Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Physical Environment

Keeyask
Hydropower Limited Partnership

June 2012

APPENDIX 4A
SURFACE WATER AND ICE REGIME TABLES

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Table 4A.1a: Stephens Lake Existing Environment Water Surface Level (m)

Stephens Lake		Percentile						
Type of Data		Min	5	25	50	75	95	Max
All Data		137.52	139.16	139.83	140.22	140.59	141.05	141.21
Seasonal	Open Water	137.52	139.05	139.73	140.14	140.47	141.09	141.18
	Winter	138.16	139.27	139.95	140.35	140.68	141.00	141.21
Monthly	January	139.01	139.57	140.17	140.53	140.75	141.01	141.15
	February	138.53	139.24	140.00	140.40	140.69	140.95	141.18
	March	138.40	138.97	139.66	140.08	140.43	140.82	141.12
	April	138.16	139.18	139.82	140.16	140.53	141.08	141.18
	May	138.54	139.23	139.99	140.42	140.78	141.11	141.18
	June	138.29	139.15	139.76	140.17	140.46	141.09	141.13
	July	138.38	139.20	139.74	140.16	140.40	141.08	141.12
	August	138.38	139.12	139.68	140.11	140.41	141.07	141.13
	September	137.92	138.81	139.66	139.99	140.30	140.94	141.13
	October	137.52	138.72	139.66	140.04	140.36	140.92	141.12
	November	138.56	139.50	140.10	140.49	140.78	141.04	141.21
	December	138.50	139.46	140.12	140.44	140.73	141.00	141.17

Table 4A.1b: Stephens Lake Existing Environment 7-Day Water Surface Level Variations (m)

Stephens Lake		Percentile						
Type of Data		Min	5	25	50	75	95	Max
All Data		0.00	0.06	0.24	0.40	0.58	0.94	2.11
Seasonal	Open Water	0.00	0.04	0.20	0.37	0.55	0.92	1.78
	Winter	0.02	0.14	0.28	0.42	0.60	0.96	2.11

Table 4A.2a: Downstream Keeyask GS Existing Environment Water Surface Level (m)

D/S Keeyask GS		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		137.76	139.41	140.21	141.24	143.19	144.62	148.17
Seasonal	**Open Water**	137.76	139.13	139.80	140.24	140.64	141.40	143.16
	Winter	138.66	140.88	142.42	143.20	143.78	145.87	148.17
Monthly	**January**	141.88	142.62	143.27	143.78	144.28	147.01	148.12
	February	141.62	142.24	143.24	143.73	144.33	146.99	148.17
	March	141.23	141.88	142.85	143.40	143.87	146.49	147.52
	April	140.53	141.24	142.08	142.62	143.20	144.65	146.97
	May	138.62	139.68	140.58	141.14	141.50	142.48	143.16
	June	138.50	139.26	139.82	140.23	140.51	141.21	141.26
	July	138.49	139.26	139.80	140.21	140.46	141.21	141.28
	August	138.50	139.20	139.74	140.15	140.46	141.18	141.30
	September	138.24	138.91	139.72	140.04	140.36	140.97	141.30
	October	137.76	138.70	139.63	140.06	140.38	140.95	141.27
	November	138.66	140.05	140.77	141.42	142.27	143.12	144.99
	December	141.55	142.36	142.82	143.21	143.50	145.02	147.05

Table 4A.2b: Downstream Keeyask GS Existing Environment 7-Day Water Surface Level Variations (m)

D/S Keeyask GS		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.04	0.11	0.25	0.48	0.89	2.21
Seasonal	**Open Water**	0.01	0.04	0.19	0.36	0.54	0.90	1.74
	Winter	0.00	0.04	0.09	0.16	0.35	0.86	2.21

Table 4A.3a: Upstream Gull Rapids Existing Environment Water Surface Level (m)

U/S Gull Rapids		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		151.24	151.66	152.14	152.78	153.43	154.14	155.22
Seasonal	**Open Water**	151.24	151.54	151.89	152.17	152.56	153.44	154.10
	Winter	151.40	152.31	152.89	153.34	153.77	154.31	155.22
Monthly	**January**	152.54	152.75	153.39	153.81	154.13	154.39	154.77
	February	152.58	152.83	153.35	153.65	153.96	154.39	155.22
	March	152.27	152.55	152.94	153.32	153.63	154.10	154.83
	April	151.76	152.03	152.37	152.79	153.05	153.58	153.78
	May	151.49	151.76	152.11	152.33	152.86	153.35	153.69
	June	151.39	151.53	151.77	152.08	152.86	153.51	153.80
	July	151.44	151.51	151.77	152.06	152.86	153.49	154.10
	August	151.40	151.57	151.81	152.06	152.48	153.30	154.10
	September	151.28	151.45	151.89	152.09	152.34	152.85	154.10
	October	151.24	151.56	152.06	152.29	152.52	153.08	154.00
	November	151.40	152.26	152.72	152.99	153.26	153.75	154.22
	December	151.93	152.65	153.30	153.63	154.03	154.41	154.78

Table 4A.3b: Upstream Gull Rapids Existing Environment 7-Day Water Surface Level Variations (m)

U/S Gull Rapids		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.02	0.04	0.08	0.14	0.28	0.62
Seasonal	**Open Water**	0.00	0.02	0.03	0.06	0.10	0.20	0.43
	Winter	0.00	0.03	0.07	0.11	0.17	0.32	0.62

Table 4A.4a: Gull Lake Existing Environment Water Surface Level (m)

Gull Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		151.43	152.01	152.54	153.16	153.94	154.84	156.67
Seasonal	**Open Water**	151.43	151.86	152.28	152.61	153.08	154.18	154.94
	Winter	151.66	152.59	153.23	153.71	154.25	155.23	156.67
Monthly	**January**	152.67	152.96	153.52	154.11	154.44	154.89	155.54
	February	152.71	153.02	153.56	154.02	154.55	155.36	156.33
	March	152.38	152.71	153.23	153.81	154.50	155.67	156.67
	April	152.02	152.24	152.61	153.36	153.83	155.40	156.14
	May	151.78	152.08	152.43	152.76	153.45	154.19	154.53
	June	151.65	151.84	152.15	152.54	153.49	154.25	154.60
	July	151.72	151.82	152.15	152.52	153.50	154.24	154.93
	August	151.67	151.89	152.20	152.51	153.03	154.01	154.94
	September	151.51	151.73	152.30	152.55	152.87	153.48	154.93
	October	151.43	151.79	152.47	152.73	153.05	153.51	154.83
	November	151.66	152.59	153.03	153.34	153.61	154.03	154.51
	December	152.65	152.97	153.55	153.90	154.31	154.69	155.08

Table 4A.4b: Gull Lake Environment 7-Day Water Surface Level Variations (m)

Gull Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.02	0.05	0.09	0.15	0.29	0.66
Seasonal	**Open Water**	0.00	0.02	0.04	0.07	0.12	0.23	0.54
	Winter	0.01	0.03	0.07	0.12	0.19	0.34	0.66

Table 4A.5a: Portage Creek Existing Environment Water Surface Level (m)

Portage Creek		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		152.05	152.83	153.60	154.53	156.05	158.37	159.86
Seasonal	**Open Water**	152.05	152.64	153.19	153.66	154.26	155.52	156.28
	Winter	152.08	153.77	154.69	155.97	157.43	158.85	159.86
Monthly	**January**	153.69	154.62	155.92	156.68	157.42	158.49	159.17
	February	153.69	154.72	155.93	157.60	158.38	159.18	159.86
	March	153.90	154.72	155.81	157.65	158.37	159.24	159.86
	April	153.27	153.83	154.92	156.30	157.19	158.48	159.06
	May	152.54	153.01	153.72	154.20	155.14	155.94	156.21
	June	152.36	152.61	153.01	153.50	154.65	155.52	155.90
	July	152.46	152.58	153.02	153.48	154.66	155.50	156.27
	August	152.39	152.68	153.08	153.47	154.11	155.25	156.28
	September	152.17	152.47	153.21	153.52	153.91	154.63	156.27
	October	152.05	152.51	153.39	153.73	154.13	154.63	156.16
	November	152.08	153.36	153.82	154.17	154.49	154.97	155.77
	December	153.47	154.16	154.65	155.11	156.16	157.16	158.23

Table 4A.5b Portage Creek Existing Environment 7-Day Water Surface Level Variations (m)

Portage Creek		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.03	0.07	0.13	0.25	0.62	1.80
Seasonal	**Open Water**	0.00	0.02	0.05	0.09	0.15	0.35	0.71
	Winter	0.01	0.05	0.11	0.20	0.34	0.87	1.80

Table 4A.6a: Two Goose Creek Existing Environment Water Surface Level (m)

Two Goose Creek		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		153.62	154.60	155.44	156.31	158.51	160.67	161.82
Seasonal	**Open Water**	153.70	154.39	155.04	155.58	156.24	157.61	158.42
	Winter	153.62	155.49	156.41	158.53	160.02	160.92	161.82
Monthly	**January**	155.92	156.49	157.58	159.14	160.10	160.63	161.35
	February	156.73	157.83	159.68	160.44	160.75	161.31	161.82
	March	156.80	158.14	159.20	160.09	160.66	161.20	161.53
	April	155.75	156.85	158.01	158.71	159.44	160.33	160.84
	May	154.28	154.83	155.76	156.34	157.23	158.00	158.38
	June	154.07	154.37	154.83	155.39	156.67	157.61	158.02
	July	154.19	154.33	154.84	155.37	156.68	157.59	158.41
	August	154.10	154.44	154.91	155.36	156.07	157.32	158.42
	September	153.85	154.20	155.06	155.41	155.85	156.65	158.41
	October	153.70	154.28	155.25	155.61	156.02	156.45	158.29
	November	153.62	154.93	155.46	155.75	156.08	156.51	157.23
	December	155.04	155.69	156.05	156.42	157.27	159.18	160.62

Table 4A.6b: Two Goose Creek Existing Environment 7-Day Water Surface Level Variations (m)

Two Goose Creek		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.01	0.03	0.07	0.14	0.27	0.71	2.18
Seasonal	**Open Water**	0.01	0.03	0.05	0.09	0.17	0.41	0.79
	Winter	0.01	0.05	0.12	0.21	0.39	0.95	2.18

Table 4A.7a: Downstream Birthday Rapids Existing Environment Water Surface Level (m)

D/S Birthday Rapids		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		155.63	156.53	157.22	157.92	160.34	162.36	163.70
Seasonal	**Open Water**	155.84	156.37	156.89	157.34	157.94	159.14	159.92
	Winter	155.63	157.21	157.92	160.36	161.84	162.56	163.70
Monthly	**January**	157.47	157.90	158.62	160.36	162.07	162.55	163.03
	February	158.18	160.04	161.75	162.05	162.41	162.88	163.70
	March	159.41	160.34	161.28	161.85	162.22	162.75	163.36
	April	158.13	159.11	159.99	160.59	161.13	161.73	162.55
	May	156.27	156.72	157.57	158.12	158.84	159.56	159.92
	June	156.12	156.35	156.72	157.18	158.27	159.11	159.48
	July	156.21	156.32	156.72	157.16	158.27	159.09	159.84
	August	156.14	156.41	156.78	157.15	157.75	158.84	159.85
	September	155.95	156.22	156.90	157.20	157.56	158.25	159.84
	October	155.84	156.28	157.07	157.39	157.74	158.16	159.72
	November	155.63	156.67	157.20	157.46	157.79	158.12	158.85
	December	156.74	157.27	157.60	157.86	158.31	160.82	162.78

Table 4A.7b: Downstream Birthday Rapids Existing Environment 7-day Water Surface Level Variations (m)

D/S Birthday Rapids		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.03	0.06	0.13	0.26	0.70	2.35
Seasonal	**Open Water**	0.00	0.02	0.05	0.08	0.15	0.38	0.71
	Winter	0.01	0.04	0.11	0.21	0.36	1.06	2.35

Table 4A.8a: Upstream Birthday Rapids Existing Environment Water Surface Level (m)

U/S Birthday Rapids		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		157.41	158.39	159.16	159.73	161.17	162.69	164.00
Seasonal	**Open Water**	157.41	158.17	158.82	159.30	159.84	160.92	161.54
	Winter	157.81	159.11	159.65	161.00	162.20	162.91	164.00
Monthly	**January**	159.08	159.45	159.80	160.76	162.38	162.89	163.32
	February	159.89	160.66	161.98	162.34	162.68	163.20	164.00
	March	160.25	161.02	161.78	162.24	162.57	163.12	163.68
	April	159.34	160.08	160.85	161.38	161.79	162.32	163.10
	May	158.05	158.59	159.34	159.83	160.61	161.11	161.52
	June	157.82	158.14	158.60	159.13	160.23	160.96	161.25
	July	157.95	158.10	158.61	159.11	160.23	160.94	161.53
	August	157.86	158.22	158.68	159.10	159.73	160.73	161.54
	September	157.58	157.96	158.82	159.16	159.54	160.21	161.53
	October	157.41	158.33	159.05	159.38	159.69	160.02	161.44
	November	157.81	158.67	159.17	159.41	159.68	159.94	160.60
	December	158.04	159.04	159.38	159.54	159.77	161.20	163.11

Table 4A.8b: Upstream Birthday Rapids Existing Environment 7-Day Water Surface Level Variations (m)

U/S Birthday Rapids		Percentile						
Type of Data		Min	5	25	50	75	95	Max
All Data		0.00	0.03	0.06	0.11	0.20	0.54	1.64
Seasonal	Open Water	0.00	0.02	0.05	0.08	0.15	0.34	0.70
	Winter	0.00	0.03	0.08	0.15	0.27	0.86	1.64

Table 4A.9a: Downstream Clark Lake Existing Environment Water Surface Level (m)

D/S Clark Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		162.41	163.02	163.50	163.83	164.12	164.57	165.17
Seasonal	**Open Water**	162.51	162.91	163.28	163.58	163.93	164.67	165.17
	Winter	162.41	163.46	163.79	163.98	164.17	164.44	164.76
Monthly	**January**	163.18	163.65	163.89	164.02	164.17	164.36	164.55
	February	163.73	163.94	164.09	164.21	164.33	164.55	164.76
	March	163.54	163.80	163.97	164.11	164.29	164.48	164.64
	April	163.17	163.32	163.61	163.80	163.97	164.45	164.68
	May	162.85	163.07	163.48	163.76	164.12	164.60	164.83
	June	162.73	162.90	163.16	163.48	164.20	164.73	164.95
	July	162.79	162.88	163.17	163.47	164.21	164.71	165.17
	August	162.75	162.94	163.21	163.46	163.87	164.56	165.17
	September	162.60	162.80	163.29	163.50	163.74	164.19	165.17
	October	162.51	162.90	163.47	163.70	163.94	164.26	165.10
	November	162.41	163.22	163.62	163.81	164.03	164.24	164.71
	December	162.64	163.32	163.67	163.87	164.02	164.24	164.44

Table 4A.9b: Downstream Clark Lake Existing Environment 7-Day Water Surface Level Variations (m)

D/S Clark Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.02	0.04	0.06	0.10	0.20	0.96
Seasonal	**Open Water**	0.00	0.01	0.03	0.05	0.09	0.18	0.42
	Winter	0.00	0.02	0.04	0.07	0.11	0.21	0.96

Table 4A.10a: Clark Lake Existing Environment Water Surface Level (m)

Clark Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		165.11	165.60	166.02	166.49	167.07	167.46	167.86
Seasonal	**Open Water**	165.15	165.49	165.82	166.07	166.41	167.29	167.86
	Winter	165.11	166.04	166.59	166.97	167.24	167.51	167.75
Monthly	**January**	166.53	166.77	167.08	167.29	167.44	167.63	167.75
	February	166.42	166.62	166.95	167.14	167.34	167.59	167.75
	March	166.01	166.30	166.64	166.84	167.03	167.36	167.50
	April	165.57	165.70	166.05	166.34	166.55	167.05	167.21
	May	165.44	165.61	165.89	166.12	166.50	167.20	167.40
	June	165.34	165.49	165.73	166.04	166.78	167.35	167.61
	July	165.40	165.47	165.74	166.03	166.78	167.34	167.86
	August	165.35	165.53	165.78	166.02	166.43	167.17	167.86
	September	165.23	165.40	165.86	166.05	166.30	166.77	167.86
	October	165.15	165.40	165.94	166.12	166.35	166.60	167.78
	November	165.11	166.03	166.39	166.67	166.89	167.15	167.34
	December	166.13	166.72	167.04	167.20	167.35	167.53	167.75

Table 4A.10b Clark Lake Existing Environment 7-Day Water Surface Level Variations (m)

Clark Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.02	0.03	0.06	0.10	0.20	0.52
Seasonal	**Open Water**	0.00	0.01	0.03	0.05	0.09	0.17	0.42
	Winter	0.00	0.02	0.04	0.07	0.12	0.22	0.52

Table 4A.11a: Split Lake Existing Environment

Split Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		165.49	166.09	166.64	167.07	167.49	168.06	168.61
Seasonal	**Open Water**	165.49	165.98	166.39	166.75	167.16	168.24	168.61
	Winter	165.60	166.47	167.02	167.34	167.64	167.99	168.49
Monthly	**January**	166.83	166.92	167.32	167.65	167.86	168.09	168.34
	February	166.75	166.96	167.31	167.55	167.81	168.16	168.37
	March	166.46	166.65	167.02	167.27	167.48	167.76	168.00
	April	165.96	166.21	166.53	166.89	167.10	167.44	167.73
	May	165.85	166.20	166.51	166.80	167.16	168.06	168.61
	June	165.73	165.96	166.28	166.68	167.06	168.45	168.58
	July	165.83	165.93	166.28	166.60	167.27	168.46	168.58
	August	165.81	166.02	166.33	166.67	167.16	168.15	168.43
	September	165.62	165.85	166.45	166.68	167.06	167.41	167.82
	October	165.49	165.98	166.68	166.95	167.23	167.46	167.88
	November	165.60	166.36	166.97	167.18	167.45	167.67	167.95
	December	166.20	166.72	167.21	167.50	167.76	168.03	168.49

Table 4A.11b: Split Lake Existing Environment 7-Day Water Surface Level Variations (m)

Split Lake		Percentile						
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		0.00	0.02	0.05	0.09	0.15	0.26	0.64
Seasonal	**Open Water**	0.01	0.02	0.05	0.08	0.13	0.25	0.64
	Winter	0.00	0.02	0.06	0.10	0.16	0.27	0.50

Table 4A.12a: Stephens Lake Future Environment Water Surface Level (m)

Stephens Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		139.1	140.1	141.1
Open Water - With Project	**Base loaded**	139.1	140.1	141.1
	Peaking	139.1	140.1	141.1
Winter - Without Project		139.3	140.4	141.0
Winter - With Project	**Base loaded**	139.3	140.4	141.0
	Peaking	139.3	140.4	141.0

Table 4A.12b: Stephens Lake Future Environment 1-day Water Surface Level Variations (m)

Stephens Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		0.0	0.0	0.0
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0

Table 4A.12c: Stephens Lake Future Environment 7-day Water Surface Level Variations (m)

Stephens Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		0.0	0.0	0.0
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0

Table 4A.13a: Downstream Keeyask Future Environment Water Surface Level (m)

D/S Keeyask		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		139.1	140.1	141.1
Open Water - With Project	**Base loaded**	139.1	140.1	141.1
	Peaking	139.1	140.1	141.1
Winter - Without Project		141.1	142.9	143.7
Winter - With Project	**Base loaded**	139.4	140.5	141.1
	Peaking	139.3	140.5	141.2

Table 4A.13b Downstream Keeyask Future Environment 1-day Water Surface Level Variations (m)

D/S Keeyask		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	<0.1
Winter - Without Project		<0.1	<0.1	0.1
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.1	0.3

Table 4A.13c Downstream Keeyask Future Environment 7-day Water Surface Level Variations (m)

D/S Keeyask		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	<0.1
Winter - Without Project		<0.1	0.2	0.7
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.1	0.2	0.3

Table 4A.14a: Upstream Gull Rapids Future Environment Water Surface Level (m)

U/S Gull Rapids		Percentile		
Type of Data		5	50	95
Open Water - Without Project		151.6	152.3	153.4
Open Water - With Project	**Base loaded**	159.0	159.0	159.0
	Peaking	158.1	158.6	159.0
Winter - Without Project		152.6	153.4	154.1
Winter - With Project	**Base loaded**	159.0	159.0	159.0
	Peaking	158.0	158.5	159.0

Table 4A.14b: Upstream Gull Rapids Future Environment 1-day Water Surface Level Variations (m)

U/S Gull Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.5	0.8
Winter - Without Project		0.0	<0.1	<0.1
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.1	0.5	0.8

Table 4A.14c: Upstream Gull Rapids Future Environment 7-day Water Surface Level Variations (m)

U/S Gull Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	1.0	1.0
Winter - Without Project		0.0	<0.1	0.2
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	1.0	1.0	1.0

Table 4A.15a: Gull Lake Future Environment Water Surface Level (m)

Gull Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		151.9	152.8	154.1
Open Water - With Project	**Base loaded**	159.0	159.0	159.1
	Peaking	158.1	158.6	159.1
Winter - Without Project		152.9	153.8	154.7
Winter - With Project	**Base loaded**	159.0	159.0	159.1
	Peaking	158.1	158.5	159.0

Table 4A.15b: Gull Lake Future Environment 1-day Water Surface Level Variations (m)

Gull Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.5	0.8
Winter - Without Project		0.0	<0.1	<0.1
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.1	0.5	0.8

Table 4A.15c: Gull Lake Future Environment 7-day Water Surface Level Variations (m)

Gull Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	1.0	1.0
Winter - Without Project		<0.1	0.1	0.2
Winter - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	1.0	1.0	1.0

Table 4A.16a: Portage Creek Future Environment Water Surface Level (m)

Portage Creek		Percentile		
Type of Data		5	50	95
Open Water - Without Project		152.7	153.8	155.3
Open Water - With Project	**Base loaded**	159.0	159.1	159.3
	Peaking	158.2	158.7	159.3
Winter - Without Project		153.9	156.0	158.6
Winter - With Project	**Base loaded**	159.1	159.2	160.0
	Peaking	158.4	158.9	159.9

Table 4A.16b: Portage Creek Future Environment 1-day Water Surface Level Variations (m)

Portage Creek		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.5	0.7
Winter - Without Project		0.0	<0.1	0.2
Winter - With Project	**Base loaded**	0.0	<0.1	<0.1
	Peaking	0.1	0.5	0.7

Table 4A.16c: Portage Creek Future Environment 7-day Water Surface Level Variations (m)

Portage Creek		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	1.0	1.0
Winter - Without Project		<0.1	0.2	1.1
Winter - With Project	**Base loaded**	<0.1	<0.1	0.2
	Peaking	0.5	0.9	1.0

Table 4A4.17a: Two Goose Creek Future Environment Water Surface Level (m)

Two Goose Creek		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		154.5	155.7	157.3
Open Water - With Project	**Base loaded**	159.1	159.3	159.8
	Peaking	158.4	158.9	159.8
Winter - Without Project		155.5	158.6	160.8
Winter - With Project	**Base loaded**	159.3	160.5	162.1
	Peaking	158.9	160.5	162.1

Table A.4.17b: Two Goose Creek Future Environment 1-day Water Surface Level Variations (m)

Two Goose Creek		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.4	0.7
Winter - Without Project		<0.1	<0.1	0.2
Winter - With Project	**Base loaded**	<01	<0.1	0.1
	Peaking	<0.1	0.2	0.6

Table A.4.17c: Two Goose Creek Future Environment 7-day Water Surface Level Variations (m)

Two Goose Creek		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.9	1.0
Winter - Without Project		<0.1	0.2	1.1
Winter - With Project	**Base loaded**	<0.1	0.1	0.5
	Peaking	0.2	0.4	0.9

Table A.4.18a: Downstream Birthday Rapids Future Environment Water Surface Level (m)

D/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		156.4	157.5	158.9
Open Water - With Project	**Base loaded**	159.2	159.6	160.4
	Peaking	158.6	159.2	160.4
Winter - Without Project		157.2	160.5	162.5
Winter - With Project	**Base loaded**	159.9	162.1	163.8
	Peaking	159.5	162.0	163.8

Table A.4.18b: Downstream Birthday Rapids Future Environment 1-day Water Surface Level Variations (m)

D/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.3	0.6
Winter - Without Project		0.0	<0.1	0.2
Winter - With Project	**Base loaded**	<0.1	<0.1	0.1
	Peaking	<0.1	0.1	0.4

Table A.4.18c: Downstream Birthday Rapids Future Environment 7-day Water Surface Level Variations (m)

D/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.7	0.9
Winter - Without Project		<0.1	0.2	1.3
Winter - With Project	**Base loaded**	0.1	0.2	0.8
	Peaking	0.1	0.2	1.0

Table A.4.19a: Upstream Birthday Rapids Future Environment Water Surface Level (m)

U/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		158.3	159.4	160.7
Open Water - With Project	**Base loaded**	159.5	160.1	161.1
	Peaking	159.0	159.8	161.1
Winter - Without Project		159.1	161.2	162.9
Winter - With Project	**Base loaded**	160.2	162.6	164.0
	Peaking	160.0	162.5	164.0

Table A.4.19b: Upstream Birthday Rapids Future Environment 1-day Water Surface Level Variations (m)

U/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.2	0.4
Winter - Without Project		0.0	<0.1	0.2
Winter - With Project	**Base loaded**	<0.1	<0.1	0.1
	Peaking	<0.1	0.1	0.3

Table A.4.19c: Upstream Birthday Rapids Future Environment 7-day Water Surface Level Variations (m)

U/S Birthday Rapids		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.4	0.6
Winter - Without Project		<0.1	0.1	1.0
Winter - With Project	**Base loaded**	0.1	0.2	0.8
	Peaking	0.1	0.2	0.9

Table A.4.20a: Downstream Clark Lake Future Environment Water Surface Level (m)

D/S Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		163.0	153.7	164.6
Open Water - With Project	**Base loaded**	163.1	163.7	164.6
	Peaking	163.1	163.7	164.6
Winter - Without Project		163.5	164.0	164.3
Winter - With Project	**Base loaded**	163.6	164.8	165.4
	Peaking	163.6	164.7	165.2

Table A.4.20b: Downstream Clark Lake Future Environment 1-day Water Surface Level Variations (m)

D/S Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		0.0	<0.1	<0.1
Winter - With Project	**Base loaded**	<0.1	<0.1	0.1
	Peaking	<0.1	<0.1	0.1

Table A.4.20c: Downstream Clark Lake Future Environment 7-day Water Surface Level Variations (m)

D/S Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		<0.1	<0.1	0.1
Winter - With Project	**Base loaded**	<0.1	0.1	0.3
	Peaking	<0.1	0.1	0.3

Table A.4.21a: Clark Lake Future Environment Water Surface Level (m)

Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		165.6	166.2	167.2
Open Water - With Project	**Base loaded**	165.6	166.2	167.2
	Peaking	165.6	166.2	167.2
Winter - Without Project		166.3	167.0	167.4
Winter - With Project	**Base loaded**	166.3	167.0	167.4
	Peaking	166.3	167.0	167.4

Table A.4.21b: Clark Lake Future Environment 1-day Water Surface Level Variations (m)

Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		0.0	<0.1	<0.1
Winter - With Project	**Base loaded**	0.0	<0.1	<0.1
	Peaking	0.0	<0.1	<0.1

Table A.4.21c: Clark Lake Future Environment 7-day Water Surface Level Variations (m)

Clark Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		<0.1	0.1	0.1
Winter - With Project	**Base loaded**	<0.1	0.1	0.2
	Peaking	<0.1	0.1	0.2

Table A.4.22a: Split Lake Future Environment Water Surface Level (m)

Split Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		166.0	166.9	168.2
Open Water - With Project	**Base loaded**	166.0	166.9	168.2
	Peaking	166.0	166.9	168.2
Winter - Without Project		166.7	167.4	167.9
Winter - With Project	**Base loaded**	166.7	167.4	167.9
	Peaking	166.7	167.4	167.9

Table A.4.22b: Split Lake Future Environment 1-day Water Surface Level Variations (m)

Split Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		0.0	<0.1	<0.1
Winter - With Project	**Base loaded**	0.0	<0.1	<0.1
	Peaking	0.0	<0.1	<0.1

Table A.4.22c: Split Lake Future Environment 7-day Water Surface Level Variations (m)

Split Lake		Percentile		
Type of Data		**5**	**50**	**95**
Open Water - Without Project		0.0	0.0	0.0
Open Water - With Project	**Base loaded**	0.0	0.0	0.0
	Peaking	0.0	0.0	0.0
Winter - Without Project		<0.1	0.1	0.1
Winter - With Project	**Base loaded**	<0.1	0.1	0.1
	Peaking	<0.1	0.1	0.1

APPENDIX 4B
SURFACE WATER AND ICE REGIMES
DESCRIPTION OF NUMERICAL MODELS AND METHODS

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4B-0. APPENDIX 4B – DESCRIPTION OF NUMERICAL MODELS AND METHODS

4B-1. ONE-DIMENSIONAL OPEN WATER MODEL – HEC-RAS

A calibrated one-dimensional steady-state backwater model was developed using the US Army Corps of Engineers' HEC-RAS and HEC-GeoRAS software programs (USACE 1999 and 2002). The model was then used to estimate the one-dimensional water regime characteristics along the Keeyask study reach under the existing environment and Post-project flow conditions. These include the water depth and water surface profile estimates. For the model, cross-sections were extracted from the Digital Terrain Model (DTM) using the HEC-GeoRAS tool, and then imported into the HEC-RAS hydraulic modelling software. The model was then calibrated by adjusting the hydraulic roughness, ineffective flow areas, and localized areas of bathymetry so that modelled water levels matched rating curves that were based on measured water levels. Overall, the modelled water levels were calibrated to within ± 0.10 m - 0.30 m, while the majority of the reach was calibrated to ± 0.10 m - 0.15 m. The model is less accurate within Gull Rapids due to complex hydraulic conditions that are present within the rapids, as well as the general lack of real bathymetric data. Once the Existing Environment model was calibrated, it was modified to include the Project components and used to simulate the hydraulic conditions for the Post-project environment. These one-dimensional models can be used to effectively simulate open-water hydraulic conditions for a range of flows between 1,000 m^3/s to 6,000 m^3/s as this is the range of flow the models were calibrated to.

For the Existing Environment, the dynamic inflow hydrograph developed for the 1977 to 2006 period (Section 4.2.5.8) was used for the inflow boundary condition of the model with Stephens Lake water level providing the downstream boundary condition. This resulted in fluctuating water levels throughout the reach and when coupled with measured water levels from gauges at the key sites, provided the basis for the water level variation analysis of the existing environment. For the Post-project scenarios, the upstream boundary was specified as a steady inflow value that corresponded to the percentile flow being modelled and the downstream boundary was the Keeyask reservoir water level as defined by either the baseloaded or peaking mode of operation (Section 4.4.2).

As described in Section 4.3.2, the existing environment water regime conditions are expected to accurately represent the future environment without the Project in place. In some cases though, additional simulations needed to be run for the Future Environment without the Project with similar steady upstream boundary conditions as those used in the Post-project scenarios so that direct comparisons between the two Future Environment scenarios could be made. This was done using the Existing Environment models with the modified boundary conditions described above and is consistent with the analysis done for the winter water regime.

4B-2. TWO-DIMENSIONAL OPEN WATER MODEL - MIKE 21

MIKE 21, a two-dimensional hydraulic model developed by DHI Water and Environment (DHI 2004), was calibrated and used to estimate depth-averaged velocities within the study area for both existing environment and Post-project conditions. Specifically, this two-dimensional depth-averaged finite volume hydraulic Computational Fluid Dynamics (CFD) software program has applications in oceanographic, coastal, and overland flooding. The system is based on the numerical solution of the two-dimensional Reynolds Averaged Navier-Stokes equations, assuming hydrostatic pressure. The spatial domain is discretized by subdivision into non-overlapping elements. In this application, the computational meshes are generated using unstructured triangular elements, and the variables are associated to the cell centre. The model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. Turbulence is modelled using an eddy viscosity concept, where vertical and horizontal transport is described separately.

The MIKE 21 hydraulic model for the existing environment was developed for the river reach between Clark Lake and Stephens Lake. The existing environment DTM was imported into MIKE 21, and initial bed roughness heights were applied and adjusted during calibration. The model was calibrated by adjusting the bed roughness and localized areas of bathymetry until simulated water levels matched rating curves based on measured water levels within a tolerance of approximately 0.2 m. Riverbed levels were adjusted in areas where limited information was available, usually in higher velocity zones where surveys could not be conducted safely. For verification, simulated velocities also compared well with measured velocity profiles collected at several specific locations along the reach. Once the existing environment model was calibrated, it was modified to include the Project components and used to simulate the hydraulic conditions for the Post-project environment.

4B-3. H01E BACKWATER MODEL

The H01E software package is a steady state, one-dimensional backwater model that was set up and used to support investigations of the river management strategies proposed for implementation on the Project. The H01E model is a standard step backwater program that was originally developed by Acres Manitoba Limited over 35 years ago and has been used extensively in the past for these types of hydraulic investigations. Like HEC-RAS, the model was initially calibrated by adjusting the hydraulic roughness, ineffective flow areas, and localized areas of bathymetry so that modelled water levels matched rating curves that were based on measured water levels. Once the existing environment model was calibrated, it was modified to include the Project cofferdams and diversion structures, and used to simulate the hydraulic conditions expected during construction of the Project.

4B-4. FLOW-3D MODEL

A three-dimensional numerical model, FLOW-3D, was used to provide multi-dimensional estimates of flow velocities and patterns under i) the existing condition, ii) during construction, and iii) under Post-project operating conditions. The FLOW-3D program is distributed and supported by Flow Science Incorporated, of Los Alamos, New Mexico. This program simulates the dynamic behaviour of fluid in three dimensions through a solution of the complete Navier-Stokes equations simulating free surface flows, including transitions between supercritical and subcritical flow within a single model setup. One of the major strengths of FLOW-3D is its ability to accurately model problems involving free surface flows.

The three-dimensional models utilized in these engineering analyses were developed based on existing topographic and bathymetric data in the area. Digital Terrain Models (DTM) of the area were created and imported into the model. These models covered an area of approximately 3.3 km x 2.7 km (length x width). The models were calibrated by adjusting the bed roughness and localized areas of bathymetry until simulated water levels matched observed rating curves, which were developed based on measured water levels. Riverbed levels were adjusted in areas where limited information was available, usually in higher velocity zones where surveys could not be conducted safely. For verification, simulated velocities were also compared to data collected within the physical model, and the two corroborated very well. Once the Existing Environment model was calibrated, it was then modified to include the Project components and used to simulate the hydraulic conditions for the construction phase, and also for the Post-project environment.

4B-5. SPLASH MODEL

The Post-project monthly average flow file was determined using Manitoba Hydro's System Simulation Model (SPLASH). The SPLASH model simulates the long term operation of Manitoba Hydro's hydro-electric system using hydrologic input data from all major reservoirs, local basins and hydro-electric sites (current and proposed) in the system. SPLASH is an energy based model that simulates the entire hydro-electric system, evaluates system-side energy productions and computes incremental benefits of various system expansion options. SPLASH generates monthly average flow data which are scenario based and each scenario corresponds to a combination of a predicted electricity load and a possible status of system generation capacity. Since the SPLASH simulated monthly average discharges are located at Lake Winnipeg outlet and Notigi Control, the Post-project flow files were computed by adding local inflows between these two locations and the Split Lake outlet.

4B-6. DIGITAL ELEVATION MODELS

The topography and bathymetry of the study area is a critical set of data as it is used in many different models and many different studies. The development of this data set started with the collection of elevation data. Elevation data was collected from several different sources (with varying degrees or precision and resolution) and methods including:

- Field surveys (RTK, total station, sonar).
- Lidar.
- Photogrammetric mapping.
- SRTM (Shuttle Radar Topography Mission).

- Mapping from engineering model results.

Once all the input elevation data sets were assembled, they were combined into a single Digital Terrain Model representing the Existing Environment topography and bathymetry as shown in Map 4.2-3.

To create the DTM to represent the Post project landscape, engineering drawings of the Project infrastructure such as the dykes, dams, spillway and powerhouse were required. Based on these drawings, the elevation and location of the structures were imported into the existing environment DTM to create the Post-project DTM as shown in Map 4.2-4.

4B-7. PHYSICAL MODELS

Two physical hydraulic model studies were carried out to confirm and refine the spillway structure design and address potential problems during the construction of spillway Stage I and south dam Stage II diversion cofferdams. These models also provided an opportunity to validate the numerical modelling tools that had been used to support the design of the Project. In general, the match obtained between the physical model results and the numerical model results was very good.

These physical model studies were undertaken by the LaSalle Consulting Group, and included both a 1:120 scale comprehensive model of the Keeyask site, and also a smaller 1:50 scale sectional model of the spillway structure. The objective of the comprehensive model study was to test and confirm the Stage I and II diversion sequences proposed for the Project, including river closure operations. The objective of the sectional model study was to refine the discharge capacity estimates for both the diversion spillway structure, and the final structure with rollways in place.

Both models were scaled considering the equations of hydraulic similitude, based on maintaining a similar Froude Number in both the model and the prototype. Following the construction of each model, they were calibrated so that water levels within the model matched stage-discharge curves at the gauge locations where prototype measurements were available. Calibration was achieved by adding small clusters of rocks in some locations to increase the riverbed roughness, and by modifying the bed contours in other locations as required. These two modifications resulted in model rating curves that were very close to the prototype measurements.

4B-8. ONE-DIMENSIONAL WINTER MODEL - ICEDYN

The one-dimensional hydraulic ice model, ICEDYN, is a powerful ice simulation program capable of simulating typical ice formation processes including ice generation, deposition, advancement, shoving and thickening on an ice cover. In addition, the program is also capable of dynamically routing river flows and/or reservoir water level variations through the study reach. The model also has the ability to represent staging due to anchor ice formation along a river reach by way of a time dependent staging factor, which is defined based on past experience and field measurements.

The ICEDYN model was developed by Acres Manitoba Limited in 1995 as an extension of the ICESIM model, also developed by Acres, which originated in the early 1970s to assist in design calculations for river management schemes during construction of hydroelectric plants on the Nelson River. The

ICEDYN model has been continually developed over the years and the river hydraulics, which are affected by both changes in inflow to the reach under study, and the accumulation of ice, are computed through solution of the St. Venant Equations, making it a fully hydrodynamic model.

The ICEDYN and/or ICESIM models have been applied successfully on many Canadian rivers, which vary dramatically in size, climate, and geography. Past examples related specifically to hydropower projects include the simulation of ice cover development on the Nelson River for the Limestone and Conawapa generating stations. Also, ice cover development was simulated on the Burntwood River in support of EIS and dam safety studies undertaken for the Wuskwatim GS and spring ice jam effects on the construction of the Churchill River control weir near the Town of Churchill were estimated. The models were also applied to cases on other Canadian rivers including the Saint John, Saskatchewan, and Yukon Rivers.

One of the characteristics of the ICEDYN model is that it tends to overestimate water levels for winter dates beyond when peak staging occurs (after the ice front has stalled). Ice processes are difficult to simulate when this occurs due to the longer days (increased exposure to sunlight) and smoothing of the ice surface (reduction in ice roughness). These factors tend to result in an ice front recession and a reduction in water levels, which this model cannot predict. As a result, the ICEDYN model cannot directly simulate the de-staging of water levels and the subsequent return to open water levels in the spring. To accommodate this, ICEDYN modelled water levels after March 1 have a time-varying de-staging factor applied to them such that as spring progresses, the modelled water levels returned to their open water equivalents. For Existing Environment conditions, this de-staging factor is 20% over the month of March, 40% over the month of April, and 40% over the month of May. Using this method to account for the de-staging of the water levels often results in a discontinuity in the water levels around May 1, which is where the estimated water levels from the ICEDYN model switch to the estimated or measured open water levels. This is not surprising because at the end of the ICEDYN simulations, there may be some residual effects of ice on the water levels on May 1. This does not imply that the effects of ice always end on May 1; the effects may extend before or after this date depending on the hydraulic and meteorological conditions of that winter. For these reasons, the use of the ICEDYN model to predict winter water levels throughout the entire winter period must not be viewed as an absolute, but rather as an indicator of the trend.

Due to the ice processes occurring throughout the study area, modelling of the entire river reach with one model was not possible. To overcome this complication, two separate ICEDYN models were set up. One model was set up to simulate the reach upstream of Gull Rapids (between Split Lake and Gull Rapids) which will be referred to as the upstream model reach, and the other to simulate the reach downstream of Gull Rapids (between Gull Rapids and Stephens Lake) which will be referred to as the downstream model reach. Cross-sections for the model were derived directly from existing backwater datasets of the reach and are consistent with those sections utilized to model the reach from Split Lake to Stephens Lake.

Following its initial setup, the models were calibrated to match open water rating curves previously derived at a number of specific locations along the river reach using an open water backwater model. After obtaining a suitable match under open water conditions, the models were then used to simulate the development of an ice cover on the two study reaches for particular winters in which ice observation data was available. Ice parameters for the models were initially selected based on the parameter sets identified in earlier studies. These parameters were then adjusted as necessary to obtain a good match between the ICEDYN modelled levels and those measured in the field for a number of past winters.

The upstream boundary condition of the models consisted of a user defined flow hydrograph, while the downstream boundary condition consisted of a user defined stage hydrograph. Air temperature sequences utilized in the models were based on meteorological data collected at the Gillam airport.

Under open-water conditions, the models were calibrated to within 0.25 m of the open-water rating curves derived at the key locations in the study area. Under winter conditions, a good overall match was achieved between measured and modelled water level data. The upstream model was able to reproduce winter water levels at key locations upstream of Gull Rapids to within 0.5 m, on average, of those observed during the freeze-up period. Downstream of Gull Rapids, the downstream model was able to reproduce observed freeze-up water levels to within 0.75 m on average. Differences between measured and modelled water levels of up to 2 m did however exist at certain locations in some years (Birthday Rapids and downstream of the outlet of Clark Lake). Such deviations are to be expected given the lack of available data for some years on the timing and location of the ice bridge, which initiates the upstream winter cover. This lack of data made it necessary to assume bridging locations and dates for many years based on general trends observed in other years. An error in the selection of the timing or location of the bridging points could lead to differences in the modelled arrival of the ice front, which at locations more susceptible to channel blockages due to ice, can lead to these larger differences.

4B-9. FUTURE ENVIRONMENT WITH THE PROJECT WINTER MODELLING - ICEDYN

Post-project ice modelling over the study area was split at the proposed location of the Keeyask GS (Gull Rapids) into an upstream and downstream model reach. This is the same location that the numerical model developed to examine the ice regime of the existing and future environment, without the Project had to be split. For this reason, the same two ICEDYN models that were developed for that analysis could also be used to simulate the ice regime in the Post-project environment, with appropriate modifications to the boundary conditions.

To characterize the ice processes under different winter severities, the actual recorded air temperatures (Environment Canada, Gillam Airport Station) for particular winters were chosen to represent a "warm", "average", and "cold" condition. Based on a visual inspection of the temperature record, the winter seasons of 2001 to 2002, 1988 to 1989, and 1989 to 1990 were chosen to represent the warm, average, and cold winters respectively. When appropriate, average air temperature conditions were assumed for the ice regime discussion.

The 5^{th}, 50^{th}, and 95^{th} percentile average seasonal inflows (winter) were specified as the upstream flow boundary condition of the upstream model reach to assess the Project environment ice conditions. The upstream flow boundary for the downstream model was represented by the outflow out of the Project which is dependant on the mode of operation of the plant and the total inflow into the reach upstream.

The downstream boundary of the downstream model reach is represented by the 5^{th}, 50^{th}, and 95^{th} percentile levels of Stephens Lake. The levels were assumed to be constant over a simulation period. The downstream level boundary of the upstream model reach depends on the assumed mode of operation. For base loaded conditions, this level was kept constant at the Full Supply Level (FSL) of 159.0 m. For peaking operations, the reservoir level is varied over a one week period such that on-peak power generation is maximized for a given Project inflow within the constraints of the Project operating rules.

Under current conditions, freeze-up of Stephens Lake typically occurs by November 1. It is not expected that this date will be changed as a result of the Project. Given the close proximity of the reservoir to Stephens Lake and the similar water regime, it has been assumed that under the Post-project environment the date of reservoir freeze-up will also be November 1. This is the date that the numerical ice formation simulations were set to commence. Similar to the existing environment winter simulations, a de-staging factor was applied to the Post-project winter water levels to return them their open water equivalents in the spring. For Post-project conditions, a factor of 20% was applied during the month of March with the remaining 80% of de-staging occurring in the month of April. This change in the de-staging factor when compared to the existing environment reflects the shortened de-staging period that is expected to occur with the Project in place.

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