrew Lake open pit and End Grid underground mine. The potential effects are anticipated to last throughout the active mining period, following which dewatering activities will cease, and the groundwater system will recover to conditions similar to natural pre-mining conditions. Groundwater quantities extracted from dewatering activities are predicted to be low and will not affect lake levels.

Model results presented in Technical Appendix 5E suggest that the groundwater inflow to the proposed open pits would be low due to low hydraulic conductivity of the rock mass in which the pits would be excavated. Mining of the Andrew Lake and Main Zone pits is expected to take place over several years. During most of this time, the pits will be excavated in permafrost and groundwater inflows are expected to be negligible. In the final years of mining the pits are expected to extend below the bottom of permafrost; the results of the model simulations predict that groundwater inflow to the Andrew Lake and Main Zone pits will be lower than 100 m^3/year for the ultimate pit depth.

Predicted groundwater flow to the End Grid underground mine is approximately 160 m^3/day for the ultimate configuration of the mine. Most of this flow originates from the enhanced permeability zones assumed to be associated with the sub-vertical faults passing through the mine. If these faults are either not present or have a lower hydraulic conductivity than assumed then inflow to the mine would be lower than 100 m^3/day.

7.2.1.5 Determination of Significance for Changes in Groundwater Quantity

Effects of mine dewatering activities on groundwater levels are predicted to be localized within the site assessment boundary. The effects will be continuous during the mining period, but reversible in the medium-term, and are anticipated to have negligible ecological and socio-economic implications. The low hydraulic conductivity of the rock mass and the permafrost conditions will result in limited groundwater inflows to the proposed mines and lake levels will not be affected by mine dewatering activities. Therefore, the residual adverse effects from the Project on groundwater quantity are considered not significant.

7.2.2 Assessment of Changes in Surface Water Receptor Quality

7.2.2.1 Analytical Methods for Changes in Surface Water Receptor Quality

The post-decommissioning flow regime of the Kiggavik area was modelled based on the groundwater flow model presented in Technical Appendix 5D. Groundwater flow simulations were performed under steady state conditions, as would exist following decommissioning.

As presented in Table 7.2-1, field data acquisition, laboratory testing and modelling programs were developed to assess the potential long-term effects of tailings and mine rock management activities. These programs are summarized in Technical Appendix 5F for mine rock and in Technical Appendix 5J for tailings.

Table 7.2-1 Methodology for the Assessment of Long-Term Effects on Surface Water Receptor Quality

Topic	Summary Of Work Done To Date
Flow	Pre-mining and mine-dewatering groundwater flow conditions • Review of geological, hydrological and hydrogeological data • In-situ determination of ground temperatures, hydraulic conductivity and sub-permafrost hydraulic heads • Development of a steady-state regional three-dimensional (3D) flow model (Feflow™ and Modflow™ softwares) for pre-mining conditions • Development of a transient 3D flow model (Feflow™) for mine-dewatering conditions Post closure groundwater flow conditions • Laboratory determination of tailings hydraulic conductivity and geotechnical parameters • Modelling of post-consolidation tailings hydraulic conductivity • Modelling of thermal conditions of the mine rock piles • Literature review on hydrology of mine rock piles in cold climates • Evaluation of the water balance for mine rock piles and covered tailings management facilities (TMFs) • Modelling of the impact of climate warming trends on permafrost • Modelling of groundwater flow through the decommissioned TMFs for both current permafrost and no-permafrost cases
Source Term	Tailings geochemical behaviour • Laboratory determination of tailings neutralization conditions and long-term tailings behavior using aging tests • Thermodynamic modelling (PhreeqC) of minerals-solution equilibrium • Determination of constant concentration-type boundary condition values for the contaminant transport model Mine rock geochemical behaviour • Determination of solid inventory from drill core samples • Determination of mine rock pore water and leachable fractions from sequential leach tests, humidity cell tests and column tests • Determination of source term functions for the contaminant transport model
Contaminant Transport	Contaminant transport and loadings to receiving surface water bodies • Literature review on effective porosity values in crystalline fractured environment • Laboratory determination of total porosity and distribution coefficient (Kd) for sub-permafrost granite samples • Particle path analysis (Modpath), from the decommissioned TMFs to the receiving surface water bodies for both current permafrost and no-permafrost cases • Analytical modelling of contaminant transport along each particle path
Consequence Of Predictions	Consequence of predicted long-term concentrations • Sensitivity analysis to account for hydrological, hydrogeological and geochemical uncertainties • Comparison of predicted surface water concentrations with guidelines

Hydrogeological and geochemical models were first calibrated on field data and laboratory experiments. The models were then used to predict the potential loadings over time of key constituents of potential concern (COPC) at receptors. This included Pointer Lake and the flooded Andrew Lake pit. For simplicity and conservatism, maximum predicted loadings were used, regardless of the peak arrival time, and all maximum loadings were assumed to reach the waterbodies at the same time. The maximum loadings were transformed to peak incremental surface water concentrations at the receptors using average flow conditions at the receptors and neglecting removal processes in waterbodies.

Sensitivity analyses were performed to account for uncertainties in the hydrogeological and geochemical parameters. This included the assessment of combined effects of varying several key parameters simultaneously in the direction that increases the COPC concentrations in receiving surface water bodies.

Calculated long-term surface water concentrations were compared to currently applicable water quality objectives. Long-term peak incremental concentrations were found to differ negligibly from baseline conditions. As a result, a human health and ecological risk assessment was not deemed necessary for the long-term effects, as the predicted water and sediment quality are only marginally above natural background levels and are well below benchmark values. Additional information can be found in Technical Appendix 5J.

7.2.2.2 Effect Mechanism and Linkages for Changes in Surface Water Receptor Quality

Tailings management activities are identified as the main Project component for potential interaction with the groundwater regime during the post-decommissioning period. Groundwater is not used in the Project area. However groundwater represents a pathway for potential interactions between dissolved constituents in water originating from the TMFs and the surface water where the groundwater discharges. The linkage between tailings and surface water receptor quality involves a series of hydrological, hydrogeological and geochemical mechanisms, including, but not limited to, the following parameters:

- The tailings pore water long-term concentrations and the inventory of soluble constituents in the tailings, which constitute the source term for potential release of COPC into the groundwater regime.
- The flow through the decommissioned TMFs, which when multiplied by the source term provides the flux of constituents potentially released into the groundwater regime. The loadings to the surface water receptors from the TMFs through the groundwater pathway cannot exceed this flux.

- The hydraulic conductivity and effective porosity of the rock mass between the TMFs and the surface water receptors and the distribution of hydraulic heads, which generate the groundwater velocity along the flow path.
- Geochemical processes, such as mineral precipitation and adsorption, which attenuate the release and transport of constituents from the TMFs to surface water receptors.
- The flow through the surface water receptors, which transforms the flux of COPC originating from the TMFs into resulting surface water concentrations.

These processes are captured by the groundwater flow and contaminant transport models used to evaluate changes in surface water receptor quality.

7.2.2.3 Mitigation Measures and Project Design for Changes in Surface Water Receptor Quality

The proposed tailings management plan for the Project has been designed to avoid interaction between tailings and natural water bodies, to maximize the use of mine workings for long-term management of tailings and to ensure the long-term protection of terrestrial, aquatic and human environments.

The tailings treatment system in the mill and the TMFs are designed to minimize the release of COPC into the aquatic environment through geochemical and geotechnical controls.

7.2.2.4 Residual Effects for Changes in Surface Water Receptor Quality

Kiggavik TMFs area

In the current permafrost case the predicted flow through the tailings is very limited, approximately 0.01 m^3/day. Subsequently there is a very small flux to Pointer Lake for all constituents resulting in negligible incremental concentration in relation to baseline concentrations.

Figure 7.2-1 shows the simulated hydraulic head distribution and results of the particle path analysis in the sub-permafrost aquifer for the post-decommissioning scenario with an expected tailings hydraulic conductivity of $5x10^{-8}$ m/s. This simulation is considered to be the base case representative of the current atmospheric and permafrost conditions.

The hydraulic head distributions in the Kiggavik area for the baseline and post-decommissioning cases are relatively similar. Differences, due to the presence of the tailings (i.e., tailings with slightly higher permeability than the surrounding rock mass) in the post-decommissioning case, are only apparent in close proximity of the Main Zone TMF, which extents below the permafrost.

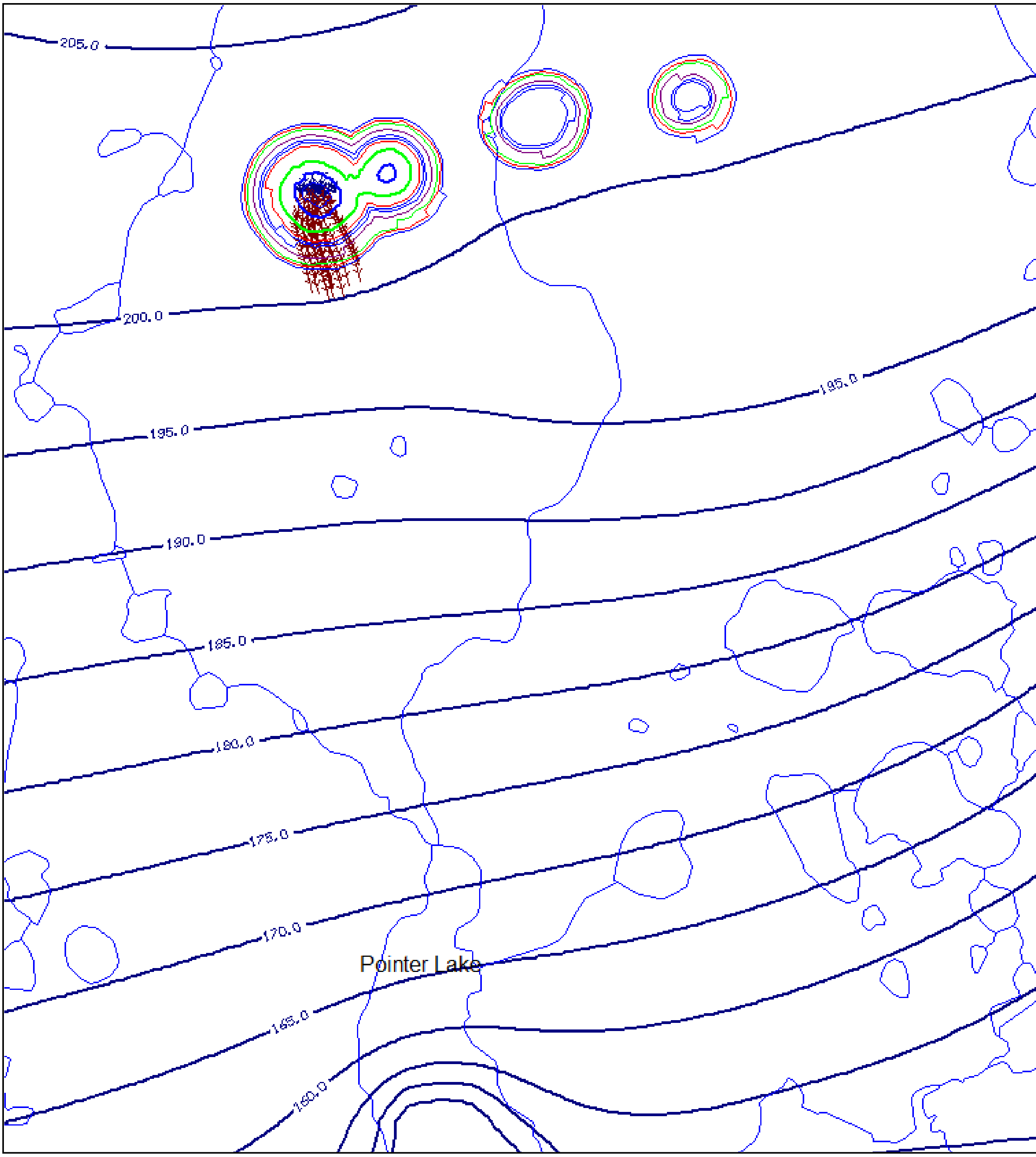

Figure 7.2-1
Pathlines from tailings for current permafrost conditions (pathlines for 10000 years, ticks every 1000 years)

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Particles were released in the model throughout the Kiggavik TMFs to track the advective groundwater flow paths to discharge locations. Because of the low hydraulic conductivity of the rock mass the travel time is extremely long. For instance Figure 7.2-1 shows that after 10,000 years particles remain in the immediate vicinity of the TMFs and do not discharge to a receiving surface water bodies.

Under steady state conditions the particles discharge to Pointer Lake. However the breakthrough time is long, in the order of million years. Predicted long-term water concentrations of solutes in Pointer Lake were compared to baseline and to the applicable surface water quality objectives. Table 7.2-2 shows that all predicted concentrations are well below applicable water quality objectives and for most constituents incremental concentrations are negligible in relation to baseline concentrations. Groundwater flow and solute transport models confirm the performance of the tailings containment system and the limited interaction between tailings and natural surface water bodies.

Table 7.2-2 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – Current Permafrost Conditions

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (µg/L)[(a)]	Guideline (µg/L)[(b)]	Mass Flux (kg/year)	Concentration (µg/L)
Aluminum	21	5 to 100	1.53E-03	1.01E-04
Arsenic	0.2	5	6.10E-05	4.04E-06
Cadmium	<0.1	0.04-0.37[(a)]	9.15E-06	6.06E-07
Chromium	<0.5	1 to 8.9	1.07E-03	7.07E-05
Cobalt	<0.1	-	3.05E-04	2.02E-05
Copper	0.8	2-4[(e)]	1.22E-03	8.08E-05
Iron	45	300	1.53E-02	1.01E-03
Lead	0.1	1 to 7[(f)]	1.22E-04	8.08E-06
Manganese	2.4	-	3.05E-03	2.02E-04
Molybdenum	<0.1	73	6.10E-04	4.04E-05
Nickel	0.4	25 to 150[(g)]	1.22E-03	8.08E-05
Selenium	<0.1	1	1.53E-04	1.01E-05
Uranium	<0.1	15	4.27E-04	2.83E-05
Vanadium	0.1	-	2.14E-03	1.41E-04

Table 7.2-2 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – Current Permafrost Conditions

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (μg/L)[(a)]	Guideline (μg/L)[(b)]	Mass Flux (kg/year)	Concentration (μg/L)
Zinc	5.8	30	9.15E-03	6.06E-04
	Baseline (Bq/L)	Guideline (Bq/L)[(c)]	Mass Flux (Bq/year)	Concentration (Bq/L)
Radon-226	<0.005	0.5	2.06E+04	1.36E-06

NOTES:

[(a)] = Baseline, September 2008 (See Tier 3 Technical Appendix 5C)

[(b)] = Guideline, Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (1999c with updates to 2014)

[(c)] = Guideline, Health Canada Guidelines for Canadian Drinking Water Quality(2012)

[(d)] = The CCME cadmium guideline is hardness dependent, the value provided is the guideline for hardness (0 to 17 mg/L and > 280 mg/L as $CaCO_3$).

[(e)] = The CCME copper guideline is hardness dependent, the value provided is the guideline for hardness 0 to 82 mg/L and > 180 mg/L as $CaCO_3$.

[(f)] = The CCME lead guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180 mg/L as $CaCO_3$.

[(g)] = The CCME nickel guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180mg/L as $CaCO_3$.

COPC = constituents of potential concern; μg/L = micrograms per litre; kg/year = kilograms per year; Bq/L = Becquerels per litre; Bq/year = Becquerels per year; - = not applicable.

Andrew Lake Flooded Pit

The Andrew Lake open pit will be flooded after operation to permanently store, underwater, the Type 3 Andrew Lake rock material that will be temporarily stored near the pit during operation. There are two possible scenarios for flooding after closure. One scenario is to allow flooding that will occur naturally as a result of the accumulation of rain and snow melt and the small amount of seepage that may be expected to occur in the active layer near ground surface. At the expected natural filling rate, complete flooding will require approximately 480 years.

Alternatively, the natural filling of the pit can be complemented by flow from a larger water body, such as Andrew Lake, and perhaps also Judge Sissons Lake, during periods of high flow in order to shorten the flooding period. Experience has shown that while leaching of metals and other COPC can occur while rock, including pit walls, is exposed to the atmosphere and natural weathering processes, such leaching tends to be insignificant to non-measurable when the same rock is submerged below water. This difference in behaviour suggests that rapid flooding may have some advantages for maintaining good water quality at some sites. However, water quality will depend on site-specific conditions, including expected leaching rates for pit rock. Therefore, the water quality in the flooded Andrew Lake pit was evaluated at a conservative screening level in order to determine whether or not natural filling would result in acceptable water quality after flooding was complete.

The Andrew Lake pit water quality was assessed by evaluating constituent loadings originating from the pit walls, rock rubble on pit floor, and benches, pore water concentrations from the temporarily stored material, and the leaching of the relocated material as the pit fills under natural conditions, as well as under accelerated pit filling conditions. These loadings were assessed to estimate the concentrations of COPC in the pit water after the pit is filled. Although all sources of constituent loadings to the Andrew Lake pit will be eliminated as the pit fills and covers the various sources of loads with water, the pit walls above the final water level will continue to be a potential source of loadings to the pit as it remains exposed to the atmosphere and weathering conditions. Therefore, the influence of the unflooded pit walls was assessed to estimate maximum concentrations of COPC when flow out of the pit occurs and over the long term. These results provided a screening level estimate of the Andrew Lake pit water quality that will potentially exist immediately after flooding is complete and into the future after the pit overflows.

The Andrew Lake pit water quality evaluation was conducted using constituent loading rates calculated from the steady-state conditions exhibited by the humidity cell tests on the Type 3 Andrew Lake rock material. The calculated field loading rate terms for the rubble, pit walls, and mine rock material were derived from the laboratory loading rates by making adjustments for expected grain size, surface area, and/or temperature. The field loading rates for the mine rock materials were also used to estimate the pore water concentration of the temporarily stored Type 3 Andrew Lake Rock material in order to account for the loadings from the pore water or resident moisture in the material when it is relocated to the open pit. The pit water quality was then determined assuming a well-mixed waterbody for a natural filling rate, which would require approximately 480 years, and two accelerated rates, which would hypothetically require 10 and 100 years. The natural filling rate was then used to calculate the water elevation as a function of time. The unflooded area of the pit floor was calculated as a function of filling time. The results are presented graphically in Technical Appendix 5F.

The calculated Andrew Lake concentrations of COPC under the natural filling rate condition were compared to Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life. The calculated pit water concentrations will be less than the guideline values for all COPC, except for aluminum and cadmium. The estimated concentration of aluminum in pit water was 0.069 mg/L, which is greater than the 0.005 mg/L CCME guideline value. The calculated aluminum concentration is considered to be very conservative as aluminum is pH sensitive, such that the expected pit water pH will likely result in lower aluminum concentrations. The estimated cadmium pit water concentration was 0.000017 mg/L, which is less than the 0.00004 mg/L CCME guideline value associated with low hardness. The calculated cadmium concentration is also extremely conservative as the detection limit was used in the loading rate estimate because the cadmium concentration in the leachate samples from the humidity cells were almost always less than the detection limit.

The pit water quality may also be improved with accelerated pit filling. The enhanced pit filling would produce water quality better than that for the natural filling scenario because more rapid filling would result in shorter exposure times for the same rock mass or surface area creating less cumulative loadings of COPC that will mix with the same total volume of water (see Technical Appendix 5F). If natural long-term filling results produce unacceptable water quality for only two constituents, more rapid filling can produce acceptable water quality.

From a Project management perspective, the outcome of flooding the pit needs to be known before the end of the physical decommissioning period. Acceptable surface water quality in the flooded pit is a prerequisite to removing the dewatering berm in Andrew Lake and thus restoring the lake to its original state. As noted previously, the Preliminary Decommissioning (PDP; Tier 3, Technical Appendix 2R) is based on flooding the pit over six years. The analysis of water quality for an accelerated time of ten years thus provides a reasonable but conservative estimate of water quality for the PDP.

The calculated initial COPC concentrations will slowly decrease in time to the steady-state concentrations associated only with the loadings from the exposed pit walls, while the net inflow, and thus discharge, remains constant. If necessary, the pit water can be treated in-situ by pH adjustment to reduce metal concentrations to levels below guideline values. Once the pit water quality is below the guideline values the concentrations will continue to decrease to the steady-state concentrations, which are well below the CCME guidelines, thus assuring the long-term management strategy. This evaluation therefore suggests that the pit water will not represent a risk to aquatic life and can be discharged to surrounding surface water bodies without concern after closure.

7.2.2.5 Determination of Significance for Changes in Surface Water Receptor Quality

As outlined in the previous sections the assessment of potential long-term effects of groundwater and contaminant flux to surface waters from the Kiggavik TMFs and the Sissons mining area indicated minimal effects on background concentrations of constituents of concern in local lakes. As such, potential effects to surface waters are expected to fall within the range of background concentrations (i.e., low magnitude). The long-term effects are considered reversible and have negligible ecological and socio-economic implications. The potential long-term effects are, therefore, considered not significant.

7.3 Cumulative Effects Analysis for Hydrogeology

7.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to groundwater occur only within the LAA and, as described above, are not expected to be significant. Should monitoring results identify any remaining residual effects to the hydrogeology outside the LAA, these effects would have potential to overlap with other projects and activities that occur or may occur in the future, and may therefore act cumulatively on groundwater hydrogeology.

The screening for cumulative effects to groundwater was conducted to determine if cumulative effects are likely to occur. Potential cumulative effects exist if Project-related effects to groundwater overlap spatially and temporally with those of other past, present and future projects, and activities. Projects considered for cumulative environmental effects are described in Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect groundwater within the spatial (i.e., LAA) and temporal (i.e., throughout the duration of the Project effects) associated with the Project boundaries. Therefore, no cumulative effects to groundwater are predicted for the Project.

7.4 Effects of Climate Change on Project and Hydrogeology

7.4.1.1 Scenarios

The effects of climate change on the project in the short and long term will depend on the degree and rate of warming. To assess the worst case potential for the transport of COPC, a conservative approach is to consider the warming trend because of its impacts on permafrost extent. Cooling of climate is not considered here because it would not have a negative impact on the permafrost extent and only enforce the containment of material stored in the TMFs.

Two successive scenarios were considered to assess the potential effects of climate change on hydrogeology:

- The first scenario considered a warming trend over 100 years from a mean annual surface temperature of -7 °C to -2 °C (i.e. 5 degree rise in temperature). The objective of this scenario was to assess the effect of a significant warming trend on the extent of permafrost in the TMFs area.
- The second scenario, a worst case scenario, simply assumed there is no permafrost. The objective of this scenario was to predict groundwater flow conditions in a very long term scenario, where the permafrost has melted and the hydrogeological system has stabilized to a new pseudo-equilibrium state. The objectives of this model were to predict the worst

case changes in transport of solutes from tailings and mine rock in the Main, Centre, and East Pits to potential receptors.

7.4.1.2 Effect of a Warming Trend on the Local Permafrost Regime

Figure 7.4-1 shows the computed change in permafrost depth for the 5 degree warming trend. Model results (see Technical Appendix 5J) show that if the mean annual surface temperature rises, the change is manifested as a reduction in depth of permafrost at the base, and not at the surface. Figure 7.4-1 suggests that the warming trend may result in long term permafrost depths of about 90 m from surface. Therefore it is conservative to conclude that the base of all the TMF's may be exposed to a thawed state over the long term.

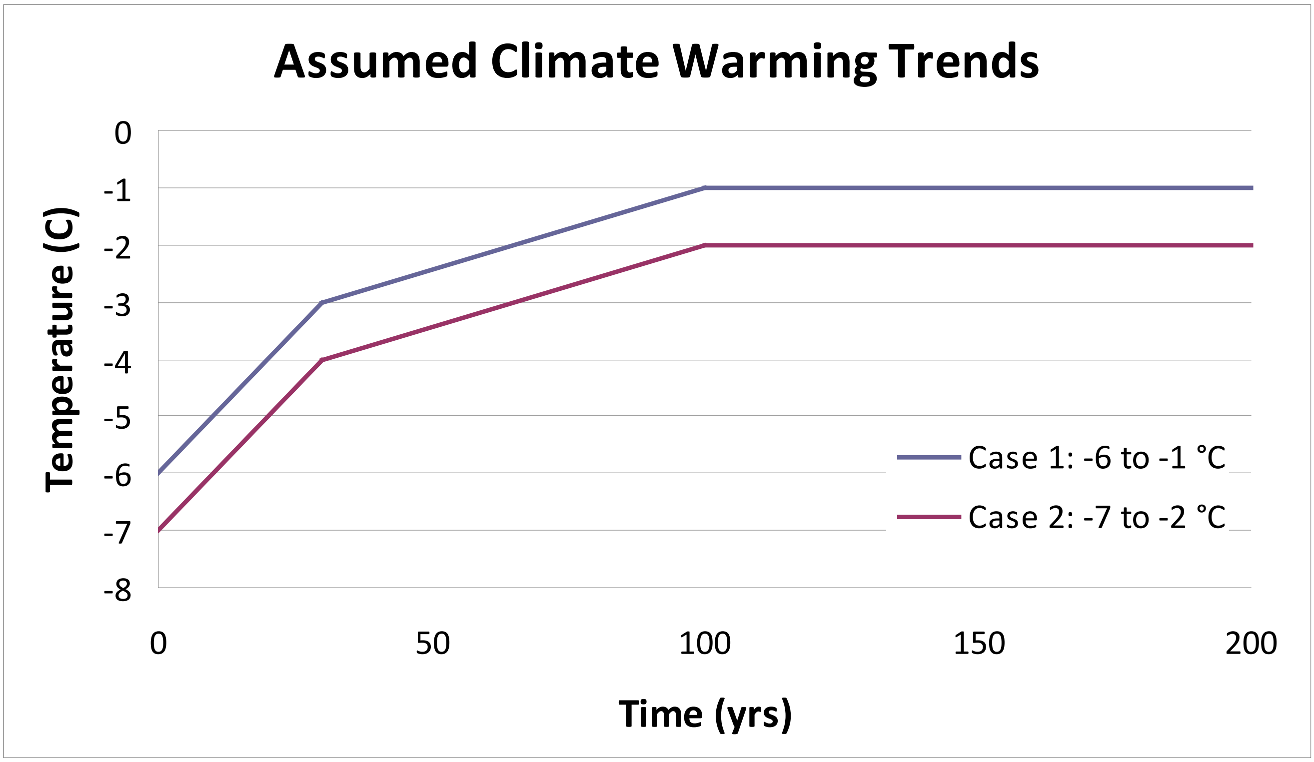
7.4.1.3 No-Permafrost Case

This scenario assumes complete melting of permafrost. With removal of the confining permafrost layer (aquitard), piezometric levels would likely equilibrate to near ground surface levels, except in low topographical locations, which would act as discharge zones for the groundwater system.

The absence of permafrost would be a fundamental change to the groundwater flow system. Surface components of the hydrological system would be in direct connection with the underlying hydrogeological flow system across the region, and not just through the open taliks. This would have a significant effect on the pressure distribution and hydraulic heads, such that flow would not be pushed in and out of taliks, but would begin to move laterally.

Hydraulic Conductivity

Under no-permafrost conditions the hydraulic conductivity distribution would change for units that were previously located in the permafrost layer.



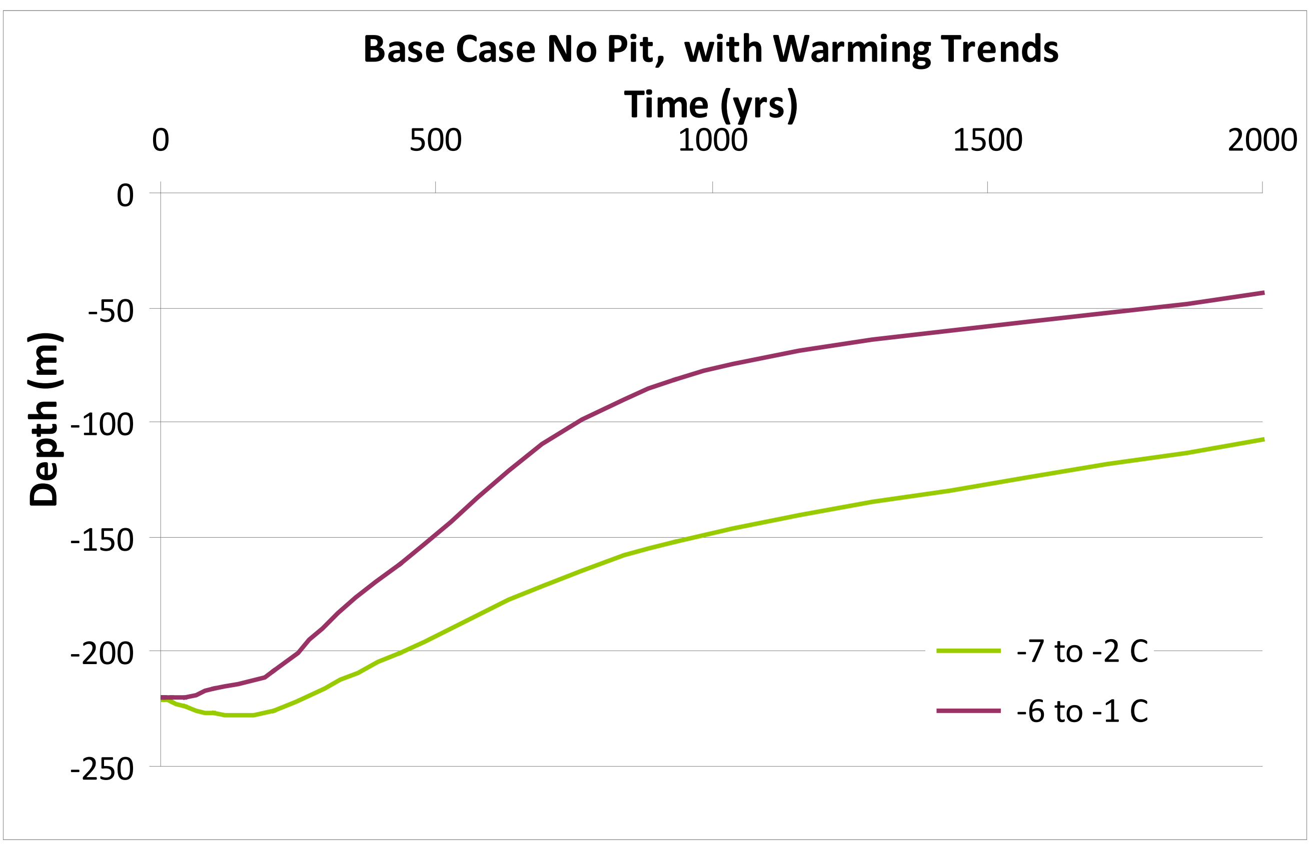


Figure 7.4-1
Natural ground permafrost degradation with climate warming

Recharge

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase, the magnitude is not expected to compensate for the increases in precipitation. Therefore, both runoff and recharge are expected to increase relative to the current permafrost conditions. However, recharge is not expected to increase as much as precipitation because the thin soils and weathering profile and the underlying low permeability bedrocks will limit the infiltration rate.

To account for the expected change in hydrology, groundwater recharge from precipitation was included as a boundary condition in the no-permafrost groundwater flow model. A maximum “reasonable” recharge rate was estimated by increasing the recharge rate in the model until the simulated hydraulic heads are equal or higher than ground surface in areas of the model located at sufficient distance from boundary conditions such as drains and lakes. This iterative process resulted in a recharge value of 15 mm/year. Any additional recharge above this value was found to cause unrealistic mounding of groundwater above ground surface.

Lakes

The location of the lakes was not changed in the no-permafrost model, assuming no geomorphic changes to ground surface. However, the following four lakes were removed from the model: Ridge Lake, Felsenmeer Lake, Escarpment Lake, and Mushroom Lake, since with thawing of the permafrost, they would likely drain into the underlying rock and become dry depressions rather than annual lake bodies. This assumption was based on the observation that the lake elevations are much higher than the surrounding groundwater head. Therefore it is reasonable to assume that these lakes may be “perched” on frozen ground.

Stream Channels

Drain boundary conditions were added along stream channels at the top surface of the no-permafrost model to prevent excessive mounding of the water table as a result of the applied recharge flux, particularly in areas away from lakes. The stream channels were simulated as drains allowing groundwater to exit the model but not recharge the model. This assumption is considered to be reasonable because the water table is close to ground surface and the drainage channels are the lowest points along topography. The drains added to the model were selected to match topographical depressions and existing channels.

Contaminant Transport Calculation

As detailed in Technical Appendix 5J, analyses for the Main Zone TMF were conducted considering the Main Zone TMF full to capacity with tailings

Under the current permafrost conditions, the flow through the tailings mass in Main Zone TMF was simulated to be 0.01 m^3/day. Flow through the tailings in Main Zone increases to 0.88 m^3/day for the no permafrost scenario. The increase is due in part to the increased hydraulic conductivity of the surrounding unfrozen rock mass. The increase is also attributable to the increased amount of surface recharge that reaches the tailings through the unfrozen cover. Under the current permafrost conditions, the Centre Zone and East Zone TMFs are located entirely within permafrost and there is virtually no groundwater flow through the tailings mass. In the no permafrost case, the calculated flow through the tailings in Centre Zone and East Zone increases to 0.32 m^3/day and 0.23 m^3/day, respectively.

Under the no-permafrost case, the pathlines originating from the TMFs also discharge in Pointer Lake. Relative to the current permafrost conditions, the breakthrough time is shortened, in the order of thousand years as opposed to million years. The key output of the contaminant transport modelling is the predicted loadings (mass flux) to surface water. Predicted long-term water concentrations of solutes in Pointer Lake were compared to baseline and to the applicable surface water quality objectives. Even under this hypothetical worst case scenario with no permafrost, Table 7.4-1 shows that all predicted concentrations are well below applicable water quality objectives and for most constituents incremental concentrations are negligible in relation to baseline concentrations. Groundwater flow and solute transport models confirm the performance of the tailings containment system and the limited interaction between tailings and natural surface water bodies, even in case of dramatic climatic change.

Table 7.4-1 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – No Permafrost Scenario

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (µg/L)[(a)]	Guideline (µg/L)[(b)]	Mass Flux (kg/year)	Concentration (µg/L)
Aluminum	21	5 to 100	2.61E-01	1.72E-02
Arsenic	0.2	5	1.04E-02	6.90E-04
Cadmium	<0.1	0.04	1.57E-03	1.03E-04
Chromium	<0.5	1 to 8.9	1.83E-01	1.21E-02
Cobalt	<0.1	-	5.22E-02	3.45E-03

Table 7.4-1 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – No Permafrost Scenario

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (µg/L)[(a)]	**Guideline (µg/L)[(b)]**	**Mass Flux (kg/year)**	**Concentration (µg/L)**
Copper	0.8	2	2.09E-01	1.38E-02
Iron	45	300	2.61E+00	1.72E-01
Lead	0.1	1 to 7	2.09E-02	1.38E-03
Manganese	2.4	-	5.22E-01	3.45E-02
Molybdenum	<0.1	73	1.04E-01	6.90E-03
Nickel	0.4	25 to 150	2.09E-01	1.38E-02
Selenium	<0.1	1	2.61E-02	1.72E-03
Uranium	<0.1	15	7.31E-02	4.83E-03
Vanadium	0.1	-	3.65E-01	2.41E-02
Zinc	5.8	30	1.57E+00	1.03E-01
	Baseline (Bq/L)	**Guideline (Bq/L)[(c)]**	**Mass Flux (Bq/year)**	**Concentration (Bq/L)**
Radium-226	<0.005	0.5	3.53E+06	2.33E-04

NOTES:

[(a)] = Baseline, September 2008 (See Technical Appendix 5C)

[(b)] = Guideline, Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (1999c with updates to 2014).

[(c)] = Guideline, Health Canada Guidelines for Canadian Drinking Water Quality(2012)

[(d)] = The CCME cadmium guideline is hardness dependent, the value provided is the guideline for hardness (0 to 17 mg/L and > 280 mg/L as $CaCO_3$).

[(e)] = The CCME copper guideline is hardness dependent, the value provided is the guideline for hardness 0 to 82 mg/L and > 180 mg/L as $CaCO_3$.

[(f)] = The CCME lead guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180 mg/L as $CaCO_3$.

[(g)] = The CCME nickel guideline is hardness dependent, the value provided is the guideline for hardness 0 to 60 mg/L and > 180mg/L as $CaCO_3$.

COPC = constituents of potential concern; µg/L = micrograms per litre; kg/year = kilograms per year; Bq/L = Becquerels per litre; Bq/year = Becquerels per year; - = not applicable; < = less than.

7.5 Summary of Residual Effects on Hydrogeology

Effects on hydrogeology, groundwater and surface water receptors where groundwater discharges resulting from Project activities are expected to be low, for both current permafrost conditions and potential no-permafrost conditions that would result from dramatic warming conditions.

Given the project design features and the low hydraulic conductivity of the rock mass, all project effects on hydrogeology are predicted to be not significant.

7.6 Cumulative Effects

Activities associated with the Project are not expected to contribute to cumulative effects on hydrogeology and groundwater.

7.7 Compliance and Environmental Monitoring for Hydrogeology

Monitoring of hydrogeological effects can be completed through the collection of specific data at waterbodies potentially affected by project activities (i.e., End Grid Lake, Mushroom Lake and Pointer Lake) in a manner consistent with monitoring for changes in surface hydrology (see section 6.2.1.6).

Water quality in lakes and streams adjacent to and downstream of the Kiggavik and Sissons mine sites will be monitored during the spring freshet each year during the operational life of the Project to confirm that COPC do not increase as a result of tailings management of mine rock management activities.

In addition a groundwater monitoring program will be implemented. The program will consist of an array of monitoring points to track changes in ground temperature, pressure gradients (flow direction) and water quality in the deep, sub-permafrost, groundwater flow regime. The proposed monitoring system will be phased in as the project moves from planning and design, through operations, and finally into closure. Groundwater pressures and chemistry will be established in the rock mass surrounding the proposed TMF prior to excavation of the pits, and then monitored as the excavation base penetrates the permafrost base and as the pit is filled with tailings material. This will require an increasing array of monitoring points in order to detect changes brought about by the mining activities.

Contingency plans are intended to address unforeseen circumstances which could result in a significant increase in the mass flux of solutes to the receptors. Extensive investigations into the chemical and physical properties of tailings has been undertaken at Kiggavik and will continue to be undertaken as part of a Tailings Optimization and Validation Program (TOVP), similar to the program that was initiated at McClean Lake Operation and has been a successful audit program for the behaviour of the tailing produced at that site in Northern Saskatchewan.

8 Assessment of Project Effects on Water Quality

8.1 Scope of the Assessment for Water Quality

The Nunavut Impact Review Board (NIRB) Guidelines for the Kiggavik Project (the Project) (NIRB, 2011) identify water quality as a Valued Environmental Component (VEC). The scope of the assessment for water quality focuses on the physical and chemical characteristics of water quality, as well as its value as a critical component in the maintenance of healthy aquatic ecosystems. Thus, water quality is a VEC in its own right, as well as being crucial to the functioning and maintenance of other aquatic VECs such as aquatic plants, fish habitat, and fish populations. Water quality is also an important attribute of waters that may be used as a supply of drinking water for humans and wildlife. Maintaining suitable water quality for wildlife, fish and humans was a theme identified during many engagement conversations (EN-KIV OH 2009[133]; EN-RI RLC 2009[134]; EN-RI COC 2013[135]; EN-BL CLC 2009[136]; EN-BL NIRB 2010[137]; EN-BL OH 2012[138]).

Refer to Section 4.1 for a discussion of issues and concerns raised during Inuit Qaujimajatuqangit (IQ) interviews and engagement initiatives.

Refer to Section 4.1.1 for a description of the influence of IQ and engagement data on the water quality assessment.

[133] EN-KIV OH 2009: *How will uranium affect our water, fish, etc.?*
[134] EN-RI RLC 2009: *Can you take radiation out of water?*
[135] EN-RI COC 2013: *Will there be affects on water?*
[136] EN-BL CLC 2009: *What will happen with water from wasterock?*
[137] EN-BL NIRB 2010: *Concerns over not being allowed to drink water from the lake.*
[138] EN-BL OH 2012:*If this project is to get up and running, there is a river that flows into Baker Lake and there are small ponds around Kiggavik. My concern is how water will be treated around the area.*

8.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement activities and IQ interviews (e.g., EN-BL HTO 2009[139]; IQ-RIHT 2009[140], EN-CI NIRB 2010[141]; EN-RI OH 2010[142][143]; EN-CI OH Nov 2013[144] , EN-RB OH 2010[145][146])to identify Project activities that have potential to interact with the freshwater aquatic environment (Section 4, Table 4.4-1). Project components and activities listed in Table 4.4-1 (Section 4) that are not expected to interact with water quality were given a ranking of 0 (zero). Interactions between the Project and water quality that are likely to be removed by environmental design features and mitigation measures were also given a 0 ranking. Category 0 interactions have been omitted from Table 8.1-1; no further discussion of these interactions is provided in this section. Project activities that have the potential to interact with surface water quality by affecting its physical or chemical makeup are listed in Table 8.1-1. Interactions that were ranked Category 1 or 2 are included in the table. The rationale for ranking interactions as Category 1 is presented below. Those interactions ranked as Category 2 are discussed in more detail in the following sections.

Table 8.1-1 Project – Environment Interactions and Effects – Water Quality

Project Phase	Project Activities/Physical Works	Change in Water Quality
Construction:		
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	1
	Construct/install in-water/shoreline structures	1
	Water transfers and discharge	1
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing)	1

[139] EN-BL HTO 2009: *I'm concerned about how far the buildings and the pits are from each other. I think you should have had a legend. I see a lot of creeks here and we don't know where they run to, how are we going to protect them? There is a slope to the deposits and what if wastes flow into the water surrounding the area?*
[140] IQ-RIHT 2009: *Participants in the Rankin Inlet focus groups were also concerned about the potential for contaminants to be spread through the water.*
[141] EN-CI NIRB 2010: *Concerns over the safety of storing tailings underground. How do we know the models/technology (southern models) that will be used will work in the arctic and in the permafrost? How do they know the tailings will be safe underground and there will not be any spills? Concerns over the potential impacts from the tailings (leaching/spills) to Baker Lake and eventually to Chesterfield Inlet.*
[142] EN-RI OH 2010: *What will you do with all the water during the high spring melt? Rock piles and tailings pit. North is different from south and there will be more snow piling up and spring runoff will create more contamination.*
[143] EN-RI OH 2010: *Will water from the ore pile be contained?*
[144] EN-CI OH Nov 2013*: If AREVA opens, my concern is that the water released will travel to Baker Lake and the dust in the air will affect the animals and the people.*
[145] EN-RB OH 2010:*Can you drink this water in TMF?*
[146] EN-RB OH 2010: *Would water flow through the tailings? So you're saying the water will flow around the tailings?*

Table 8.1-1 Project – Environment Interactions and Effects – Water Quality

Project Phase	Project Activities/Physical Works	Change in Water Quality
Operation		
Mining	Mining ore (blasting, loading, hauling)	2
	Mining special waste (blasting, loading, hauling)	2
	Mining clean waste (blasting, loading, hauling)	2
	Mine dewatering	1
Water Management	Collection of site and stockpile drainage	1
	Water and sewage treatment	1
	Discharge of treated effluents (including greywater)	2
	Disposal of sewage sludge	1
Transportation	Marine transportation	1
	Truck transportation	2
	General traffic (Project-related)	2
Final Closure		
General	Ongoing withdrawal, treatment and release of water, including sewage	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	1
	Remove surface drainage containment	1
	Remove in-water/shoreline structures	1
	Water transfers and discharge	1
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1

NOTES:

Category 1 activities are those having an interaction with water quality that is likely to result in a minor environmental change, but a negligible residual effect on a Valued Component (VC) relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects of other existing or reasonably forseeable projects. As noted in the following section, screening of these Project interactions indicates that Project effects will be minimal and no further assessment is warranted.

Category 2 activities are those activities that do interact with water quality and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned mitigation. Further assessment of the effects of these interactions on water quality is warranted and is presented in this environmental assessment report.

Construction

Construction of Freshwater Diversions and Site Drainage Containment Systems; Site Clearing and Pad Construction

During the Project construction phase, land clearing and earth moving will be carried out to prepare areas for mine and mill site infrastructure development. This work will include diverting existing surface drainage systems, as well as excavating mine pits and pads for storage of mine rock and ore. Soil disturbance will also occur as a component of developing other mine infrastructure such as the ore haul road between the Kiggavik and Sissons Mine Sites, the access roads to the water intake locations and effluent discharge point, and the airstrip. All Project activities involving land clearing or earth movement have the potential to increase surface water runoff and cause soil erosion into adjacent waterbodies. To reduce these effects, best management practices (BMPs) have been incorporated into the Project design to control surface water runoff and minimize the potential for erosion. Tier 3, Technical Appendix 5O includes a listing of BMPs that may be implemented to minimize the potential for erosion and the transfer of soil and/or sediment to surface waterbodies. To minimize changes in water quality that could result from inter-basin transfer of diverted water, watercourses diverted away from the mine site development areas will be reconnected to the same drainage system, but at a location downstream of the mine site. This will also minimize contact between Project components and nearby streams. Diversion channels will also incorporate sedimentation ponds to settle any suspended sediments prior to release back into the environment. The site Water Management Plan (Tier 3, Volume 2, Appendix 2I) provides consolidated information on water management strategies for intercepting, collecting, containing, and monitoring potentially contaminated water from the site, to manage site runoff and mitigate effects on the aquatic environment.Because no long term or large-scale changes to surface water quality are anticipated, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

Final-closure

Removal of Freshwater Diversions and Site Drainage Containment Systems; Pad Removal

Surface water runoff and erosion effects at Project closure are expected to be similar to those described for the Project construction period. No long term or large-scale changes to surface water quality are anticipated; therefore, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

Construction

Construction of In-Water/Shoreline Structures

In-water structures that will be installed during the construction phase of the Project include:

- water intake structures and connecting water intake lines in Mushroom and Siamese Lakes;
- effluent diffuser structures and effluent discharge lines in Judge Sissons Lake;
- culverts and bridges, as well as an optional ferry landing apron on the Thelon River; and
- the temporary spud barge dock in Baker Lake.

These structures are likely to result in some disturbance to the lake bottom and/or stream sediments with accompanying increases in turbidity and total suspended solids (TSS) levels in the water. Similar effects are also expected during the Project final-closure phase when the water intake structures, effluent diffuser structures, stream-crossing structures and temporary spud barge dock are removed.

Turbidity and TSS released during the installation of the water intake structures and connecting water intake lines, effluent diffuser structures and effluent discharge lines, road crossing structures, and temporary spud barge dock will be kept to acceptable levels by using a turbidity curtain, where required, to separate the installation/construction activities from the surrounding lake or stream environment. Refer to Tier 3, Technical Appendix 5O, Section 2 for Project activities identified as requiring an erosion and sediment control plan and/or monitoring during construction, operations and decommissioning phases. The mitigation measures and monitoring activities provided in this document provide a conceptual basis; some combination of best management practices identified for each activity group will be used to mitigate changes in water quality from activities in and around water.

Water quality near the construction activity will be monitored during installation of the in-water structures (e.g., water intakes, effluent diffusers and the spud barge dock), and preventative actions taken if turbidity/TSS levels approach a pre-determined threshold. If turbidity readings were to exceed the threshold level, all construction activities would stop until a more effective construction method could be instituted. Because these interactions are limited in areal extent, are of short duration, can be mitigated by use of a turbidity curtain, and will be monitored closely, they are ranked as Category 1 interactions and are not carried forward to the detailed analysis of residual effects.

Final closure

Removal of In-Water/Shoreline Structures

Removal of water intake structures and connecting water intake lines, effluent diffuser structures and effluent discharge lines, road crossing structures, and the spud barge dock in Baker Lake will result in similar disturbances to lake bottom and stream sediments and surrounding water quality as resulted during construction and installation of the in-water structures. However, the disturbance effects are likely to be of smaller magnitude and shorter duration than those associated with the construction and installation of the in-water/shoreline structures. The anticipated Project-environment interactions will be limited in areal extent and will be of short duration. Because in-water structure removal can be effectively mitigated using turbidity curtains and turbidity monitoring during the removal process (Tier 3, Appendix 5O, Section 2.8), this activity is ranked as a Category 1 interaction and is not carried forward to the detailed analysis of residual effects.

Construction

Water Transfers and Discharge

In order to begin development of the Andrew Lake Pit, a dyke will be constructed across the east end of Andrew Lake and that portion of Andrew Lake dewatered. Construction of the dyke and dewatering the east section of Andrew Lake will result in increased turbidity and TSS levels in the water. The increases in turbidity/TSS released to the downstream environment will be maintained within acceptable levels by using a turbidity curtain to separate the dyke construction activity from the larger western portion of Andrew Lake. Refer to Tier 3, Technical Appendix 5O Section 2.9 for a discussion of the conceptual erosion and sediment control plan and associated best management practices for Andrew Lake Pit and Berm construction. Water quality will be monitored during dyke construction and actions taken if turbidity/TSS levels approach an unacceptable, pre-determined threshold. If turbidity readings exceed the threshold level, all construction activities will stop until a more effective construction method can be instituted.

Following dyke construction, the east portion of Andrew Lake will be dewatered by pumping it into the larger, remaining portion of Andrew Lake. Pumping will only take place once turbidity levels in that portion of the lake have fallen below the established threshold level. If turbidity levels are too high to allow discharge into the downstream environment, the water will be treated at the WTP. Because water quality effects on the downstream environment will be small in magnitude and short lived in duration, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

Final closure

Water Transfers and Discharge

During the final closure phase, the water will be pumped from Judge Sissons Lake to flood the Andrew Lake Pit. Pumping is expected to completely fill the pit in four years if pumping takes place at a rate of 1 cubic metre per second (m^3/second) during the open water period each year (mid-June through mid-September). This rate of pumping (1 m^3/sec) represents less than 3 percent (%) of the average annual peak flow. Once the Andrew Lake Pit is full, the water quality of the pit water will be assessed. If the water quality meets surface water quality objectives (i.e., the Saskatchewan Surface Water Quality Objectives [SSWQOs] and Canadian Water Quality Guidelines [CWQG]), then the dyke separating the Andrew Lake Pit and Andrew Lake could be breached to reconnect the two water bodies. If Andrew Lake Pit water quality does not meet SSWQO and CWQG, then the dyke separating the two waterbodies will be maintained. Because there will be no water quality effects on the downstream environment (the Andrew Lake drainage system), this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

Operation

Marine Transport

Marine vessels (i.e., barges) will be used to transport mill reagents, fuel and other supplies to the dock facility in Baker Lake (Tier 2, Volume 7). Marine transport activities that will occur on Baker Lake include barge movement and positioning, docking, off-loading, and uptake of ballast water. As a transport vessel moves within Baker Lake, it may produce vessel wake (i.e., vessel movement that creates secondary waves). Because vessel wake may result in increased wave activity along the shoreline of the lake, it is possible that some shoreline erosion may occur, thereby increasing sediment releases to surrounding water. However, any increases in TSS are expected to be small in magnitude, shore-lived in duration and intermittent due to the infrequent nature of shipping activities. It is estimated that a maximum of 31 barge deliveries to the Baker Lake dock site will occur over the approximately 60 day open-water shipping period (Tier 2, Volume 7).

Operation of marine vessels will be in compliance with standard management practices (e.g., *Canada Shipping Act, 2001).* Consideration of accidents and manfunctions associated with marine transportation (e.g. fuel spill) is provided in Tier 2, Volume 10 Accidents and Malfunctions and associated appendices, e.g. Tier 3, Volume 10B Spill Contingency and Landfarm Management Plan and Tier 3, Technical Appendix 2J Marine Transportation.

Following off-loading, barges may need to take on ballast water before travelling back to Hudson Bay. Because ballast water uptake, rather than water release, will occur in Baker Lake, it is not anticipated that significant volumes of marine water will be introduced into Baker Lake. Refer to

Tier 2, Volume 7, Section 4.3.1.2 for a discussion of ballast water as it related to non-indigenous and invasive species. Residual effects to surface water quality in Baker Lake from marine transport activities are expected to be within acceptable levels. Therefore, this interaction is ranked as a Category 1, and is not carried through the assessment. Because no significant residual effects to water quality are expected, effects of Marine Transport on sediment quality, aquatic biota, fish habitat and fish in Baker Lake will be negligible, and are therefore considered "Category 0" interactions throughout the remainder of Tier 2, Volume 5.

Mining Ore; Mining Mine Rock; Truck Transportation; General Project-Related Traffic

Air emissions and dust deposition from vehicle and heavy equipment operation, and from blasting, loading, and hauling mine ore and mine rock during the operations phase of the Project has the potential to affect surface water quality. Minor changes in TSS are anticipated from the deposition of dust that settles on LAA vegetation in summer and fall, and snow in winter, being carried into lakes and streams along with spring snowmelt.

Although increases in TSS are expected to be small in magnitude and short lived in duration, this project-environment interaction is being carried forward for more detailed analysis to confirm whether there will be residual effects on water quality. In addition, components in wind-borne dust and air emissions from mining have the potential to acidify poorly buffered Arctic surface waters. Because air emission and dust deposition may interact with the aquatic environment, and the resulting effect may exceed acceptable levels without implementation of specified mitigation, further assessment of the potential effects of these interactions on water quality is warranted.

The environmental assessment of potential changes in water quality related to dust deposition is presented in Section 8.2.2.

The environmental assessment of potential changes in water quality related to acid deposition is presented in Section 8.2.3.

Operation

Mine Dewatering; Collection of Site and Stockpile Drainage; Water and Sewage Treatment

Water removed from the pits and underground mine workings, as well as water collected from site and stockpile drainage, will be used in the mill as process water, or sent to the Kiggavik or Sissons WTP and processed to meet required standards before being released to the environment. Domestic sewage will also be treated to meet required standards before being released to the environment. The Waste Water Systems Effluent Regulations will be used as guidance to establish the criteria, monitoring methods, volumes, parameters tested, and quality assurance/quality control (QA/QC) requirements at sewage discharge locations.

A screening calculation was completed to consider sewage discharge to Judge Sissons Lake (JSL-2 compartment) during the summer months. The bounding scenario considered the construction phase of the Project and assumed that 750 workers would be present, generating 0.2 m^3 sewage per day per person. It was assumed that treated sewage is held within a lagoon during the winter and discharged during the open water season; therefore, seven months of sewage effluent was conservatively assumed to be released during a one month period, along with the one months of sewage generated during this period. The sewage effluent was considered to be diluted within the summer volume of JSL-2 and the average clean water daily inflow during the summer months. There is a dilution factor of 1:568 between the assumed sewage release and JSL-2, and the estimated concentrations of ammonia, TSS, BOD5 (the amount of oxygen consumed by the biological oxidation of the waste contaminants in 5 days), and phosophorus are below applicable water quality objectives. Overall the treated sewage effluent plant release to Judge Sissons Lake is not expected to affect the quality of the lake.

Because no mine water, site and stockpile drainage waters, or sewage wastes will be released to the environment without having been treated, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

Operation

Discharge of Treated Effluents

Effluent and waste water entering the environment were identified as concerns during public engagement (EN-KIV OH 2009[147]; EN-RI OH 2010[148]; EN-RB KIA 2007[149]). Treated effluent discharge from the Kiggavik and Sissons WTP may affect surface water quality. The potential change in the concentrations of water quality constituents due to effluent release from the WTP will be examined. The particular focus is on treated effluent discharges to Judge Sissons Lake for the extended 25 year operating period.

Because the treated effluent discharge may interact with the aquatic environment, and the resulting effect may exceed acceptable levels, further assessment of the potential effects of these interactions on water quality is warranted. The environmental assessment of changes in water quality due to effluent discharge is presented in Section 8.2.1.

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[147] EN-KIV OH 2009: *What about water pollution?*
[148] EN-RI OH 2010: *Will water from the ore pile be contained?*
[149] EN-RB KIA 2007: *Would water flow through the tailings? So you're saying the water will flow around the tailings?*

Final closure

Discharge of Treated Effluents

During the final closure phase of the Project, there will be an ongoing requirement for water withdrawal, and effluent treatment and discharge (including sewage and greywater). The quality of site drainage and runoff waters will necessitate treatment before it can be discharged to the environment. Water treatment may be required for a number of years before the quality of untreated site drainage and runoff reaches a level where it can be allowed to flow directly into natural receiving waters. The environmental assessment of changes in water quality due to treated effluent discharge is presented in Section 8.2.1.

8.1.2 Indicators and Measurable Parameters

In assessing Project effects on surface water quality, four measurable parameters were selected:

1. physical properties of water such as temperature and concentrations of TSS;
2. major ions and nutrient concentrations;
3. total and dissolved metals concentrations; and
4. concentrations of radionuclides (Table 8.1-2).

Changes in any of these measurable parameters provide a direct method of quantifying project effects on water quality. Sufficient baseline water quality information is available for lakes in the LAA to confidently estimate potential effects through these measurable parameters.

Table 8.1-2 Measurable Parameters for Water Quality

Environmental Effect	Measurable Parameter	Notes or Rationale for Selection of the Measurable Parameter
Change in Water Quality	• Physical properties (e.g., temperature, turbidity/TSS) • Major ions and nutrients • Total and dissolved metals • Radionuclides	The physical properties of water (e.g., temperature, TSS/turbidity), and major ion, nutrient, total and dissolved metals, and radionuclide concentrations strongly influence the abundance and distribution of aquatic biota and fish in the receiving environment.

8.1.3 Residual Environmental Effects Criteria

General descriptions of residual environmental effects criteria are presented in Section 4.6 and apply to effects on water quality. However, more specific descriptions apply to the magnitude of residual environmental effects for water quality.

For some water quality parameters, magnitude is defined as the amount of change in a parameter relative to the natural range of variability found in the undisturbed existing environment baseline (e.g., temperature, turbidity measurements). Thus, a high magnitude is defined as a change in water temperature relative to background levels, of more than 5°C. Changes in water temperature greater than 5°C can influence the timing of fish spawning migrations, and affect the vigour and health of juvenile fish and other aquatic biota. A medium magnitude change in water temperature would be in the order of 3 or 4°C. Changes in water temperature less than 3°C would be considered to be small in magnitude.

Based on the Newcombe and Jensen (1996) model's predicted effects on adult salmonids including Arctic grayling TSS, levels that exceed 148 mg/L would be considered to be of high magnitude. TSS levels between 55 and 148 mg/L are considered to be moderate in magnitude. TSS levels below 55 mg/L are considered to be of low magnitude. For other water quality parameters (e.g., metals), magnitude is defined by whether measured values exceed a threshold value such as those contained in the Canadian Council of Ministers of the Environment's (CCME) Canadian Water Quality Guidelines (CWQG)..

8.1.4 Standards or Thresholds for Determining Significance

The significance of changes in water quality parameters is determined by the user of the water resource. Thus, the determination of significance of changes to water quality, should they occur, is included in the evaluation of effects on vegetation, wildlife, aquatic resources, human and ecological health, land use and traditional land use. The effects of the Project on water quality are assessed in terms of their consequence, evaluated by comparing measured values with established water quality guidelines. Table 8.1-3 provides a summary of the water quality guidelines used in the assessment. These values were obtained from the CCME and are based on the protection of aquatic life; the impact of water quality on human health (i.e., via drinking water) is assessed in Volume 8. A low consequence is one in which the changes to water quality are not expected to affect water users. A high consequence is one in which the changes are expected to affect users.

Table 8.1-3 Summary of Water Quality Guidelines Used in Assessment

Constituent	Units	Value	Source
Arsenic	µg/L	5	CWQG
Cadmium	µg/L	0.04 - 0.37	CWQG –0.04 ug/L at hardness between 0 and 17 mg/L; at hardness between 17 mg/L and 280 mg/L = $10^{\{0.83(\log[hardness]) - 2.46\}}$; 0.37 ug/L at hardness greater than 280 mg/L
Cobalt	µg/L	4	BCMOE BCWQG
Copper	µg/L	2-4	CWQG - 2 ug/L at hardness between 0 and 82 mg/L; at hardness between 82 mg/L and 180 mg/L = 0.2 x $e^{\{0.8545(\ln[hardness]) - 1.465\}}$; 4 ug/L at hardness greater than 180 mg/L
Lead	µg/L	1-7	CWQG - 1 ug/L at hardness between 0 and 60 mg/L; at hardness between 60 mg/L and 180 mg/L = $e^{\{1.273(\ln[hardness]) - 4.705\}}$; 7 ug/L at hardness greater than 180 mg/L
Molybdenum	µg/L	73	CWQG
Nickel	µg/L	25-150	CWQG: 25 ug/L at hardness between 0 and 60 mg/L; at hardness between 60 mg/L and 180 mg/L = $e^{\{0.76(\ln[hardness]) - 1.06\}}$; 150 ug/L at hardness greater than 180 mg/L
Selenium	µg/L	1	CWQG
Uranium	µg/L	15	CWQG
Zinc	µg/L	30	CWQG
Ammonia (un-ionized)	mg/L	0.019	CWQG
Chloride	mg/L	120	CWQG
Sulphate	mg/L	128 218 309	BCMOE - BCWQG for very soft water (0-30 mg/L) BCMOE - BCWQG for soft water (31-75 mg/L) BCMOE - BCWQG for moderate water (76-180 mg/L)
TDS	mg/L	500	CDWQG
Hardness	mg/L	-	
Thorium-230	Bq/L	0.6	CDWQG (Appendix A, Health Canada 2010a)
Radium-226	Bq/L	0.11	Historical SSWQO, retained in absence of other guidelines
Lead-210	Bq/L	0.2	CDWQG
Polonium-210	Bq/L	0.1	CDWQG (Appendix A, Health Canada 2010a)

NOTES:

For those constituents of potential concern (COPC) with no water quality objective, an assessment of the potential effect is made based on the change from baseline as well as comparison to values that are protective of aquatic biota (see Sections 10 and 11).

Bq/L = Becquerel per litre; $CaCO_3$ = calcium carbonate; CWQG = Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME 1999c with updates to 2014) CCME = Canadian Council of Ministers of the Environment; CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); BC MOE = British Columbia Ministry of Environment (2013); µg/L = micrograms per litre; mg/L = milligrams per litre; SSWQO = Saskatchewan Surface Water Quality Objective for the Protection of Aquatic Life (WSA 2006); TDS = total dissolved solids

8.2 Effects Assessment for Water Quality

The effect of the Project on the Water Quality VEC is the initiation of changes in water quality. This effect is assessed in the following section.

8.2.1 Assessment of Changes in Water Quality Due to Effluent Discharge

The potential change in water concentrations due to effluent release from the WTP will be examined. The particular focus is on Judge Sissons Lake. Effluent, runoff, and mine water treatment, containment and potential contamination of surface water were concerns identified during public engagement sessions and IQ interviews (IQ-RIHT 2009[150] EN-KIV OH Oct 2009[151]; EN-BL NIRB April 2010[152] EN-BL OH 2012[153]).).

A detailed assessment of the potential changes to contaminant levels in the receiving environment was undertaken as outlined in the following sections and detailed in Tier 3, Technical Appendix 8A. In addition, consideration was given to the potential for a temperature change due to the effluent discharge and the effect on aquatic biota. The effluent at both the Sissons site and Kiggavik location discharge year-round near the bottom of the lake with diffusers. The effluent is release to a holding pond where it is stored for 24-36 hours before being released. Adverse effects from temperature changes are a function of both the dose (i.e. exposure temperature), and the length of time the aquatic organism is exposed. Because of the holding times (24-36 hours), the ΔT value (which represents the extent to which the temperature in the plume exceeds the ambient temperature) is expected to be low, and the plume is likely very small based on a diffuser design. Furthermore, since the discharge temperature is not continuous, no significant impact on aquatic life is expected.

8.2.1.1 Analytical Methods for Changes in Water Quality Due to Effluent Discharge

Treated effluent discharge from the Kiggavik and Sissons (WTP) may affect surface water quality. Parameters in water that were identified as constituents of potential concern (COPC) include: ammonia, chloride, sulphate, radionuclides (uranium-238, thorium-230, radium-226, lead-210, and polonium-210), and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). Constituents, such as aluminum, chromium, iron, mercury, and silver, were observed at elevated levels in the receiving environment; however, these constituents were not selected as COPC for the assessment because the assessment is related to the potential impacts on

[150] IQ-RIHT 2009*: Participants in the Rankin Inlet focus groups were also concerned about the potential for contaminants to be spread through the water.*
[151] EN-KIV OH Oct 2009: *What about water pollution?*
[152] EN-BL NIRB April 2010: *Will there be contaminants in the lakes?*
[153] EN-BL OH 2012: *If the project proceeds, there is a river that flows to the Baker Lake area. The project has small ponds around it. My concerns are with the water treatment around the area, and how the lakes and ponds are treated and assessed. Thank you if there is a big turnout for employment.*

the receiving environment from Project releases and if the chemicals are not related to the Project, it is not necessary to consider them in the assessment. The natural thorium decay chain (Th-228, etc.) was looked at and found not to be an issue for this site. The levels of thorium measured in samples collected from the ore and waste rock from the site are within typical background levels and do not show any association with the ore. As the dose criteria are based on the incremental exposure from the project it is not necessary to include radionuclides that are not associated with the Kiggavik operations and thus the natural thorium series was not included.

Detailed modelling of concentration of these COPC in the receiving environment, Judge Sissons Lake (JSL), was completed using the LAKEVIEW model.

The LAKEVIEW dispersion model has been applied to several uranium mining projects in northern Saskatchewan to simulate constituent transport and concentrations in the aquatic environment. For application at the Kiggavik Project, the LAKEVIEW model was modified to simulate the effects of extensive ice cover on Judge Sissons Lake (on the order of 2 m thick) as well as the effects of prolonged periods (up to 8 months in any year) with no flow. Important processes incorporated into the LAKEVIEW model include horizontal (lateral) and vertical transport of dissolved species, chemical and biochemical reactions in the sediment and in the water column, settling of particulate matter, and sediment exchange processes. LAKEVIEW incorporates a detailed computational protocol for estimating the flux of dissolved chemical species in and out of the sediment together with chemical reactions (reduction or oxidation) and solid phase and solid solution partitioning along with conventional sorption equilibrium. A detailed description of the LAKEVIEW module and its application to the Kiggavik Project is provided in Tier 3, Technical Appendix 8A.

Where possible, site-specific data or data reported for similar environments (e.g. northern Saskatchewan) were used to characterize inputs to the LAKEVIEW model. These inputs include baseline water and sediment quality in the Kiggavik Project area and water-to-sediment distribution coefficients for estimation of constituent concentrations in sediment resulting from changes in concentrations in the water column of affected waterbodies.

Although different discharge locations and duration of release were examined, the bounding scenario carried through the assessment was based on separate discharges from the Kiggavik WTP and Sissons WTP, an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required. This scenario was selected primarily because it has discharge to two separate locations (Kiggavik WTP to segment JSL-2 and Sissons WTP to JSL-8, Figure 8.2-5) and therefore, the risks associated with this scenario are considered to be representative or conservative of any of the options that may be selected. This scenario represents the most probable plan with respect to discharge locations. It was illustrated (Tier 3, Technical Appendix 8A) that differences in COPC concentrations between the scenarios considered were sufficiently small that they are within the range of model accuracy. The assessment accounted for the uncertainty and variability in the emissions and the behaviour in the environment.

Tables 8.2-1 through 8.2-3 summarize the water quality distributions assumed to characterize the Kiggavik WTP, Sissons WTP, and Kiggavik Reverse Osmosis (RO) effluent, respectively. Figures 8.2-1 through 8.2-3 present the assumed monthly flows for the selected bounding scenario.

Table 8.2-1 Effluent Concentration Distributions for Kiggavik WTP Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean[(a)]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.002	2.24	0.0002	0.02
Thorium-230	0.011	2.05	0.0013	0.10
Lead-210	0.052	1.54	0.014	0.19
Radium-226	0.008	2.53	0.0005	0.13
Polonium-210	0.007	2.10	0.0007	0.06
Arsenic	0.021	1.76	0.004	0.11
Cadmium	0.007	1.44	0.0023	0.02
Cobalt	0.007	2.12	0.0007	0.07
Copper	0.002	2.41	0.0001	0.02
Lead	0.002	2.63	0.0001	0.04
Molybdenum	0.2	1.75	0.038	1.1
Nickel	0.02	1.57	0.005	0.08
Selenium	0.01	1.28	0.0047	0.02
Zinc	0.003	2.06	0.0003	0.03
Ammonia	17.3	1.36	6.9	44
Calcium	470	1.29	219	1010
Chloride	237	1.49	71	792
Sulphate	2199	1.29	1027	4708
TDS[c]	3115	1.31	1373	7068

NOTES:

[a] Geometric means from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

[b] GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

[c] TDS calculated as the sum of the anions and cations (as available).

GSD = geometric standard deviation; COPC = constituent of potential concern; mg/L = milligrams per litre; Bq/L = Becquerels per litre; TDS = total dissolved solids

Table 8.2-2 Effluent Concentration Distributions for Sissons WTP Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean[(a)]	Geometric Standard Deviation[(b)]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.034	2.24	0.003	0.38
Thorium-230	0.19	2.05	0.022	1.64
Lead-210	0.59	1.54	0.16	2.17
Radium-226	0.10	2.53	0.006	1.62
Polonium-210	0.17	2.10	0.018	1.58
Arsenic	0.018	1.76	0.003	0.10
Cadmium	0.0001	1.44	0.00004	0.0004
Cobalt	0.0003	2.12	0.00003	0.003
Copper	0.001	2.41	0.00007	0.014
Lead	0.0005	2.63	0.00003	0.009
Molybdenum	0.085	1.75	0.016	0.46
Nickel	0.001	1.57	0.0003	0.005
Selenium	0.004	1.28	0.002	0.008
Zinc	0.014	2.06	0.002	0.12
Ammonia	3.1	1.36	1.24	7.86
Calcium	336	1.29	157	721
Chloride	846.6	1.49	254	2825
Sulphate	167.0	1.29	78	357
TDS[c]	1528	1.31	673	3466

NOTES

[a] – Geometric means from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

[b] – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

[c] – TDS calculated as the sum of the anions and cations (as available).GSD = geometric standard deviation; COPC = constituent of potential concern; mg/L = milligrams per litre; Bq/L = Becquerels per litre.

Table 8.2-3 Effluent Concentration Distributions for Kiggavik RO Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean[(a)]	Geometric Standard Deviation[(b)]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.0003	2.25	0.00003	0.003
Thorium-230	0.002	2.05	0.0002	0.02
Lead-210	0.005	1.54	0.001	0.02
Radium-226	0.013	2.42	0.0009	0.19
Polonium-210	0.002	2.10	0.0002	0.02
Arsenic	0.001	1.60	0.00025	0.00
Cadmium	0.0003	1.44	0.0001	0.001
Cobalt	0.0003	2.12	0.0000	0.003
Copper	0.0004	2.04	0.00005	0.003
Lead	0.0002	2.63	0.00001	0.004
Molybdenum	0.03	1.69	0.006	0.13
Nickel	0.001	2.31	0.0001	0.01
Selenium	0.001	2.42	0.000071	0.0142
Zinc	0.0001	2.28	0.00001	0.001
Ammonia	1.11	1.63	0.254	4.84
Calcium	1.06	1.29	0.494	2.28
Chloride	1.0	1.49	0.300	3.34
Sulphate	5.2	1.29	2.4	11.2
TDS[(c)]	11	1.31	4.7	24.0

NOTES:

[a] Kiggavik RO values provided by AREVA were assumed to be geometric mean values for the distributions; ammonia geometric mean value is from the Midwest RO. The use of Midwest RO for ammonia GM is conservative.

[b] GSDs from McClean (2011) for the JEB WTP (future quality) for all but nickel. The GSD for nickel was based on the Midwest RO GSD due to high variability in the JEB WTP. The Midwest RO GSD was based on the measured JEB dewatering well system discharge.

[c] TDS calculated as the sum of the anions and cations (as available).

RO = reverse osmosis; GSD = geometric standard deviation; COPC = constituent of potential concern; mg/L = milligrams per litre; Bq/L = Becquerels per litre.

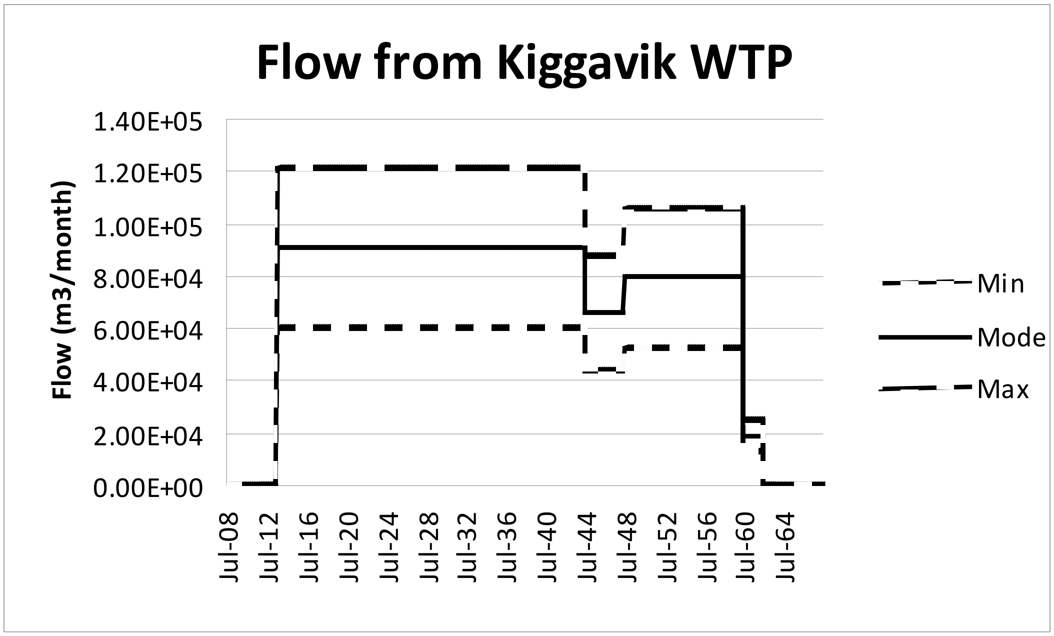


Figure 8.2-1 Assumed Flow Distributions for the Kiggavik WTP

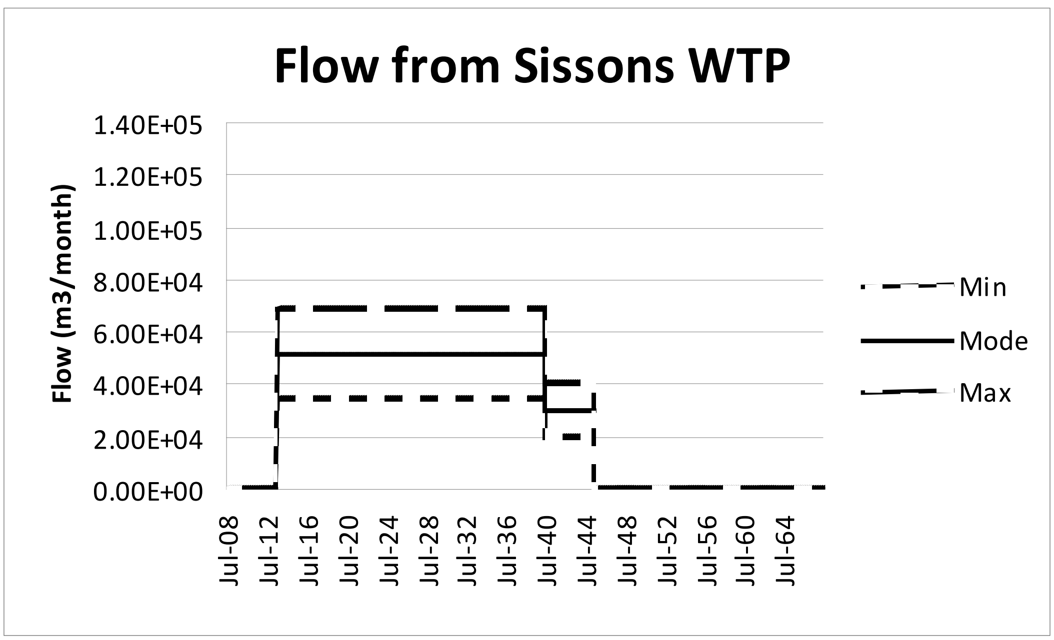


Figure 8.2-2 Assumed Flow Distributions for the Sissons WTP

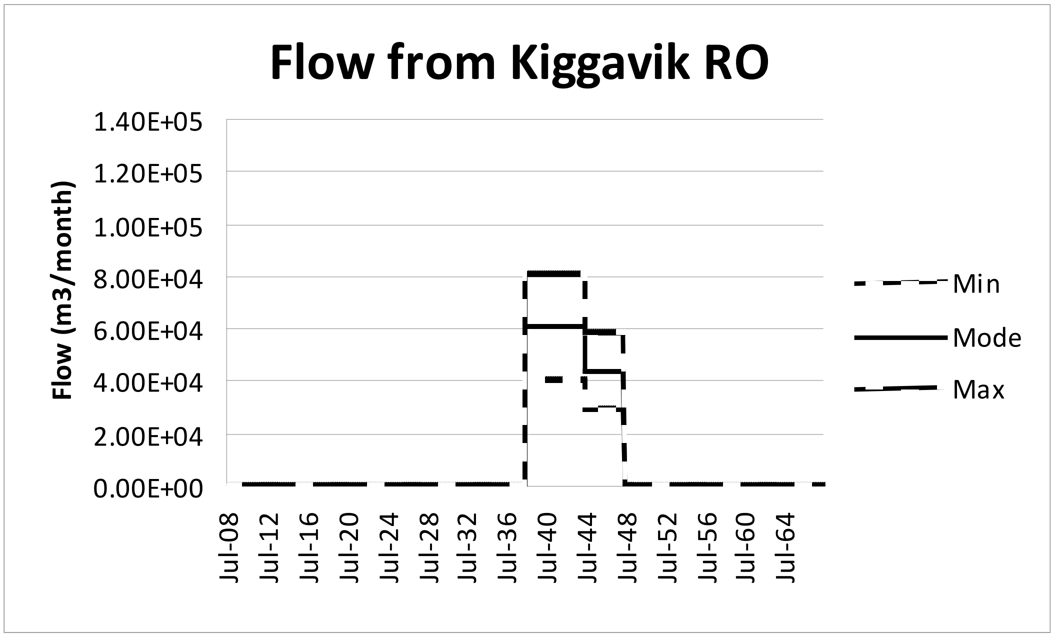


Figure 8.2-3 Assumed Flow Distributions for the Kiggavik RO

Treated effluent discharge from the Kiggavik and Sissons WTPs may affect surface water quality. Changes in surface water affect the sediment through processes such as deposition of settling solids, adsorption and diffusion.

The potential effects of the Project on water and sediment quality were assessed using the LAKEVIEW dispersion model. This is described in detail in Tier 3, Technical Appendix 8A.

8.2.1.2 Baseline Conditions for Changes in Water Quality Due to Effluent Discharge

Baseline water quality in the area is good, characterized by low-hardness water. Section 5.3 provides a summary of the data collected from the baseline monitoring program. Compared to available guidelines, all samples were below the water quality guidelines for arsenic, nickel, selenium, uranium, and zinc. The majority of the data for copper and lead were below the water quality objectives as the upper 95th percentile concentration was at or below the applicable guideline. The assessment of baseline water quality for cadmium is complicated as the analytical detection limit reported by the laboratory is generally above the water quality guideline, although it is noted that cadmium had been detected a number of times at a concentration of 0.1 µg/L which is above the water quality guideline. Additional low level analysis for cadmium was completed in 2013 on samples from Judge Sissons Lake and Squiggly Lakes. The method detection limit achieved for this analysis was 0.000053 µg/L, a summary of the program and results is provided in Tier 3, Technical Appendix 5C, Attachment 5C-1.

8.2.1.3 Effect Mechanism and Linkages for Changes in Water Quality Due to Effluent Discharge

The release of COPCs from the WTP can affect water quality in the receiving environment. Changes in water quality can affect the concentration of COPCs in sediment. The quality of the water is critical for evaluating the potential effect on aquatic biota. The linkages between water quality and other environmental compartments are illustrated in Figure 8.2-4. The effect on water quality will change with different phases of the Project (e.g., operational period, closure). In the post-decommissioning period the recovery of the system can be predicted.

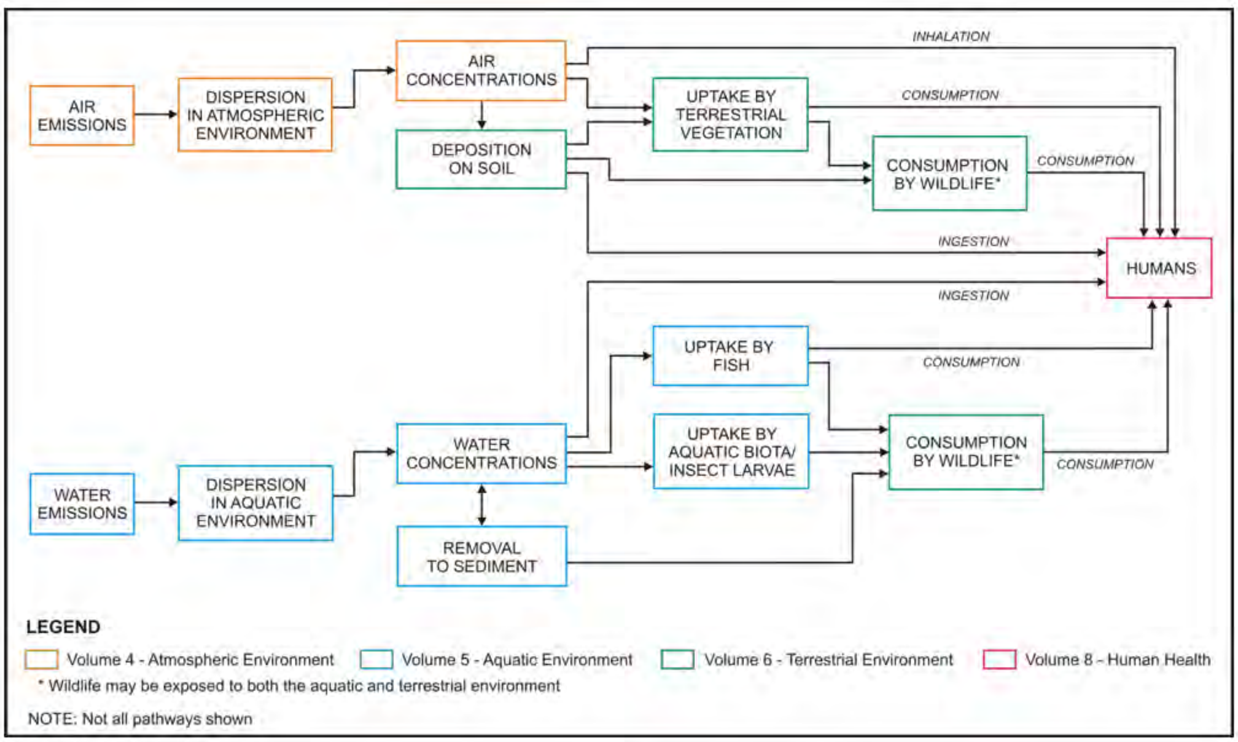


Figure 8.2-4 Linkages Between Water Quality and Other Environmental Components

8.2.1.4 Mitigation Measures and Project Design for Changes in Water Quality Due to Effluent Discharge

The Kiggavik WTP has two effluent streams; RO permeate and chemical WTP effluent. During operation, it is expected that the RO permeate will be recycled to the mill for use in mill process. The preferred water treatment option at Sissons is a 3-stage chemical WTP. The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations such as the discharge limits for deleterious substances as stipulated in Metal Mining Effluent Regulation (MMER) as well as site-specific discharge limits. Environmental considerations were paramount in the selection of the appropriate technology for the WTP.

Further detail on the design of the WTPs can be found in Tier 2, Volume 2, Section 9, Water Management.

8.2.1.5 Residual Effects for Changes in Water Quality Due to Effluent Discharge

To examine the implication of the two discharge locations on Judge Sissons Lake, the lake was divided into eight segments (Figure 8.2-5) which were defined as summarized in Tier 3, Technical Appendix 8A, Table 2.7-1. The model takes into account the effects of ice formation on the concentrations of the COPC in both the water column and in sediments. Ice thickness of 2 m is typical in the study area and ice cover typically lasts 8 to 9 months per year. JSL-7 is shallow (average depth of 1.1 m) and therefore, there is very little free-flowing water in the winter months below the ice cover. The deepest segment is JSL-4 with an average depth of 8.8 metres. The model considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8.

Figure 8.2-6 presents the monthly predicted water concentrations in the eight segments of Judge Sissons Lake for the bounding effluent release scenario. The four phases of effluent release are indicated on the figures are:

- baseline conditions (pre-operation),
- operation phase,
- final closure phase, and
- post-closure phase.

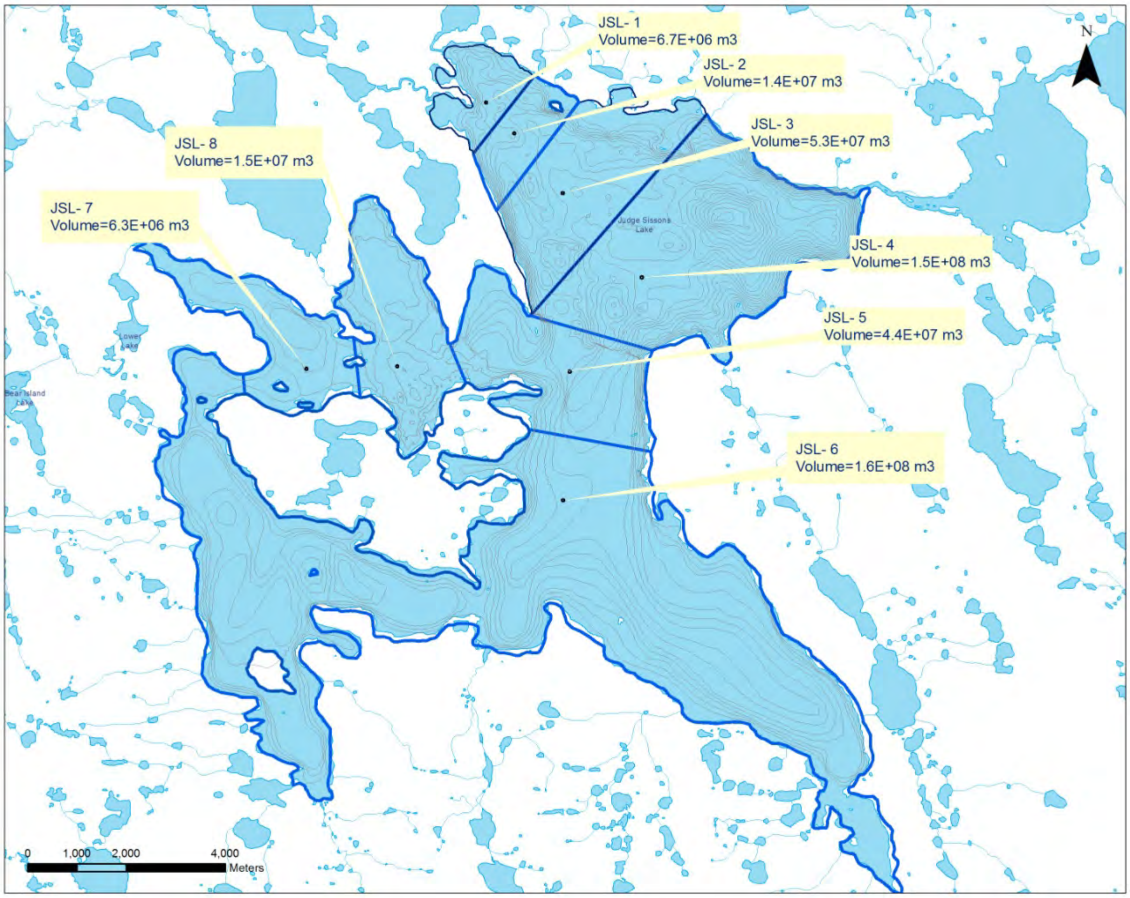


Figure 8.2-5 Water Quality Modeling Segments in Judge Sissons Lake (JSL)

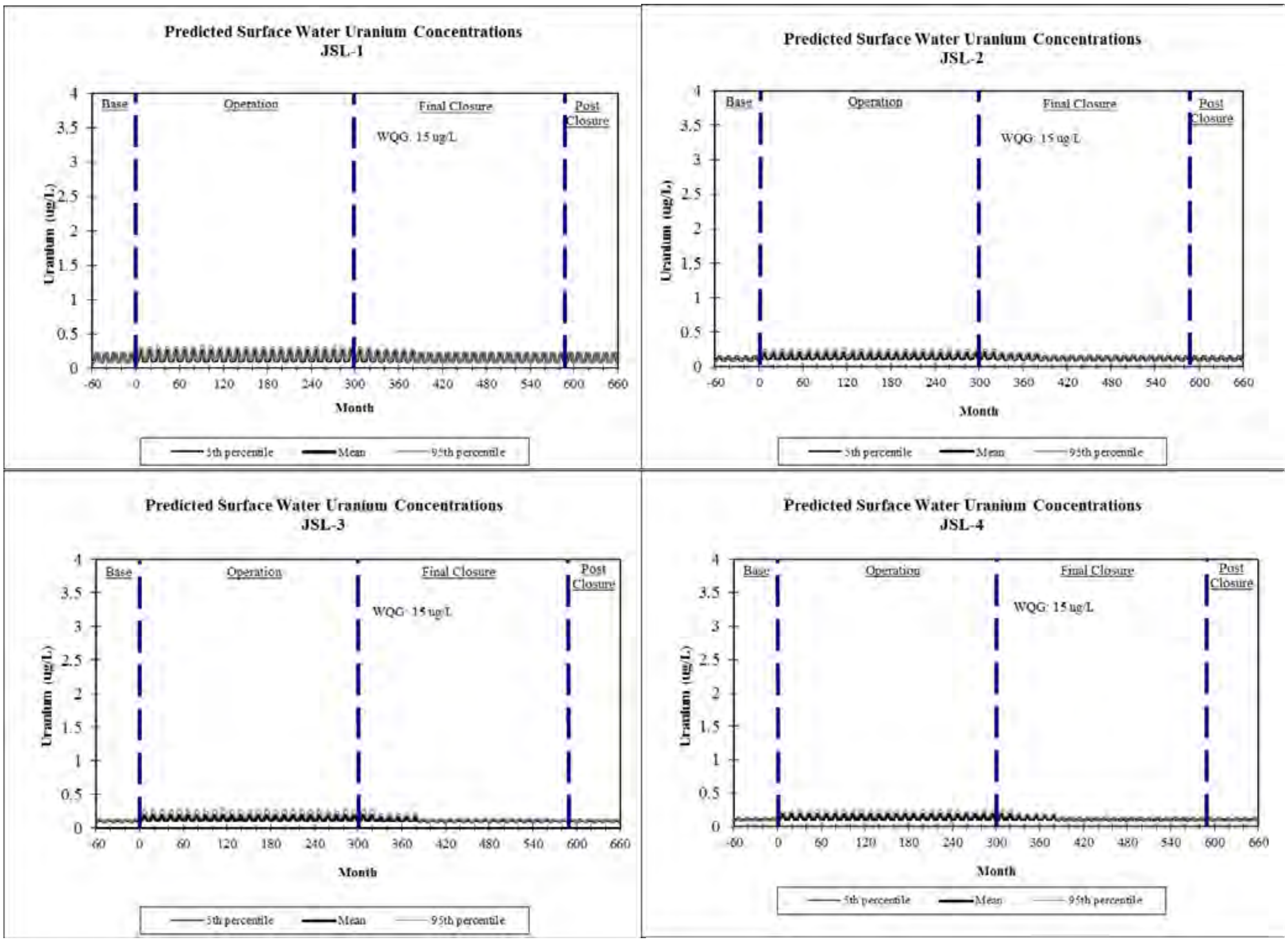


Figure 8.2-6 Water Quality Predictions

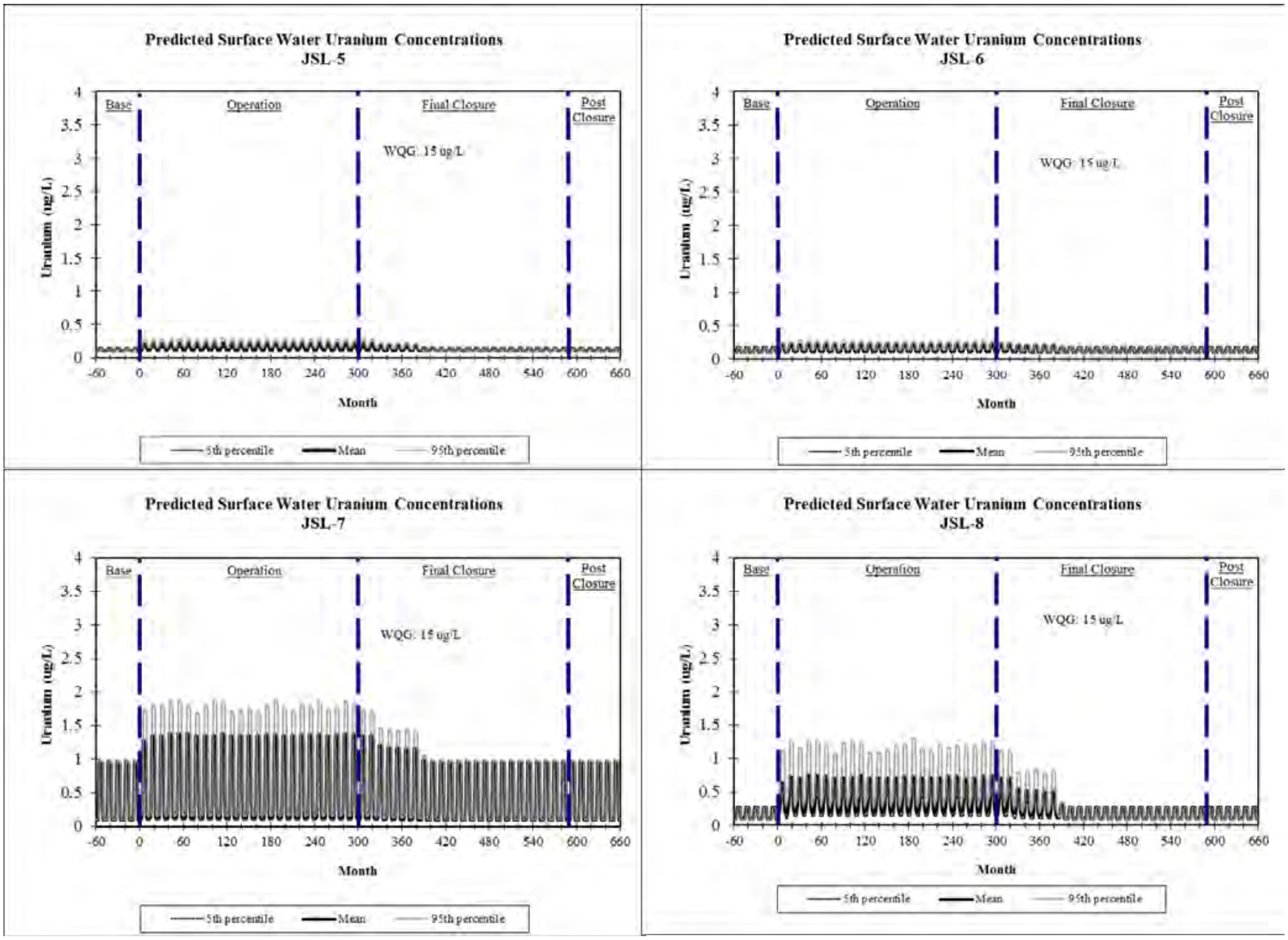


Figure 8.2-6 Water Quality Predictions (Cont'd)

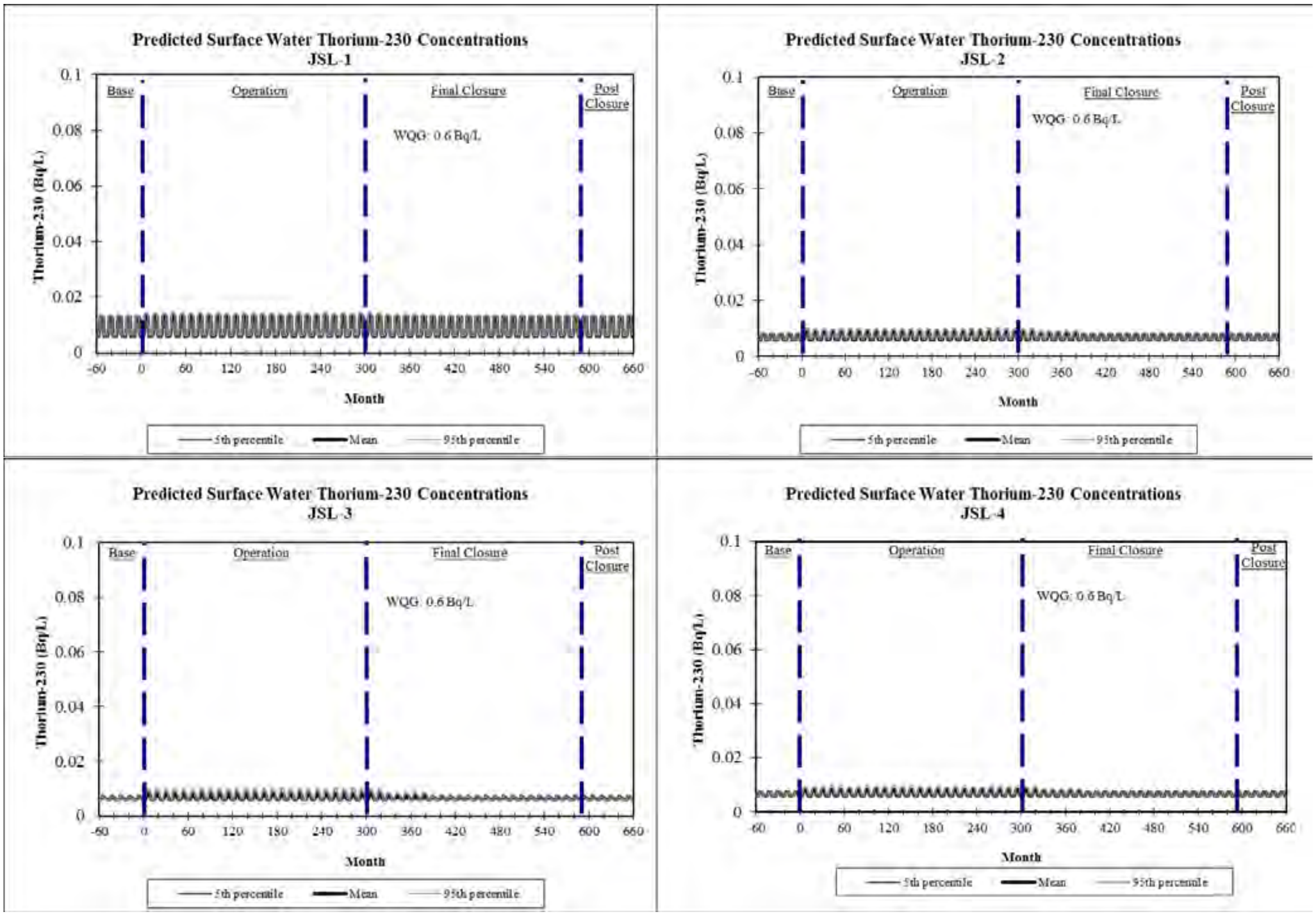


Figure 8.2-6 Water Quality Predictions (Cont'd)

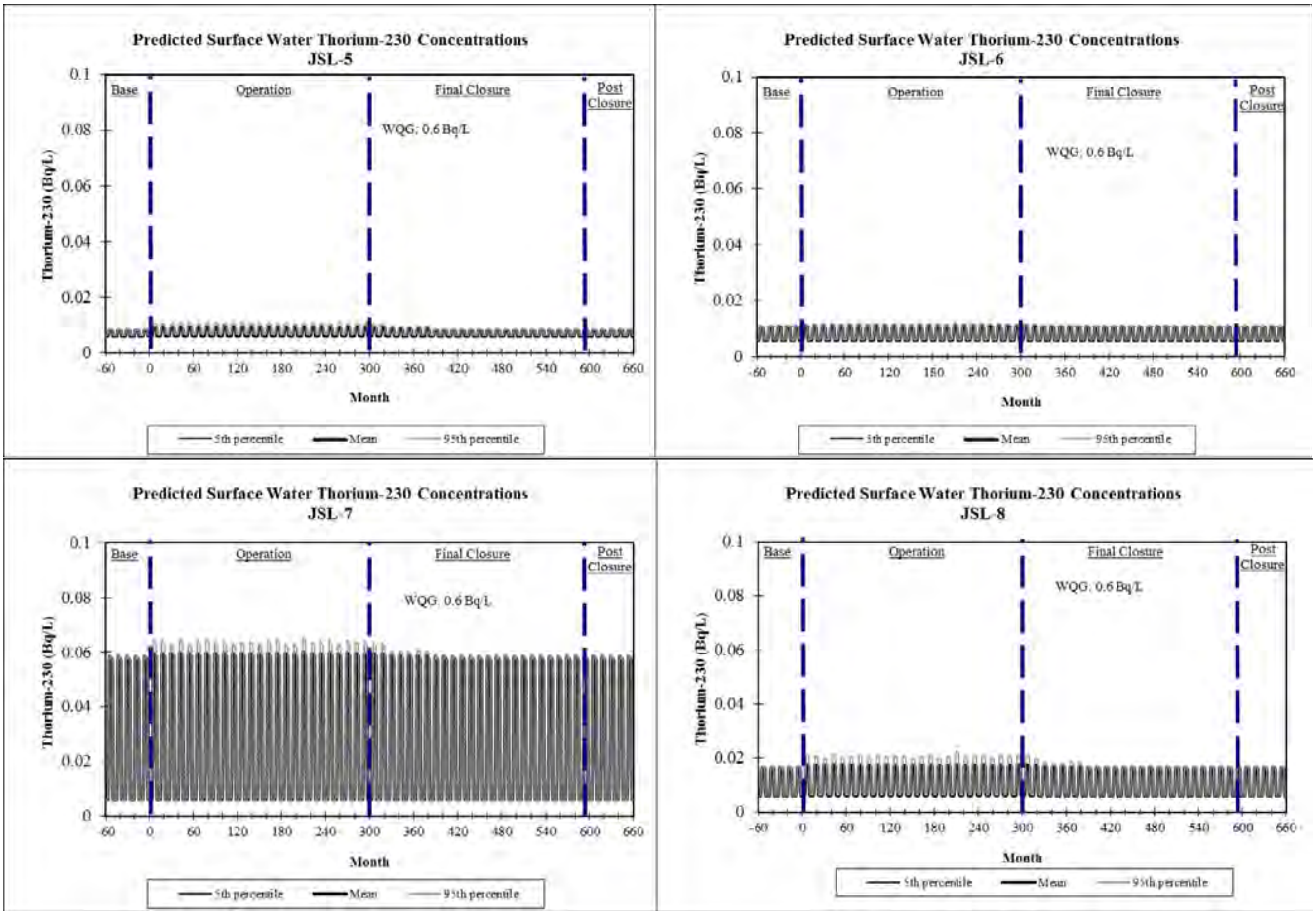


Figure 8.2-6 Water Quality Predictions (Cont'd)

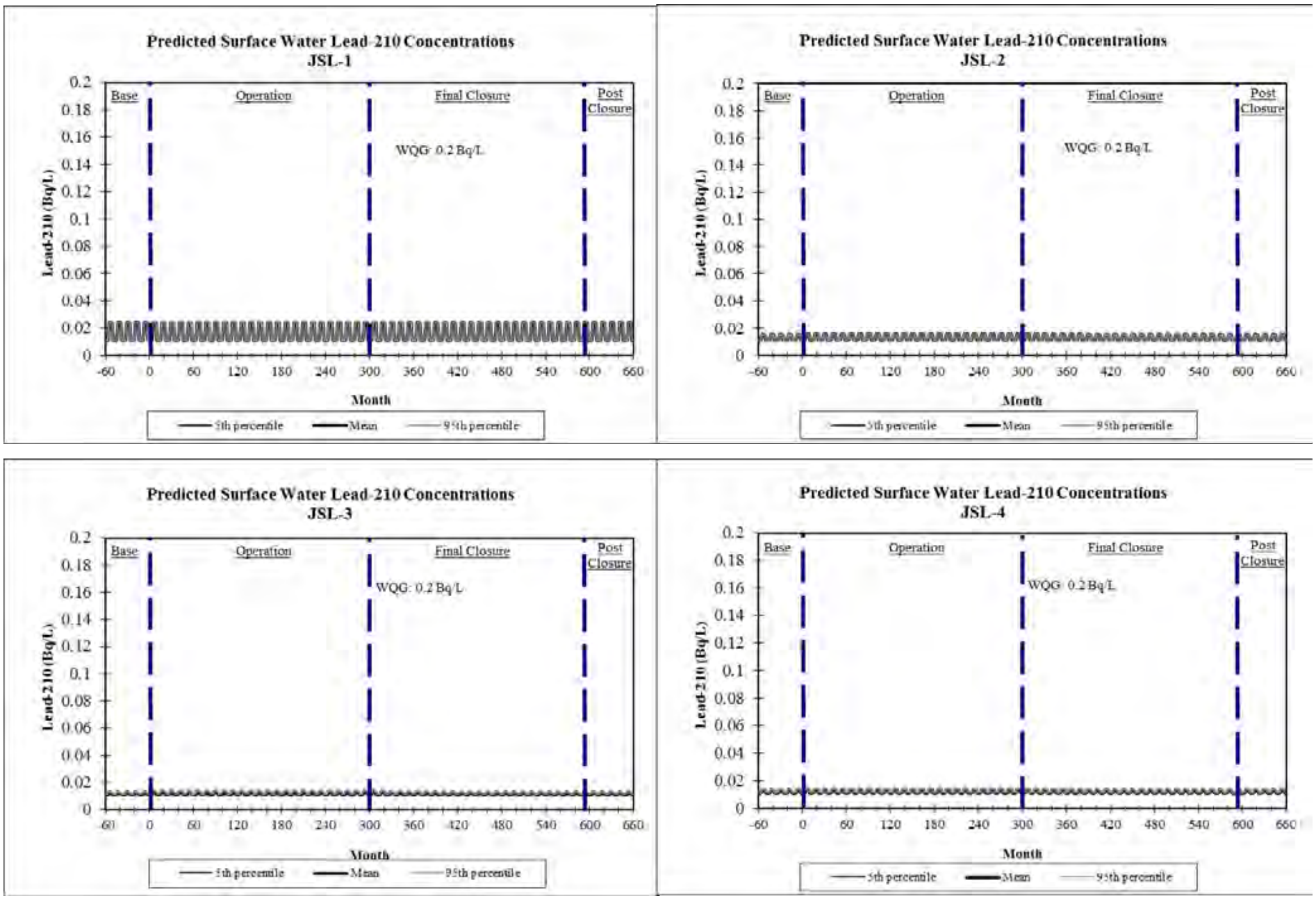


Figure 8.2-6 Water Quality Predictions (Cont'd)

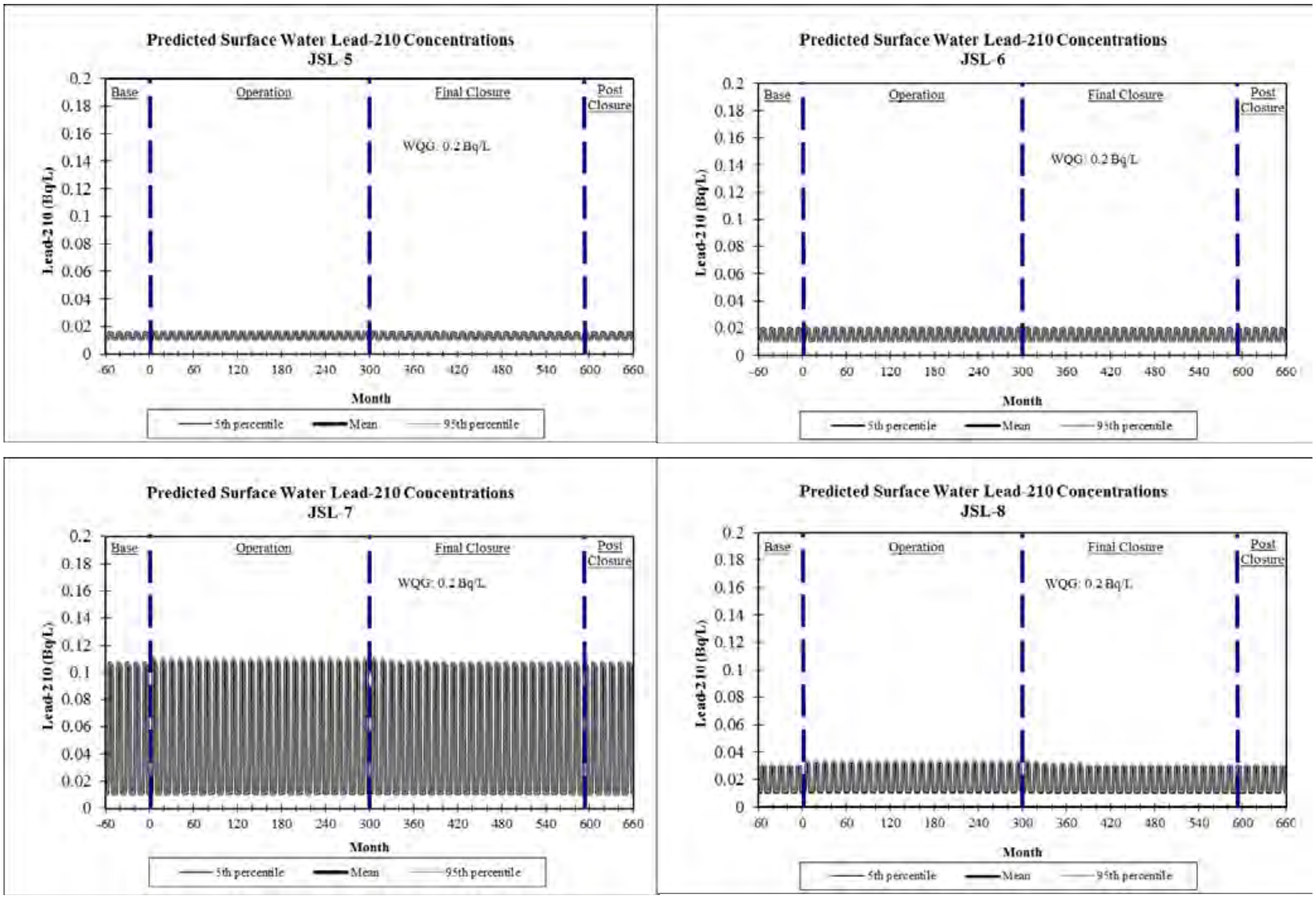


Figure 8.2-6 Water Quality Predictions (Cont'd)

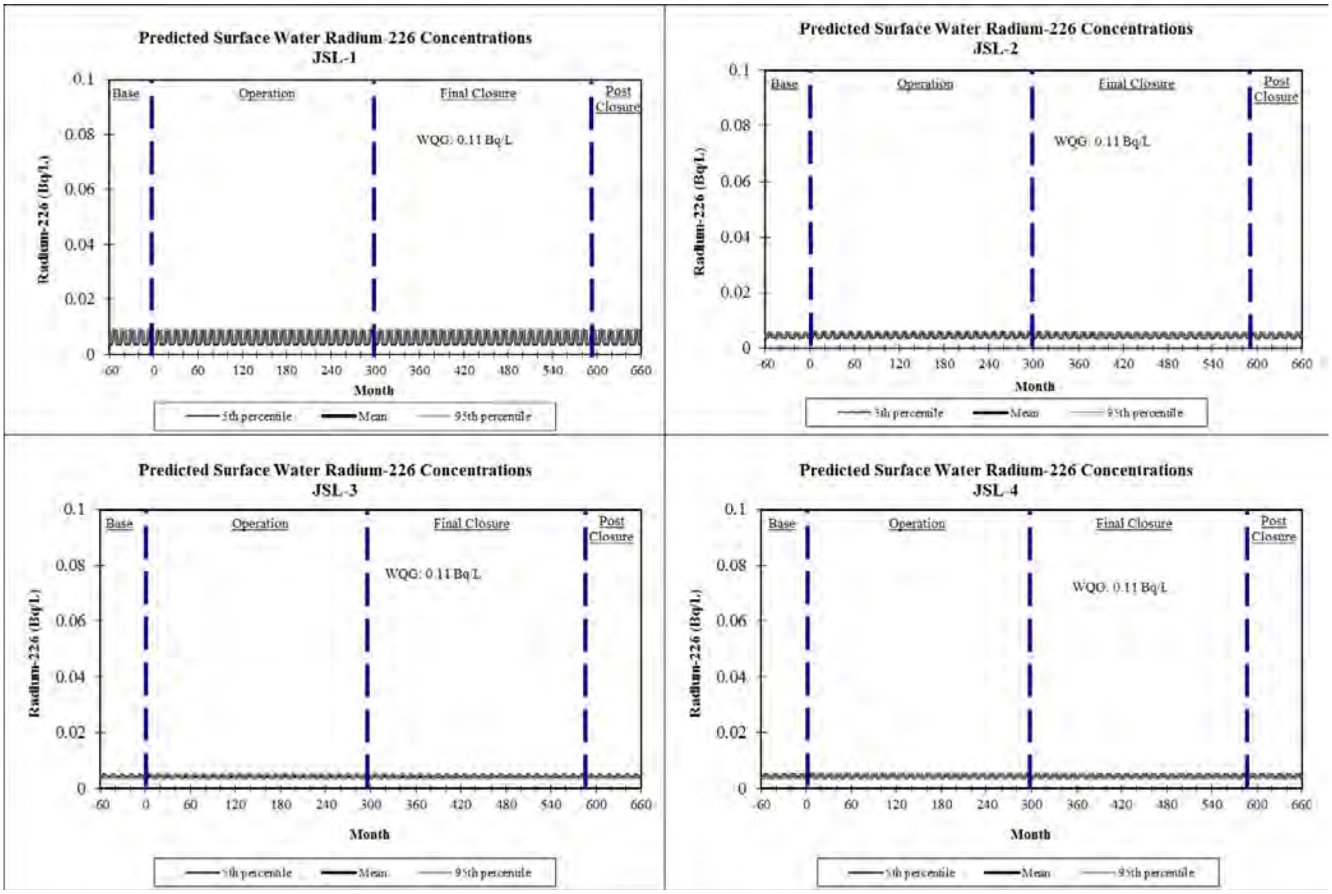


Figure 8.2-6 Water Quality Predictions (Cont'd)

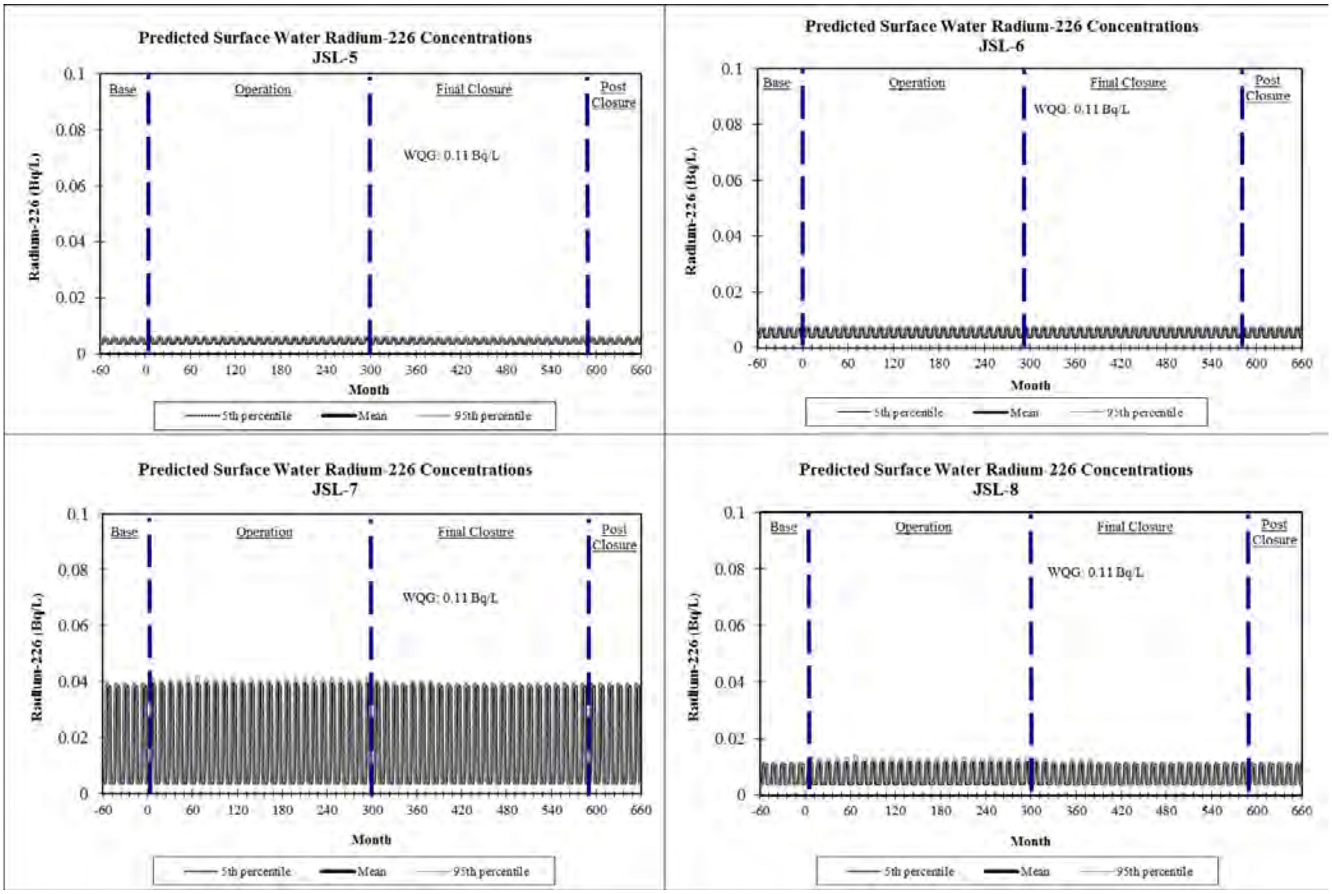


Figure 8.2-6 Water Quality Predictions (Cont'd)

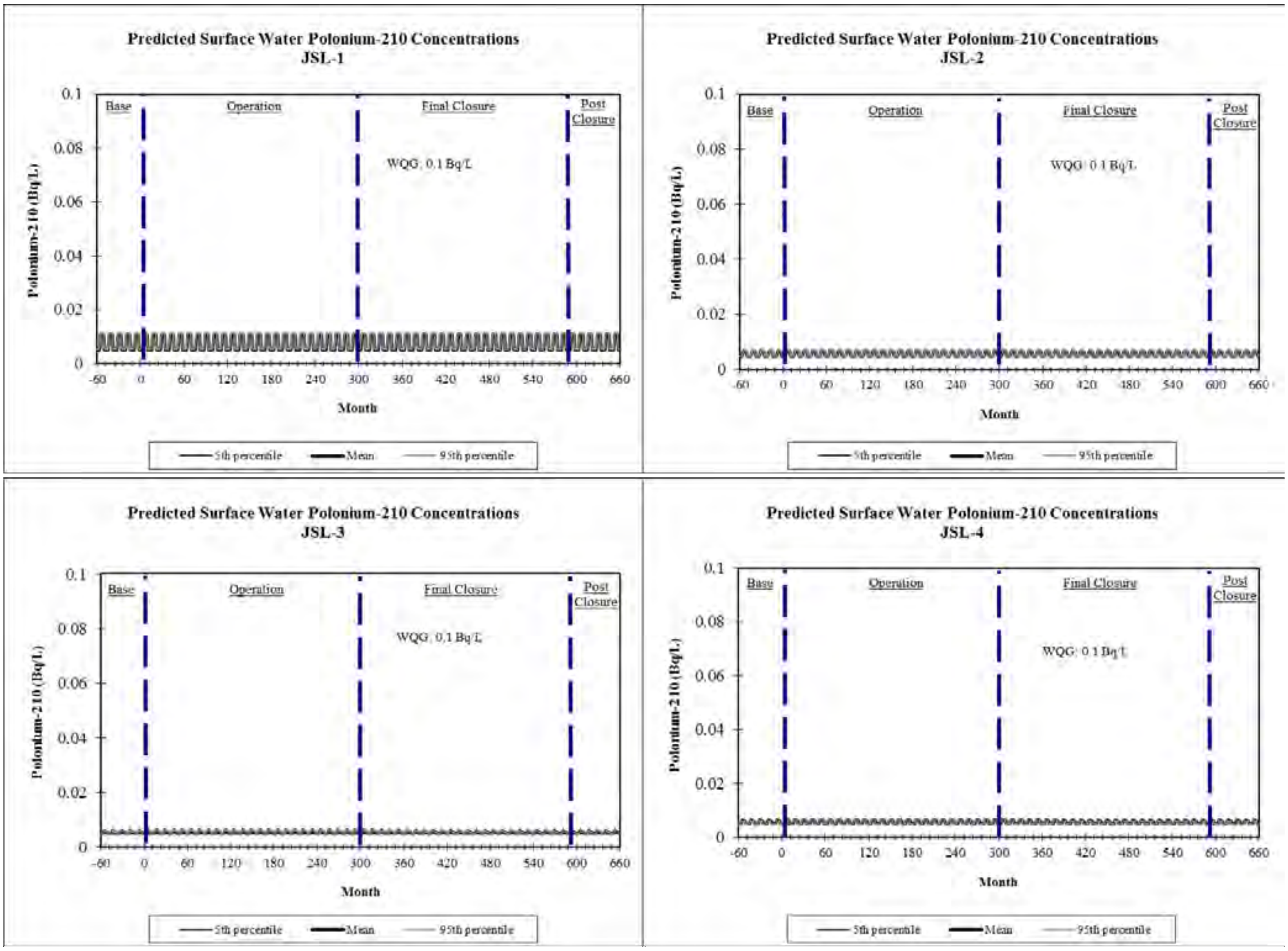


Figure 8.2-6 Water Quality Predictions (Cont'd)

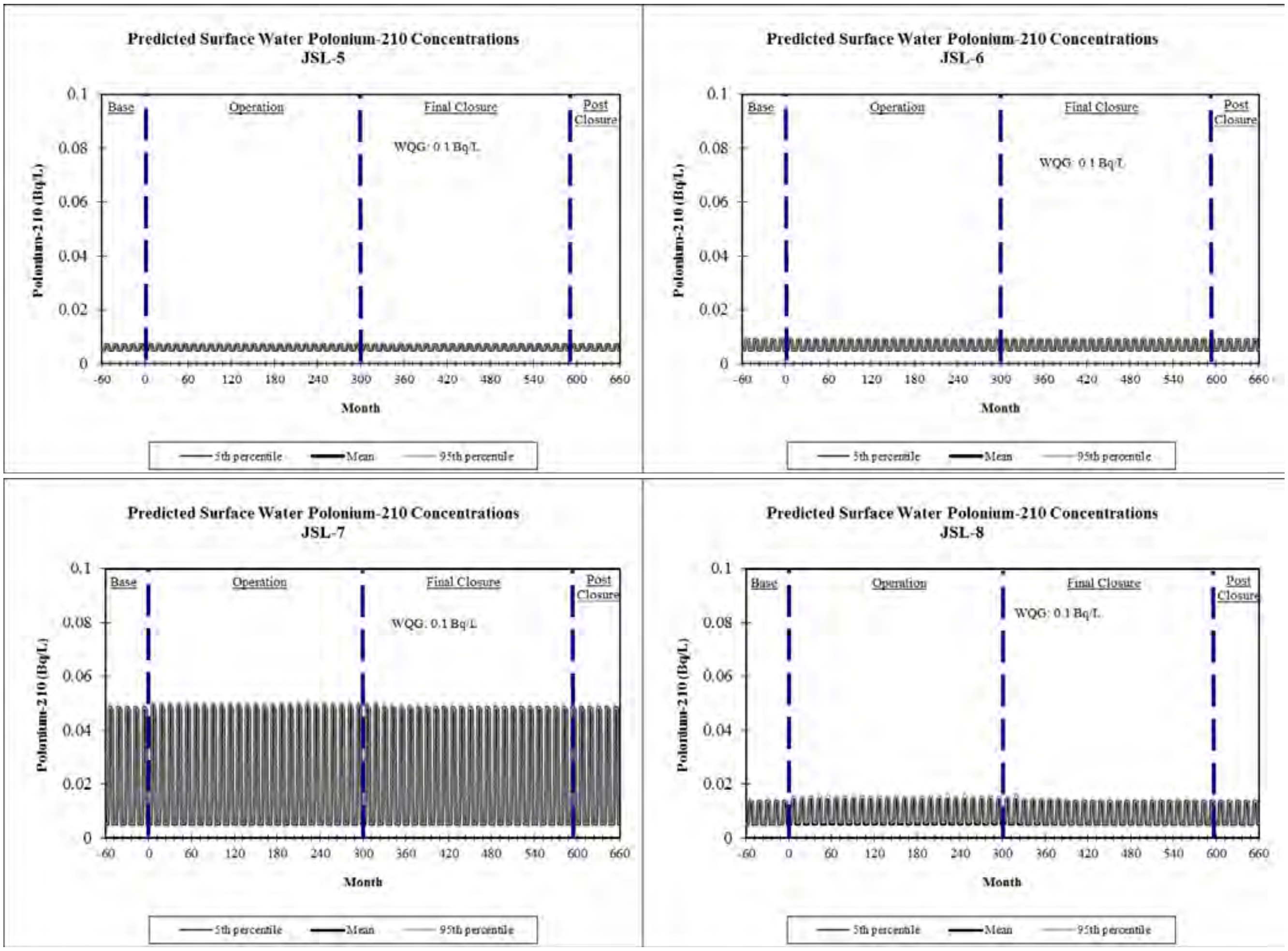
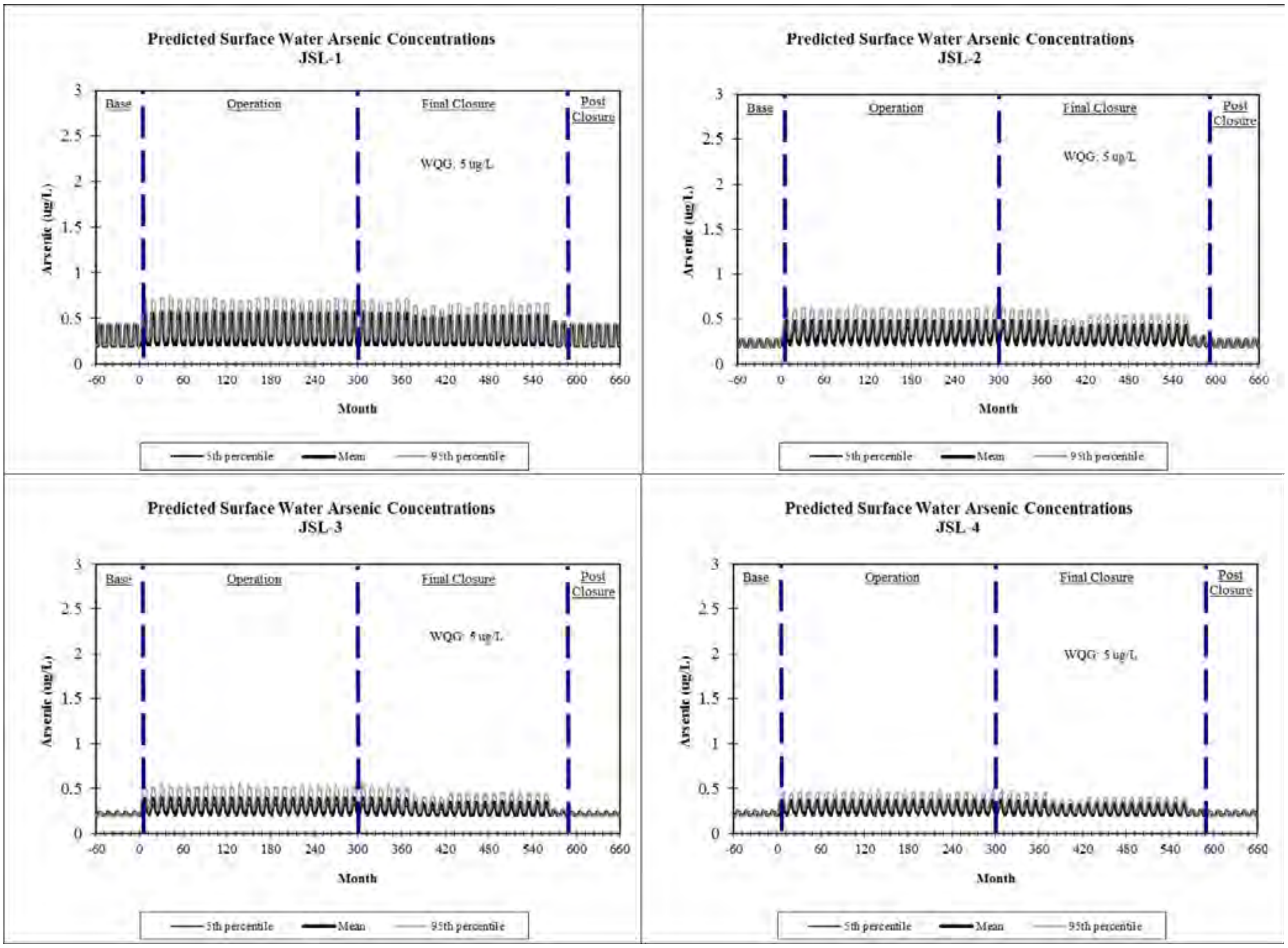


Figure 8.2-6 Water Quality Predictions (Cont'd)



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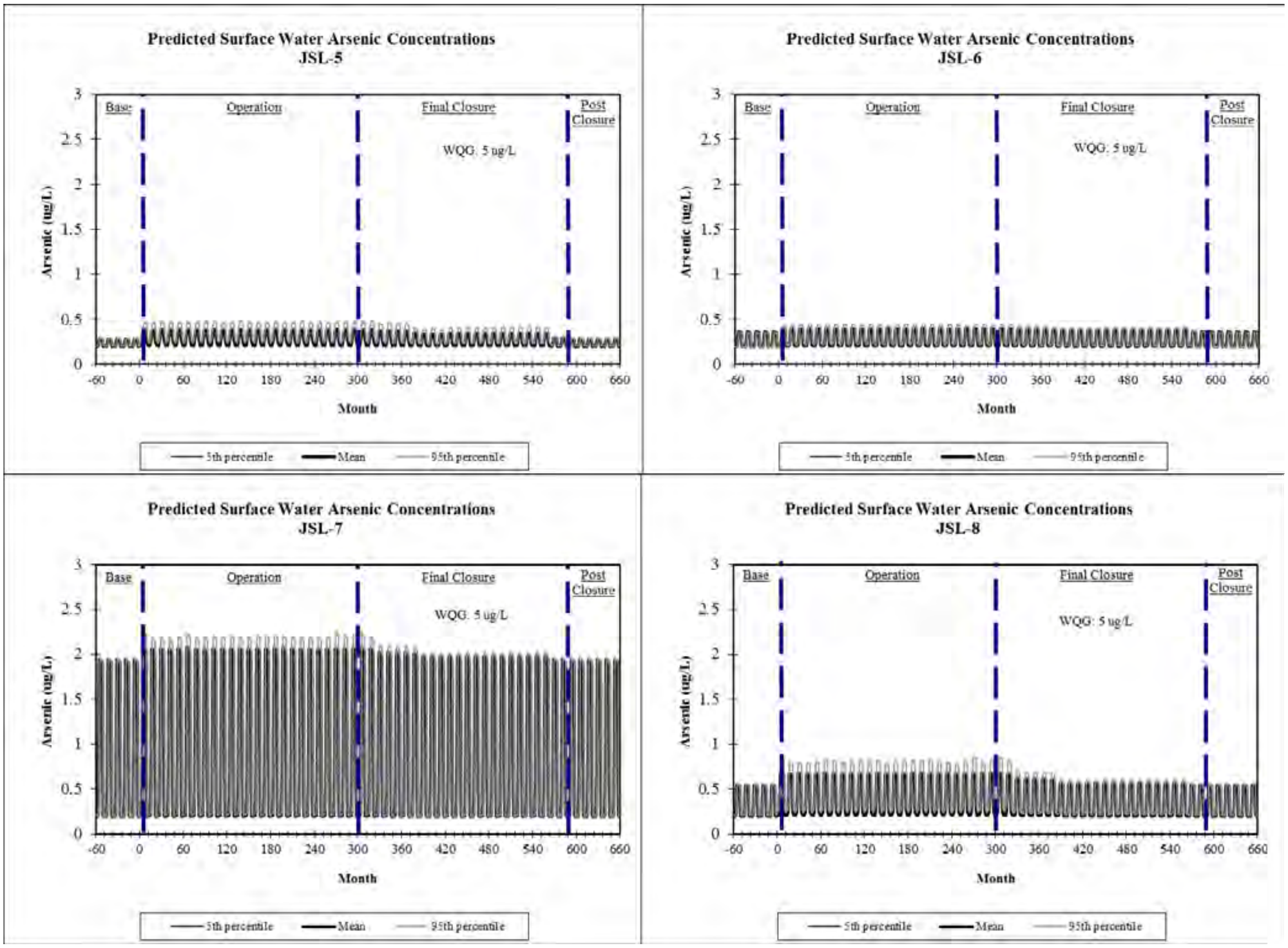

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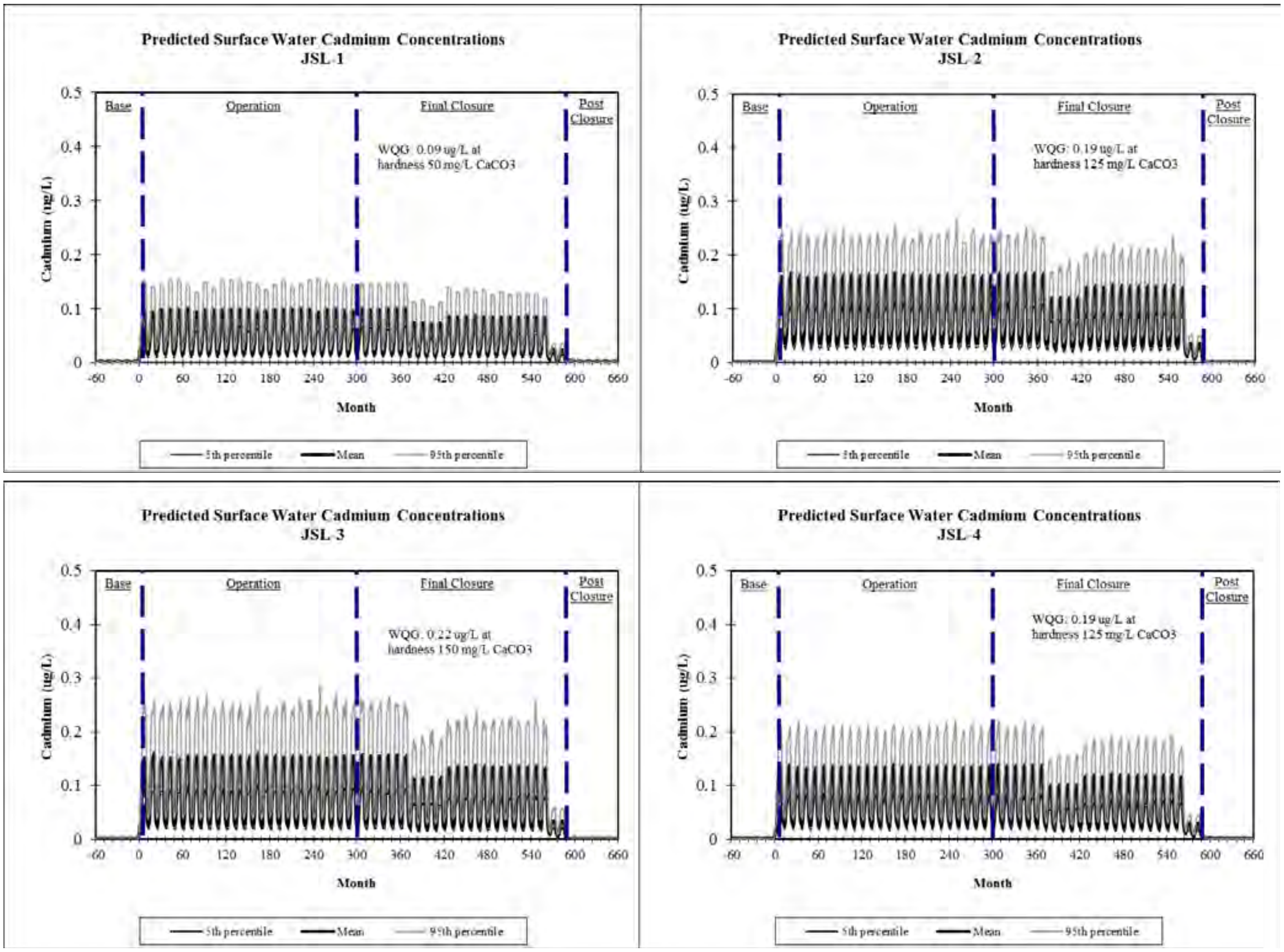

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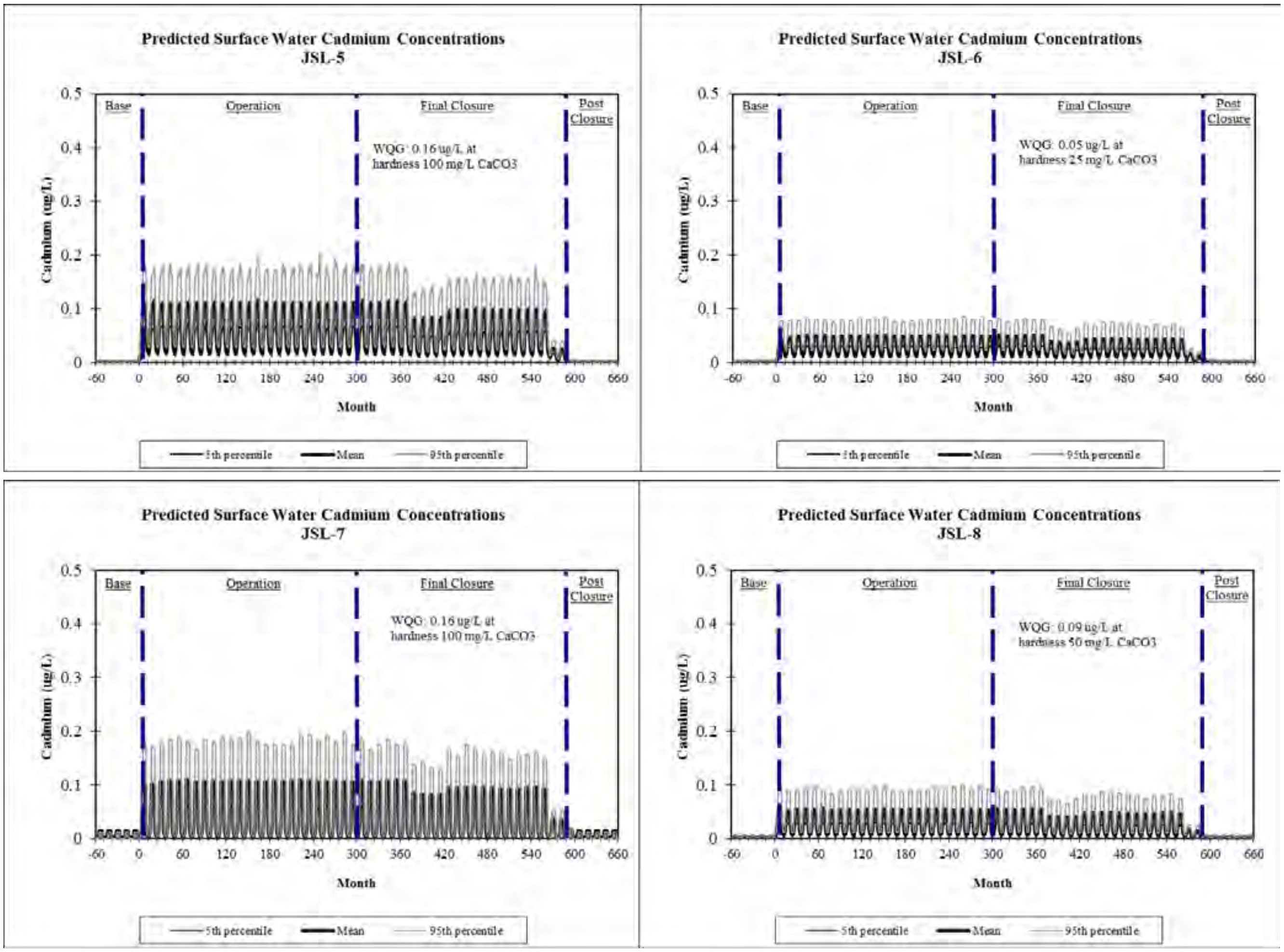

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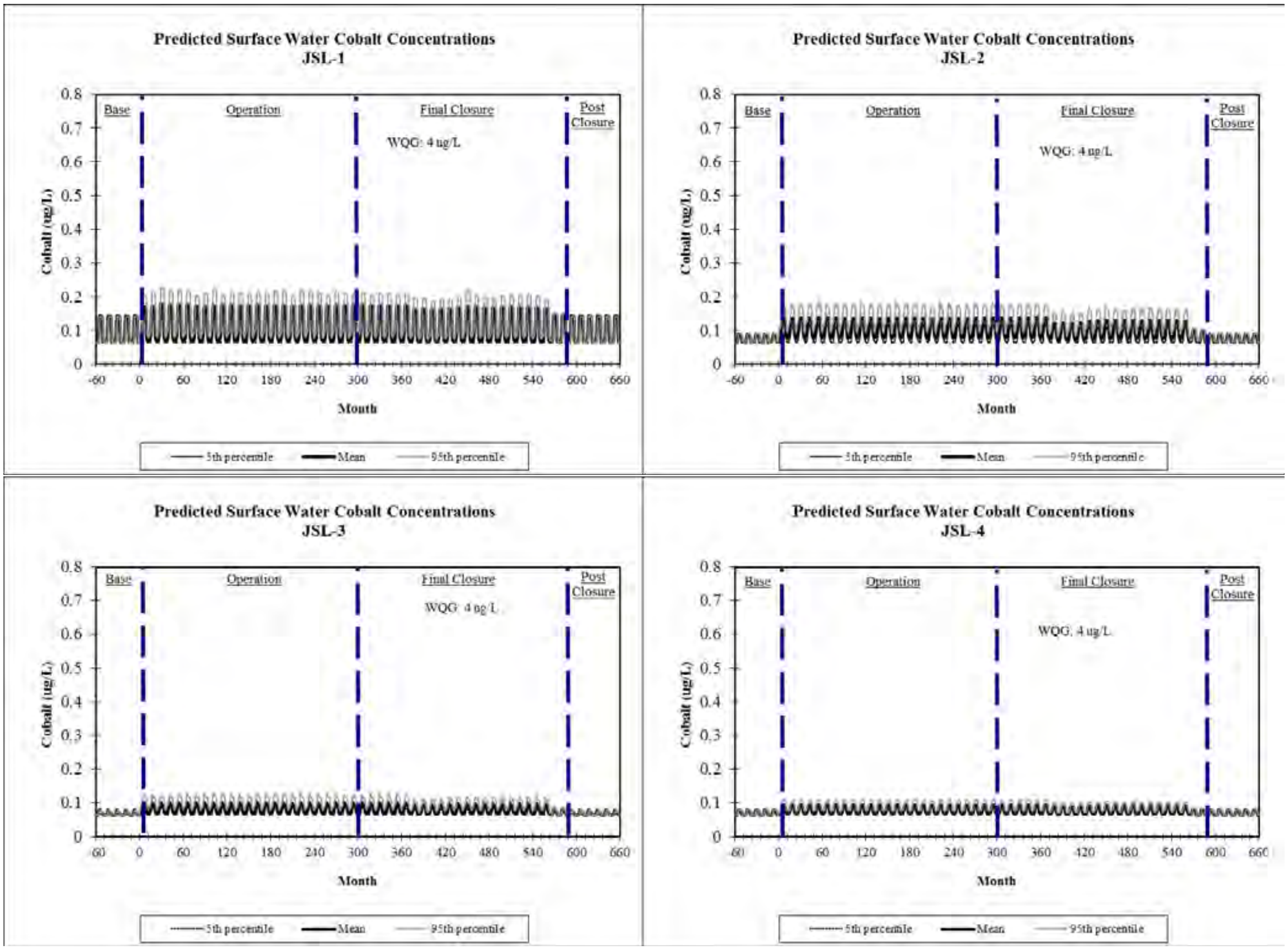

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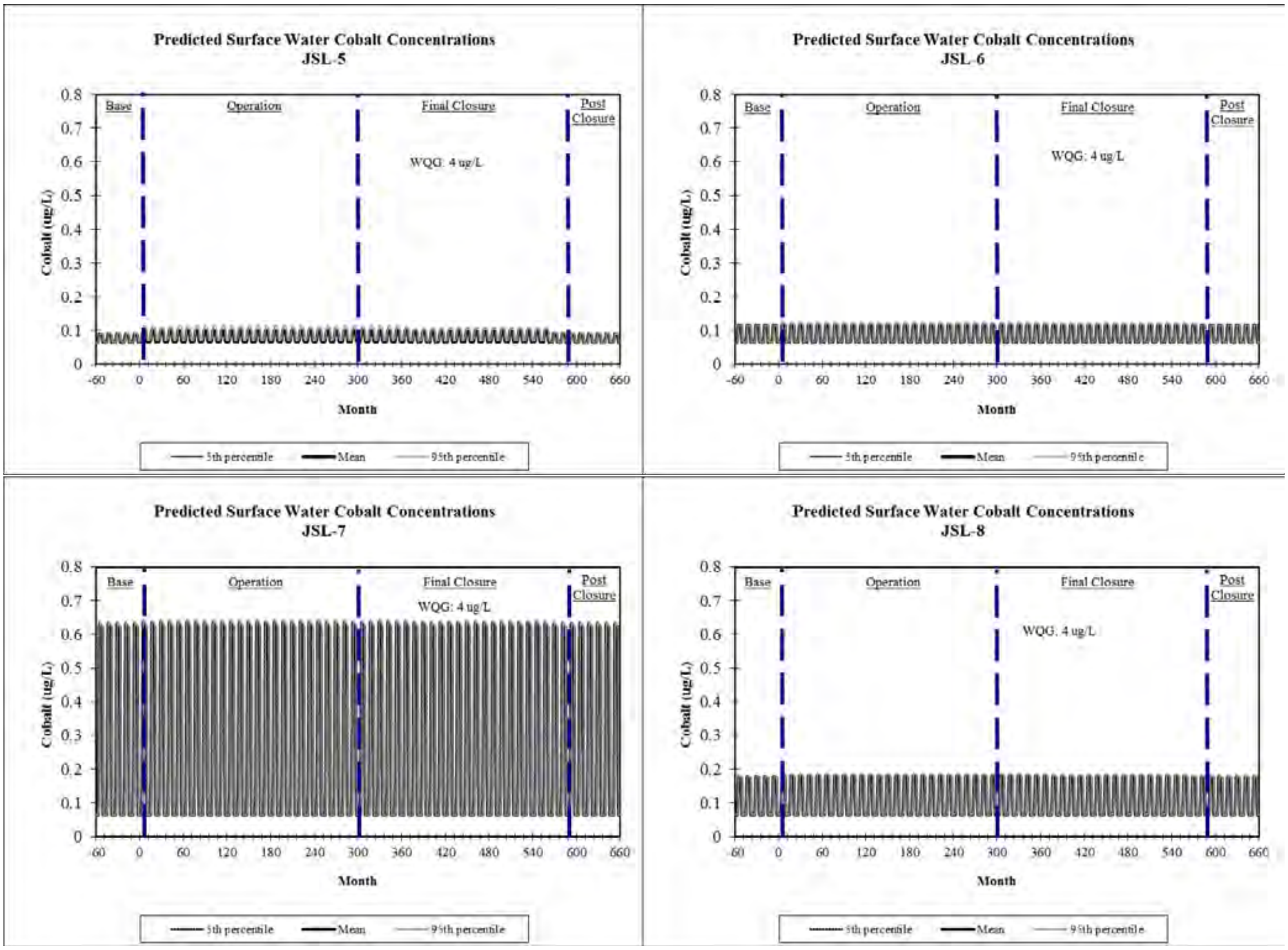

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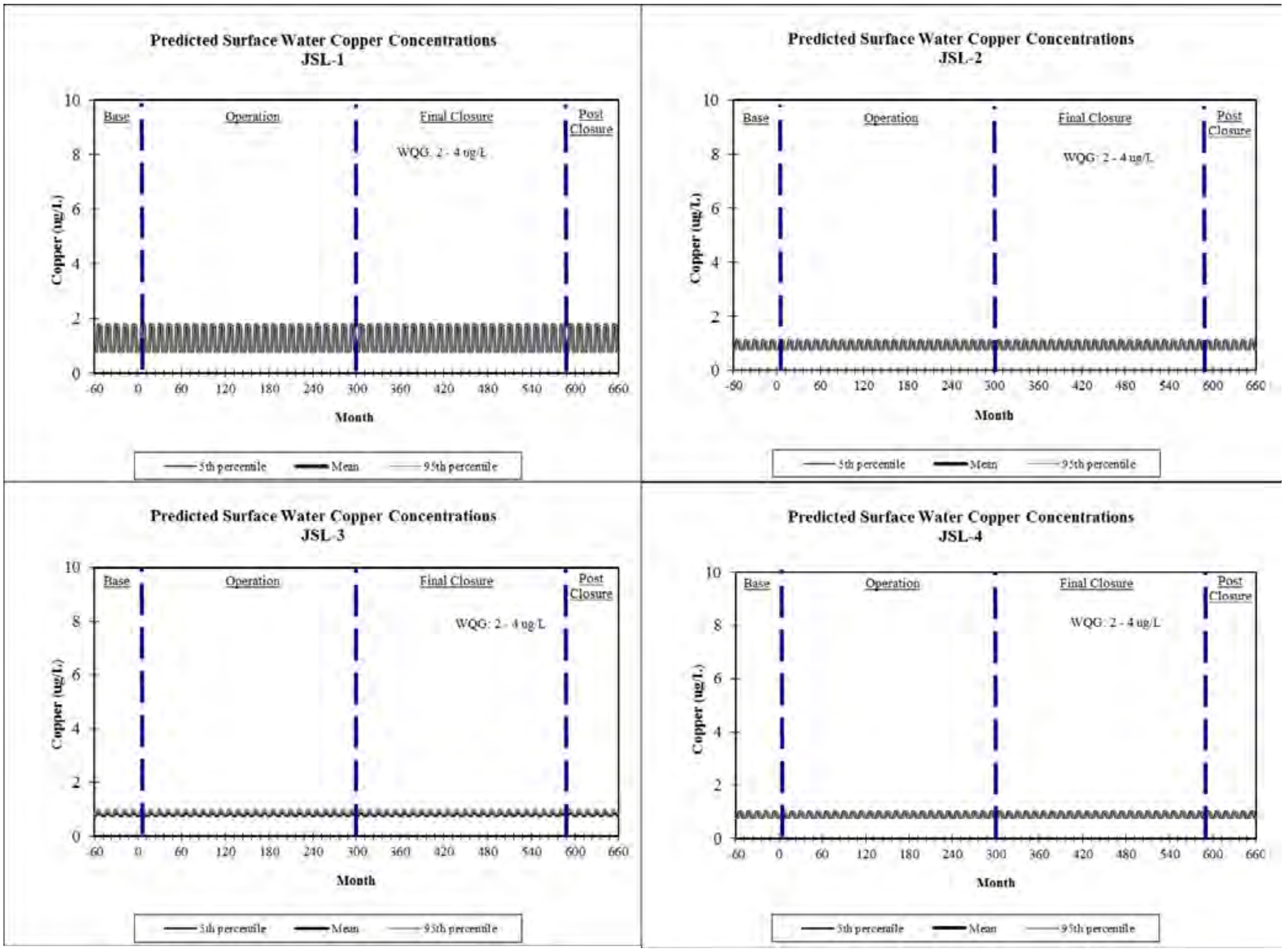

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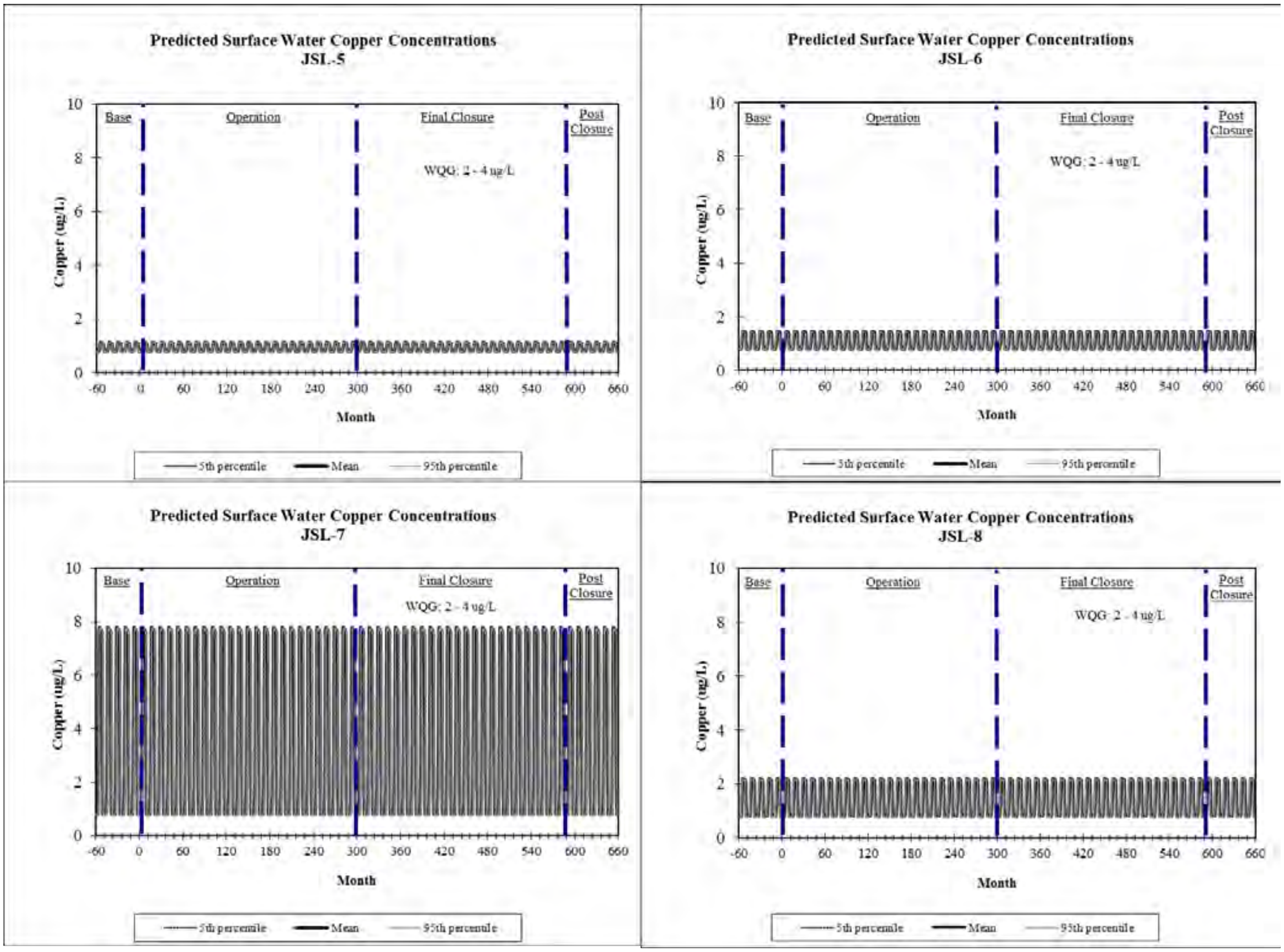

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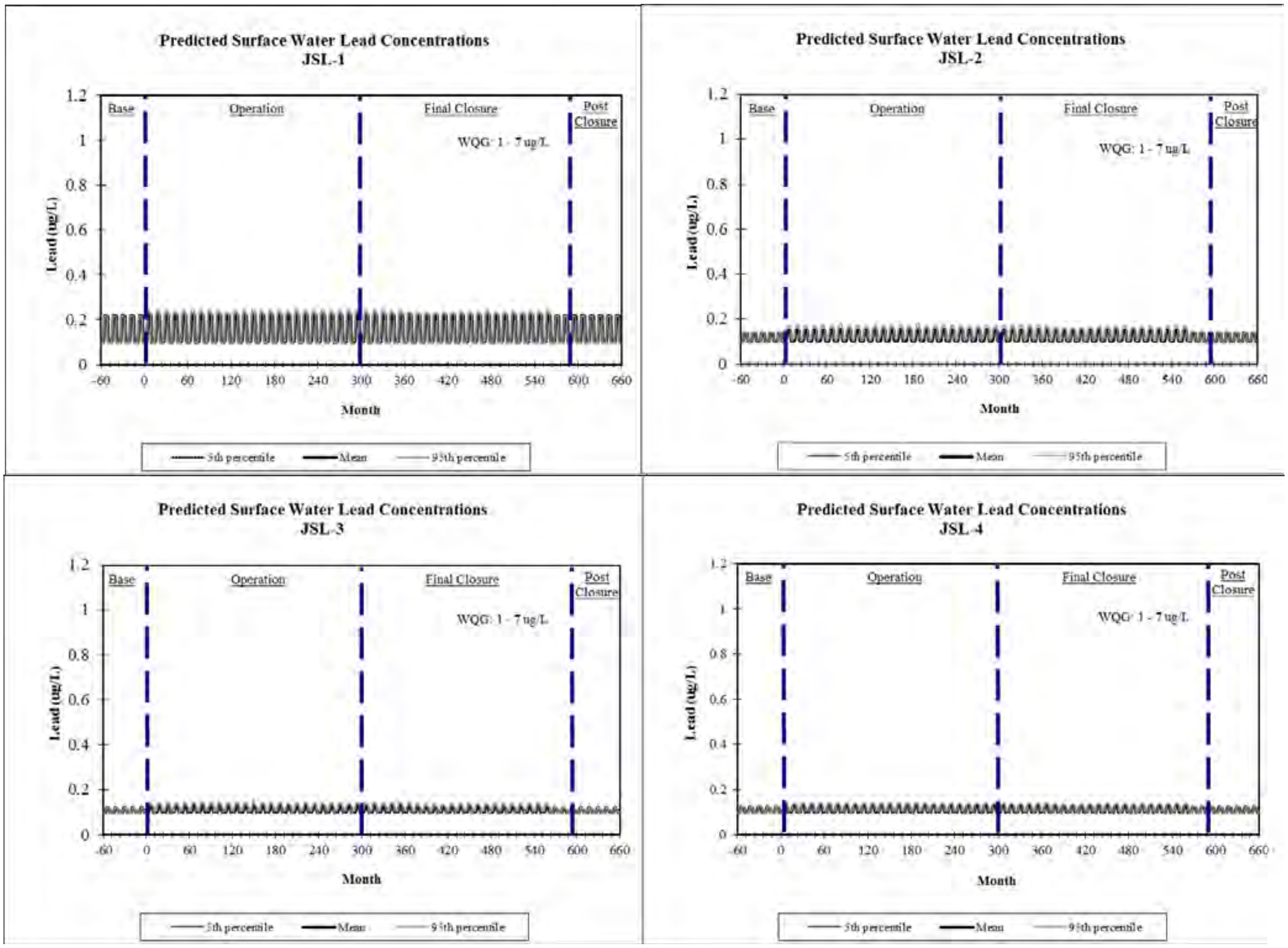

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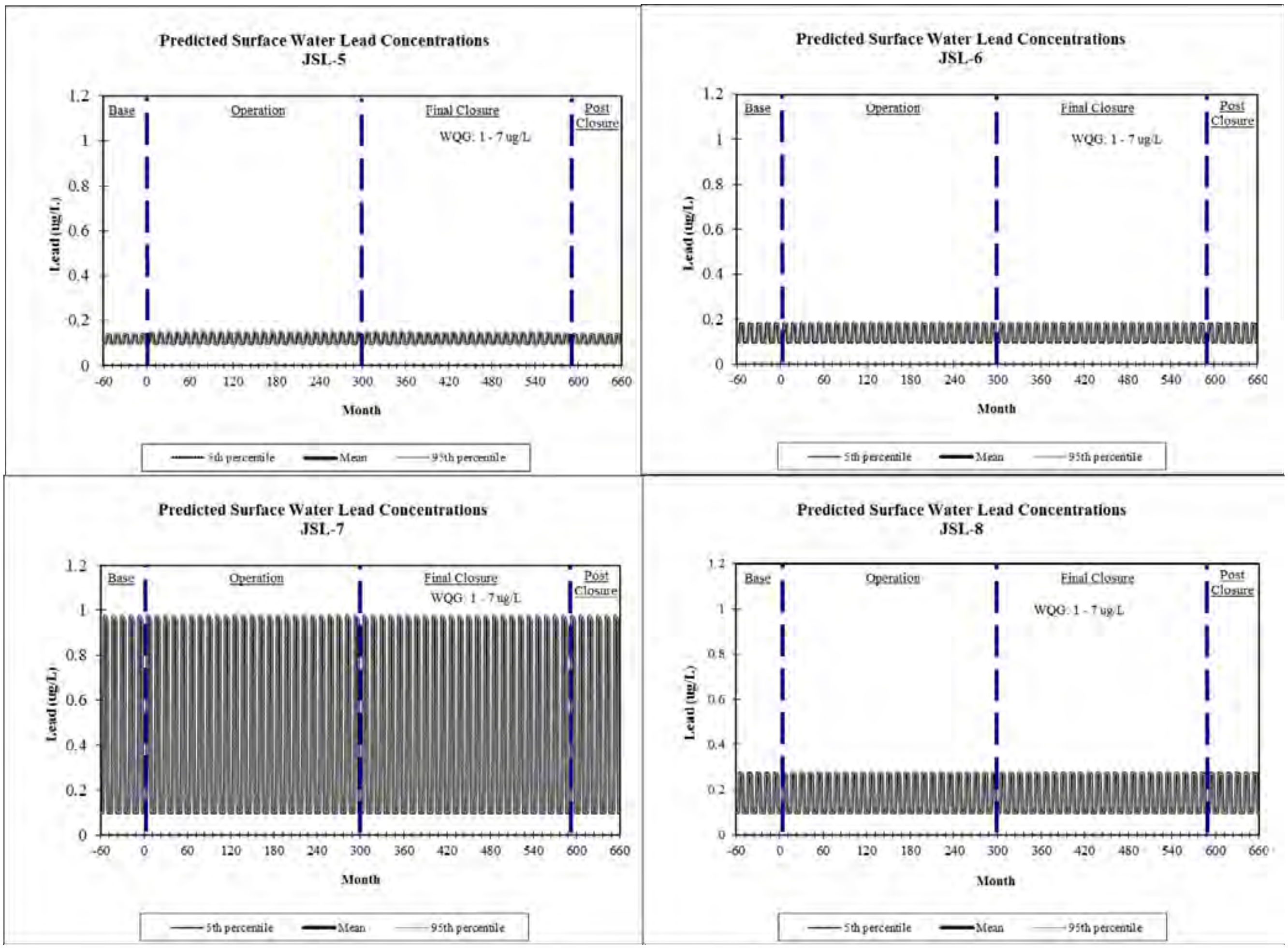

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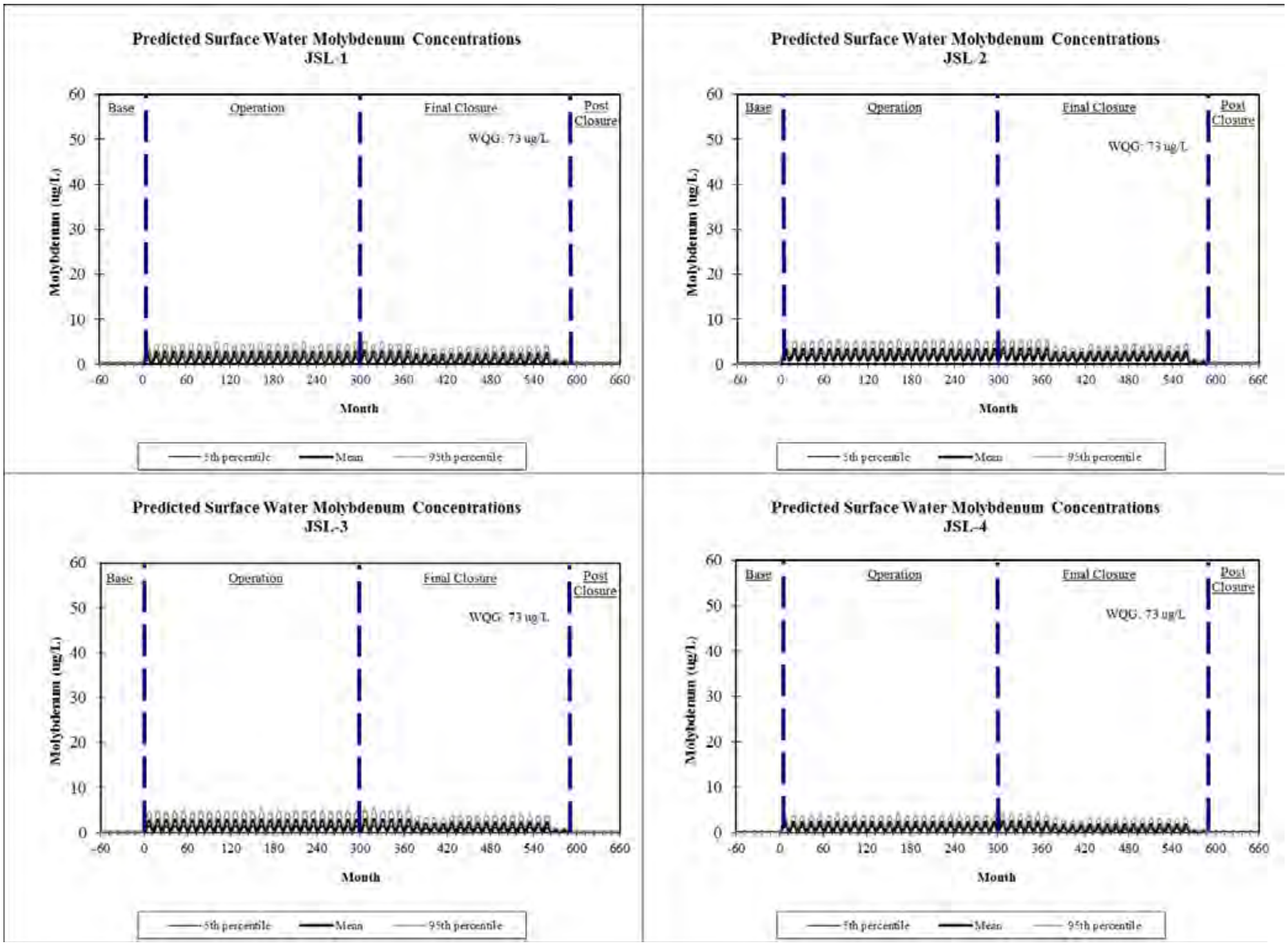

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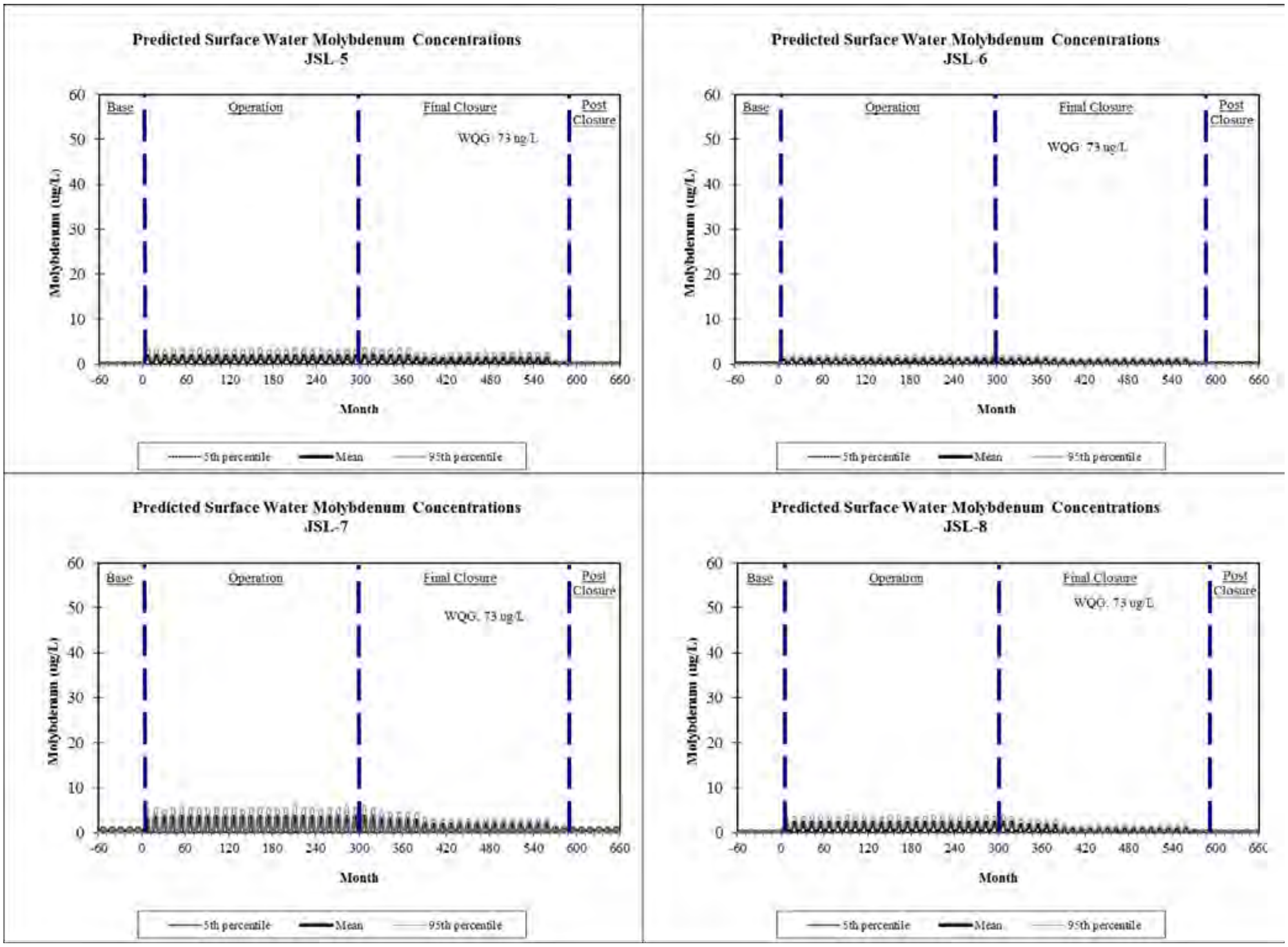

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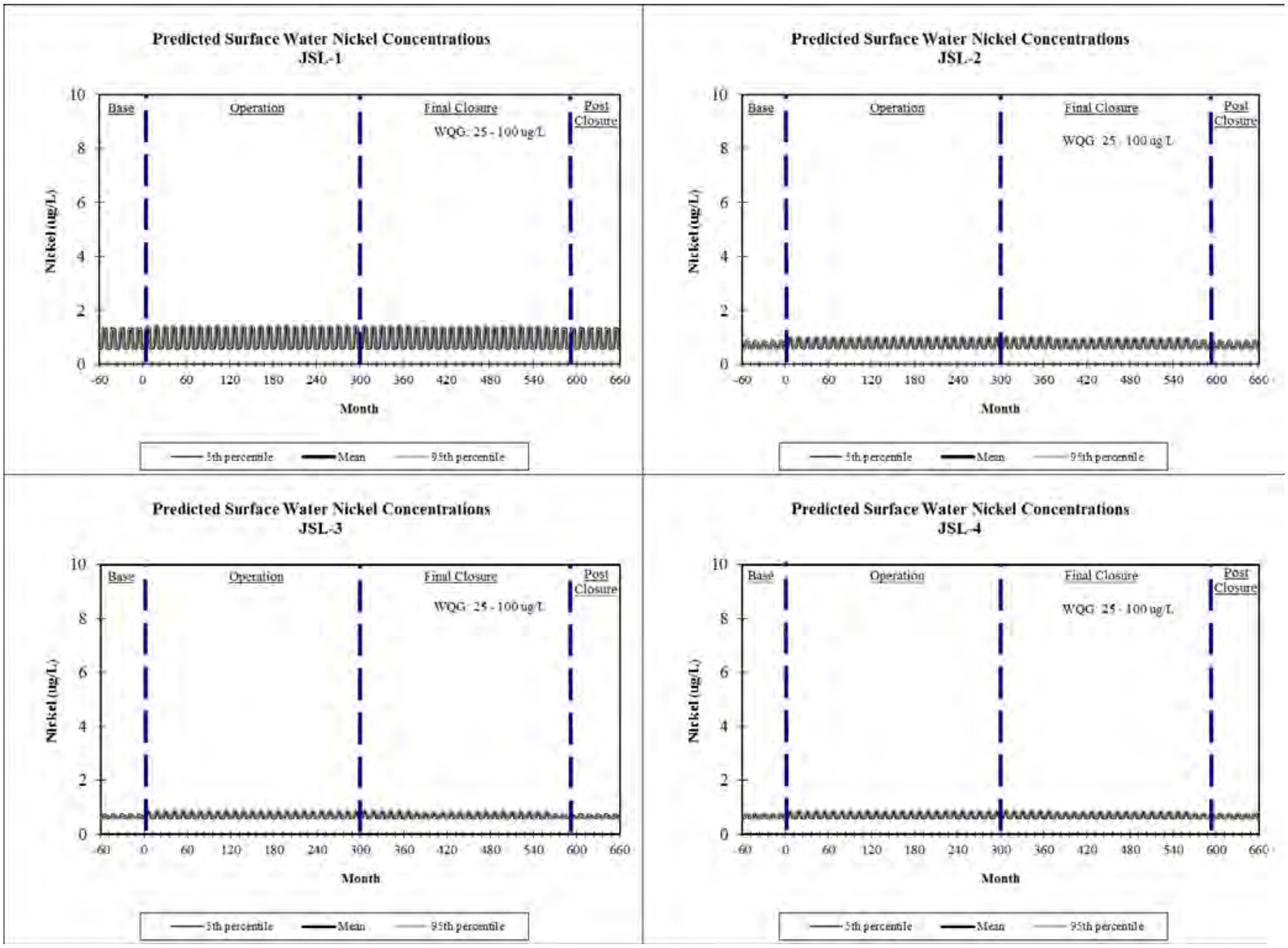

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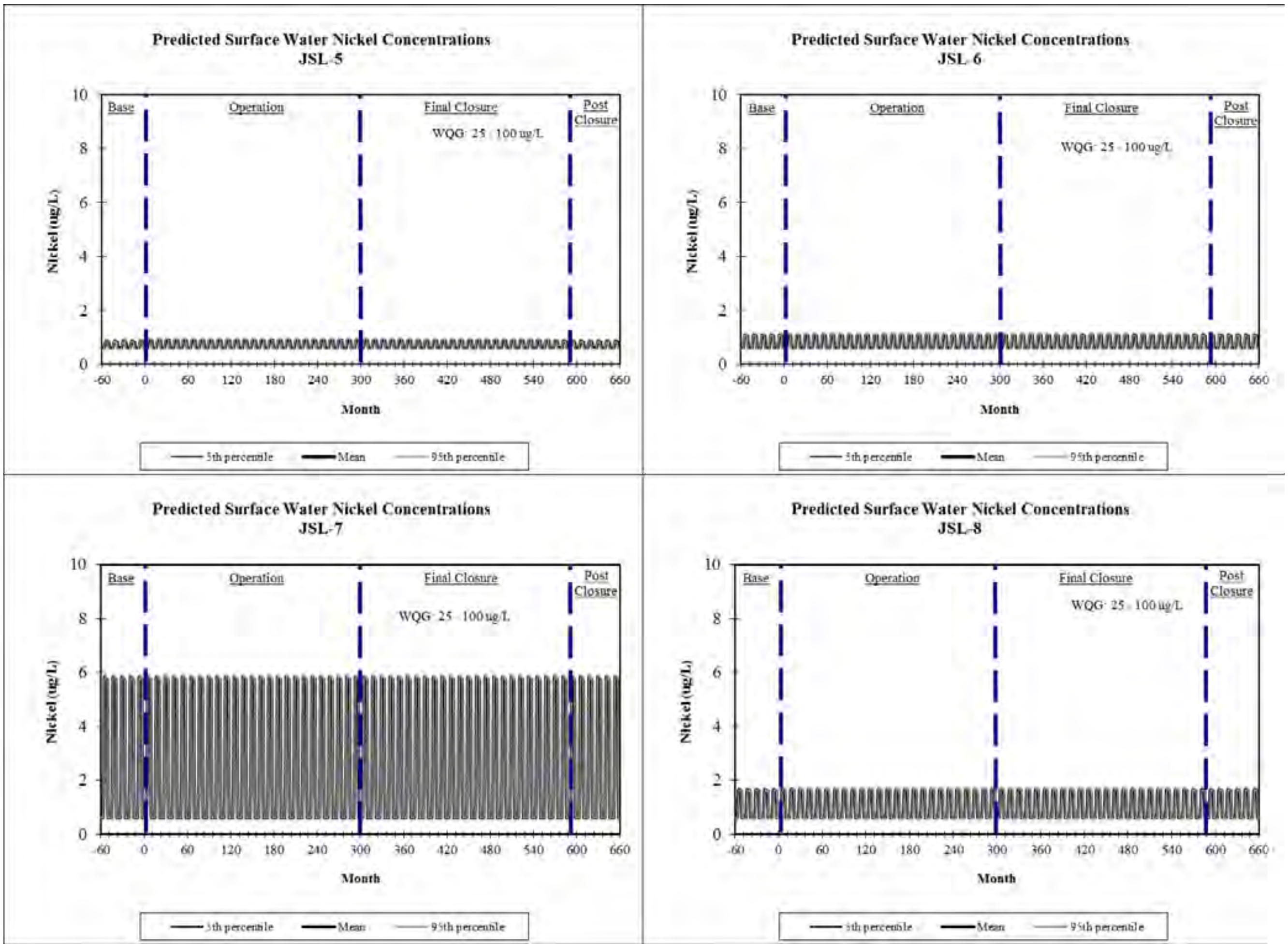

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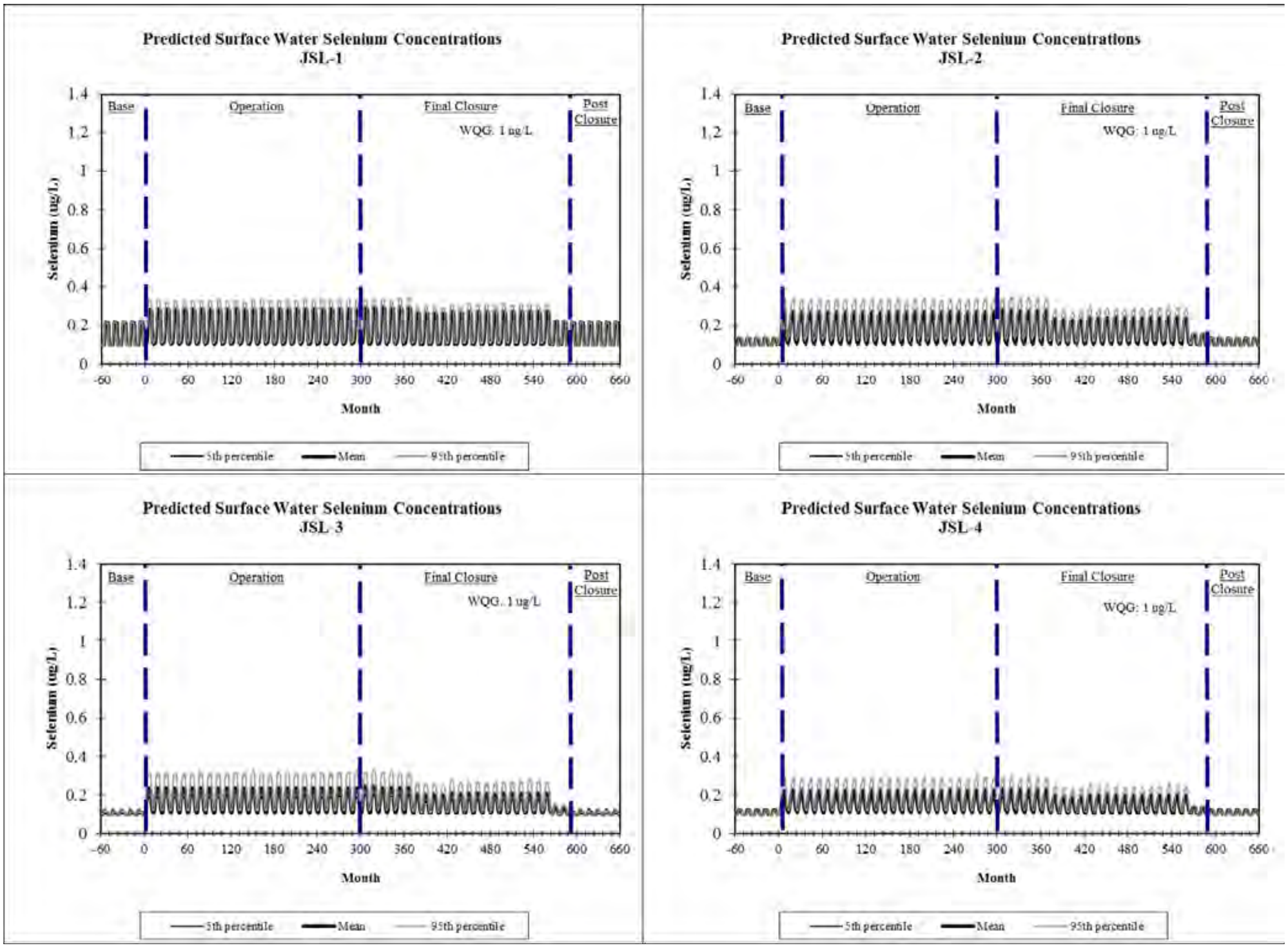

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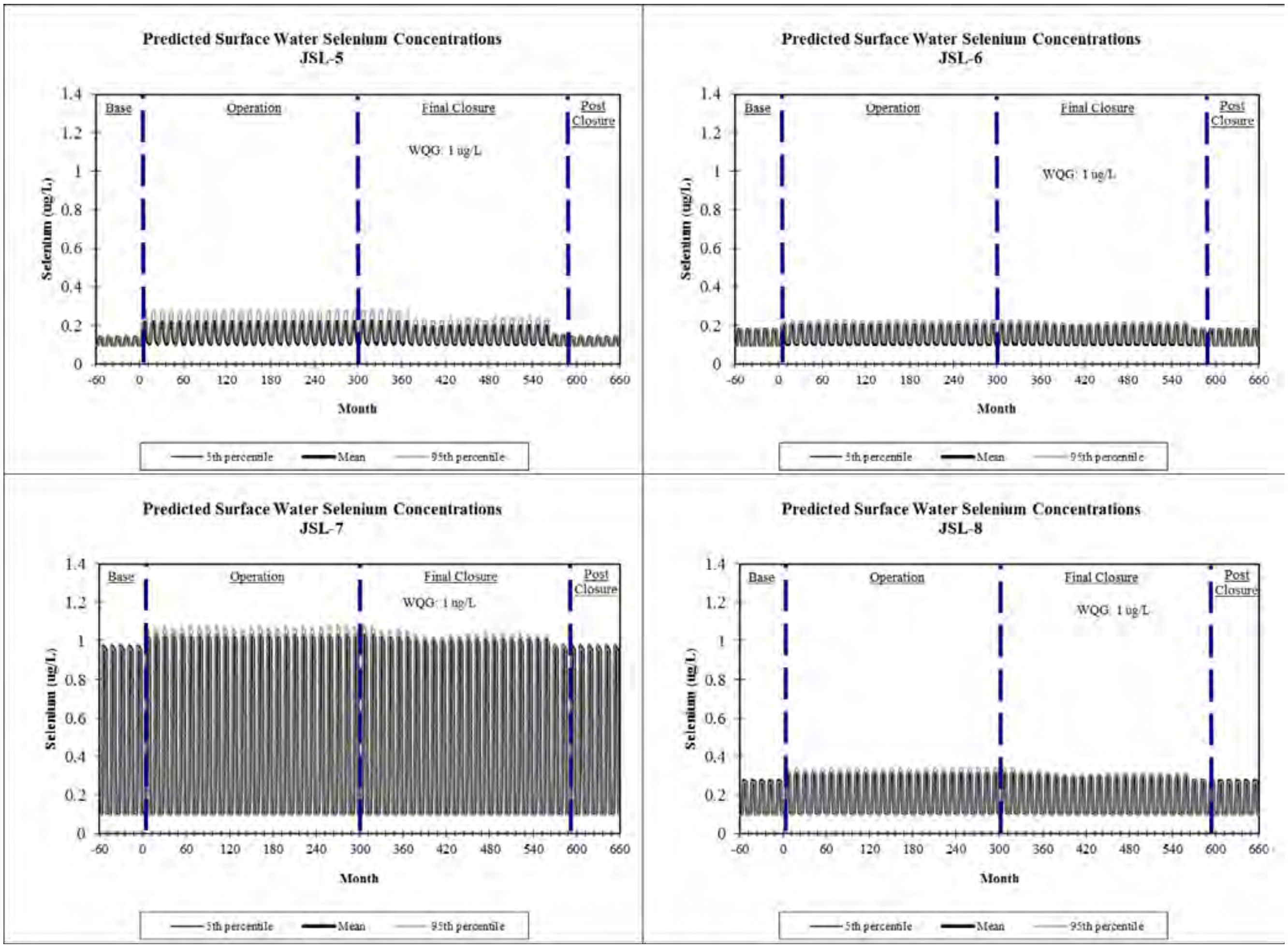

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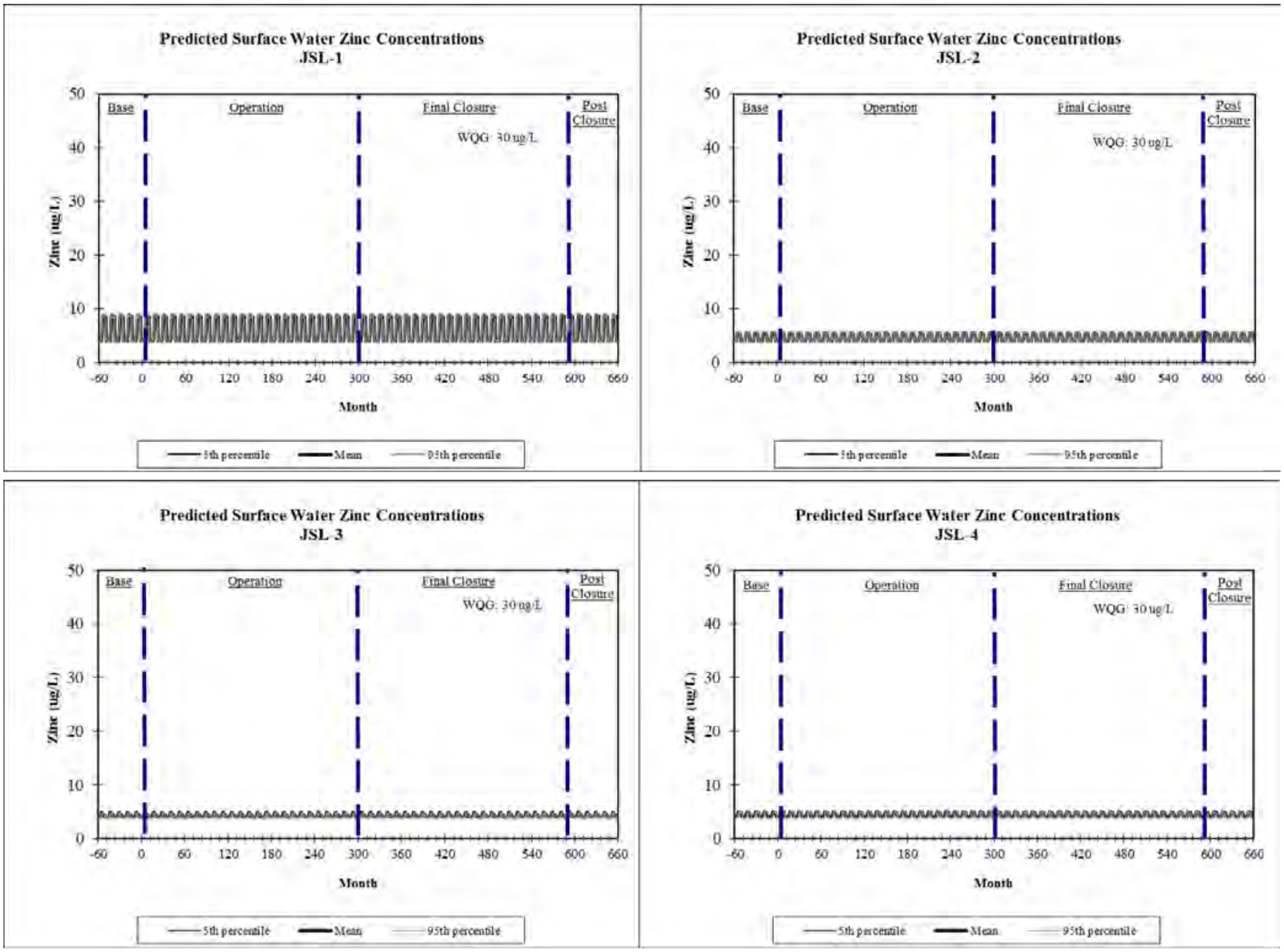

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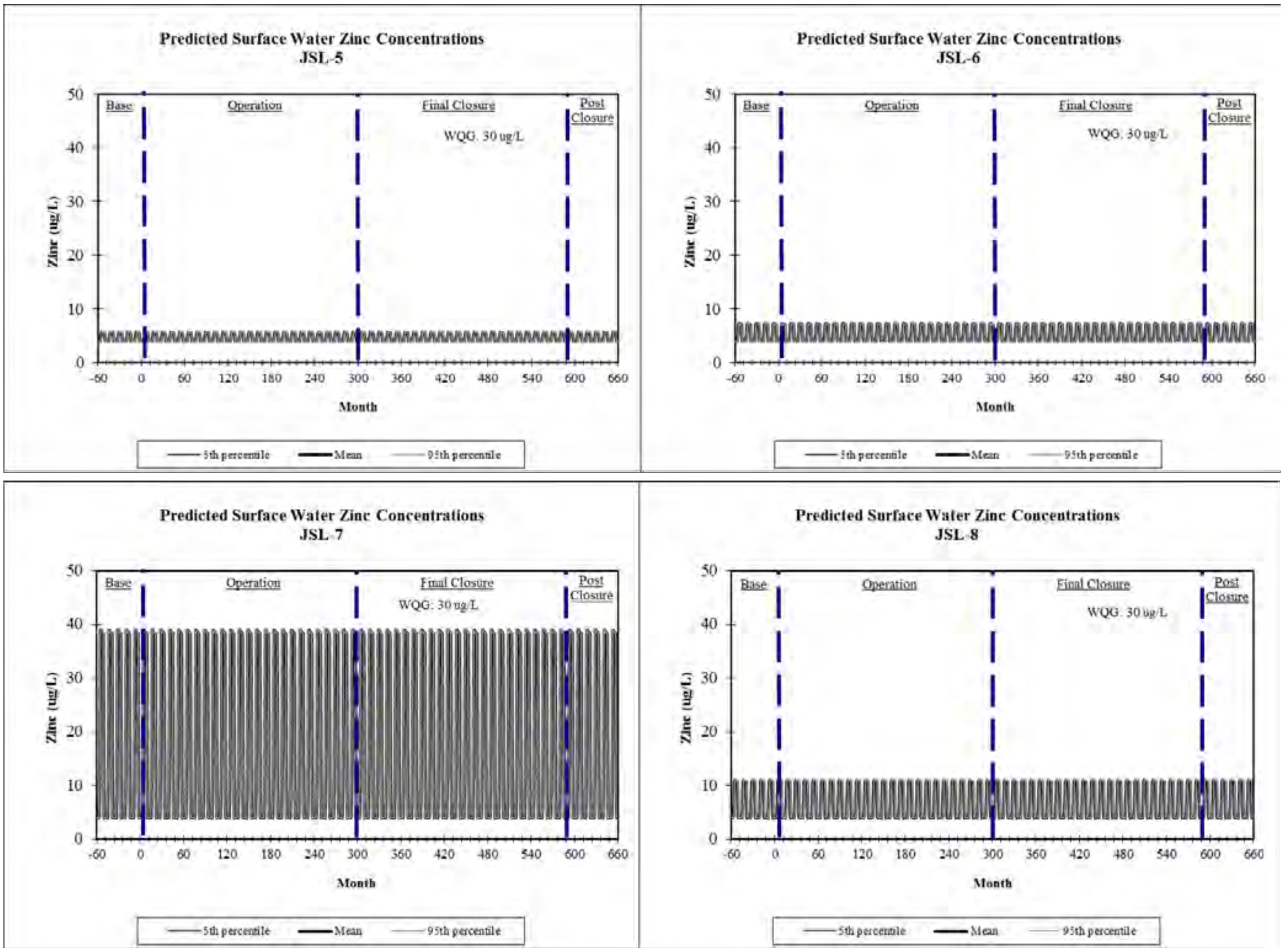

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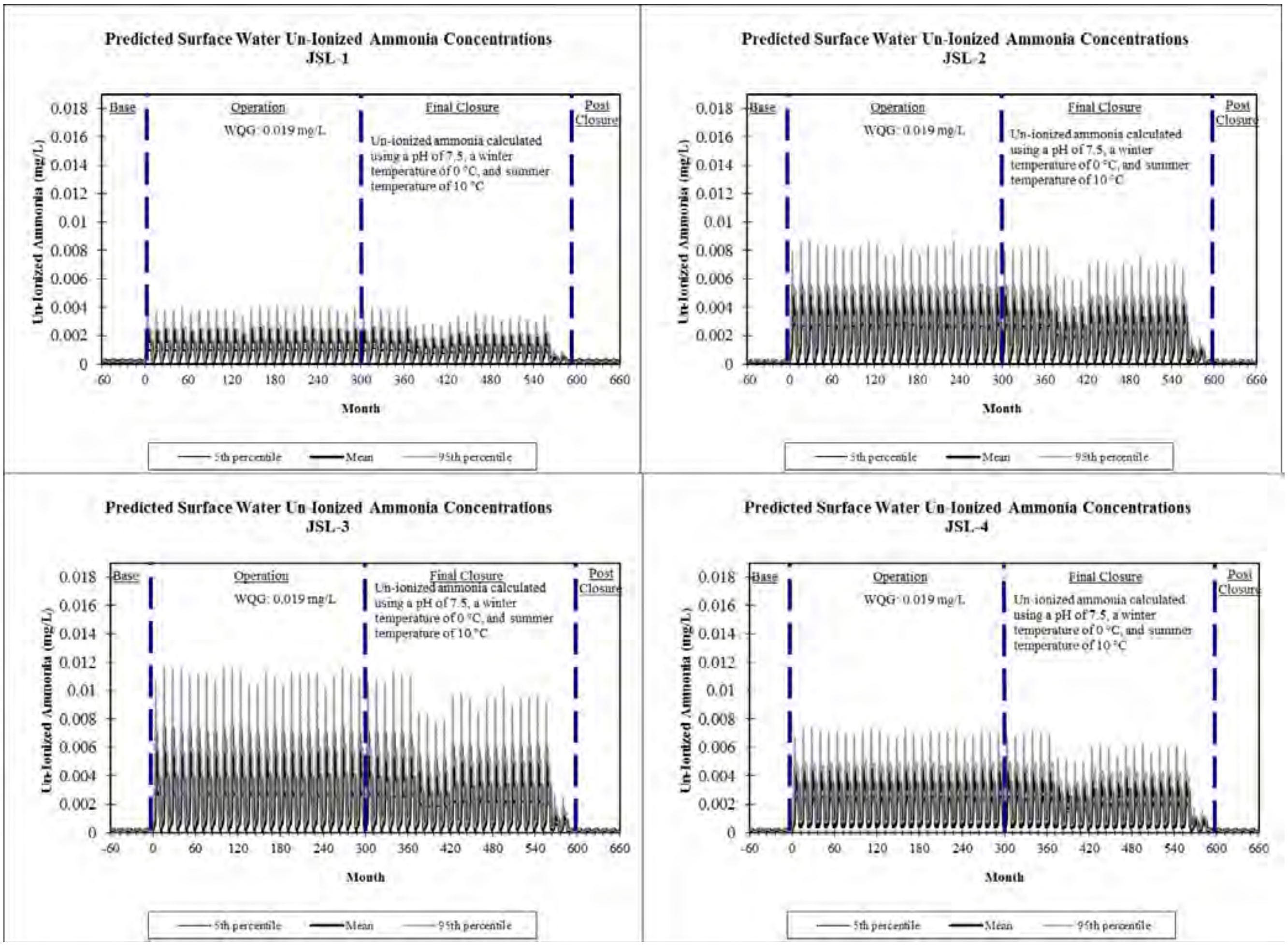

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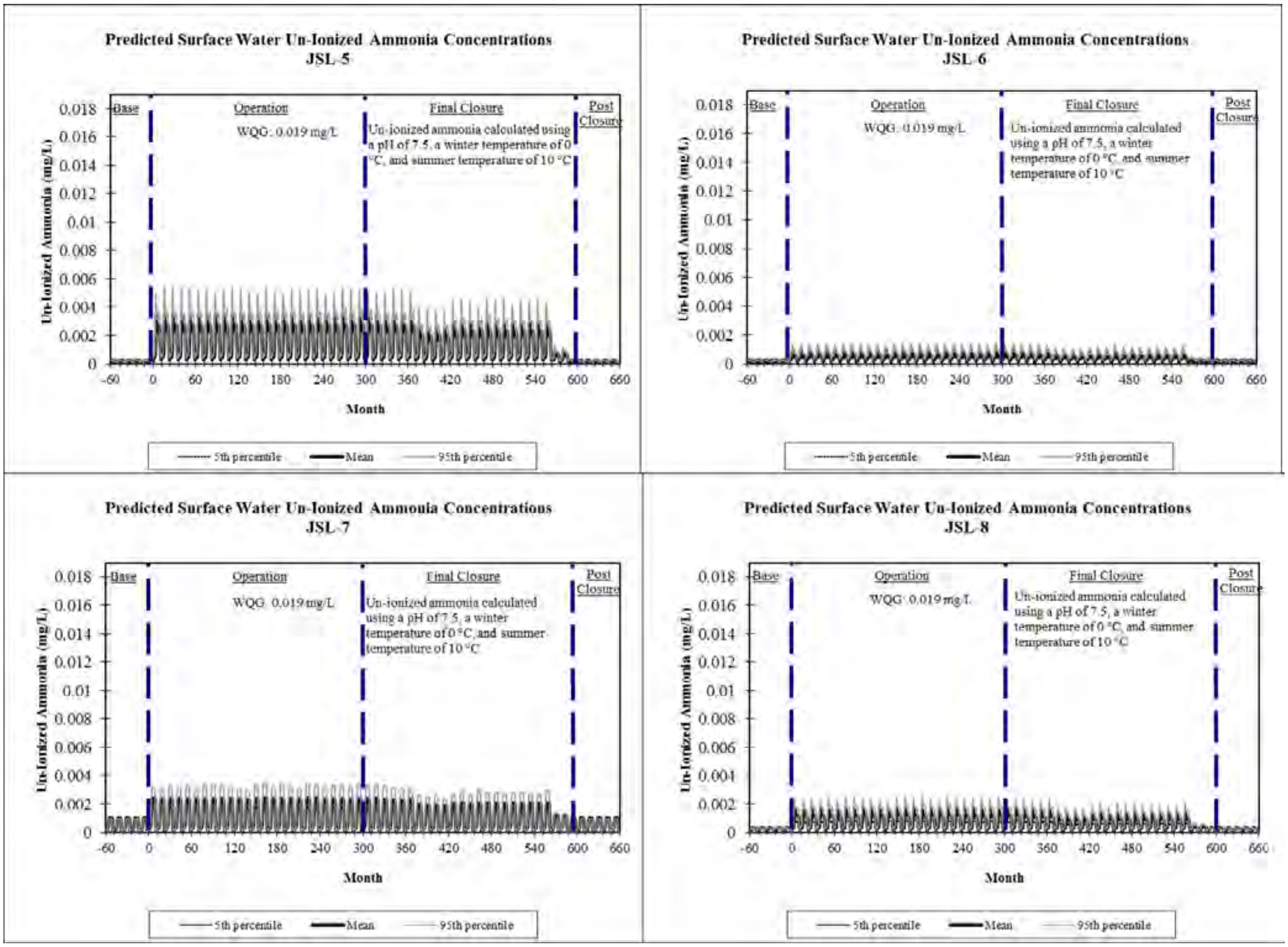

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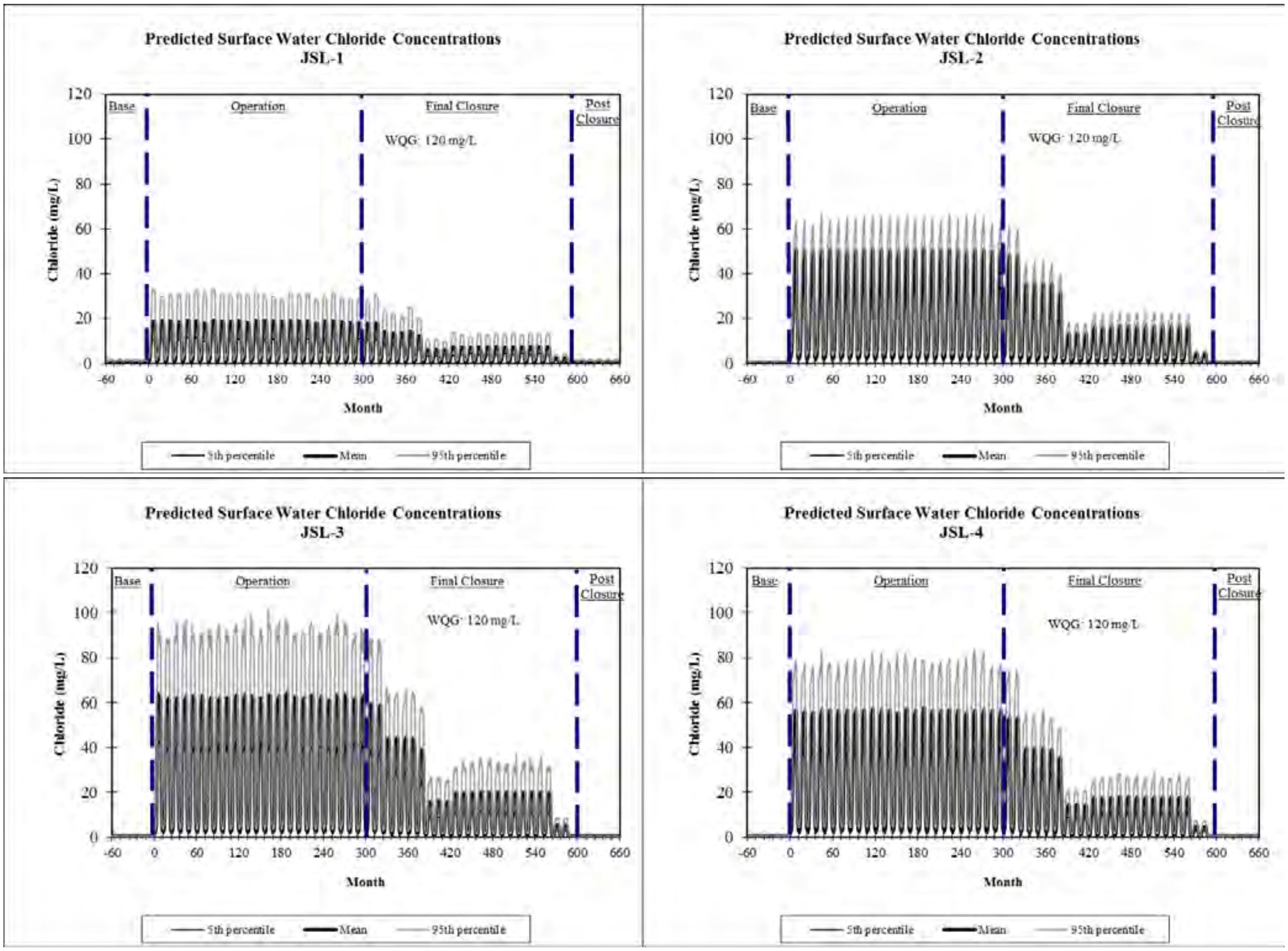

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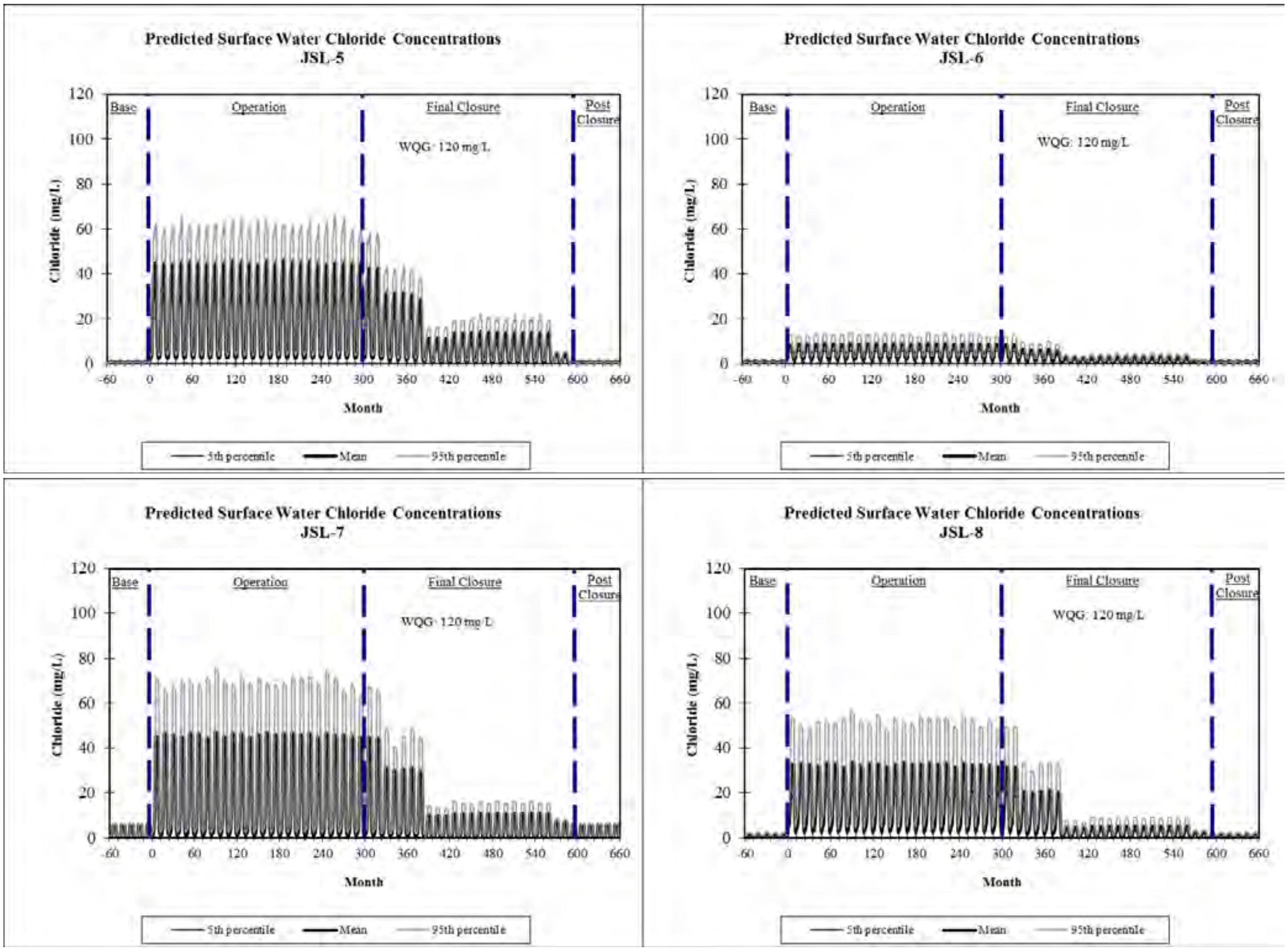

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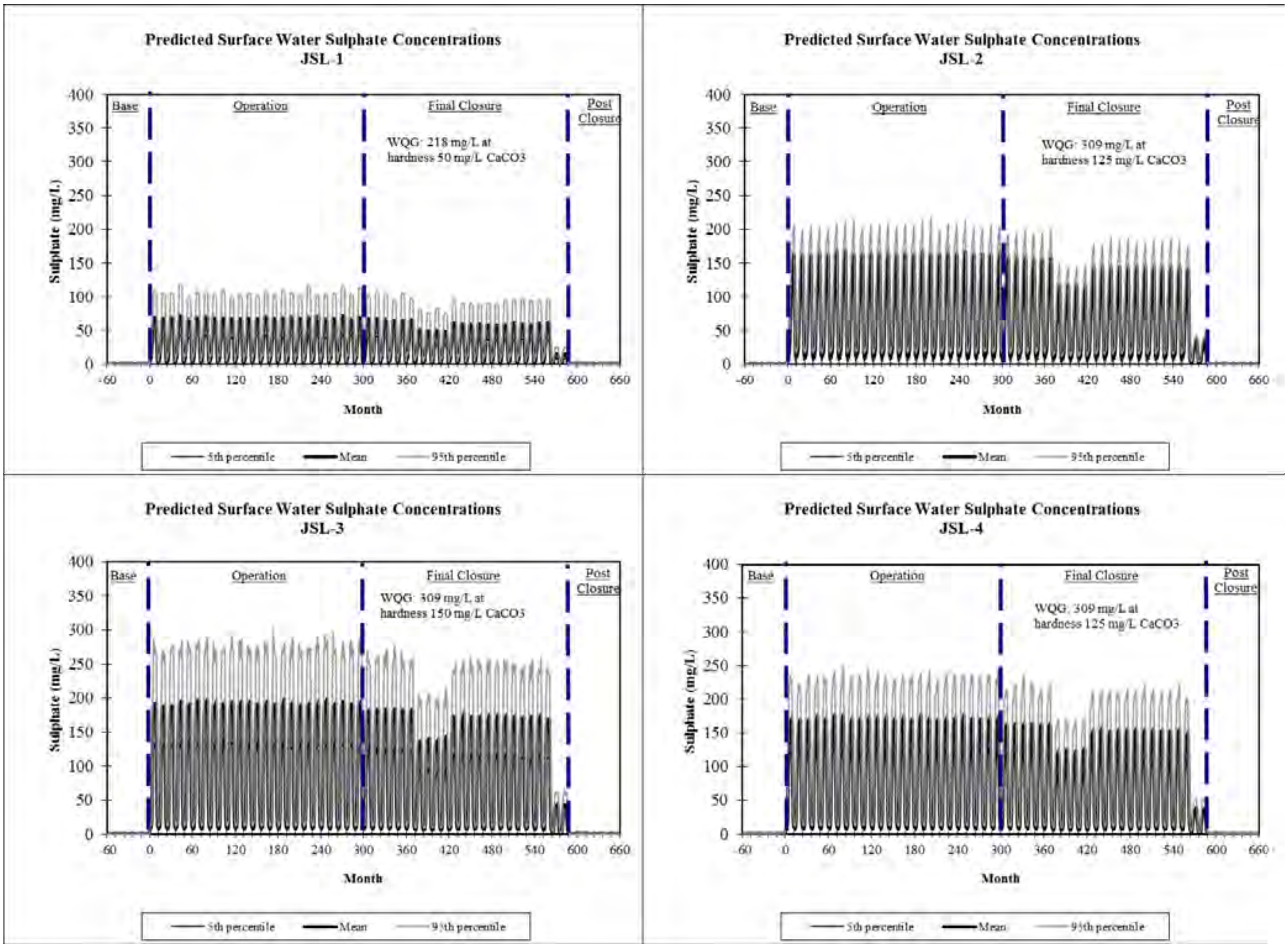

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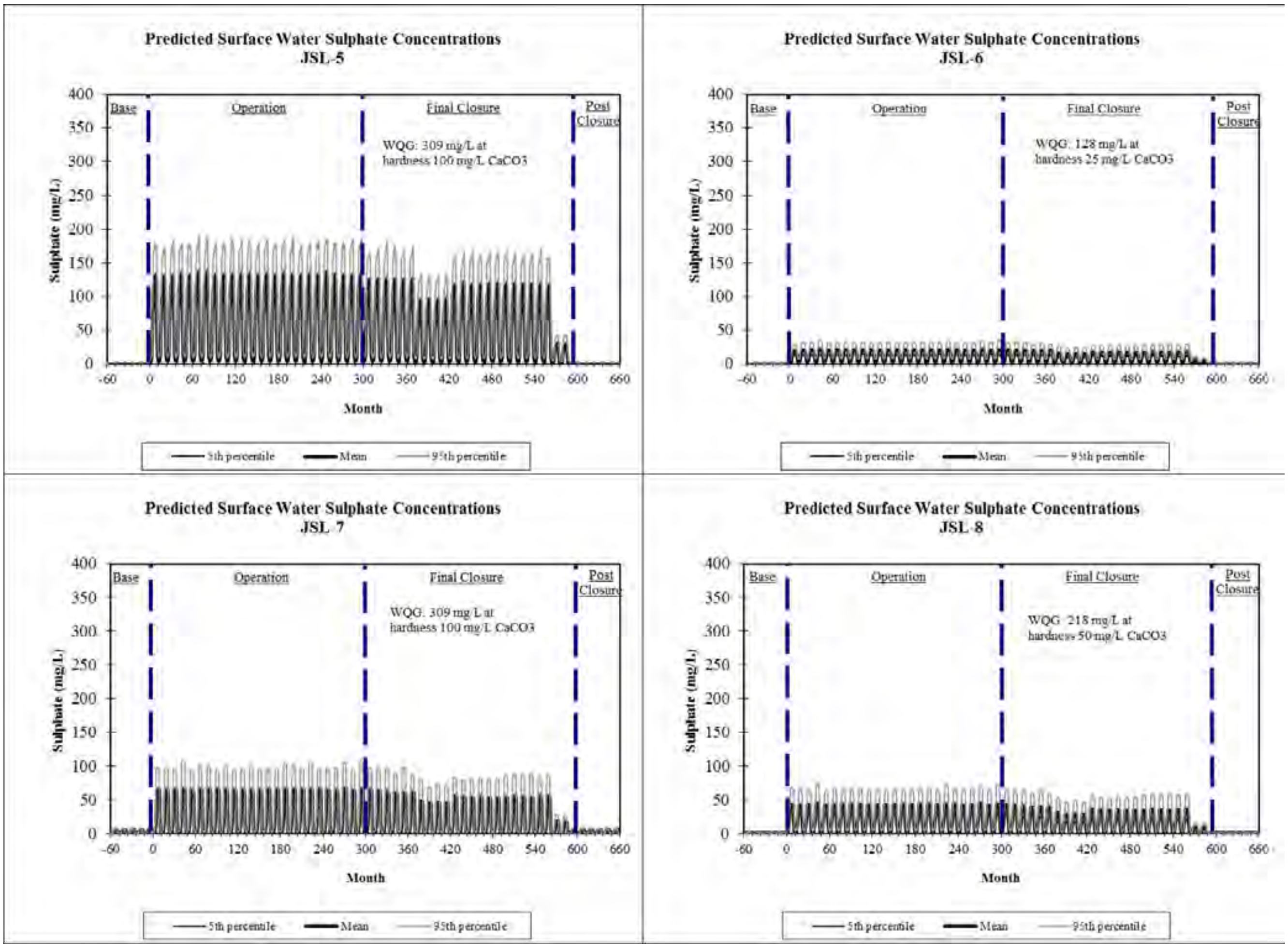

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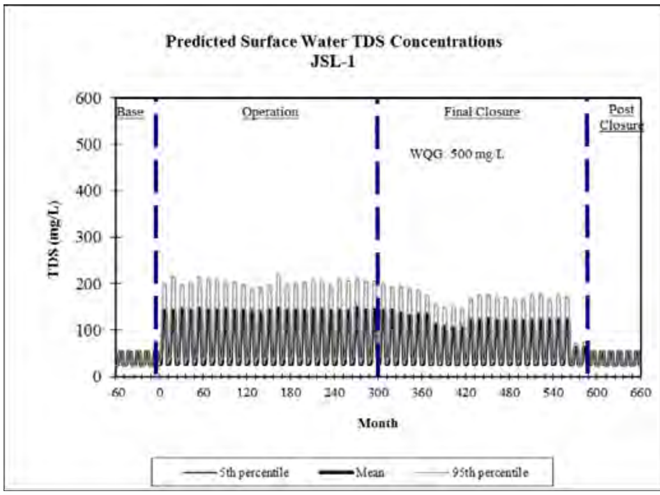

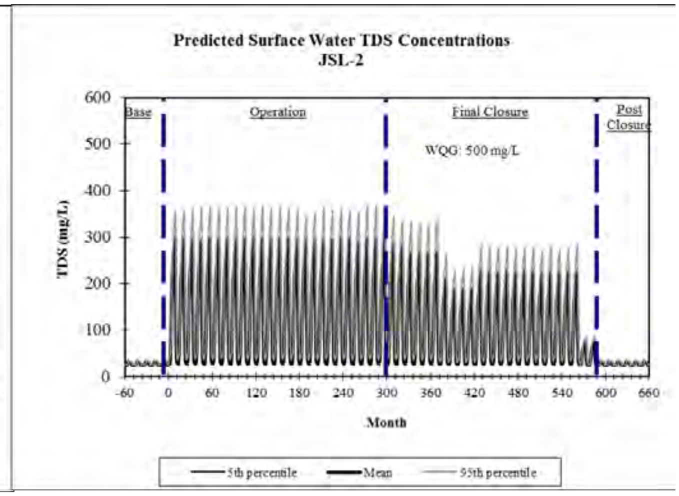

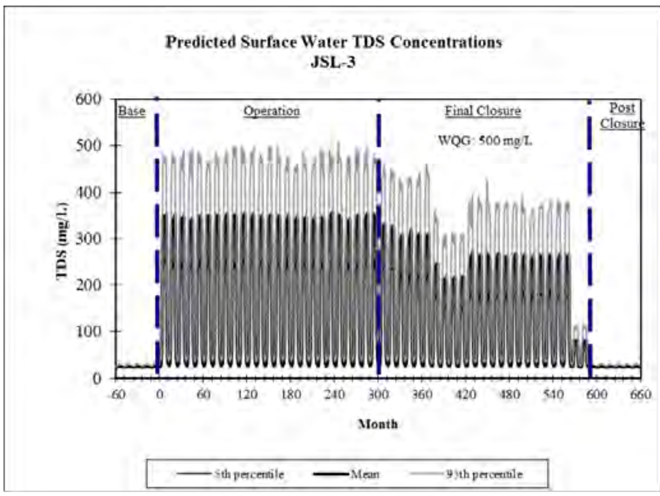

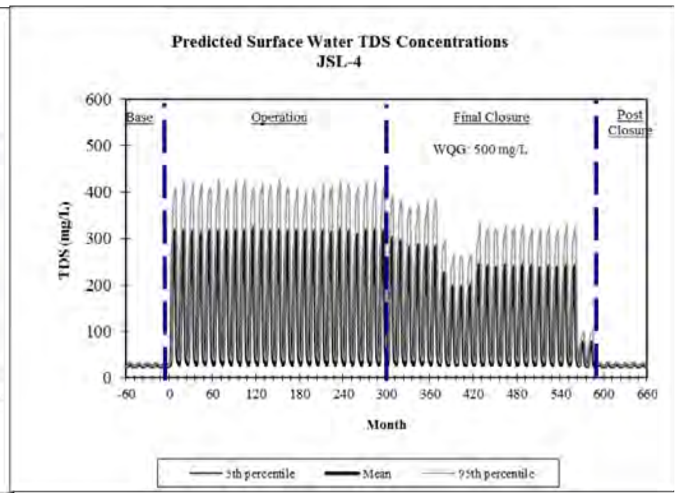

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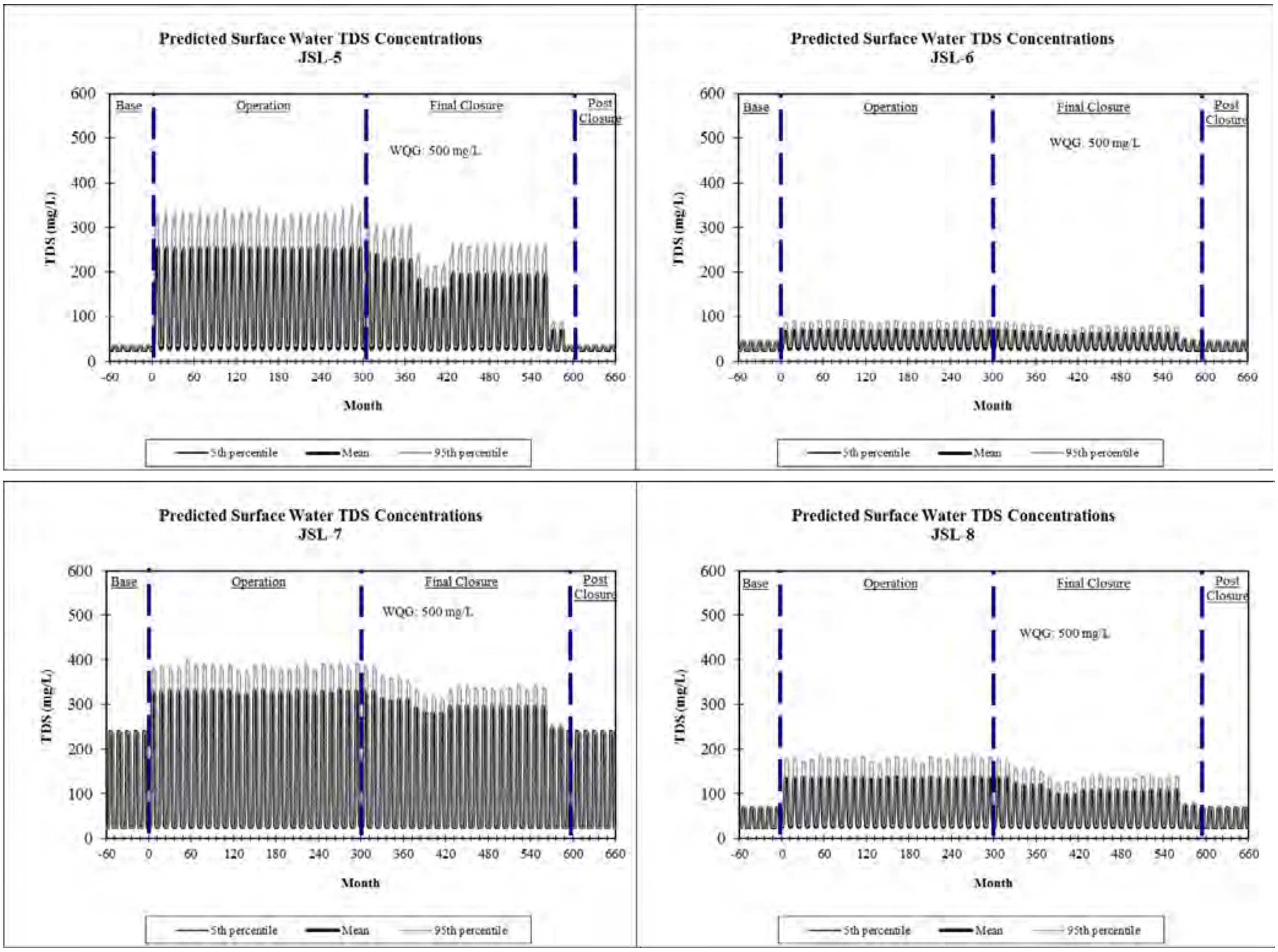

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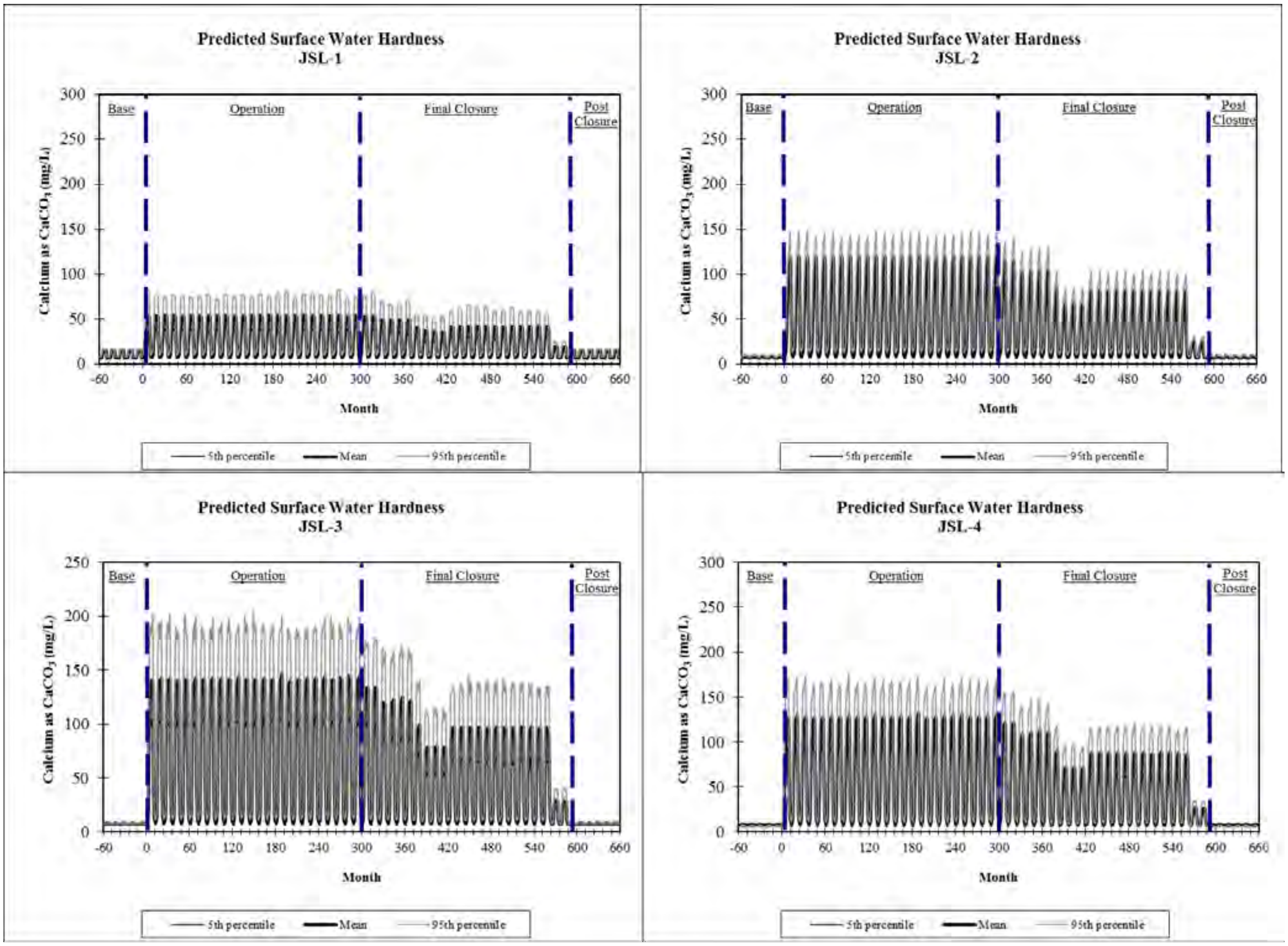

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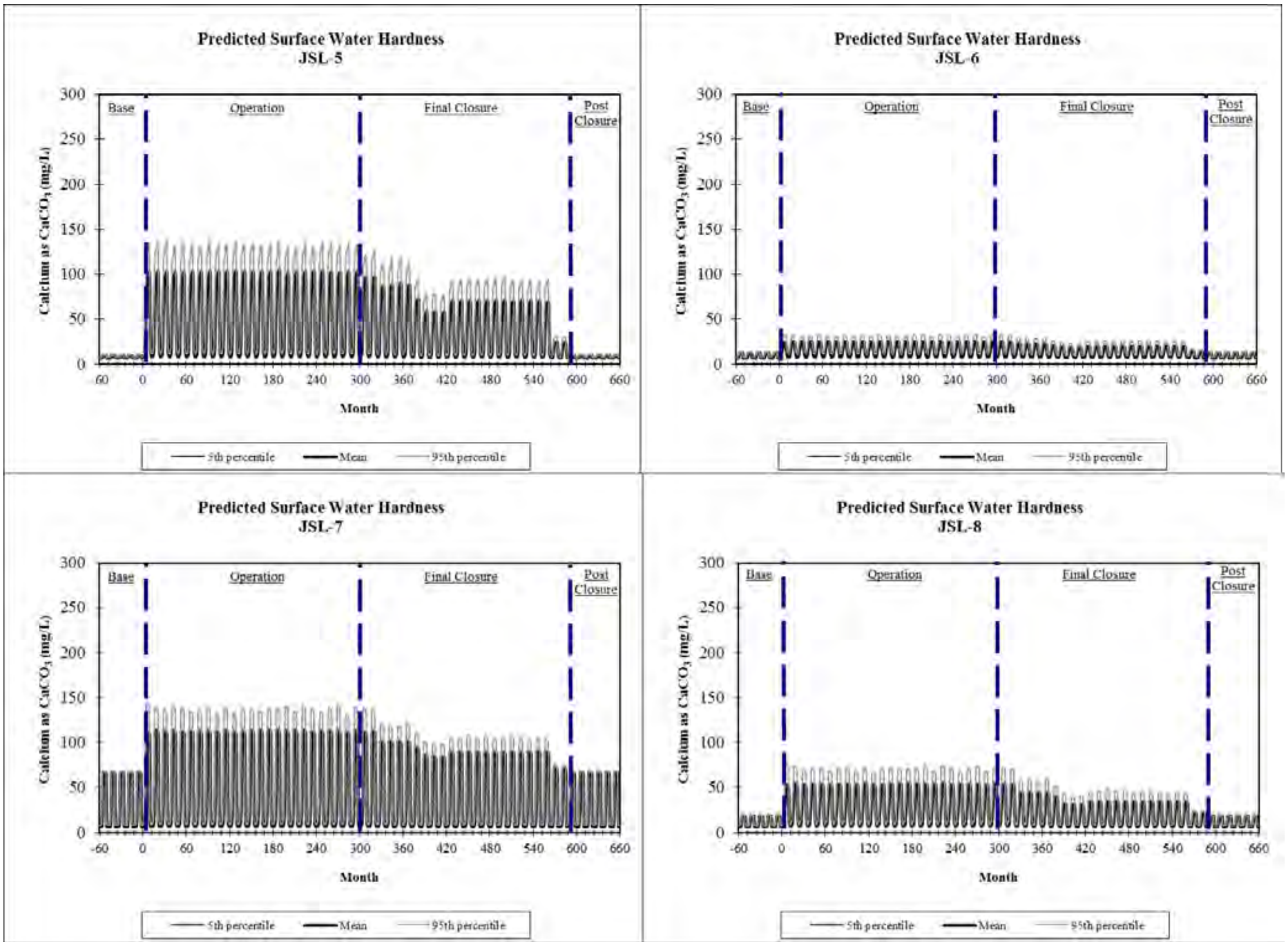

Figure 8.2-6 Water Quality Predictions (Cont'd)

The baseline results provide the water quality in each segment under natural conditions and the impact of the winter ice cover is evident in this phase of the simulation. Comparison of the range of concentrations in the baseline phase among the various Judge Sissons Lake segments illustrates the effect of the ice cover on the different segments. For example, JSL-1 is shallow compared with JSL-4 and, therefore, there is a larger fluctuation between the summer and winter concentrations in JSL-1 (for uranium, from 0.1 to 0.22 µg/L) compared with concentrations in JSL-4 (for uranium, from 0.1 to 0.12 µg/L).

The operation phase shows the predicted water quality results under the assumed effluent release for the extended operation, which considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8. The effluent is distributed throughout Judge Sissons Lake by natural flow processes and horizontal dispersion. Figure 8.2-6 illustrates the range of predicted water concentrations in each of the Judge Sissons Lake segments during the operation phase. Comparison of the baseline phase with the operation phase gives an indication of which COPCs in the effluent have more of an impact on the Judge Sissons Lake segments. For example, comparison between the baseline and operation phase concentrations of arsenic at JSL-1 shows that arsenic in the effluent discharge creates a noticeable difference, while concentrations of thorium-230 are essentially the same between the two phases. Comparison among Judge Sissons Lake segments indicates that concentrations of COPC in the southeast basin (JSL-6) show a small measurable change during the operation phase relative to the baseline phase. The magnitude of the change is appreciably lower than those changes predicted in northern basins (e.g., JSL-4). Given the location of the Project in the northern portion of the lake, and the direction of water flow within the lake (from south and west portions of the lake northeast towards the outflow in JSL-4), the impact of the effluent appears to be localized within the northern portion of the lake.

The final closure phase represents the predicted water quality under the bounding case decommissioning scenario with 22-years of Main Zone consolidation. Figure 8.2-6 shows that water quality is predicted to return to slightly elevated levels above baseline as effluent releases are gradually decreased through this phase. The system responds quickly to changes in the effluent release scenario.

Finally, the post-closure phase shows the recovery of predicted water quality for Judge Sissons Lake after effluent releases have stopped. Again, the system responds quickly and returns to baseline/pre-operation conditions, and the water effluent scenario assessed for the Project does not have long-term impacts on the water quality of Judge Sissons Lake.

The associated water quality guidelines are indicated on the graphs (Figure 8.2-6). For uranium, thorium-230, lead-210, radium-226, polonium-210, arsenic, cobalt, lead, molybdenum, nickel, un-ionized ammonia, chloride, sulphate, and TDS which have applicable with water quality guidelines, the predicted concentrations of were below the guidelines in all segments of Judge Sissons Lake. Copper concentrations in JSL-7 and JSL-8 and zinc concentrations in JSL-7 are predicted to exceed their respective WQG. However, this is predicted to occur during the winter in the shallow segments and the Project has no influence on the copper and zinc concentrations in Judge Sissons Lake.

For cadmium, predicted concentrations in water exceed the CWQG of 0.04 µg/L at all points of the assessment. Effluent discharge is expected to have an influence on cadmium concentrations in water.

For selenium, predicted water concentrations in Judge Sissons Lake are below the WQG of 1 µg/L, with the exception of JSL-7. Under baseline conditions, seasonal fluctuations of selenium in water in JSL-7 are indicated to closely approach the WQG. During the operation and final closure phases of the Project, predicted water concentrations of selenium in JSL-7 increase slightly above the WQG due to effluent discharge.

The lake water concentrations are predicted to be the highest during winter ice cover when water flows, volumes and dissolved oxygen levels are reduced. Climate change could potentially reduce the thickness and duration of the ice cover in Judge Sissons Lake thereby reducing seasonal fluctuations in predicted water concentrations.

Hardness is not a COPC but is carried through the assessment to be used in the interpretation of potential effects on aquatic biota. Based on the results above, potential residual effects with respect to cadmium and selenium levels in water quality have been identified.

8.2.1.6 Determination of Significance for Changes in Water Quality Due to Effluent Discharge

A residual effect was identified with respect to cadmium and selenium water quality based on a comparison to CWQG. A more detailed assessment of this effect was therefore undertaken to determine its significance.

The updated 2014 CCME CWQG for cadmium (CCME 1999c) is related to hardness. As discussed previously, due to the presence of the ice cover in Judge Sissons Lake there is expected to be fluctuation in concentrations during the year. This was examined for JSL-1 which is a shallow segment directly adjacent to the Kiggavik WTP discharge location and JSL-4 a larger segment that represents the outflow from the lake. Table 8.2-4 provides the estimated hardness; the calculated hardness-specific criterion from CCME; and, the estimated cadmium concentration for JSL-1 and JSL-4 separately for the summer and winter periods. This table shows that cadmium levels, both at the mean and 95th percentile, remain below the WQG during summer months at JSL-1 and JSL-4. In the winter months, the mean concentration is within the WQG, but the 95th percentile exceed the WQG. As summer is the period of growth and reproduction, this is the period of most relevance.

Table 8.2-4 Summary of Cadmium Water Concentrations and Appropriate Criteria for the Summer and Winter Periods

	Estimated Hardness (mg/L)	Calculated Cadmium Water Quality Criterion[(a)] (µg/L)	Estimated Cadmium Concentration in Water (µg/L)	
			Mean	95th
JSL-1				
Summer	8	0.04	0.02	0.03
Winter	55	0.10	0.09	0.15
JSL-4				
Summer	10	0.04	0.03	0.04
Winter	130	0.20	0.14	0.21

NOTES:

[a] Water quality criterion calculated following the approach adopted by the US EPA

JSL-1 = Judge Sissons Lake, segment 1; JSL-4 = Judge Sissons Lake, segment 4; mg/L = miligrams per litre; µg/L = micrograms per litre.

For selenium, predicted water concentrations in JSL-7 exceed the WQG of 1 µg/L during the operation and final closure phases of the Project. This is largely due to baseline conditions and seasonal fluctuations; however , the effluent discharge does result in a minor exceedance of the WQG (95th percentile is predicted to rise to 1.1 µg/L). While the CCME WQG is exceeded, it is noted that the draft selenium guideline from the U.S. EPA (2014) of 1.3 µg/L is not exceeded in JSL-7, which suggests that potential effects on aquatic life in this segment will be limited. Predicted selenium concentrations in other segments of Judge Sissons Lake are below the WQG.

Table 8.2-5 Application of Residual Effects Criteria for Water Quality

Attribute	Description	Rating	Comment
Direction	The ultimate long-term trend of the environmental effect	Negative	Levels of COPC are expected in increase due to Project emissions
Magnitude	Amount of change in a measurable parameter relative to the baseline case or relative to a threshold	Low	It is expected that cadmium concentrations in Judge Sissons Lake would be elevated compared to baseline and may exceed the appropriate threshold in the winter months at the 95th percentile predicted concentrations. Selenium concentrations in one segment of Judge Sissons Lake are expected to exceed the threshold during the operation and final closure phases of the Project; however, these exceedances are largely due to baseline and seasonal fluctuations. Other COPC are not expected to be present at levels that exceed a threshold.

Table 8.2-5 Application of Residual Effects Criteria for Water Quality

Attribute	Description	Rating	Comment
Geographic Extent	The geographic area within which an environmental effect occurs	Local	Effect confined to the select segments of Judge Sissons Lake.
Frequency	Number of times that an effect may occur over the life of the project	Regular	Effect occurs seasonally throughout the project.
Duration	Length of time over which the effect is measurable	Medium term	More than one year, but not beyond the end of project decommissioning.
Reversibility	Likelihood that a measurable parameter for a VEC will recover from an environmental effect to baseline conditions	Reversible	Will likely recover to baseline conditions in the post closure phase.
Note: VEC = valued environmental component			

As discussed, for those COPCs with a threshold, the concentrations are expected to be below the appropriate value with the exception of cadmium and selenium. For cadmium, the expected concentrations within Judge Sissons Lake are predicted to be below the CCME CWQG once seasonal changes in hardness are considered; however, 95th percentile predicted concentrations exceed the CWQG in winter months. For selenium in JSL-7, concentrations during the operation and final closure phases of the Project are shown to seasonally exceed the CWQG; this is largely due to baseline conditions and seasonal fluctuations (Figure 8.2-6). The changes in water quality are expected to occur during the operation and final closure stages of the Project but return to baseline levels at post closure. Overall, no significant adverse effects on water quality are expected.

It is also important to note that the significance of changes in water quality parameters is determined by the user of the resource. Thus, the determination of significance of changes to water quality is also included in the evaluation of effects on aquatic biota (Section 10) and fish (Section 11).

8.2.1.7 Compliance and Environmental Monitoring for Changes in Water Quality Due to Effluent Discharge

Wastewater/effluent discharge quality will be analysed and documented regularly according to Nunavut regulatory requirements and the MMER during mine operations, and during and after mine closure. In addition, water quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored on a monthly basis during the operations and closure phases of the Project, and on an annual basis during the post-closure phase.