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REPORT

COMMUNITY OF RANKIN INLET

Nipissar Lake and Lower Landing Lake Water Balance Assessment

(Char River, July 10, 2015)

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Executive Summary

The Community of Rankin Inlet currently depends on Nipissar Lake to service its year-round municipal water supply requirements. Given that the Nipissar Lake watershed is frozen over for approximately seven to nine months a year, the raw water supplies within Nipissar Lake at the outset of winter need to be sufficient to service the community over the winter until snowmelt runoff replenishes the lake during the following freshet.

In addition to the seasonal restrictions limiting replenishment of the Community's raw water supply, work completed by FSC Architects & Engineers and Resource Management Strategies Inc. in 2009 concluded that increased water consumption associated with continued population growth was exceeding annual water yields within the Nipissar Lake basin.

A water supply pipeline from the nearby Char River to augment water supplies in Nipissar Lake was consequently constructed; however, concerns regarding the viability of this secondary supply source have been expressed in light of sustainable flow and water depth objectives imposed by the Nunavut Water Board (NWB) and Canada Department of Fisheries and Oceans (DFO).

While continued population growth in view of finite basin yields is cited as the primary water supply stressor, concerns regarding the Community's water supply have also been articulated in view of changing climate normals that may further decrease net basin yields to Nipissar Lake and the Char River.

Lower Landing Lake, immediately upstream of the Char River intake, was evaluated as a potential tertiary water supply alternative to ascertain its long-term viability for delivering sustainable water supplies to the Community. Although this source would open up an additional supply of water for the community, water takings from Lower Landing Lake need to be considered in the context of flow regime within the Char River. Based on DFO guidelines, water takings will need to be limited to within 10% of the flow in Char River. Two water taking options were considered in order to meet demand; firstly, a pump rate that matched 10% of the instantaneous flow within Char River until freshet ends; and secondly, a water taking configuration that would allow for continuous pumping throughout the open water season up to 10% of the total annual flow within Char River. Although the first option would technically meet the literal definition of DFO's water taking guideline, this option was dismissed due to the logistical complications of varying pump rates over several orders of magnitude. The second option, although minor reductions in the hydroperiod for Char River are anticipated, was considered optimal as it allowed for a constant pump rate to be applied over the full open water season while addressing the spirit of the DFO guideline. It is noteworthy that the Char River is not considered to provide permanent habitat for fish while there are no other known uses for water within the Char River.

Using field data collected during this and previous studies, as well as meteorological and bathymetric data available from government sources, Golder Associates (Golder) developed an integrated water balance model that allows supplementation needs and water supply availability to be estimated for prospective consumption rates and future climate scenarios.

In general terms, small increases in basin yields and shorter anticipated winter durations associated with climate change projections are estimated to marginally reduce over-winter supplementation needs. Similarly, projected longer summer periods will increase the available supplementation window.

In view of projected population growth, Lower Landing Lake is estimated to be able to provide sufficient supplementary water supplies to offset the water taking deficit from Nipissar Lake under low and moderate daily consumption rates (i.e.,1,600 m^3/day and 3,300 m^3/day, respectively). Under significantly increased population sizes, when consumption rates reach approximately 5,300 m^3/day, the annual deficit at Nipissar Lake will exceed 10% of the median outflow conditions of Lower Landing Lake. For context, this finding suggests that flows in Char River would likely decrease by more than 10% of baseline conditions once population growth has exceeded that projected for the year 2082 (7,800 people), even if the existing per capita consumption rate (0.68 m^3/person/day) is maintained.

While this report provides reasonable long-term context to the availability of water under future daily consumption rates and climate scenarios, the results should be used only for the purposes of long-term water supply planning rather than short-term water budgeting. A water supply forecasting tool will be provided under separate cover for shorter term budgeting

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1.0 INTRODUCTION

This report has been prepared by IMG-Golder Corporation (IMG-Golder) in partnership with Golder Associates Ltd. (Golder); hereafter collectively referred to as IMG-Golder, for the Department of Community and Government Services (CGS), Government of Nunavut (GN), in accordance with Proposal Number P1534002, dated June 26, 2015. The report documents the water balance assessments carried out for Lower Landing Lake and the Char River, located to the northwest of the Community of Rankin Inlet (Kangiqtiniq), Nunavut (the Community; Figure 1) and Nipissar Lake, the current water supply source for the Community.

1.1 Background

The Community currently depends on Nipissar Lake to service its year-round municipal water supply requirements. Given that the Nipissar Lake watershed is frozen over for approximately seven to nine months a year, the raw water supplies within Nipissar Lake at the outset of winter need to be sufficient to service the community over the winter until snowmelt runoff replenishes the lake during the following freshet.

In addition to the seasonal restrictions limiting replenishment of the Community's raw water supply, work completed by FSC Architects & Engineers and Resource Management Strategies Inc. in 2009 concluded that increased water consumption associated with continued population growth was outstripping water yields within the Nipissar Lake basin.

A water supply pipeline from the nearby Char River to augment water supplies in Nipissar Lake was consequently constructed; however, concerns regarding the viability of this secondary supply source have been expressed in light of sustainable flow and water depth objectives imposed by the Nunavut Water Board (NWB) and Canada Department of Fisheries and Oceans (DFO).

While continued population growth in view of finite basin yields is cited as the primary water supply stressor, concerns regarding the Community's water supply have also been articulated in view of changing climate normals that may further decrease net basin yields to Nipissar Lake and the Char River.

Based on a bathymetric survey completed by the Geological Survey of Canada in 2009, Lower Landing Lake, to the immediate west of the Char River intake, was identified as a potential tertiary water supply alternative that should be evaluated to ascertain its long-term viability for delivering sustainable water supplies to the Community. Logistically, this source is ideally sited due to its close proximity to the Char River pipeline.

The success of Lower Landing Lake water supply option will hinge on the ability to forecast net basin yields for Nipissar Lake and Lower Landing Lake and determine whether sufficient seasonal surplus can be transferred to Nipissar Lake on an annual basis. In addition to the influences of changing climate on water supply and the effects of population growth on water demand, the viability of this tertiary source will need to be examined in the context of modified flow regime within the Char River, to ensure that adequate flow can be maintained to satisfy the NWB and DFO.

In order to provide a reliable determination of annual refill requirements, generated water balances therefore need to consider the full range of historic meteorological records, but also account for potential water balance effects associated with climate change. It is noteworthy that low basin yields from the Nipissar Lake watershed will likely coincide with lower than average basin yields in Lower Landing Lake watershed and the Char River, meaning that the effects of using this tertiary water supply alternative will need to be adequately demonstrated to support CGS's permitting efforts. Seasonal watershed yields and daily lake level fluctuations will need to be examined to ensure that an optimum approach to balancing the Community's needs with the hydrological regime of the Char River is identified. The endorsement and support from the NWB and DFO will be a significant component of identifying this optimum approach.

In addition to evaluating anticipated water supplementation volumes and developing a hydrographic characterisation of the Char River, the availability of a validated water balance model will allow the Community to forecast refill requirements for the upcoming summer in a proactive manner. In other words, the developed water balance model should allow the Community to input recorded meteorological observations (from nearby Environment Canada stations) and residual lake levels before the outset of the freshet to develop an estimate of summer refill requirements to ensure that sufficient water is available in the lake for each subsequent winter. Any unanticipated conditions leading to potential water supply deficits could therefore be identified at an early point in time in order to address these in a timely manner. This latter aspect will be imperative to ensure that the Community can adequately augment raw water supplies or, if necessary, impose water conservation measures on an annual basis to meet Community needs.

1.2 Assessment Objectives

There were two primary objectives associated with Lower Landing Lake and the Char River water balance assessment:

- Development of an integrated water balance model linking the Nipissar and Lower Landing watersheds with hydrographic characteristics of the Char River, including:
  - A determination of water supply deficits for Nipissar Lake under historic and projected climatic conditions in consideration of a range of potential water consumption values;
  - An estimate of corresponding basin yield surpluses for Lower Landing Lake; and
  - A hydrographic characterisation of the Char River accounting for historic and projected future climatic variation and for the effects of water withdrawals from Lower Landing Lake;
- Development of a Water Supply Forecasting and Management Tool that would allow the Community to forecast its short- and medium-term water supplies in order to predict potential supplementation requirements and/or water conservation measures.

1.2.1 Development of Integrated Water Balance Model

A reliable determination of annual water supply supplementation requirements and availability requires that water balance estimates consider the full range of historic meteorological conditions based on data available from nearby Environment Canada climate stations. It is also important to account for potential effects associated with climate change. It is anticipated that low basin yields from the Nipissar Lake watershed will likely coincide with lower than average basin yields in Lower Landing Lake and, potentially, lower flows in the Char River. The effects of water supplementation from Lower Landing Lake on flows in the Char River will need to be fully understood to support the Community's water license application process.

1.2.2 Development of a Water Supply Forecasting and Management Tool

In addition to providing the necessary water balance information to support regulatory discussions and permitting, the ability to forecast basin yields will also allow the Community to plan for supplementation requirements each upcoming summer in a proactive manner. It is expected that the forecasting tool developed as part of this study would allow the Community to input observed meteorological observations (from nearby Environment Canada stations) and residual lake levels before the onset of the spring melt period to develop an estimate of summer supplementation requirements to confirm whether sufficient water is available in the lake for the subsequent winter period. Any unanticipated conditions leading to potential water supply deficits can therefore be identified at an early point in time in order to address these in a timely manner. This latter aspect will be an important precursor to allowing the Community to decide whether it can adequately augment lake supplies and/or, if necessary, impose water conservation measures on an annual basis to meet the Community's needs. A detailed description of tool functionality and application is provided outside the framework of this report.

1.3 Report Objectives

The specific objectives of this report are to present:

- A water balance estimate for Lower Landing Lake and Nipissar Lake watersheds using available hydrometric data collected within Nipissar Lake, at the Community's water supply intake, and on the Char River;
- The potential implications of anticipated future climatic conditions on these water balance estimates;
- The effects of varying climatic conditions and water consumption rates on available water supplies;
- Available options to replenish Nipissar Lake by diverting water from Lower Landing Lake and assess the implications on the hydrographic regime of the Char River; and
- The necessary information with which the Community can inform its supplementary water supply design requirements and water license application process.

2.0 DATA REVIEW

The following sources of information, generally obtained through CGS and from Environment Canada, were considered for the purposes of this study.

2.1 Government of Nunavut

The following information was received by IMG-Golder from CGS:

- Report on Nipissar Lake Watershed Model (Stanley, 1996);
- Report on Rankin Inlet Water Supply Upgrades (2009 consumption review) (FSC, 2009);
- Report on 2009 Nipissar Lake Intake Repair (Advanced Subsea Services Ltd., 2009);
- Report on Water Supply Capacity, Consumption and Conservation Study (RMSi & FSC, 2010);
- Report on Design of Pipeline System to Replenish Nipissar Lake (FSC, 2010);
- Report on Nipissar Lake and Lower Landing Lake Bathymetry from September 29 to October 4, 2009 (Budkewitsch *et al*., 2011);
- Data detailing streams, rivers, lakes, shorelines and contours for the Community of Rankin Inlet (CGS, 2012);
- Letter Report on the Char River Channel Topographic Survey (AMEC, 2014);
- Report on Seasonal Replenishment of Nipissar Lake (Stantec, 2014);
- 2014 Nipissar Lake Intake Inspection Report (Advanced Subsea Services Ltd., 2014);
- Data detailing Nipissar Water Levels from June 2008 to June 2012 (Community of Rankin Inlet, 2013); from June 2014 to July 2015 (Community of Rankin Inlet, 2015e);
- Annual Municipal Consumption Report of the Rankin Inlet Utilidor System (2011 to first quarter of 2015) (Community of Rankin Inlet, 2012 to 2015);
- Data detailing Daily Pumping Rates from the Char River to Nipissar Lake (June 18 to July 10, 2015) (Community of Rankin Inlet, 2015b); and
- Data detailing Daily Intake Withdrawal Rates from Nipissar Lake (April 2 to June 30, 2015) (Community of Rankin Inlet, 2015c).

2.1.1 Watershed Land Cover

Differentiating between different types of land cover is important in order to infer appropriate soil storage characteristics and water holding capacities in different areas of the watershed. In the absence of detailed surficial geology mapping, visual interrogation of available digital imagery (ESRI DigitalGlobe, 2010) enabled land and water-covered portions of each watershed to be differentiated. Further differentiation between till veneer and bedrock was achieved by visual inspection of satellite imagery information. Accordingly, the distribution of land cover was assumed to correspond to 20% till veneer and 80% bedrock.

2.1.2 Watershed Delineations

Topographic data (Government of Canada, accessed July 7, 2015) were used to assist in the delineation of the Nipissar Lake and the Lower Landing Lake watersheds. Although these topographic data covered both watersheds, the data were limited to 10 m contour intervals, rendering delineations only approximate. The Lower Landing Lake and Nipissar Lake watersheds were estimated to cover approximately 66.9 square kilometres and 3 square kilometres, respectively. Figure 2 depicts the Lower Landing Lake watershed delineation; the delineation for the Nipissar Lake watershed is presented on Figure 3.

2.1.3 Bathymetry

Bathymetric data for both lakes provided by Natural Resources Canada (Budkewitsch *et al*., 2011) were used to generate stage-storage relationships for each lake in order to allow for straightforward conversion between lake level and volumes. The bathymetric data provided a reasonably detailed characterisation of lake geometry at depth intervals of 1 m. However, the data were only referenced to the lake level at the time of the surveys and not tied to a known geodetic datum. To generate a bathymetric representation above the lake elevation at the time of survey (the limit of the existing data), the lake geometry was extrapolated.

2.1.3.1 Nipissar Lake

For Nipissar Lake, the stage-storage relationship developed from the bathymetric data collected by Natural Resources Canada (Budkewitsch *et al*., 2011) was adjusted to provide general agreement with a previous stage-storage relationship developed by Stanley (1996), which had related storage volume to lake elevation expressed in metres above sea level (masl).

To account for additional storage above the lake surface at the time of the survey, the adjusted stage-storage relationship was extrapolated from 13.685 masl (IMG-Golder estimated water level at time of the survey) to 14.235 masl (elevation corresponding to the invert of the lowest of two culverts located along the western perimeter of the lake) to account for the increased surface area of the basin at higher elevations (see Figure 4). As a final step, storage volumes for the adjusted stage-storage relationship for Nipissar Lake were then modified to ignore dead storage, and reflect only active storage above the elevation of the Community's intake, situated at 9.5 masl.

2.1.3.2 Lower Landing Lake

Given the absence of any information regarding water levels and no known withdrawals from the lake that could significantly reduce water levels, Lower Landing Lake was assumed to be filled to its natural control elevation at the time of the surveys (September 29 to October 4, 2009), corresponding to an estimated lake surface elevation of 11.269 masl. A bathymetric contour plot for Lower Landing Lake is provided in Figure 5. A stage-storage relationship for Lower Landing Lake was consequently developed using the unadjusted bathymetric data provided by Budkewitsch *et al*. (2011).

2.1.3.3 The Char River

Bathymetry for the Char River was obtained for thirteen cross-sectional previously surveyed (AMEC, 2014). The data for each cross-section were referenced to orthometric elevation, allowing for easy integration with the stage-storage relationship developed for Lower Landing Lake.

2.1.4 Hydrometric Data

Limited hydrometric data have been collected for the study area including some spot flow measurements in the Char River in 2000 and occasional water level measurements for Nipissar Lake (which are, however, referenced to a combination of orthometric or arbitrary benchmarks with unknown geodetic elevations). Based on IMG-Golder's knowledge, no hydrometric data for Lower Landing Lake had been collected prior to this study.

IMG-Golder installed water level monitoring stations at the Char River, Lower Landing Lake and Nipissar Lake on July 11, 2015. These hydrometric stations include a staff gauge and a water level logger to allow continuous monitoring of water levels to be undertaken and adjusted for barometric pressure variation using a barometric logger installed nearby. It is recommended that all three stations be tied into a geodetic datum by a CGS contractor at the earliest opportunity.

2.1.4.1 Nipissar Lake

Water level measurements for Nipissar Lake were obtained from CGS and provided throughout several references (Stanley, 1996; Community of Rankin Inlet, 2013; Community of Rankin Inlet, 2015e). Given the variety of benchmarks and measurement techniques, recorded water levels were modified by estimating adjustment factors, so that a crude comparison could be made using a common datum (masl). The modified water level data for Nipissar Lake, with opinions regarding their reliability, are presented in Table 1.

Table 1: Water Levels at Nipissar Lake

Date	Estimated Elevation (masl)[1]	Source	Assumed Reliability[1]	Explanation
08/06/1994	14.345	Stanley, 1996	High	Expressed in masl
15/06/1994	14.351	Stanley, 1996	High	Expressed in masl
22/06/1994	14.371	Stanley, 1996	High	Expressed in masl
29/06/1994	14.386	Stanley, 1996	High	Expressed in masl
06/07/1994	14.379	Stanley, 1996	High	Expressed in masl
13/07/1994	14.365	Stanley, 1996	High	Expressed in masl
20/07/1994	14.319	Stanley, 1996	High	Expressed in masl
27/07/1994	14.291	Stanley, 1996	High	Expressed in masl
03/08/1994	14.253	Stanley, 1996	High	Expressed in masl
10/08/1994	14.223	Stanley, 1996	High	Expressed in masl
17/08/1994	14.223	Stanley, 1996	High	Expressed in masl
24/08/1994	14.209	Stanley, 1996	High	Expressed in masl
31/08/1994	14.231	Stanley, 1996	High	Expressed in masl
07/09/1994	14.263	Stanley, 1996	High	Expressed in masl
14/09/1994	14.277	Stanley, 1996	High	Expressed in masl
21/09/1994	14.287	Stanley, 1996	High	Expressed in masl
28/09/1994	14.298	Stanley, 1996	High	Expressed in masl
05/10/1994	14.280	Stanley, 1996	High	Expressed in masl

Table 1: Water Levels at Nipissar Lake (continued)

Date	Estimated Elevation (masl)[1]	Source	Assumed Reliability[1]	Explanation
11/06/2008	13.945	Community of Rankin Inlet, 2013 [2]	Medium	Inconsistent benchmark
24/06/2009	13.655	Community of Rankin Inlet, 2013 [2]	Low	Inconsistent benchmark, water consumption data unavailable
11/08/2009	13.665	Community of Rankin Inlet, 2013 [2]	Low	Inconsistent benchmark, water consumption data unavailable
30/09/2009	13.685	Estimated based on NRC 2009 Bathymetric Survey	Low	Inconsistent benchmark, water consumption data unavailable
14/06/2010	13.555	Community of Rankin Inlet, 2013 [2]	Low	Inconsistent benchmark, water consumption data unavailable
20/06/2011	13.820	Community of Rankin Inlet, 2013 [2]	Medium	Inconsistent benchmark
22/06/2012	13.907	Community of Rankin Inlet, 2013 [2]	Medium	Inconsistent benchmark
04/06/2014	13.212	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
11/07/2014	13.165	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
17/07/2014	13.123	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
21/07/2014	13.117	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
05/08/2014	13.066	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
14/08/2014	13.057	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
29/08/2014	13.041	Community of Rankin Inlet, 2015	High	Consistent method between measurement sets
19/06/2015	12.954	Community of Rankin Inlet, 2015	Low	Inconsistent benchmark and method between measurement sets
26/06/2015	12.989	Community of Rankin Inlet, 2015	Low	Inconsistent benchmark and method between measurement sets
07/07/2015	13.006	Community of Rankin Inlet, 2015	Low	Inconsistent benchmark and method between measurement sets
11/07/2015	13.007	Golder, 2015	Low	Inconsistent benchmark, unfavourable measurement conditions (waves)

Table 1: Water Levels at Nipissar Lake (continued)

Date	Estimated Elevation (masl)[1]	Source	Assumed Reliability[1]	Explanation
13/07/2015	13.118	Golder, 2015	Medium	Inconsistent benchmark

Notes:
1. Assumed reliability reflects the dependability of the measurements and the supporting data available for the year of interest.
2. Water level data provided in attached document to 2012 Annual Consumption Report (Community of Rankin Inlet, 2013)

For the purposes of this assessment, the estimated lake surface elevation for Nipissar Lake at the time of the bathymetric survey (September 29 to October 4, 2009) was assumed to correspond to the water level measured on August 11, 2009 (Community of Rankin Inlet, 2013). The water level data collected between 2008 and 2015 were all referenced to a local benchmark without an orthometric or geodetic elevation and were collected using different measurement techniques. As such, these data are not considered particularly dependable. Older water level data, reported by Stanley (1996), were referenced to an orthometric datum and are therefore considered more meaningful for the purposes of providing an understanding of historic water level records.

2.1.4.2 Lower Landing Lake

No measured water level data are available for Lower Landing Lake; however, an assumption regarding the lake surface elevation of Lower Landing Lake between September 29 and October 4, 2009 was made to facilitate the development of a stage-storage relationship, as previously discussed in Section 2.1.3.

2.1.4.3 The Char River

Spot flows were collected by AMEC (2000) on 5 occasions between June 14 and September 19, 2000. Water levels for the Char River were inferred from these spot flow measurements using a theoretical rating curve developed by IMG-Golder (Appendix B) which relates flow depth to discharge based on available cross-sectional information.

IMG-Golder also measured flow and corresponding water levels during a field campiagn at the Char River on July 11, 2015. For the purposes of this assessment, IMG-Golder selected the flow measurements collected in 2000 and collected at the new bridge crossing in 2015 (Table 2).

Table 2: Hydrometric Data at the Char River

Date	Flow (m^3/s)	Location
14/06/2000	5.040	Unknown [1]
16/06/2000	9.450	Unknown [1]
18/06/2000	9.000	Unknown [1]
21/06/2000	4.360	Unknown [1]
24/06/2000	0.130	Unknown [1]
19/09/2000	0.259	Unknown [1]
11/07/2015	0.630	At the new bridge (62°51’31.83”N, 92°08’32.59”W)
11/07/2015	0.578	Upstream from the Char River water taking
11/07/2015	0.450	Downstream from the Char River water taking

Notes:
1. The location along the Char River where these measurements were taken is unknown.

2.1.5 Spillway/Outlet Configurations

2.1.5.1 Nipissar Lake

Detailed lake outlet rating curves for Nipissar Lake are documented by Stanley (1996). The lake outlet comprises two culverts with upstream inverts located at elevations of 14.235 masl (700 mm diameter culvert) and 13.955 masl (600 mm diameter culvert) (Stanley, 1996). Given the elevation of the lake outlet control and the documented reduction in Nipissar Lake water levels over recent years, these culverts are assumed to have rarely, if at all, conveyed flow in recent years.

2.1.5.2 Lower Landing Lake

Lower Landing Lake discharges directly to the Char River, which subsequently drains to Hudson Bay. No surveyed data for the lake outlet were available in order to provide a detailed representation of the lake's water level control. Based on an examination of satellite imagery (ESRI DigitalGlobe, 2010) and local accounts (Lusty M., 2015a), the lands in the immediate vicinity of the lake outlet flood annually as a result of the freshet, suggesting that the lake's water level control may vary across the full range of the hydrograph during the early period of the open-water season. Given the lack of detailed information with which to characterise the outlet control, a reiterative approach, using a modified rating curve from cross-section 13 (Appendix B), was employed in order to best replicate measured in-stream flows in 2000 and thus represent the outlet of Lower Landing Lake.

2.1.6 Intake Configuration

2.1.6.1 Nipissar Lake

The Nipissar Lake intake structure is composed of two 10-inch pipes (Advanced Subsea Services Ltd., 2014) with an estimated minimum pumping level of 9.5 masl (Arctic Divers, 1986). The elevation of the intake screens from the lake bed appears to have changed over time. Stanley (1996) reported that the intake screens were located 0.5 m above the lake bottom in 1994, while the 2014 Inspection Report (Advanced Subsea Services Ltd., 2014), places them 3 feet (approximately 0.9 m) above the lake bed. For the purposes of this study, these changes are assumed to have a negligible effect on the active storage volumes maintained above elevations of 9.5 masl.

2.1.6.2 Lower Landing Lake

The configuration of the proposed Lower Landing Lake intake has not been provided for consideration in this assessment. Because there is likely a reasonable degree of flexibility in determining its configuration, the water taking volumes considered in this assessment are assumed to be unaffected by the configuration that will eventually be selected.

2.1.7 Historic Intake Withdrawal Rates from Nipissar Lake

Monthly water consumption volumes for Nipissar Lake from 2011 to the first quarter of 2015 were used to simulate the effects of water consumption on water levels over the corresponding period. An estimate of daily water consumption values estimated from the reported monthly volumes (Table 3) was subsequently developed for use by the water balance model.

Table 3: Summary of Daily Intake Withdrawal Rates 2011 to 2015 for Nipissar Lake

Year	Daily Water Consumption Rate (m^3/day)		
	Minimum	Average	Maximum
2011	2,181	2,536	3,063
2012	1,342	1,474	1,739
2013	1,503	1,654	1,771
2014	1,350	1,591	1,748
2015[2]	1,281	2,022	2,681

Notes:
1. Daily values calculated from reported monthly consumptions published in the Annual Consumption Report (2011 to 2015)
2. Estimates based on the 2015 first quarterly consumption report

2.1.8 Projected Population Growth and Anticipated Effect on Water Demand

Population projections from the Nunavut Bureau of Statistics (Nunavut Bureau of Statistics, 2014) were used to forecast potential future increases in water consumption. The Nunavut Bureau of Statistics provides population forecasts until 2035 at an average annual exponential growth rate of 1.53%. For the purposes of estimating population growth beyond 2035, a continued annual growth rate of 1.53% was therefore applied in order to estimate population numbers and consumption volumes corresponding to 2050 and 2080.

2.2 Environment Canada

2.2.1 Meteorological Data

Although a number of other factors were considered, the water balance model can essentially operate with only two meteorological inputs to calculate water balance surpluses, including daily average air temperature and total daily precipitation.

Meteorological data were obtained and reviewed for four Environment Canada (EC) climate stations in the Study Area (Table 4). The two Rankin Inlet A climate stations (Station IDs 2303401 and 2303405) were selected to represent meteorological conditions in the Study Area, as these provided the most comprehensive period of record spanning January 1981 to March 13, 2013 for Station 2303401 and from March 14, 2013 to present for Station 2303405. According to Environment Canada, the stations are 0.71 km apart but installed at the same elevation (32.30 masl). Regional data are available from other meteorological stations, at Whale Cove, located approximately 80 km south from the area of study, and at Chesterfield Inlet, located 150 km north.

Table 4: Available Environment Canada Climate Station Records in the Vicinity of Rankin Inlet

Station Name	Station ID	Period of Record	Measurement Resolution	Distance from Study Area
Rankin Inlet A	2303401	1981 to March 2013	Daily, Hourly, Monthly	0 km
Rankin Inlet A	2303405	March 2013 to Present	Daily, Hourly	0.71 km
Whale Cove A	2303986	1985 to 2007	Daily, Hourly, Monthly	80 km
Chesterfield Inlet A	2300707	1985 to 2013	Daily, Hourly, Monthly	150 km

Notes:

1. Data obtained from the Environment Canada website.

Over the period of record, the selected climate period (1981 to 2015) is missing only 66 days of data; the maximum climate data gap corresponds to 9 continuous days of missing data between December 22 and 31 1992, while the mean gap duration is 2 days. Because the water balance model used for this assessment requires daily data without gaps, and other stations were not located in the immediate vicinity, data gaps were infilled using the average of values for the preceding and subsequent day(s).

2.2.2 Flow Data

Government collected flow data for the Study Area were not available to characterise inflow or outflows for either Nipissar Lake or Lower Landing Lake. However, data from nearby Water Survey of Canada (WSC) flow gauges (presented in Table 5) were examined in order to provide an understanding of characteristic runoff for the region. The Diana River station (06NC001), which provides a 7 year period of record (January 1989 to December 1995) and is located in closest proximity to the Study Area, was used to estimate rainfall runoff and snow melt responses in the Nipissar Lake and Lower Landing Lake watersheds.

Table 5: Available Environment Canada Hydrometric Station Records in the Vicinity of Rankin Inlet

ID	Name	Start	End	Catchment Area (km^2)	Distance from Study Area (km)
06NC001	Diana River near Rankin Inlet	1989	1995	1,460	12.9
06OA002,4,5	Saqvaqjuac Inlet, Various	1977	1981	0.16 to 607	116.6
06NB002	Ferguson River below O'Neil Lake	1979	1995	12,400	152.9
06OA001	Lorillard River Above Daly Bay	1978	1992	11,000	184.4
06MB001	Quoich River above St. Clair Falls	1972	1994	30,100	184.5
06LC001	Kazan River above Kazan Falls	1965	2010	70,000	204.2
06NB001	Ferguson Lake Near Internat. Nickel Co. Camp	1963	1964	-	235.3

2.3 Additional Information Sources

The following information was obtained by IMG-Golder from additional information sources:

- Digital imagery of the Study Area obtained from ESRI Imagery resource (ESRI DigitalGlobe, 2010); and
- Base data downloaded from a Government of Canada website (accessed on July 7, 2015) UTM NAD83 Z15. These contours enabled the watershed delineation for Nipissar Lake and Lower Landing Lake, respectively.

3.0 METHODOLOGY

The following section details the conceptual approach and methods used to conduct the water balance assessment for the Study Area, based on the available information discussed in Section 2.

3.1 Conceptual Approach

The approach used to predict water supply outcomes for Nipissar Lake, Lower Landing Lake and the Char River in response to various combinations of meteorological determinants, physiographic modifiers and water consumption was based on the development of an integrated water balance model.

Water supplies in Lower Landing Lake and Nipissar Lake are dependent on the individual water yields generated from each catchment as a result of meteorological determinants (such as precipitation and evaporation) and subsequent physiographic modifiers (such as land cover, slope and lake storage). Water supplies in Nipissar Lake are currently further modified by the rate of water consumption from the Community, while water supplies in both lakes would be ostensibly affected under the proposal to supplement Nipissar Lake with supplies from Lower Landing Lake. Under the Community's proposal, and because the hydrographic characteristics of the Char River are directly dependent on water levels with Lower Landing Lake, the use of Lower Landing Lake as a supplementary water supply would effectively establish a dynamic and co-dependent relationship between all three water bodies.

By representing the key meteorological determinants, physiographic modifiers and water consumption associated with each water body within a numeric modelling framework, an elemental characterisation of this relationship could be established and compared against historic observations for 'goodness of fit'. Using an iterative approach, minor adjustments to the key variables underlying these determinants could be made as part of the model calibration process in order to improve model performance until a satisfactory 'goodness of fit' was achieved. Model performance was subsequently tested against a separate validation period for verification.

Once considered fit for purpose, and based on the assumption that physiographic determinants remain constant in time, the model was subsequently used to determine how variations in climate and population (read consumption) would affect water supplies in Nipissar Lake and Lower Landing Lake as well as corresponding flows in the Char River.

While this assessment ostensibly focuses on the maximum water taking required to supplement water supplies in Nipissar Lake, the adopted approach was also geared to examining the differences of two approaches that could be used in pumping water from Lower Landing Lake and their corresponding effects on the Char River.

Two options were considered as potential strategies to address water supply deficits in Nipissar Lake. Both approaches are focused on the use of a floating pump platform within Lower Landing Lake and intended to limit water takings to 10% of the Char River flow.

3.2 Model Limitations

It should be noted that the model used to simulate the conveyance and fate of meteorological surpluses throughout the watershed is a considerable simplification of the overarching processes that affect the hydrological behaviour and availability of water supplies within the Nipissar Lake and Lower Landing Lake watersheds. The water balance model is essentially a one-dimensional representation of connectivity between sources and termini within each watershed and lacks the capability to simulate travel time, accurately reflect the varying effects of snow and ice compaction, formation and melt, and replicate the full spectrum of hydrological processes that may influence short-term variations in hydraulic response.

Rather, model setup has been configured to focus only on the key determinants affecting the availability of water supply and minimise the potential for net errors to cause large and permanent deviations between modelled and observed results.

3.3 Development of Lake Stage-Storage Relationships

Individual stage-storage relationships were developed for Nipissar Lake and Lower Landing Lake in ESRI 3D Analyst using the bathymetric survey data for Nipissar Lake and Lower Landing Lake (Budkewitsch *et al*., 2011) [see Figures 4 and 5] and the methodology described in Section 2.1.3. The updated stage-storage relationships, presented in Tables 6 and 7, were used to represent lake storage for Nipissar Lake and Lower Landing Lake, respectively, within the water balance model.

3.3.1 Nipissar Lake

The stage-storage relationship developed to characterise water supply for Nipissar Lake is presented in Table 6.

Table 6: Stage-Storage Relationship of Available Water Supply in Nipissar Lake

Elevation (masl)[1]	Volume (m^3)	Surface Area (m^2)
14.235	3,000,000	1,062,567
14.000	2,885,000	1,016,956
13.685	2,564,659	966,276
12.685	1,702,313	776,585
11.685	1,019,435	603,533
10.685	496,597	454,449
9.685	95,590	341,514
9.50	0	311,648

Note:

1. Available water supply volumes assume the intake structure is at 9.50 masl.

3.3.2 Lower Landing Lake

The stage-storage relationship developed to characterise water supply for Lower Landing Lake is presented in Table 7.

Table 7: Stage-Storage Relationship of Water Supply in Lower Landing Lake

Elevation (masl)	Volume (m^3)	Area (m^2)
13.269	6,125,981	1,423,639
12.269	5,155,414	1,197,103
11.269	4,184,847	970,567
10.269	3,352,334	744,031
9.269	2,732,963	501,632
8.269	2,271,552	424,260

Table 7: Stage-Storage Relationship of Water Supply in Lower Landing Lake (continued)

Elevation (masl)	Volume (m^3)	Area (m^2)
7.269	1,871,615	374,091
6.269	1,525,373	325,362
5.269	1,222,581	281,026
4.269	963,887	237,865
3.269	751,562	190,534
2.269	577,452	160,335
1.269	429,078	137,052
0.269	302,675	115,975
-0.731	197,997	94,088
-1.731	118,505	66,614
-2.731	63,293	48,058
-3.731	24,133	30,762
-4.731	5,621	12,502
-5.731	0	2,084

Note:

1. The stage-storage relationship for Lower Landing Lake does not account for any dead storage, because the future intake structure elevation was not available.

3.4 Effects of Lake Ice Formation on Lake Storage

Ice formation on Nipissar Lake throughout the winter affects the active storage capacity of the lake because the ice cover stores a portion of the available water supply, making this water unavailable for consumption during the winter months. At the end of the winter season, the lowest available water supply also coincides with the maximum thickness of ice, therefore exacerbating the water supply issue during this period.

In order to account for this temporary loss in water supply, lake ice volumes (and commensurate water supplies) were estimated at Nipissar and Lower Landing Lakes by simulating the ice formation process. Late-winter ice thickness on freshwater lakes in the area has ranged from 1.00 m to about 2.40 m (Golder, 2009). Ice covers are initiated by the end of October and are laterally formed by early November.

Ice formation was simulated to reach a maximum thickness of 2.0 m at the end of the winter season for the median (i.e., 50th percentile) winter duration. To account for differences in ice thickness between shorter and longer winter periods, simulated ice thicknesses were adjusted according to the length of individual winters (with shorter winters incurring less ice thickness and longer winters incurring greater ice thicknesses). As such, the lake volumes unavailable for consumption at the end of winter could be determined for any number of different winter duration scenarios.

3.5 Development of Projected Water Consumption Estimates

According to Statistics Canada, Rankin Inlet had a population of 2,636 in 2011. Population growth is projected to increase the population of Rankin Inlet to 3,794 by 2035, which equates to an approximate annual growth rate of 1.53% (exponential). For the purpose of this study, this growth rate was extended to 2050 for an estimated population of 4,766, and to 2080 for an estimated population of 7,516.

Table 8 shows daily water consumption ($m^{3/}$day) for a combination of historic, current and projected population and selected values of daily per capita consumption rate (m^3/person/day).

Table 8: Projected Water Consumption Rates for Community of Rankin Inlet based on Available Population Growth Estimates

Year	Population (High Projection)	Total Daily Water Consumption (m^3)		
		0.4 m^3/person/ day[1]	0.6 m^3/person/ day	0.8 m^3/person/ day
2006	2,470	988	1,482	1,976
2011	2,636	1,054	1,582	2,109
2015	2,801	1,120	1,681	2,241
2020	3,022	1,209	1,813	2,418
2025	3,260	1,304	1,956	2,608
2030	3,518	1,407	2,111	2,814
2035	3,795	1,518	2,277	3,036
2040	4,094	1,638	2,456	3,275
2050	4,766	1,906	2,860	3,813
2060	5,547	2,219	3,328	4,438
2070	6,457	2,583	3,874	5,166
2080	7,516	3,006	4,510	6,013
2090	8,748	3,499	5,249	6,998
2100	10,182	4,073	6,109	8,146

Notes:

1. 0.39 m^3/person/day corresponds to the GNWT MACA guideline for a community the size of Rankin Inlet on a piped system.

Based on annual intake reports for the 2011 to 2014 period provided by CGS, the average daily consumption for Rankin Inlet experiences large fluctuations from year to year, ranging from a maximum of 2,500 m^3/day in 2011, to a minimum of 1,500 m^3/day in 2012. Average daily water consumption for the period 2011 to 2014 was approximately 1,800 m^3, or 0.68 m^3/person/day, based on the 2011 Rankin Inlet population. Although the 2011 to 2014 consumption rate exceeds the desirable consumption rate according to the GNWT MACA (FSC, 2009) guideline of 0.39 m^3/person/day for communities on piped systems of the size of Rankin Inlet. This is given the use of bleeders by the Community which increase consumption relative to this guideline.

The following daily consumption rates were selected to assess water supplementation requirements (i.e., predicted water supply deficit and potential number of days in water deficit) under historic and future climate regimes:

- Low consumption rate, corresponding to 1,600 m^3/day;
- Moderate consumption rate, corresponding to 3,300 m^3/day; and
- High consumption rate, corresponding to 5,300 m^3/day.

3.6 Development of Water Balance Model

The development of the water balance model was predicated on the assumption that if observed precipitation surpluses (i.e., rainfall runoff and snowfall accumulation) could be suitably replicated for the calibration and validation periods (during years when reliable water level records and consumption data were available), it would also be suitable for predicting precipitation surpluses over longer-term historic and future meteorological conditions.

3.6.1 Water Balance Methodology

The total amount of surface water that flows from a particular discharge point is a function of how much water is gained and lost in the upstream catchment area. In purely meteorological terms, total precipitation (rainfall and snowmelt) represents the input to the system, while evapotranspiration (mainly during above-zero temperatures), sublimation (mainly during sub-zero temperatures) and soil storage (during frost-free periods) represent losses from the system. When inputs exceed losses, net precipitation (or surplus) is available in the form of runoff or snowfall accumulation.

The water balance characterisation can be simplified as follows:

(Rainfall + Snowmelt) – (Evapotranspiration + Sublimation) – Change in Soil Storage = Surplus (Runoff and Snow Melt)

The various water balance components presented above are typically quantified in millimetres (mm) over their respective catchment areas, and represent the amount of water generated per unit of watershed area on a daily basis. The two forms in which net precipitation (net snowfall accumulation or rainfall runoff) can be generated differ considerably in terms of the rate at which they are delivered to each lake and, hence, become available for consumption. While lake inputs from rainfall runoff are delivered relatively quickly following a precipitation event, net snow accumulation is generally stored within the watershed until sufficient warming can melt the snow within the watershed and the ice overlying the lake at the onset of spring. The surplus associated with snowfall accumulation is calculated by determining the amount of snow stored over the catchment area on the thaw date.

3.6.2 Water Balance Inputs

Meteorological inputs to the system include rainfall and snowfall. Depending on the meteorological (evaporation or sublimation rates) and physiographic (available soil and lake storage) conditions at the time of precipitation, a portion of these inputs is subsequently lost to the atmospheric (see Section 3.6.3.2) in order to derive net surplus (basin yields).

The meteorological data used to drive the model were obtained from Environment Canada's Rankin Inlet A climate station (Climate ID 2303401 and 2303405). Of the four local stations examined, this station provides the most complete and longest period of record (July 1981 to present) for the Study Area. Data gaps for the period of record (0.65%) were filled using the approach outlined in Section 2.2.1.

3.6.2.1 Precipitation

Total precipitation, as recorded by the Rankin Inlet A climate station, is a direct input to the model and considered as rainfall or snowfall within the model depending on whether air temperatures are greater or lower than specific air temperature benchmarks. The distinction between rainfall and snowfall is important, as they are subsequently computed differently as further outlined below.

3.6.2.1.1 Rainfall

In the absence of detailed physiographic information, rainfall runoff is considered to occur instantaneously (i.e., on the same day). As such, runoff to either lake occurs more quickly than would be expected under observed conditions; however, discharges from either lake are attenuated based on outlet controls that limit the rate of discharge.

3.6.2.1.2 Snowfall

Snow is a major component, if not the primary consideration, of the hydrological cycle in an arctic environment (Dingman, 1973; Kane et al., 1991, Woo et al., 1983), and the subsequent spring snowmelt greatly affects the hydrology of permafrost areas (Church, 1974; Kane et al., 1991).

Due to the open terrain, limited shelter and characteristically high winds across the region, arctic snow cover experiences significant redistribution. As a result, snow cover depth and snow water equivalent (SWE) are highly variable. Yang and Woo (1999) noted that most of the snow drifted into sheltered gullies and valleys and snow cover was generally shallow on exposed terrains, including rolling uplands, plateaus and lakes. Snow surveys at two sites showed that rolling hills in the area also develop snow accumulations as much as 65% greater than average on lee slopes of only 2 to 3 degrees.

In most cases, measured precipitation tends to underrepresent actual precipitation in a phenomenon known as ‘undercatch’. Three main factors contributing to this underrepresentation include: (i) wind turbulence at the gauge which deflects some precipitation (particularly snowfall) away from the gauge opening; (ii) wetting of gauge surfaces, which evaporates water without being recorded; and (iii) trace events which are not captured by the gauge. The cumulative effect of these factors is larger in northern climates given the high incidence of wind during snowfall events and the higher frequency of trace events compared to southern regions.

Meteorological data are conventionally adjusted and published by Environment Canada to correct for ‘undercatch’; however, in the case of EC Rankin Inlet A climate station, no adjusted data set has been published. Accordingly, recorded precipitation at the EC Rankin Inlet A climate station was initially adjusted using snowfall correction factors developed by Environment Canada for the Rankin Inlet region (Mekis & Vincent, 2011), with further refinements being made throughout the model calibration process. The typical correction factor developed by Environment Canada for the region and the correction factor applied to the water balance model are presented in Table 9.

For the purposes of this assessment, snowfall accumulation in the Nipissar Lake and Lower Landing Lake watersheds are adjusted up from those recorded at the EC Rankin Inlet climate station using an adjustment factor of 1.30.

Table 9: Snowfall Adjustment Factors to compensate for ‘Undercatch’ at EC Rankin Inlet A Climate Station

Climate Station	EC Typical Adjustment	Water Balance Model Adjustment
Rankin Inlet A	1.50	1.30

3.6.3 Water Balance Losses

Ignoring water consumption associated with pumping, losses from the watershed system include evapotranspiration (ET) and sublimation. However, soil storage components within the catchment (depending on antecedent conditions) may intercept a component of the rainfall and snow melt inputs, thus making them unavailable to the lake.

3.6.3.1 Soil Storage

The Water Holding Capacity (WHC) represents the total amount of water that can be stored in the soil and is defined as the water content between the field capacity and wilting point (the practical maximum and minimum soil water content, respectively). WHCs are specific to the soil type and land use, whereby low values are a reasonable representation for arctic environments. A WHC value of 15 mm was applied to represent till veneer in both catchments, while a WHC value of 3 mm was applied to represent bedrock.

Surplus water remains in the system after actual ET has been removed (ET demand is met) and the maximum WHC is exceeded (soil-water storage demand is met). The surplus can be further allocated to runoff or infiltration and is largely dependent on catchment conditions (i.e., land use and soil characteristics/properties).

3.6.3.2 Evapotranspiration (ET)

The potential evapotranspiration (PET) is estimated by the empirical Thornthwaite equation (1948) and represents the maximum amount of water that could be evaporated or transpired if water was continuously available for the specific climatic conditions. Actual evapotranspiration (AET) is the amount of evapotranspiration estimated to occur due to available soil-water storage, for specific climatic conditions. AET is typically less than PET because once the water storage in the soil is exhausted, no other ET can occur. The ET process is largely negligible during the winter months and a standard rate of sublimation is instead adopted during the winter period.

3.6.3.3 Sublimation

Due the long winter period in the region, sublimation represents a significant loss of moisture from the system. Although watershed topography varies, causing localised snow accumulation in some parts of the watershed, the catchment is largely exposed to solar radiation and wind due to the lack of significant vegetation. Because a determination of actual sublimation rates would need to be based on a comprehensive range of site-specific data, Golder applied sublimation at a constant rate over the period of snow cover.

Literature estimates for suitable sublimation values in artic or alpine areas can account for as much as 15% to 22% of the total annual snowfall (Liston and Sturm, 1998 and Hood et al., 1999). Ohmura (1982) found that sublimation increased from a low of 0.03 mm/day in late April to 0.6 mm/day on the last days of the dry snow period at a site on Axel Heiberg Island. In one instance, sublimation losses reported on Devon Island were over one-quarter of the snow cover (Ryden, 1977). Variation of sublimation estimates were examined in exposed and sheltered areas (Reba, Pomeroy, Marks, & Link, 2011) revealing sublimation rates averaging approximately 0.3 mm/day.

3.7 Development of Future Climate Variables

In keeping with accepted practices, climate trends were analyzed by describing the current climate using available long-term (30-year) data from 1981 through 2010 and discussing the range of future climate projections (2040 through 2069 and 2070 through 2099). The climate regime from this period was compared to the climate change projections to assess the significance of the potential change.

3.7.1 Generic Approach

The projected ranges of future climate were described using the outputs from general circulation models (GCMs) accepted by the Intergovernmental Panel on Climate Change (IPCC) for various emission scenarios developed by the IPCC. Future climate projection data for Rankin Inlet (i.e., for the appropriate GCM grid square) were extracted from the Canadian Climate Data and Scenarios interface (CCDS, accessed July 6th, 2015) for all available GCMs (30) and the three representative concentration pathways (RCP 2.6, RCP 4.5 and RCP 8.5 – detailed in section below) in the IPCC Fifth Assessment Report (AR5). The model projections were summarized for magnitude of change from the climate regime baseline for the following two time horizons:

- 2040 to 2069 (denoted as 2050s); and
- 2070 to 2099 (denoted as 2080s).

In order to graphically represent the individual model output in a comparable and meaningful way, the data must have a consistent baseline. For each model, the change in temperature and precipitation was calculated relative to the respective modelled baseline values, which are unique to each model. This change was then imposed onto the historic climate baseline for Rankin Inlet.

3.7.2 Projected Concentration Pathways (RCP 8.5, RCP 4.5, RCP 2.6)

Global climate models require extensive inputs in order to characterize the physical processes and social development paths that could alter climate in the future. In order to represent the wide range of the inputs possible to global climate models, the IPCC has established a series of representative concentration pathways (RCPs) that help define the future levels of radiative forcing of the atmosphere. The IPCC identifies four scenarios but this report focuses on the three RCPs currently available from CCDS, namely, RCP 2.6, RCP 4.5 and RCP 8.5. The pathways are named after the radiative forcing projected to occur by 2100. These three RCPs have been described more fully by van Vuuren *et. al.* (2011) in their paper “The representative concentration pathways: an overview” and have been summarized in Table 10. The climate projections for 2050 and 2080 used in this study have are generated using the arithmetic mean of the three selected RCPs.

Table 10: Characterization of Representative Concentration Pathways

Name	Radiative Forcing in 2100	Characterization
RCP 8.5	8.5 W/m²	Increasing greenhouse gas emissions over time, with no stabilization, representative of scenarios leading to high greenhouse gas concentration levels.
RCP 4.5	4.5 W/m²	Total radiative forcing is stabilized shortly after 2100, without overshoot. This is achieved through a reduction in greenhouse gases over time through climate policy.
RCP 2.6	2.6 W/m²	“Peak and decline” scenario where the radiative forcing first reaches 3.1 W/m² by mid-century and returns to 2.6 W/m² by 2100. This is achieved through a substantial reduction in greenhouse gases over time through stringent climate policy.

Note:
[1.] Summarized from van Vuuren et. al (2011)

3.7.3 Discretization of 2050 and 2080 Climate Scenario Variation

The following tables summarize the magnitude of model-predicted changes during the 2050s and 2080s from the historic climate scenario. Figures 7 and 8 depict the monthly mean projected temperatures in Rankin Inlet for all future projections for the 2050s and 2080s. The figures also show a dashed line, which represents the mean of all the modelled projections. The solid line in the figures represents the monthly observed climate scenario based on data from 1981 through to 2010. The figures show a noticeable increase between the historic and projected monthly temperature means.

Figures 9 and 10 present the monthly mean projected precipitation in Rankin Inlet for all future projections for the 2050s and 2080s. Figure 9 shows a noticeable difference between the projected and historic monthly precipitation means for the fall. In Figure 10, the noticeable difference increases over the same season. For both figures, the largest uncertainty occurs in the late summer. The remaining months are comparable between the projected and historic monthly means for both figures.

The differences between the historic climate normal and the projected means for the 2050s and the 2080s climate scenarios are shown in Tables 11 and 12, respectively. Overall, the model projected means are greater than the historic climate normals, showing an increase in both, temperature and precipitation.

Table 11: Model Projected Mean and Current Climate Normal for Rankin Inlet for the 2050s

Month	Temperature [°C]			Precipitation [mm (equivalent)]		
	Historic Climate Normal[1]	Projected Mean	Difference	Current Climate Normal[1]	Projected Mean	Difference
January	-30.47	-27.17	3.29	9.16	10.51	1.35
February	-30.06	-27.25	2.81	8.23	9.64	1.41
March	-24.94	-22.28	2.66	12.32	13.83	1.51
April	-15.61	-13.47	2.15	19.86	21.45	1.59
May	-5.75	-3.28	2.47	19.50	21.42	1.92
June	4.19	6.53	2.34	26.61	29.16	2.55
July	10.50	12.91	2.40	42.03	43.60	1.57
August	9.72	12.19	2.48	57.36	60.24	2.88
September	3.80	6.17	2.38	42.89	45.75	2.86
October	-4.61	-1.47	3.14	38.00	43.98	5.98
November	-16.99	-13.04	3.95	21.74	25.50	3.76
December	-25.47	-21.47	4.01	12.50	14.20	1.70

Note:

1. Refers to historic climatic conditions for the 1981 to 2010 period.

Table 12: Model Projected Mean and Historic Climate Scenario in Rankin Inlet for the 2080s

Month	Temperature [°C]			Precipitation [mm (equivalent)]		
	Current Climate Normal[1]	Projected Mean	Difference	Current Climate Normal[1]	Projected Mean	Difference
January	-30.47	-25.92	4.54	9.16	11.21	2.05
February	-30.06	-25.99	4.08	8.23	10.34	2.11
March	-24.94	-21.37	3.57	12.32	14.26	1.94
April	-15.61	-12.62	2.99	19.86	21.71	1.85
May	-5.75	-2.25	3.50	19.50	22.04	2.54
June	4.19	7.49	3.30	26.61	29.50	2.90
July	10.50	13.84	3.33	42.03	44.13	2.10
August	9.72	13.05	3.34	57.36	59.52	2.16
September	3.80	7.03	3.23	42.89	46.21	3.32
October	-4.61	-0.42	4.18	38.00	45.90	7.90
November	-16.99	-11.62	5.37	21.74	27.21	5.47
December	-25.47	-19.93	5.54	12.50	15.32	2.82

Note:

1. Refers to historic climatic conditions for the 1981 to 2010 period.

3.7.4 Application of Climate Scenario Variations

The projected climate scenario variations, included in Tables 11 and 12, were applied to the historic meteorological record. The data from both climate scenarios were used to modify the historic recorded data using the same method.

The temperature differences for each of the climate scenarios were added to the historic temperature record on a monthly basis. Therefore, each day of each specific month was increased or decreased by the temperature difference associated with the specific month for the associated climate scenario.

The change in precipitation is also detailed on a monthly basis, presenting the total precipitation difference for each month for the given climate scenario. The prorated monthly precipitation difference was proportionally applied to each precipitation event of the month (i.e., weighted to each event), to account for the total monthly change for each climatic scenario.

All other meteorological parameters remained unchanged from the historic data set.

3.8 Calibration/Validation of Water Balance Representations

The purpose of the model calibration/validation exercise was to optimise the accuracy of simulated mechanisms affecting the prediction of lake levels and, hence, the availability of water supplies in Nipissar Lake and Lower Landing Lake and flows within the Char River.

Much of the water level data for Nipissar Lake and flow data for the Char River identified as part of the data review exercise were considered limited (as detailed in Table 1) for a combination of reasons including:

- Inconsistent benchmarks, measurement methods and/or technologies were employed between measurements;
- Specific locations of flow and corresponding level measurements were not provided;
- Water consumption data were unavailable or approximate; and
- Unfavourable measurement conditions were present.

This resulted in the selection of a limited number of data periods with which to calibrate and validate the model. The first stage of the model calibration exercise was focused on June 4, 2014 to July 13, 2015, owing to the best available combination of meteorological, hydrometric and water consumption data available for Nipissar Lake. The second stage of the model calibration exercise was focused on June 14, 2000 to September 9, 2000, as this was the only continuous period for which multiple flow measurements were available within the Char River, providing a hydraulically-connected means of evaluating water level predictions in Lower Landing Lake.

Model validation was focused on June 8 to October 5, 1994 for Nipissar Lake, coinciding with the most comprehensive and dependable water level data and consumption data available over the entire period of record.

Using an iterative calibration approach to gradually improve representation of the calibration parameters (see Section 4.8.2), model performance over the calibration period was progressively improved until the magnitude of predicted and observed water levels in Nipissar Lake and flow rates in the Char River were suitably matched. Once the model was calibrated, simulations were undertaken for the validation period to evaluate whether observed data could be reasonably predicted and the model could thus be regarded as ‘suitable for purpose’.

3.8.1 Calibration Parameters

Two calibration parameters, the snowfall factor and potential evapotranspiration adjustment factors, were selected for the purposes of improving model performance. Given their temporal and spatial variation, in-field measurements for these parameters are difficult to apply over a watershed-scale area or prolonged timeframe in a representative manner.

It has been documented (Yang and Woo, 1999; Woo et. al. 1999) that arctic snowfall measurements collected at airport-based meteorological stations can significantly under-represent snowfall amounts in the rest of the watershed and therefore require application of a ‘correction factor’ in order to provide a more suitable representation of snowfall for the watershed as a whole. Similarly, theoretical or even empirical evapotranspiration measurements available from literature sources are not always appropriate for transposition into different watersheds and therefore need to be determined from back-calculation.

Accordingly, potential differences in actual and representational values for both parameters frequently can be, and need to be, resolved through the calibration process.

Model performance was judged based on the difference between observed and predicted water levels following snowmelt and at the time of lake freeze-up. Although quantification of the differences between observed and predicted values was also evaluated throughout the simulation periods as a whole, this was regarded as a secondary model performance indicator, being less significant to the prediction of available water supply at key points in time than the former two factors.

3.8.1.1 Evapotranspiration

To correct for differences in potential evapotranspiration (PET) and actual evapotranspiration (AET) over the ice-free period, PET was modified iteratively to obtain an optimum value that provides the best model performance for the calibration period. The calibrated PET value was identified as 0.48 times that of the value calculated using Thornthwaite.

3.8.1.2 Snowfall Factor

Section 3.6.2.1.2 discusses the 'undercatch' phenomenon and its impact on the lake's water levels. The calibration process provided with an optimized value to correct the snowfall magnitudes, respectively, from those published by Environment Canada. A factor of and 1.3 was applied to snowfall. These values were found to provide the optimum input to correct the precipitation data recorded by the Environment Canada meteorological station Rankin Inlet A.

3.8.2 Model Calibration

3.8.2.1 Calibration of Nipissar Lake Levels

The numeric and graphical results of the calibration exercise for Nipissar Lake are presented in Table 13 and depicted on Figure 11, respectively. Overall, model output for the calibration period corresponded very well to measured data as demonstrated by the root mean squared (RMSQ) error values presented in Table 13. The overall RMSQ error over the year is 3.4 cm. At the intake level (elevation of 9.5 masl), the 3.4 cm difference corresponds to an error of approximately 10,500 m^3.

The Pearson correlation between predicted and measured values appears somewhat subdued due to the relatively low variability in available water level data over the period, which is predominantly an effect of the lack of over-winter and early freshet data for the lake. The fact that the only reliable water level measurement for Nipissar Lake in 2015 provides a reasonable match to predicted water levels generates an element of confidence regarding over-winter and freshet water level transition; however, collection of reliable over-winter water level data that is tied to a verifiable geodetic or orthometric datum should be prioritised in order to further examine the model's accuracy during this crucial period.

Table 13: Water Balance Model Performance Statistics for Calibration Period (June 4 2014 to July 13 2015)

Calibration Measure	Result
Pearson Correlation	0.80
RMSQ Error over Period	0.034 m
RMSQ Error at end of Spring Melt	0.039 m

3.8.2.2 Calibration of the Char River Flows

In the absence of water level data for Lower Landing Lake, the calibrated water balance configuration for the Nipissar Lake watershed was applied to the Lower Landing Lake watershed based on the assumption that the same meteorological and similar physiographic factors were influencing both watersheds.

In the absence of detailed information regarding the outlet configuration of Lower Landing Lake, the relationship of water levels in Lower Landing Lake and ensuing flows in the Char River were developed by applying a modified rating curve from the upstream end (cross-section 13) of the Char River HEC-RAS model (see Appendix B) to the lake outlet and iteratively reducing the cross sectional area until the predicted flow response in the Char River was a reasonable replicate of the individual flow measurements obtained during the summer of 2000.

The numeric and graphical results of the calibration exercise for the Char River are presented in Table 14 and depicted on Figure 12. Based on the tabulated results alone, it is apparent that while correlation between predicted and measured flows appears reasonable, the RMSQ error appears high. This difference is predominantly a function of disparity in the timing of the peak hydrograph, with predicted peak flows occurring approximately three to four days after those measured in the field. While this difference initially appears discomforting, it is noteworthy that this difference is an artifact of differences between actual timing of the snowmelt within the watershed and the timing of the snowmelt within the model. Actual flow responses are subject to physical attenuation and have extended travel times (as a function of distance from source).

While the shape of the predicted hydrograph therefore differs slightly from the measured data, the magnitude and duration of the spring freshet is well replicated within the model, as are the two flow magnitudes measured later in the year. From a perspective of annual flow volume and duration, therefore, the available data do not prompt any particular cause for concern, although further flow and water level monitoring should continue to be pursued to build a more uninterrupted understanding of measured flows.

Table 14: Water Balance Model Performance Statistics for Calibration Period (June 14 2000 to September 9 2000)

Calibration Measure	Result
Pearson Correlation	0.86
RMSQ Error over Period	0.88 m^3/s

3.8.3 Model Validation

Following model calibration, a further simulation was carried out to examine whether the model was capable of independently generating reasonable water level predictions for Nipissar Lake, with water level results presented in tabular and graphical form in Table 15 and Figure 13, respectively.

In general, predicted water levels over the summer period provide a reasonable reflection of measured water level fluctuations in Nipissar Lake. There are some minor differences in predicted and observed water levels during the period between the end of June and end of July, which is likely due to the model's inability to replicate flow attenuation throughout the greater watershed. The Pearson correlation appears to provide a better fit during the validation period than during the calibration period; however, the larger RMSQ error over the period under scrutiny reinforces that data collected over a greater range of water level conditions is required in order to increase the significance of this measure. At the intake level, an overall RMSQ error of 7.7 cm corresponds to an error of approximately 23,950 m^3.

Table 15: Water Balance Model Performance Statistics for Validation Period (June 8 1994 to October 5 1994)

Calibration Measure	Result
Pearson Correlation	0.87
RMSQ Error over Period	0.077 m
RMSQ Error at end of Spring Melt	0.071 m

3.8.4 Calibration – Validation Findings

The calibration-validation process, although constrained by the number of independent periods available due to a limited set of congruous and reliable water level measurements, particularly during the winter months, suggests that the model provides a reasonably good representation of meteorological surpluses and flows, though further data are required to verify the model's performance during, and towards the end of, the winter season when water supplies will be at their most critical.

A further finding is that instantaneous elevation differences between modelled and observed records, particularly during the summer months, may result from the modelled rates at which rainfall runoff is attenuated within the watershed and delivered to the lake. It is noted that these differences appear to be at a minimum at specific points of interest, including immediately prior to freeze-up and immediately following the spring melt period.

Notwithstanding these limitations and given the goals for its use, the model is considered fit for the purposes outlined in this report.

3.9 Simulation and Representation of Historic Event Probabilities

3.9.1 Simulation of Screened Meteorological Years

Once the model was deemed suitably calibrated and validated, simulations of each of the 32 individual years were carried out, specifically excluding the anthropogenic modifiers of water consumption via intakes at Nipissar Lake and the Char River, supplementary augmentation and any potential constraints associated with lake storage capacity. By focusing model output on the determination of daily watershed surpluses (in the form of snowmelt and rainfall runoff) as well as freeze and thaw dates only, any combination of potential water consumption, supplementary augmentation and/or residual lake storage scenarios could be retrospectively applied in order to predict the magnitude and timing of future water supplies.

3.9.2 Development of Long-Term Historic Database Representations

Having generated freeze and thaw dates, daily snow accumulation, and daily rainfall runoff volumes for each of the modelled years, snow accumulation and rainfall runoff yields were calculated based on the probability of them occurring over the full range of historic observations. It should be noted that the differentiation between daily snow accumulation and daily rainfall runoff was considered key for the purposes of predicting when basin yields would be delivered to the lakes.

Average daily snow accumulation and average daily rainfall runoff yields were consequently calculated for each meteorological probability based on the number of 'winter' days occurring between corresponding freeze and thaw dates and the number of 'summer' days occurring between corresponding thaw and freeze dates. While this normalisation process necessarily eliminated the natural variability associated with individual storm events in different precipitation years, it allowed basin yields to be represented without undue complexity, recognising that water supply forecasts need not be geared to the prediction of individual, but cumulative, events occurring over each 'winter' or 'summer'.

3.10 Simulation and Representation of Climate Change Event Probabilities

3.10.1 Simulation of Future Climate Representations

Modifying the raw precipitation and air temperature data employed for the purposes of simulating historic annual water balances to account for monthly changes in both parameters anticipated for the 2050s and the 2080s climate regime, water balance simulations for all 32 years were repeated to represent daily snow accumulation, rainfall runoff and freeze and thaw dates corresponding to the 2050s and 2080s regime.

3.10.2 Development of Long-Term (2050s) Future Climate Representations

Using the same approach outlined in Section 3.9.1., daily snow accumulation and rainfall runoff yields were generated for each probabilistic year according to corresponding freeze and thaw date probabilities and stored in a database representing water supply generation for the 2050s climate regime.

3.10.3 Development of Long-Term (2080s) Future Climate Representations

Lastly, the process described above was again completed to generate daily water supply generation values under corresponding 'winter' and 'summer' conditions corresponding to the 2080s climate regime.

3.11 Probabilistic Determination of Water Supplies, Days Without Water, and Supplementation Rates

Databases for all three of the climate scenarios could consequently be used in a probabilistic framework to predict the availability of water supplies associated with a combination of nominal snow accumulation and rainfall runoff probability as well as any freeze and thaw date scenarios, while tracking the daily cumulative effects of any user-defined water consumption/supplementation rates. In other words, the net water supply in each lake and flows within the Char River on any given day could be calculated based on the number of days of accrued snow accumulation and rainfall runoff based on whether or not snow melt had occurred, what the daily consumption rate was and accounting for any lake overflow that may have happened.

This approach allows available water supplies for any given scenario to be examined in terms of the potential shortfalls, both in magnitude (volume) and duration (days without water) at Nipissar Lake, which could be encountered unless a defined supplementation volume from Lower Landing Lake can be added to the lake and/or appropriate water conservation measures are implemented. Moreover, the effect of supplementation from Lower Landing Lake could then also be translated into a net effect on flow magnitude and hydroperiod (the time before the river runs dry under existing conditions) in the Char River.

Having accounted for potential evapotranspiration losses during the simulations, the forecasted water supply deficit therefore provides a direct representation of supplementation requirements for any given basin yield probability that can be directly used for water management purposes. However, the key underlying assumption is that the determination of water supplies, as well as corresponding shortfalls and supplementation rates, are a function of the range of meteorological conditions represented within the historic data set and may not be representative of the full range of meteorological conditions that could be encountered in the future.

3.12 Nipissar Lake Water Supply Supplementation Pump Rates

In order to meet Nipissar Lake supplementation demand, water pumping is evaluated from Lower Landing Lake. Two options were evaluated as strategies to pump water from Lower Landing Lake recognising that the feasibility of Option 1 is logistically challenging and unlikely to proceed.

The water taking from Lower Landing Lake is intended to meet the withdrawal limit of 10% of the Char River flows. The Char River flows were estimated using the water balance estimated surplus from the Lower Landing Lake watershed (i.e., the outflow from Lower Landing Lake).

Option 1

Option 1 is based on the assumption that water takings from Lower Landing Lake would have to be limited to 10% of the instantaneous flow within the Char River. This approach does not consider any practical limitations that may be associated with pumping during periods of lake ice cover or the logistical challenges associated with continuously varying pump rates to match the 10% flow target, but does ensure that the shape and duration of the baseline hydrograph are maintained.

Option 2

Option 2 proposes an alternative approach to water takings from Lower Landing Lake because it is recognised that there are significant challenges associated with Option 1. While Option 2 seeks to comply with the spirit of the 10% flow criterion, this approach is based on applying a constant flow rate across a longer period following freshet in order to avoid variable pump rates and possible issues with lake ice. The net hydrological effect of this approach is that each year’s water takings from Lower Landing Lake are subsequently replaced by the following year’s freshet. While this would likely result in a significant reduction in peak flows, only minor reductions in baseline hydroperiod, would be expected. Based on information provided by CGS, the water depth of the river is sufficiently low for freezing of the entire water column to occur (Lusty M., 2015b). This indicates that the presence of fish within the Char River may be opportunistic (some fish use the Char River during periods of flow but are not resident) and temporary (no fish are sustained over the subsequent winter). The absence of year-round fish habitat, and because there are no other known uses for water within the Char River, suggests that the effects of these hydrograph modifications do not represent a significant adverse effect.

4.0 WATER BALANCE RESULTS

Results related to long-term water supply and supplementation requirements for Nipissar Lake, Lower Landing Lake and the Char River are presented in this section, organized as follows:

- Section 4.1 presents the water balance results for Nipissar Lake watershed, including:
  - Section 4.1.1. Water Balance Results under Historic Climate Regime;
  - Section 4.1.2. Water Balance Results under 2050s Climate Regime;
  - Section 4.1.3. Water Balance Results under 2080s Climate Regime;
- Section 4.2 presents the water balance results for Lower Landing Lake watershed, including:
  - Section 4.2.1. Water Balance Results under Historic Climate Regime;
  - Section 4.2.2. Water Balance Results under 2050s Climate Regime;
  - Section 4.2.3. Water Balance Results under 2080s Climate Regime;
- Section 4.3 presents the water balance results for the Char River, including:
  - Section 4.3.1. The Char River Outflows under Historic Climate Regime;
  - Section 4.3.2. The Char River Outflows under the 2050s Climate Regime;
  - Section 4.3.3. The Char River Outflows under the 2080s Climate Regime; and
- Section 4.4 compares the two supplementation approaches discussed in Section 3.1 in terms of their range of pumping requirements and resulting hydroperiod.

4.1 Nipissar Lake Watershed

The results for the Nipissar Lake water balance corresponding to historical and future climatic conditions are presented herein.

4.1.1 Water Balance Results under the Historic Climate Regime

This sub-section presents rainfall runoff and snow accumulation yields, winter durations and supplementation requirements associated with Nipissar Lake under historic climate regime conditions.

4.1.1.1 Rainfall Runoff and Snow Accumulation Yields

The annual rainfall runoff and snow accumulation yields over historic climate regime conditions vary considerably over the 32 year period of record examined. Rainfall runoff yield accounts for evapotranspiration losses over the watershed as a whole, while snow accumulation yield accounts for losses due to sublimation.

A summary of historic occurrence probabilities corresponding to rainfall runoff and snow accumulation yields is presented in Table 16 below, noting that the effects of water consumption are entirely omitted at this stage. Defining the combined annual probabilities for rainfall runoff and snow accumulation yields is complicated because these two variables are neither entirely independent nor entirely dependent on one another. Examining the relationship between the two for each of the modelled years showed them to be neither negatively nor positively correlated meaning that they must be considered on their own, rather than their combined, probabilities. Watershed yield volumes, water supply deficit volumes and water taking volumes are often presented in megalitres (ML) for simplicity of presentation.

Table 16: Historic Probability of Rainfall Runoff and Snow Accumulation Yields for Nipissar Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	179	66	45	353	284
95	211	128	40	369	296
90	223	140	35	385	316
85	259	150	30	415	331
80	282	157	25	429	390
75	290	170	20	460	403
70	305	182	15	542	442
65	319	196	10	545	474
60	333	216	5	554	532
55	336	231	2	578	713
50	345	250	0	621	1,028

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.

4.1.1.2 Winter Durations (Freeze and Thaw Times)

An analysis of freeze and thaw times over the 1981 to 2015 period shows that the median of winter duration during historic climate regime conditions is approximately 245 days. During the winter durations presented below, the Community would need to be assured that sufficient supplementation had taken place over the previous summer period to meet water demand until the first spring melt period replenishes lake supplies and/or supplementation from a secondary source can be undertaken. As presented in Table 17, the range of historic variation suggests that the winter period could vary by over seven weeks, meaning that sufficient redundancy (surplus) of lake supplies needs to be provided to ensure water supplies are available during longer than average winters.

Table 17: Historic Probability of Freeze and Thaw Dates and Corresponding Winter Duration for Nipissar Lake

Historic Percentage Probability of Occurrence[1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than	Historic Percentage Probability of Occurrence[1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than
100	26-Sep	21-Jun	268	40	07-Oct	07-Jun	242
95	26-Sep	19-Jun	265	35	08-Oct	07-Jun	242
90	27-Sep	18-Jun	264	30	09-Oct	06-Jun	240
85	28-Sep	16-Jun	262	25	10-Oct	03-Jun	237
80	28-Sep	14-Jun	259	20	10-Oct	03-Jun	236
75	30-Sep	12-Jun	255	15	11-Oct	31-May	232
70	03-Oct	10-Jun	250	10	14-Oct	28-May	226
65	03-Oct	10-Jun	249	5	15-Oct	27-May	223
60	04-Oct	09-Jun	248	2	17-Oct	26-May	221
55	06-Oct	08-Jun	245	1	20-Oct	26-May	217
50	06-Oct	08-Jun	245	0	22-Oct	26-May	216
45	07-Oct	08-Jun	244	-	-	-	-

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.

4.1.1.3 Supplementation Requirements

Based on the range of nominal water consumption rates presented in Section 3.5 and probabilistic basin yields (for rainfall runoff and snow accumulation) and winter periods presented in sub-sections 4.1.1.1 and 4.1.1.2, a summary of predicted water supply deficits and corresponding days without water is presented in Table 18. Unlike the probabilistic basin yield results, the values tabulated below account for the storage capacity of Nipissar Lake. It should be noted that because evaporative losses from Nipissar Lake have already been factored into the basin yield estimates, the tabulated water supply deficits therefore represent the supplementation requirements required to address each scenario. A more detailed table of results is provided in Appendix A.

Table 18: Summary of Predicted Water Supply Deficits and Potential Number of Days in Water Deficit under Historic Climate Regime Conditions for Nipissar Lake

Percentage Probability of Exceedance			Daily Consumption Rate (m^3)					
			1600		3300		5300	
Winter Length[1,4]	Snow Accumulation[1]	Rainfall Runoff[1]	Water Supply Deficit (ML)[3, 5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3, 5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3]	Water Supply Deficit (ML)[3, 5]
100	100	100	271	170	892	270	**1622**	**306**
	75	75	86	53	706	214	**1436**	**271**
	50	50	0	0	608	184	**1338**	**252**
	25	25	0	0	379	115	**1109**	**209**
	0	0	0	0	0	0	258	49
50	100	100	234	146	855	259	**1585**	**299**
	75	75	31	19	652	197	**1382**	**261**
	50	50	0	0	550	167	**1280**	**242**
	25	25	0	0	310	94	1040	196
	0	0	0	0	0	0	224	42
0	100	100	189	118	809	245	**1539**	**290**
	75	75	0	0	585	177	**1315**	**248**
	50	50	0	0	479	145	1209	228
	25	25	0	0	225	68	955	180
	0	0	0	0	0	0	182	34

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e., daily consumption rate x number of winter days >than active lake storage).
3. Assumes a portion of water is unavailable for consumption due to ice formation.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17.
5. Tabulated water deficit estimates do not consider potential effects of model inaccuracy.

Based on the summary presented in Table 18 and the results presented in Appendix A, supplementation of Nipissar Lake is likely to be required in the immediate to very near future. While the required supplementation volumes are likely to be manageable in the short term (a maximum of approximately a million cubic metres per annum in more extreme probability scenarios), the projected increase in population and water consumption will make supplementation a more frequent exercise as the supplementation volumes required to attain a reasonable level of water supply security increase over the medium term.

Based on the growth projections for the Community of Rankin Inlet, a moderate consumption rate (3,300 m^3 per day) and median basin yield conditions, supplementation of the lake will likely require as much as 550,000 m^3 per year (approximately 45% of the available active lake storage volume) for a median duration winter and as much as 608,000 m^3 per year (approximately 58% of the available active lake storage volume) for a maximum duration winter. These supplementation values account for the probable amount of lake water unavailable for consumption due to ice storage.

Under extreme climatic conditions (lowest historic annual rainfall runoff [65 mm] and snowfall accumulation [38 mm]) and a maximum duration winter [268 days], winter consumption will exceed the available active winter storage capacity of the lake with a daily consumption rate of approximately 3,900 m^3.

4.1.2 Water Balance Results under the 2050s Climate Regime

The following sub-section provides the results of the water balance assessment as they pertain to 2050s climate regime conditions.

4.1.2.1 Rainfall Runoff and Snow Accumulation Yields for 2050s Climate Regime

Although the estimated 2050 air temperatures are warmer and annual precipitation is marginally higher relative to the historic climate regime (as outlined in Section 3.9), estimated average rainfall runoff yields for the 2050s climate regime are approximately 21 percent higher, while estimated average snow accumulation yields are approximately 5% lower for the median meteorological year. The trend for 2050s rainfall runoff and snow accumulation probabilities shows that for extreme events, (i.e., 100^{th} and 0^{th} percentile), the 2050s snowfall and rainfall yields are higher than those associated with the historical climate regime.

A summary of the occurrence probabilities of rainfall runoff and accumulated snow runoff yields under the 2050s climate regime is presented in Table 19.

Table 19: 2050s Climate Regime Annual Probability of Rainfall Runoff and Snow Accumulation Yields for Nipissar Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	244	106	45	424	256
95	273	114	40	437	294
90	316	128	35	445	307
85	338	166	30	481	316
80	357	173	25	535	360
75	370	183	20	567	376
70	379	194	15	577	388
65	388	202	10	602	401
60	390	213	5	622	477
55	402	230	2	643	714
50	416	238	0	683	1027

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.1.2.1.1 Winter Durations (Freeze and Thaw Times) for 2050s Climate Regime

As presented in Table 20, increased air temperatures associated with the 2050s climate regime result in a marked reduction of winter durations (from a median of 245 to 227 days) relative to the historic climate regime. This reduction in winter duration appears to be relatively consistent across most probabilities (~7%), although the reduction increases to approximately 10% for low percentage probability conditions.

The average winter period is estimated to decrease by approximately two and a half weeks, the range of expected winter durations is still over seven months, suggesting that sufficient redundancy (surplus) of lake supplies would still need to be considered to ensure water supplies are available during longer than average winters.

Table 20: 2050s Probability of Freeze and Thaw Dates and Corresponding Winter Duration for Nipissar Lake

Historic Percentage Probability of Occurrence[1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than	Historic Percentage Probability of Occurrence[1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than
100	02-Oct	12-Jun	253	40	19-Oct	29-May	222
95	03-Oct	10-Jun	250	35	20-Oct	28-May	221
90	05-Oct	09-Jun	247	30	21-Oct	26-May	217
85	08-Oct	08-Jun	243	25	21-Oct	25-May	216
80	08-Oct	07-Jun	241	20	22-Oct	23-May	213
75	09-Oct	05-Jun	239	15	22-Oct	23-May	212
70	12-Oct	04-Jun	235	10	24-Oct	21-May	210
65	13-Oct	04-Jun	234	5	25-Oct	20-May	207
60	14-Oct	03-Jun	233	2	31-Oct	19-May	199
55	15-Oct	02-Jun	229	1	03-Nov	18-May	196
50	16-Oct	31-May	227	0	04-Nov	18-May	195
45	17-Oct	29-May	224	-	-	-	-

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.

4.1.2.2 Supplementation Requirements for 2050s Climate Regime

Based on the range of nominal water consumption rates presented in Section 3.5 and probabilistic basin yields (for rainfall runoff and snow accumulation) and winter periods presented in sub-sections 4.1.1.1 and 4.1.1.2, a summary of predicted water supply deficits and corresponding days without water is presented in Table 21. It should be noted that because evaporative losses from the lake have already been factored into the basin yield estimates, the tabulated water supply deficits directly represent the supplementation requirements required to address each scenario. A more detailed table of results is provided in Appendix A.

Table 21: Summary of Predicted Water Supply Deficits and Potential Number of Days in Water Deficit under 2050s Climate Regime

Percentage Probability of Exceedance			Daily Consumption Rate (m^3)					
			1600		3300		5300	
Winter Length[1]	Snow Accumulation[1]	Rainfall Runoff[1]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]
100	100	100	192	120	**813**	**246**	**1543**	**291**
	75	75	0	0	570	173	**1300**	**245**
	50	50	0	0	431	131	**1161**	**219**
	25	25	0	0	112	34	**842**	**159**
	0	0	0	0	0	0	0	0
50	100	100	166	104	787	238	**1517**	**286**
	75	75	0	0	534	162	**1264**	**239**
	50	50	0	0	397	120	**1127**	**213**
	25	25	0	0	79	24	809	153
	0	0	0	0	0	0	0	0
0	100	100	135	84	755	229	**1485**	**280**
	75	75	0	0	491	149	1221	230
	50	50	0	0	357	108	1087	205
	25	25	0	0	39	12	769	145
	0	0	0	0	0	0	0	0

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e., daily consumption rate x number of winter days >than active lake storage).
3. Assumes a portion of water is unavailable for consumption due to ice formation.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 20.
5. Tabulated water deficit estimates do not consider potential effects of model inaccuracy.

Based on the summary presented in Table 21 and the results presented in Appendix A, supplementation requirements of Nipissar Lake are generally expected to decrease relative to the historic climate regime, due to shorter winter durations and accompanying higher rainfall runoff versus snow accumulation yields.

Assuming a moderate consumption rate and median basin yield conditions, supplementation of the lake water supplies will likely require as much as 397,000 m^3 per year (28% less than under the historic climate regime and approximately 32% of the available active lake storage volume) for a median duration winter and as much as 431,000 m^3 per year (approximately 42% of the available active lake storage volume) for a maximum duration winter. These supplementation values account for the probable amount of lake water unavailable for consumption due to ice storage.

4.1.3 Water Balance Results under the 2080s Climate Regime

The following sub-section provides the results of the water balance assessment as they pertain to 2080s climate regime conditions.

4.1.3.1 Rainfall Runoff and Snow Accumulation Yields for 2080s Climate Regime

Under median climatic conditions, combined annual rainfall runoff and snow accumulation yields for the 2080s climate regime are expected to vary more than that for the historic climate regime. 2080s climate regime water yields are expected to increase marginally against those predicted for the 2050s climate regime. This change over time is primarily related to water balance differences related to the effects of changed precipitation.

Due to warmer temperatures and marginally higher annual precipitation (as outlined in Section 3.9) relative to the historic climate regime, estimated rainfall runoff yields for the 2080s climate regime conditions are approximately 21% higher and estimated snow accumulation yields approximately 3% lower, given shorter winter periods for the 2080s climatic regime. In general terms, estimated total annual rainfall runoff yields for the 2080s climate regime average nearly twice those for snow accumulation for drier conditions, although this trend is inverted for wetter conditions.

The projected change in climate again results in higher basin yields during dry and wet conditions than during the historic climate regime.

A summary of 2080s climate regime occurrence probabilities corresponding to rainfall runoff and snow accumulation yields is presented in Table 22.

Table 22: 2080s Climate Regime Annual Probability of Rainfall Runoff and Snow Accumulation Yields for Nipissar Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	248	117	45	441	270
95	301	137	40	449	285
90	322	143	35	464	297
85	346	156	30	486	317
80	357	176	25	558	356
75	371	191	20	597	368
70	387	200	15	610	384
65	391	206	10	624	418
60	397	214	5	655	468
55	409	232	2	675	701
50	416	244	0	704	1009

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.1.3.2 Winter Durations (Freeze and Thaw Times) for 2080s Climate Regime

Projected air temperature increases associated with the 2080s climate regime result in a further reduction of winter durations relative to the historic climate regime from a median of 245 days to 221 days (see Table 23). Compared to the historic climate regime, winter durations are reduced by 8 to 11 percent.

Although the average winter duration for the 2080s climate regime is estimated to decrease by approximately three and a half weeks relative to the historic climate regime, the range of estimated winter durations now extends for over seven months, suggesting that sufficient redundancy of lake water supplies (surplus to ensure water supplies are available during longer than average winters) would become a more poignant consideration than under historic conditions.

Table 23: 2080s Climate Regime Freeze and Thaw Dates and Corresponding Probabilities of Winter Duration

Historic Percentage Probability of Occurrence[1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than	Historic Percentage Probability of Occurrence [1]	Freeze Date Later Than	Thaw Date Earlier Than	Winter Shorter Than
100	03-Oct	08-Jun	248	40	21-Oct	27-May	217
95	05-Oct	06-Jun	244	35	22-Oct	25-May	216
90	07-Oct	05-Jun	240	30	23-Oct	24-May	213
85	09-Oct	02-Jun	237	25	23-Oct	23-May	212
80	10-Oct	02-Jun	235	20	24-Oct	22-May	210
75	14-Oct	02-Jun	231	15	25-Oct	21-May	208
70	17-Oct	01-Jun	227	10	26-Oct	18-May	204
65	17-Oct	31-May	226	5	30-Oct	18-May	200
60	17-Oct	30-May	225	2	05-Nov	17-May	193
55	17-Oct	29-May	223	1	08-Nov	16-May	189
50	20-Oct	28-May	221	0	09-Nov	16-May	188
45	21-Oct	28-May	219	-	-	-	-

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.1.3.3 Supplementation Requirements for 2080s Climate Regime

Based on the range of nominal water consumption rates presented in Section 3.5 and probabilistic basin yields (for rainfall runoff and snow accumulation) and winter periods presented in sub-sections 4.1.1.1 and 4.1.1.2, a summary of predicted water supply deficits and corresponding days without water is presented in Table 24. It should be noted that because evaporative losses from the lake have already been factored into the basin yield estimates, the tabulated water supply deficits represent the supplementation requirements required to address each scenario. A more expansive table of variable ranges is provided in Appendix A.

Table 24: Summary of Predicted Water Supply Deficits and Potential Number of Days in Water Deficit under 2080s Climate Regime

Percentage Probability of Exceedance			Daily Consumption Rate (m^3)					
			1600		3300		5300	
Winter Length [1, 4]	Snow Accumulation [1]	Rainfall Runoff [1]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]	Water Supply Deficit (ML)[3,5]	Number of Days in Water Deficit[3]
100	100	100	182	114	802	243	**1532**	**289**
	75	75	0	0	576	175	**1306**	**246**
	50	50	0	0	448	136	**1178**	**222**
	25	25	0	0	142	43	872	164
	0	0	0	0	0	0	0	0
50	100	100	157	98	778	236	**1508**	**284**
	75	75	0	0	542	164	**1272**	**240**
	50	50	0	0	416	126	**1146**	**216**
	25	25	0	0	103	31	833	157
	0	0	0	0	0	0	0	0
0	100	100	128	80	748	227	**1478**	**279**
	75	75	0	0	501	152	1231	232
	50	50	0	0	377	114	1107	209
	25	25	0	0	57	17	787	149
	0	0	0	0	0	0	0	0

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e., daily consumption rate x number of winter days >than active lake storage).
3. Assumes a portion of water is unavailable for consumption due to ice formation.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 23.
5. Tabulated water deficit estimates do not consider potential effects of model inaccuracy.

Based on the summary presented in Table 24 and the results presented in Appendix A, supplementation requirements of Nipissar Lake are generally estimated to decrease relative to the historic climate regime due to shorter winter durations and accompanying higher rainfall runoff versus snow accumulation yields.

Assuming a moderate consumption rate and median basin yield conditions, supplementation of the lake water supplies will likely require as much as 416,000 m^3 per year (29% less than under the historic climate regime and approximately 34% of the available active lake storage volume) for a median duration winter and as much as 448,000 m^3 per year (approximately 45% of the available active lake storage volume) for a maximum duration winter. These supplementation values account for the probable amount of lake water unavailable for consumption due to ice storage.

4.2 Lower Landing Lake Watershed

The results for the Lower Landing Lake water balance corresponding to historical, and future climatic conditions are presented herein.

4.2.1 Water Balance Results under Historic Climate Regime

The annual rainfall runoff and snow accumulation yields over historic climate regime conditions vary considerably over the 32 year period of record examined. Rainfall runoff yield accounts for evapotranspiration losses over the watershed as a whole, while snow accumulation yield accounts for losses due to sublimation.

A summary of historic occurrence probabilities corresponding to rainfall runoff and snow accumulation yields is presented in Table 25. Defining the combined annual probabilities for rainfall runoff and snow accumulation yields is complicated because these two variables are neither entirely independent nor entirely dependent on one another. Examining the relationship between the two for each of the modelled years showed them to be neither negatively nor positively correlated meaning that they must be considered on their own, rather than their combined, probabilities.

The Lower Landing Lake yields are one order of magnitude higher than those obtained for Nipissar Lake, given the size of the catchment area.

Table 25: Historic Climate Regime Annual Probability of Rainfall Runoff and Snow Accumulation Yields for Lower Landing Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	2,063	1,450	45	5,986	6,253
95	2,710	2,822	40	6,061	6,424
90	3,072	3,086	35	6,164	6,931
85	3,641	3,320	30	6,560	7,139
80	3,984	3,475	25	7,061	8,398
75	4,170	3,753	20	7,343	8,858
70	4,595	4,019	15	9,271	9,724
65	4,962	4,327	10	9,754	10,439
60	5,246	4,776	5	9,934	11,764
55	5,502	5,115	2	10,438	15,550
50	5,726	5,537	-	11,283	22,744

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.2.2 Water Balance Results under 2050s Climate Regime

Although the estimated 2050 air temperatures are warmer and annual precipitation is marginally higher relative to the historic climate regime (as outlined in Section 3.9), average rainfall runoff yields for the 2050s climate regime are approximately 14 percent higher, while average snow accumulation yields are approximately 2% higher for the median meteorological year. The trend for 2050s rainfall runoff and snow accumulation probabilities shows that for extreme events, (i.e., 100th and 0th percentile), the 2050s rainfall yield is higher than historical climate regime.

A summary of the occurrence probabilities of rainfall runoff and accumulated snow runoff yields under the 2050s climate regime is presented in Table 26.

Table 26: 2050s Climate Regime Annual Probability of Rainfall Runoff and Snow Accumulation Yields for Lower Landing Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	1,919	2,083	45	6,957	6,276
95	3,294	2,321	40	7,343	6,634
90	3,793	2,844	35	7,443	7,149
85	4,292	3,625	30	7,478	7,425
80	5,013	3,695	25	7,662	8,387
75	5,157	3,990	20	7,863	8,685
70	5,374	4,388	15	8,856	8,873
65	5,886	4,636	10	10,813	9,432
60	6,188	4,890	5	12,177	10,973
55	6,346	5,105	2	13,082	15,765
50	6,519	5,662	0	13,739	22,032

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.2.3 Water Balance Results under 2080s Climate Regime

Under median climatic conditions, combined annual rainfall runoff and snow accumulation yields for the 2080s climate regime are estimated to vary more than that for the historic climate regime. 2080s climate regime yields are estimated to increase marginally against those predicted for the 2050s climate regime. This change over time is primarily related to water balance differences related to the effects of changed precipitation.

Due to warmer temperatures and marginally higher annual precipitation (as outlined in Section 3.9) relative to the historic climate regime, rainfall runoff yields for the 2080s climate regime conditions are approximately 9% higher and snow accumulation yields approximately 3% lower, given shorter winter periods for the 2080s climatic regime. A summary of 2080s climate regime occurrence probabilities corresponding to rainfall runoff and snow accumulation yields is presented in Table 27.

Table 27: 2080s Climate Regime Annual Probability of Rainfall Runoff and Snow Accumulation Yields for Lower Landing Lake

Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)	Historic Percentage Probability of Exceedance[1]	Rainfall Runoff (ML)	Snow Accumulation (ML)
100	2,881	2,594	45	6,559	5,980
95	4,120	3,039	40	6,774	6,297
90	4,352	3,169	35	7,221	6,563
85	5,081	3,445	30	7,515	7,007
80	5,465	3,898	25	9,018	7,865
75	5,623	4,219	20	9,358	8,133
70	5,768	4,413	15	10,021	8,504
65	5,826	4,551	10	10,646	9,245
60	5,962	4,733	5	11,307	10,361
55	5,983	5,127	2	11,883	15,496
50	6,266	5,393	-	12,011	22,323

Notes:
1. Based on the normal distribution of historic meteorological conditions examined.

4.3 The Char River

The results for the Char River water balance corresponding to historical, and future climatic conditions are presented herein.

4.3.1 Water Balance Results under Historic Climate Regime

Due to the short distance between the outlet of Lower Landing Lake and Hudson Bay, the catchment area for Lower Landing Lake and the Char River have been assumed to be identical for the purposes of this assessment. Hence, outflows from Lower Landing Lake are expected to be identical to those at the outlet of the river to Hudson Bay.

Outflows from Lower Landing Lake to the Char River were estimated from the Lower Landing Lake water balance, where calculated daily watershed surpluses were discharged directly through a theoretical rating curve at the outlet. The estimated outflows vary throughout the annual hydrograph with flows ostensibly peaking during the freshet period, and quickly receding thereafter, generally within a month and a half. Occasional high flow periods resume throughout the remainder of the summer in response to significant rainfall events.

A summary of annual outflows from Lower Landing Lake to the Char River based on the historic water balance occurrence probabilities, corresponding to simulated Lower Landing Lake outflows, are presented in Table 28, assuming no water takings from Lower Landing Lake.

Table 28: Historic Climate Regime Annual Probability of Lower Landing Lake Outlet Flows

Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)	Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)
100	2.8	2,602	45	10.3	10,607
99	3.6	3,472	40	11.2	10,715
95	5.4	5,357	35	12.4	11,432
90	6.0	5,981	30	13.1	12,427
85	7.8	6,748	25	13.4	13,490
80	8.0	7,291	20	15.0	13,561
75	8.3	7,724	15	15.4	14,059
70	8.4	7,999	10	16.9	14,960
65	8.6	8,558	5	19.6	16,539
60	9.0	9,104	2	25.4	19,696
55	9.3	9,597	1	30.1	22,028
50	10.0	10,011	0	34.7	24,360

Notes:
1. Based on the normal distribution of the maximum daily outflow from Lower Landing Lake for each year of the historic series analyzed.

The Lower Landing Lake annual peak instantaneous flows under the historic climate regime range from 2.8 m^3/day to 34.7 m^3/day (with a historic median probability of 10 m^3/day), while the annual total outflows range from 2,602,000 m^3 to 24,360,000 m^3 (with a historic median probability of 10,011,000 m^3).

4.3.2 Water Balance Results under 2050s Climate Regime

A summary of the 2050s climate regime occurrence probabilities corresponding to Lower Landing Lake outlet flows is presented in Table 29.

Table 29: 2050s Climate Regime Annual Probability of Lower Landing Lake Outlet Flows

Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)	Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)
100	5.4	5,570	45	10.6	11,008
99	5.8	5,635	40	10.8	11,329
95	6.7	5,969	35	11.1	11,575
90	7.3	6,651	30	11.6	12,215
85	7.5	6,930	25	12.2	13,363
80	8.2	7,444	20	13.5	13,905
75	8.4	7,936	15	16.9	14,329
70	8.8	8,743	10	17.1	15,268
65	9.1	9,283	5	17.9	16,370

Table 29: 2050s Climate Regime Annual Probability of Lower Landing Lake Outlet Flows (continued)

Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)	Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)
60	9.3	10,101	2	23.1	19,779
55	9.4	10,195	1	26.8	22,306
50	9.7	10,671	0	30.5	24,832

Notes:
1. Based on the normal distribution of the maximum daily outflow from Lower Landing Lake for each year of the historic series analyzed.

The Lower Landing Lake annual peak instantaneous flows under the 2050s climate regime range from 5.4 m^3/s to 30.5 m^3/s (with a historic median probability of 9.7 m^3/s), while the annual total outflows range from 5,570,000 m^3 to 24,832,000 m^3 (with a median probability of 10,671,000 m^3).

4.3.3 Water Balance Results under 2080s Climate Regime

A summary of the 2080s climate regime occurrence probabilities corresponding to Lower Landing Lake outlet flows is presented in Table 30.

Table 30: 2080s Climate Regime Annual Probability of Lower Landing Lake Outlet Flows

Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)	Historic Percentage Probability of Exceedance[1]	Peak flow (m^3/s)	Total Annual Outflow (ML)
100	4.2	5,781	45	10.4	10,579
99	4.4	5,903	40	11.1	10,900
95	5.4	6,481	35	11.3	11,463
90	7.2	7,058	30	11.8	12,400
85	7.3	7,349	25	13.0	12,808
80	7.5	7,844	20	14.1	13,607
75	7.6	8,190	15	16.7	14,200
70	7.9	8,771	10	16.9	15,022
65	8.4	9,534	5	18.0	17,017
60	8.6	9,936	2	23.0	19,999
55	9.3	10,093	1	26.6	22,489
50	10.0	10,324	0	30.2	24,978

Notes:
1. Based on the normal distribution of the maximum daily outflow from Lower Landing Lake for each year of the historic series analyzed.

The Lower Landing Lake annual peak instantaneous flows under the 2080s climate regime range from 4.2 m^3/s to 30.2 m^3/s (with a historic median probability of 10 m^3/s), while the annual total outflows range from 5,781,000 m^3 to 24,978,000 m^3 (with a median probability of 10,324,000 m^3).

4.4 Evaluation of Nipissar Lake Water Supply Supplementation Pump Rates and the Char River Flows

The two water taking options discussed in Section 3.1, to address the water supply deficit in Nipissar Lake, are presented below. Both options presented below are evaluated for historic climate conditions and a subset of water consumption daily values.

Table 31 presents estimated pumping rates for Option 1 and 2 for a median simulated Char River flow hydrograph. Blue Bold values in table 31 denote cases where the daily maximum water taking required exceeds 10% of the hydrograph peak and therefore the total supplementation cannot be met under the 50% probability occurrence Lower Landing Lake outflow hydrograph, Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e., daily consumption rate x number of winter days >than active lake storage). Results for wet and dry simulated Char River flow hydrographs are presented in Appendix C.

Table 31: Estimated Water Taking Rates for a Median Char River Flow Hydrograph Under Historic Climate Conditions

Percentage Probability of Exceedance[1]			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length[4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML)[1,2,3]	Option 1 (m^3/s)[5,6,7]	Option 2 (m^3/s)[5,8,9]	Total Water Taking (ML)[1,2,3]	Option 1 (m^3/s)[5,6,7]	Option 2 (m^3/s)[5,8,9]	Total Water Taking (ML)[1,2,3]	Option 1 (m^3/s)[5,6,7]	Option 2 (m^3/s)[5,8,9]
100	100	100	271	0.027	0.062	892	0.458	0.202	1622	0.764	0.368
	75	75	86	0.007	0.020	706	0.263	0.160	1436	0.764	0.326
	50	50	0	-	-	608	0.188	0.138	1338	0.764	0.304
	25	25	0	-	-	379	0.050	0.086	1109	0.764	0.252
	0	0	0	-	-	0	-	-	258	0.025	0.059
50	100	100	234	0.022	0.037	855	0.409	0.134	1585	0.764	0.248
	75	75	31	0.003	0.005	652	0.220	0.102	1382	0.764	0.216
	50	50	0	-	-	550	0.148	0.086	1280	0.764	0.200
	25	25	0	-	-	310	0.033	0.048	1040	0.764	0.163
	0	0	0	-	-	0	-	-	224	0.020	0.035
0	100	100	189	0.017	0.021	809	0.358	0.091	1539	0.764	0.173
	75	75	0	-	-	585	0.171	0.066	1315	0.764	0.148
	50	50	0	-	-	479	0.101	0.054	1209	0.764	0.136
	25	25	0	-	-	225	0.021	0.025	955	0.555	0.107
	0	0	0	-	-	0	-	-	182	0.016	0.020

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Tabulated water deficit estimates do not consider potential effects of model inaccuracy.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17.
5. Pumping rates based on a 50% probability occurrence hydrograph of Lower Landing Lake outlet.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the thaw season only.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.

Option 1 presents the maximum allowable water taking from Lower Landing Lake based on the limit of 10% of the instantaneous flows in the Char River. Water taking rates are estimated from the simulated flow hydrograph at the Char River. Peak flows in the river are associated with the spring freshet and only occur for a few weeks each year.

A significant challenge associated with the water taking under Option 1 is the high pumping rates during the freshet. In order to minimise the use of extremely high capacity pumps, the required pumping rate is “capped” to remove the highest water taking rates. Reducing the peak pumping rate is only possible under scenarios where the total water supply deficit is less than 10% of the total annual Char River flows. Therefore, if 10% of the Char River hydrograph is required to meet the water supply deficit, no reduction (capping) of the peak pumping rate can take place and the peak pumping rate would be 10% of the total simulated Char River hydrograph peak.

Table 31 presents the peak pumping rates associated with the median historic flow hydrograph. Option 1 daily maximum water takings in Table 31 include “capping” of the peak pumping rates, unless the table values are in bold blue. Bold blues values represent 10% of the simulated Char River peak flows because the water supply deficit cannot be met within the 10% hydrograph limit.

The 10% simulated Char River hydrograph from the median historic climate conditions is presented in Figure 14.

The 10% of simulated median historic hydrograph in Figure 14 refers to the instantaneous limit water taking under median hydrograph flow conditions. Estimated water taking under median climate conditions presents the estimated pumping schedule under median historic conditions with capping. Capping the pumping rate reduces the maximum instantaneous pumping rate to 0.148 m^3/s.

Although capping peak pumping rates reduces the challenge of water taking under Option 1, significant challenges are still required to monitor instantaneous flow rates and vary pumping rates. Due to these challenges a second option for water taking from Lower Landing Lake is proposed. Option 2 proposes the water taking limit of 10% of the total annual flow in the Char River. Water taking under this approach would take place following the spring freshet and continue until lake freeze up. This option allows water taking to be carried out with a steady pumping rate. Water taking under this second approach would reduce Lower Landing Lake water levels through the end of the open water season, with flow from the following spring melt contributing to fill Lower Landing Lake and drive the spring freshet hydrograph in the Char River.

Under medium historic climate conditions and moderate water consumption (i.e., 3300 m^3/day), both approaches will meet the supplementation requirements of Nipissar Lake and only take 10% of the outflow from Lower Landing Lake. With Option 1 taking a maximum of 10% of the instantaneous outflow, there is very little effect on the lake and downstream environment; the hydroperiod and flow pattern all remain the same, only at 90% of its original magnitude. Option 2 limits the outflow response to late summer precipitation events, delays the spring freshet of the following year and reduces its flow peaks. The Option 2 pumping rate under median climate conditions and the 10% of the median Char River hydrograph are presented in Figure 15. Although both approaches are only presented for the median Char River hydrograph under historic meteorological conditions and a subset of water consumption daily values, the advantages and limitations of either approach are consistent against all examined flow conditions. A detailed breakdown of all results is provided in Appendix C.

Operationally, Option 1 requires significant monitoring and larger, more complex water taking equipment. In order to pump 10% of the instantaneous flow, the outflow from Lower Landing Lake (or the Char River) must be accurately monitored and recorded in real time to adjust water taking to only 10% of that instantaneous flow. This option also requires higher sophistication and capacity from the water taking equipment. The water taking equipment (i.e., pump and delivery system) must vary the rate of taking regularly to match 10% of the outflow. Under 100% historical occurrence probabilities, water taking would fluctuate between 0 m^3/s to 0.458 m^3/s for medium consumption demand. Option 2 requires less monitoring and water taking technology. Option 2 requires that the outflow be monitored to estimate total annual outflow (to determine allowable pumping limit) and the approximate end of spring freshet flow response (to determine when pumping can be initiated). The water taking equipment for Option 2 only requires pumping at one rate throughout the season and is turned on at the end of the freshet response and turned off when Nipissar Lake is full or at Lower landing Lake freeze up. The water taking rate with Option 2 is 0.202 m^3/s under 100% historic occurrence probabilities and moderate consumption.

5.0 ASSUMPTIONS AND LIMITATIONS

A summary of the assumptions made as part of the study and the limitations of the model and study results are as follows:

- Meteorological data obtained from Environment Canada station at Rankin Inlet A are representative of the meteorological conditions in the Nipissar Lake and Lower Landing watersheds.
- The bathymetric representations and intake configuration, and of stage-storage relationships developed for Nipissar Lake and Lower Landing Lake, are appropriate for the purposes of this assessment.
- The distribution of land cover corresponded to 20% till veneer and 80% bedrock.
- Lower Landing Lake was filled to its natural outlet control during the surveys between September 29 and October 4, 2009.
- Nipissar Lake outlet culverts have not conveyed flow over recent years.
- Movement of Nipissar Lake intake structures is negligible and the active storage volumes are maintained above elevations of 9.5 masl.
- Estimated water taking from Lower Landing Lake will not be affected by the future intake configuration.
- The water balance model provides a suitable representation of historic and future basin yield conditions.
- All interflow generated within the Nipissar Lake and Lower Landing Lake watersheds reports to the respective lakes.
- The maximum ice depth for a given year was numerically estimated by the model. Ice depths depicted in Golder (2009) are appropriate representations of ice thicknesses in a year of median winter length.
- Reliable water level data (in quantity and quality) are essential for the calibration of the water balance model developed by IMG-Golder. Given the discrete data provided, the validation process revealed a RMSQ error of 0.09 m, indicative of the error of the model at predicting water levels at Nipissar Lake. This error is higher in early spring than during summer.
- Future climate scenarios were calculated based the methodology described in Section 4.6. General Circulation Models (GCMs) have inherent limitations that are important to bear in mind when evaluating variability and the rate of climate change (i.e., when comparing future projections to historical observations). Some of the limitations include the spatial scale of GCM (addressed by downscaling into Regional Climate Models or RCMs), occurrence of unpredictable or stochastic events, and the changes to collective understanding of climate processes.
- The watershed contributing flow to the Char River is the same as that contributing flow to Lower Landing Lake.
- Lower Landing Lake pumping scenarios will occur over 24 hours a day.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study presented in this report and subject to the assumptions and limitations (Section 5.0) used for the study, the following conclusions can be drawn:

1) The Community's water consumption is approaching the limits of available basin yields of the Nipissar Lake watershed during low precipitation years. The Community water supply will likely require supplementation in the near future.

2) The small increases in basin yields and shorter anticipated winter durations associated with climate change projections are estimated to marginally reduce over-winter supplementation needs. As such, it is estimated that climate change may reduce the risk associated of extremely dry basin yield years relative to the historic climate regime. Moreover, projected longer summer periods will increase the available supplementation window.

3) Under historic and climate change scenarios, Lower Landing Lake is estimated to have sufficient supplementary water supplies to accommodate the water taking deficit from Nipissar Lake under low and moderate consumption rates (i.e., 1,600 m^3/day and 3,300 m^3/day, respectively). Under an increased population size (i.e., year 2082) and existing per capita consumption rates (0.68 m^3/person/day) or extremely high consumption rates (5,300 m^3/day), the annual deficit at Nipissar Lake exceeds 10% of the median outflow conditions of Lower Landing Lake.

4) Option 1 and Option 2 both facilitate a water taking program from Lower Landing Lake that is limited to 10% of its annual outflow. However, although Option 1 could be geared towards matching the 10% instantaneous outflow limit, this option would require a far more sophisticated monitoring system and rely on a broad range of water taking capacities as to render it financially and technically unfeasible. Conversely, Option 2 will not be able to match the 10% instantaneous outflow limit at all times, but requires a significantly simpler monitoring and more technically robust water taking design.

5) The total outflow (surplus) from Lower Landing Lake under median historic climatic conditions is approximately 10 million m^3/year. If the total outflow was able to be utilized for consumption at Rankin Inlet, it could support consumption of approximately 40,000 people (based on the current per capita consumption rate).

6) Under extreme climatic conditions (lowest historic rainfall runoff and snowfall accumulation) and a maximum duration winter, winter consumption will exceed the available active winter storage capacity of the lake with a daily consumption rate of approximately 3,900 m^3. Utilizing the current per capita consumption rate (0.68 m^3/day/person), the daily consumption will reach 3,900 m^3 in approximately 2062.

Based on the presented information, the following recommendations are made:

1) Forecasted supplementation rates should be increased by the Community as part of their water supply planning process in order to incorporate a margin of safety. Under higher consumption rates, the available lake storage may constrain the factor of safety that can be applied. If the Community experiences very high population growth, this will inevitably accelerate the need to consider increasing over-winter storage.

2) The Community should consider installing a flow control structure at the outlet of Lower Landing Lake to store outflow during spring freshet and high flow events. This would allow more flexibility in the water taking window and may increase the total flow period of the Char River. For consideration of fish passage, the DFO should be consulted for approval of any control structure on the Char River.

3) If possible, the Community should aim to have Nipissar Lake filled to its capacity by the earliest anticipated freeze-up date for the earliest selected freeze-up probability.

4) Use level loggers and staff gauges within Nipissar Lake and Lower Landing Lake to provide information for water supply forecasting. In addition:

   a) The Community should consider surveying all water level monitoring stations to a benchmark referenced to a geodetic datum.

   b) The Community should establish a monitoring configuration that provides real-time water levels.

7.0 REFERENCES

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Report Signature Page

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12 FEB 2016
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N.W.T.

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THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
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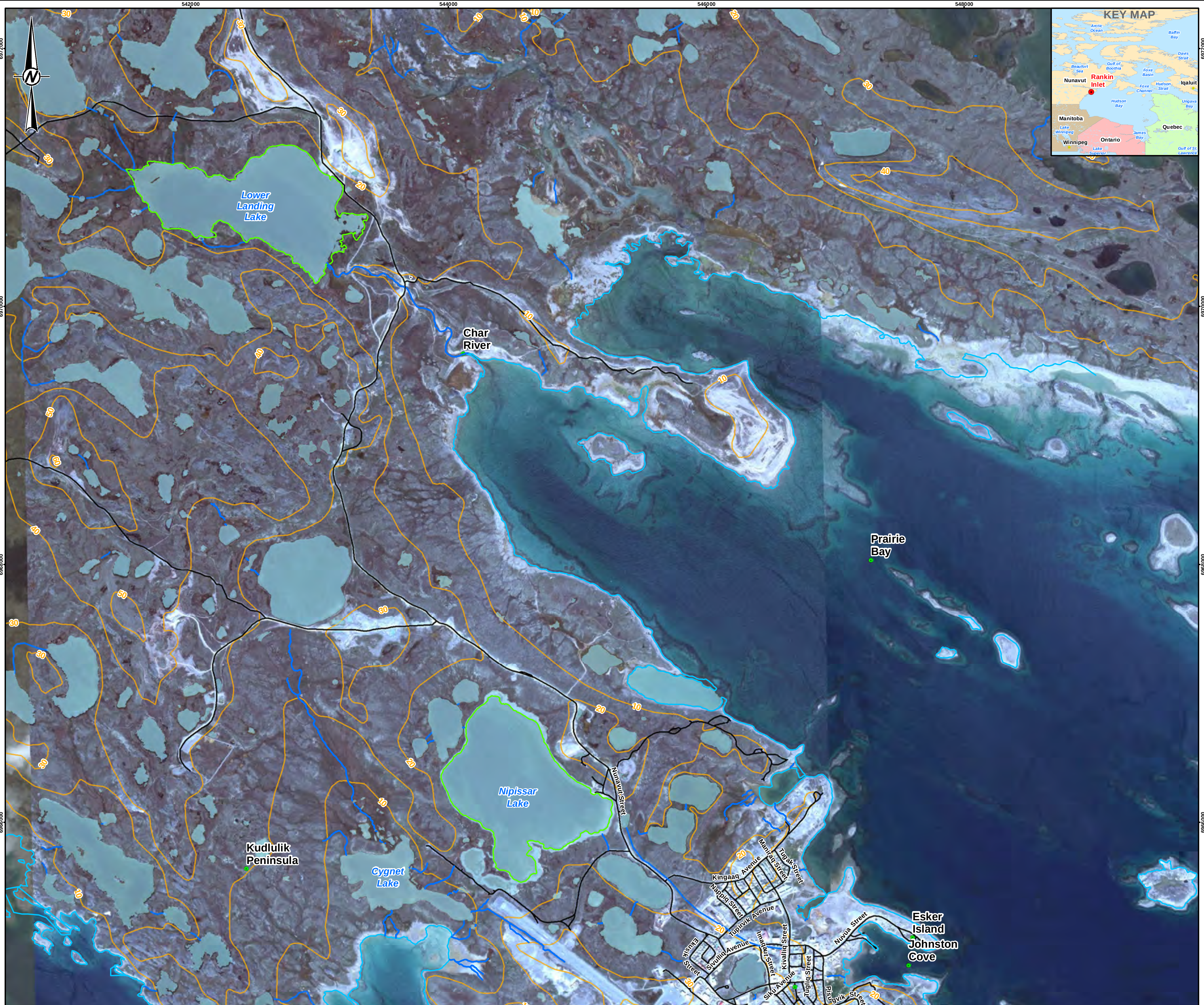
FIGURES



LEGEND

- Topographic Elevation Contour
- Road
- Watercourse
- Shoreline
- Waterbody

0 | 0.5 | 1 | 1.5 | 2 | 2.5

1:30,000 Kilometres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15
WATERCOURSES, SHORELINE AND LAKES PROVIDED BY CGS, 20150626.

CLIENT
GOVERNMENT OF NUNAVUT

PROJECT
RANKIN INLET WATER BALANCE

TITLE
GENERAL LOCATION PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

LEGEND

- Topographic Elevation Contour
- Road
- Watercourse
- Shoreline
- Waterbody
- Nipissar Lake Watershed

0 0.5 1 1.5 2

1:25,000 Kilometres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15

WATERCOURSES AND SHORELINE PROVIDED BY CGS, 20150626.

CLIENT

GOVERNMENT OF NUNAVUT

PROJECT

RANKIN INLET WATER BALANCE

TITLE

NIPISSAR LAKE WATERSHED

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
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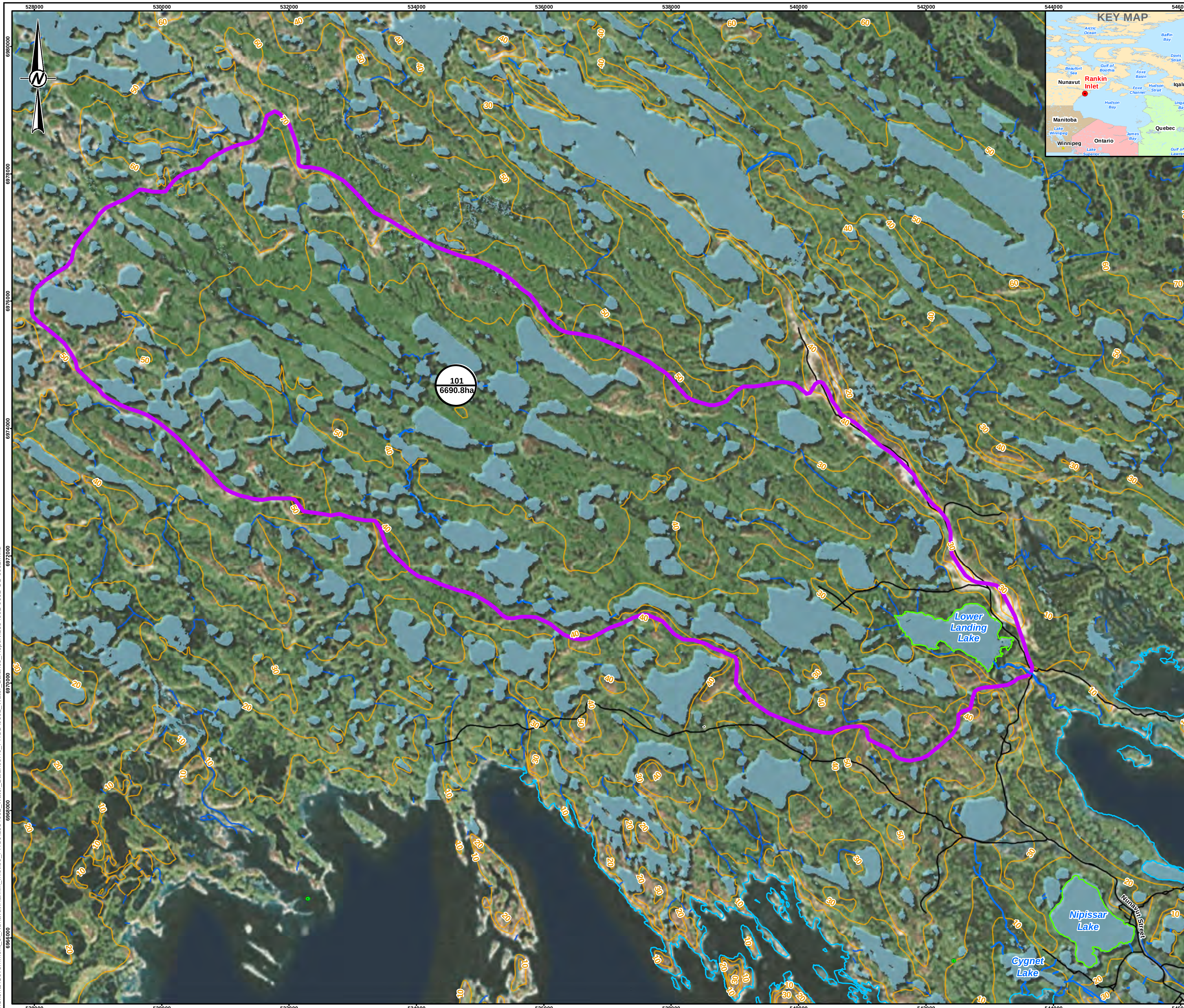

LEGEND

- Topographic Elevation Contour
- Road
- Watercourse
- Shoreline
- Waterbody
- Lower Landing Lake Watershed

0 1 2 3 4

1:60,000 Kilometres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15

WATERCOURSES AND SHORELINE PROVIDED BY CGS, 20150626.

CLIENT

GOVERNMENT OF NUNAVUT

PROJECT

RANKIN INLET WATER BALANCE

TITLE

LOWER LANDING LAKE WATERSHED

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
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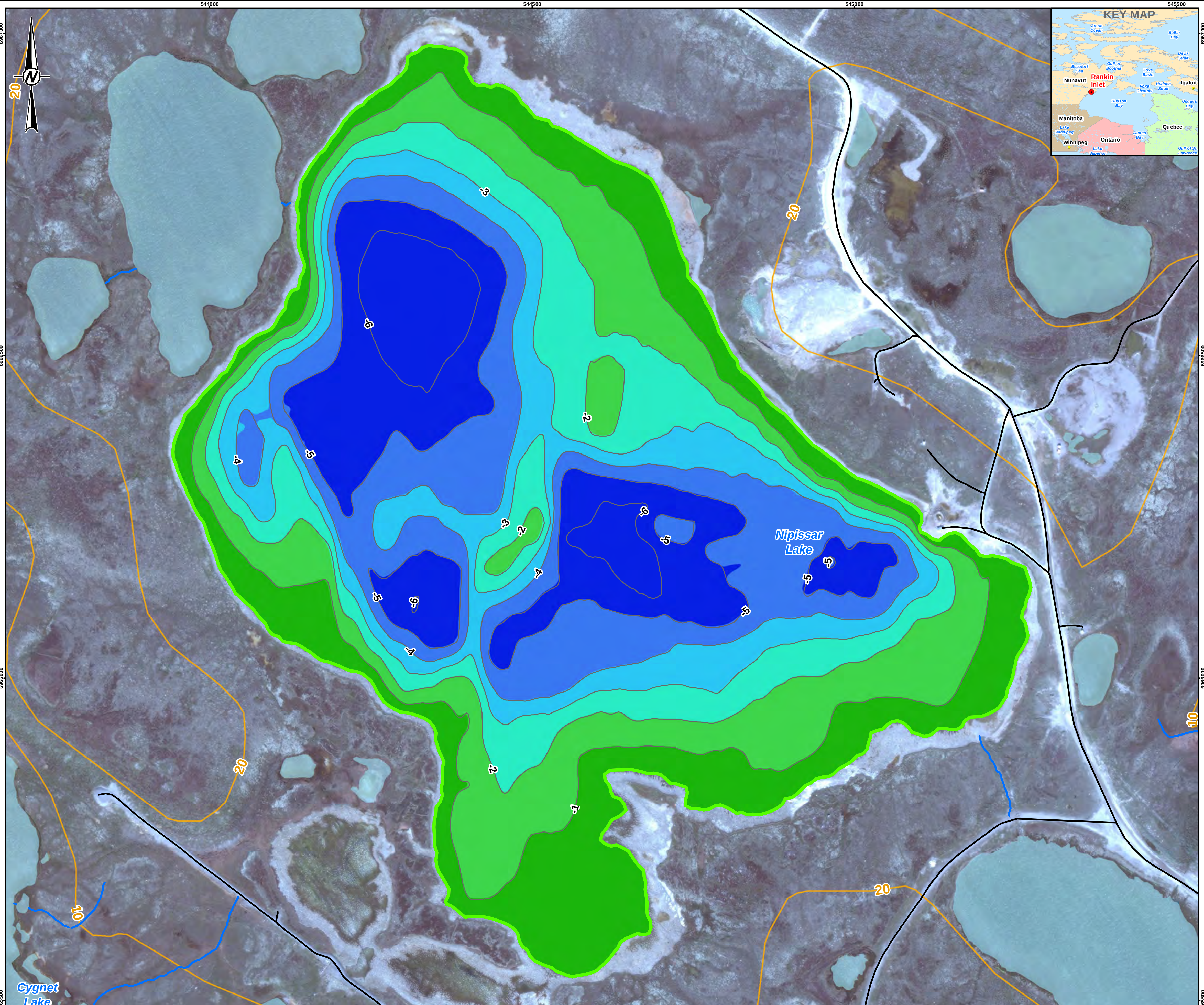

LEGEND

- Topographic Elevation Contour
- Road
- Watercourse
- Nipissar Lake Bathymetry
- Nipissar Lake Shoreline
- Waterbody

Depth (m)

- -6.2 - -5
- -5 - -4
- -4 - -3
- -3- -2
- -2 - -1
- -1 - 0

0 100 200 300 400

1:6,000 Metres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15

SURVEY POINTS, BATHYMETRY, WATERCOURSES, SHORELINE AND LAKES PROVIDED BY CGS, 20150626.

CLIENT

GOVERNMENT OF NUNAVUT

PROJECT

RANKIN INLET WATER BALANCE

TITLE

NIPISSAR LAKE BATHYMETRY

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
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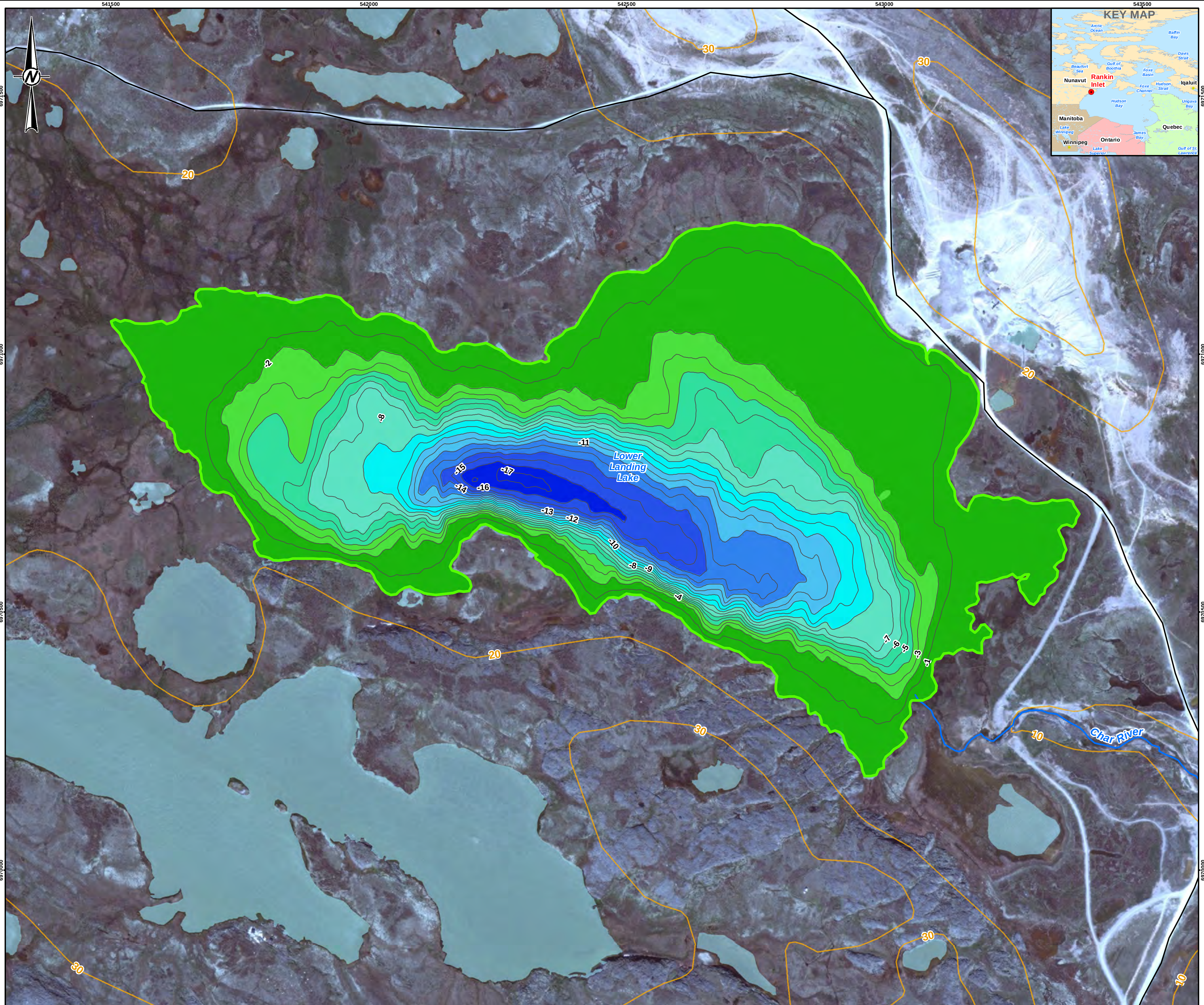

LEGEND

- Topographic Elevation Contour
- Road
- Shoreline
- Watercourse
- Lower Landing Lake Bathymetry
- Lower Landing Lake Shoreline
- Waterbody

Depth (m)

- -17 - -16
- -16 - -14
- -14 - -12
- -12 - -10
- -10 - -8
- -8 - -6
- -6 - -4
- -4 - -2
- -2 - 0

0 200 400 600

1:7,500 Metres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15
SURVEY POINTS, BATHYMETRY, WATERCOURSES, SHORELINE AND LAKES PROVIDED BY CGS, 20150626.

CLIENT
GOVERNMENT OF NUNAVUT

PROJECT
RANKIN INLET WATER BALANCE

TITLE
LOWER LANDING LAKE BATHYMETRY

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
1534002	0002	0.0	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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LEGEND

- Survey Point (20141022)
- Topographic Elevation Contour
- Road
- Shoreline
- Watercourse
- Lower Landing Lake Shoreline
- Waterbody

0 100 200 300 400

1:6,000 Metres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15
SURVEY POINTS, BATHYMETRY, WATERCOURSES, SHORELINE AND LAKES PROVIDED BY CGS, 20150626.

CLIENT
GOVERNMENT OF NUNAVUT

PROJECT
RANKIN INLET WATER BALANCE

TITLE
CHAR RIVER SECTION LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-02-11
DESIGNED	KD
PREPARED	KD
REVIEWED	MLE
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
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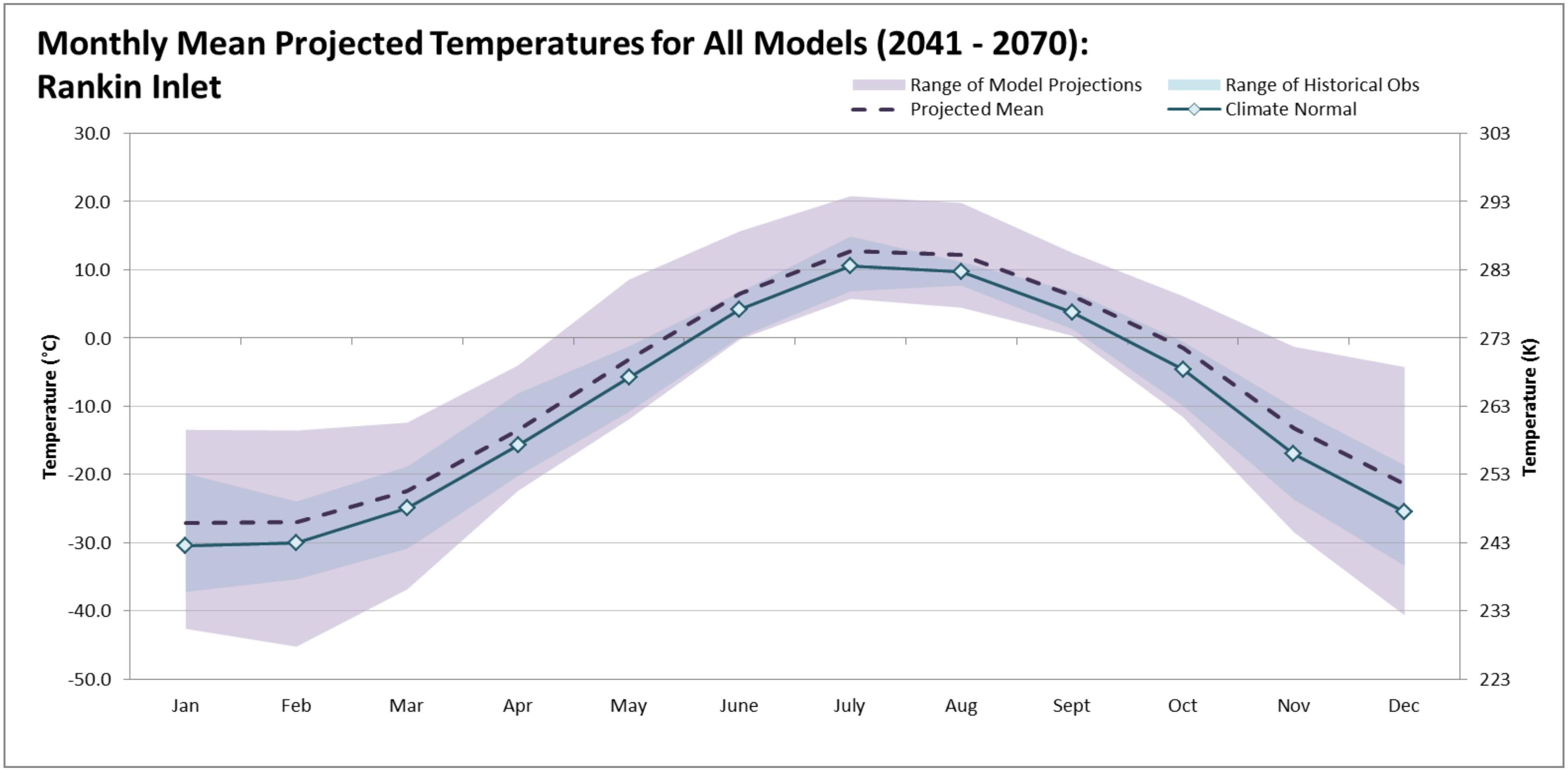
Model Projected Temperatures In Rankin Inlet for the 2050s	Figure 7



PROJECT: 1534002
DATE: February 2016

Golder Associates

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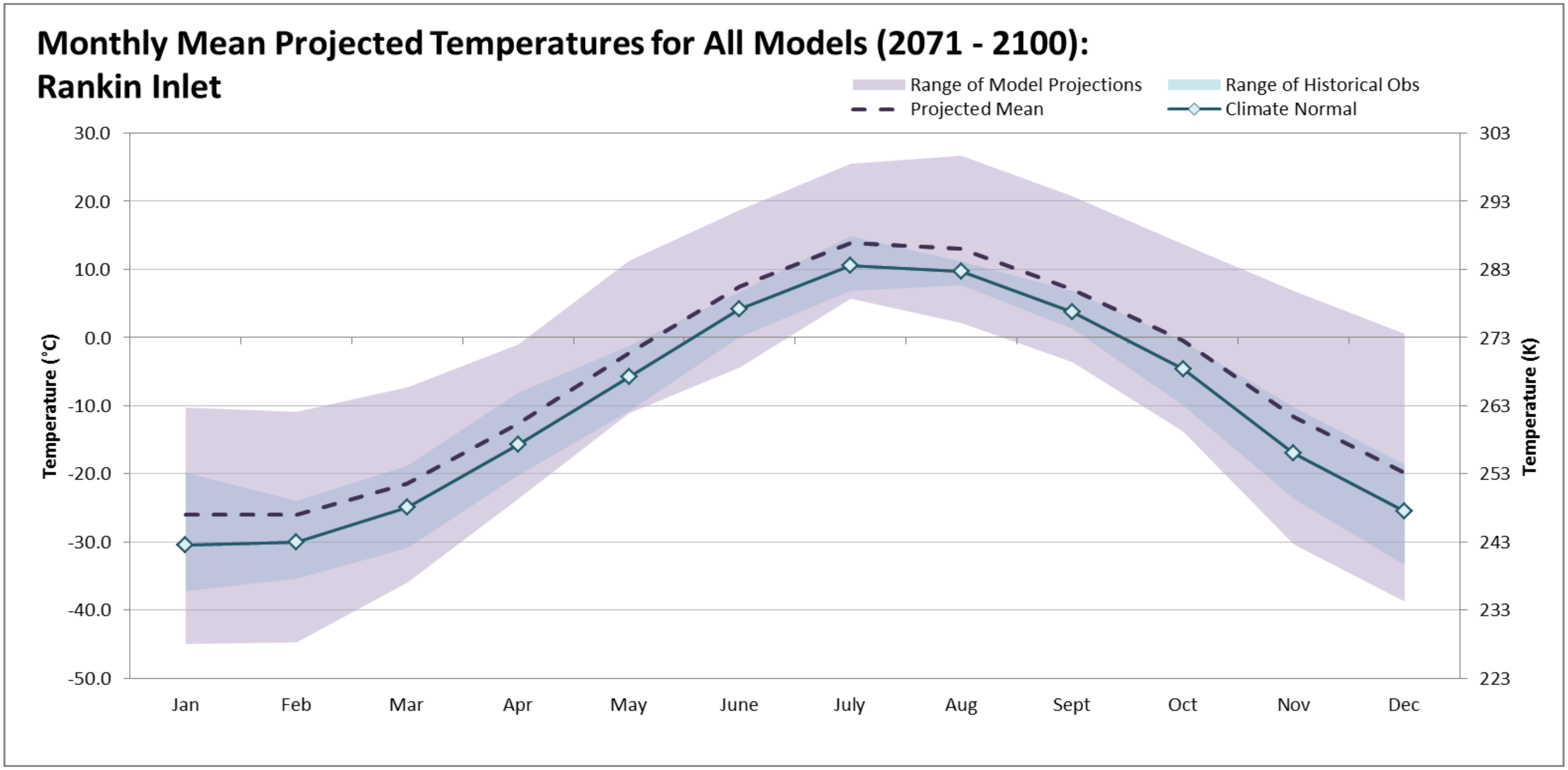
Model Projected Temperatures in Rankin Inlet for the 2080s | **Figure 8**



PROJECT: 1534002
DATE: February 2016

Golder Associates

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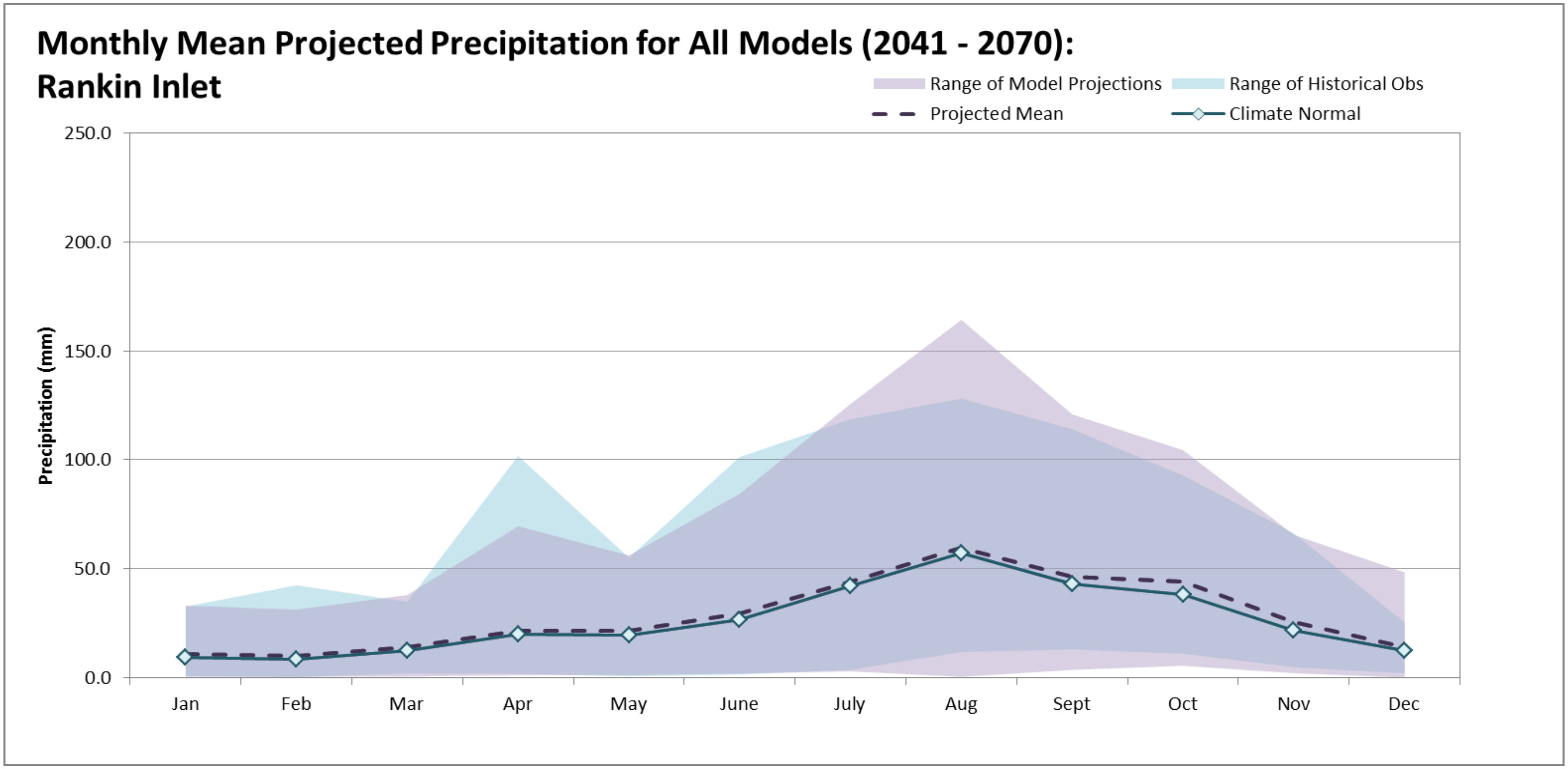
Model Projected Precipitation in Rankin Inlet for the 2050s	Figure 9



PROJECT: 1534002
DATE: February 2016

Golder Associates

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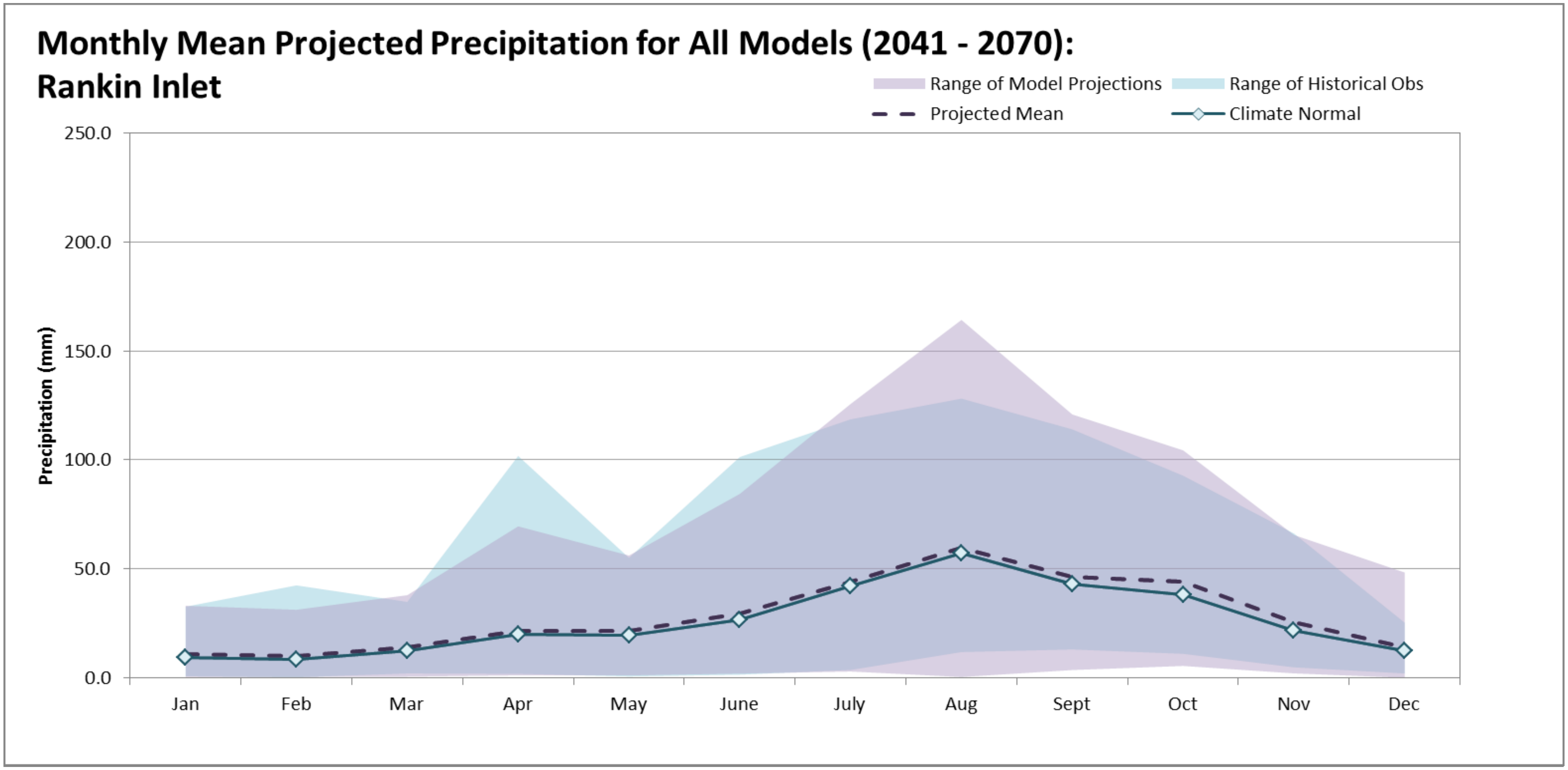
Model Projected Temperatures In Rankin Inlet for the 2080s	Figure 10



PROJECT: 1534002
DATE: February 2016

Golder Associates

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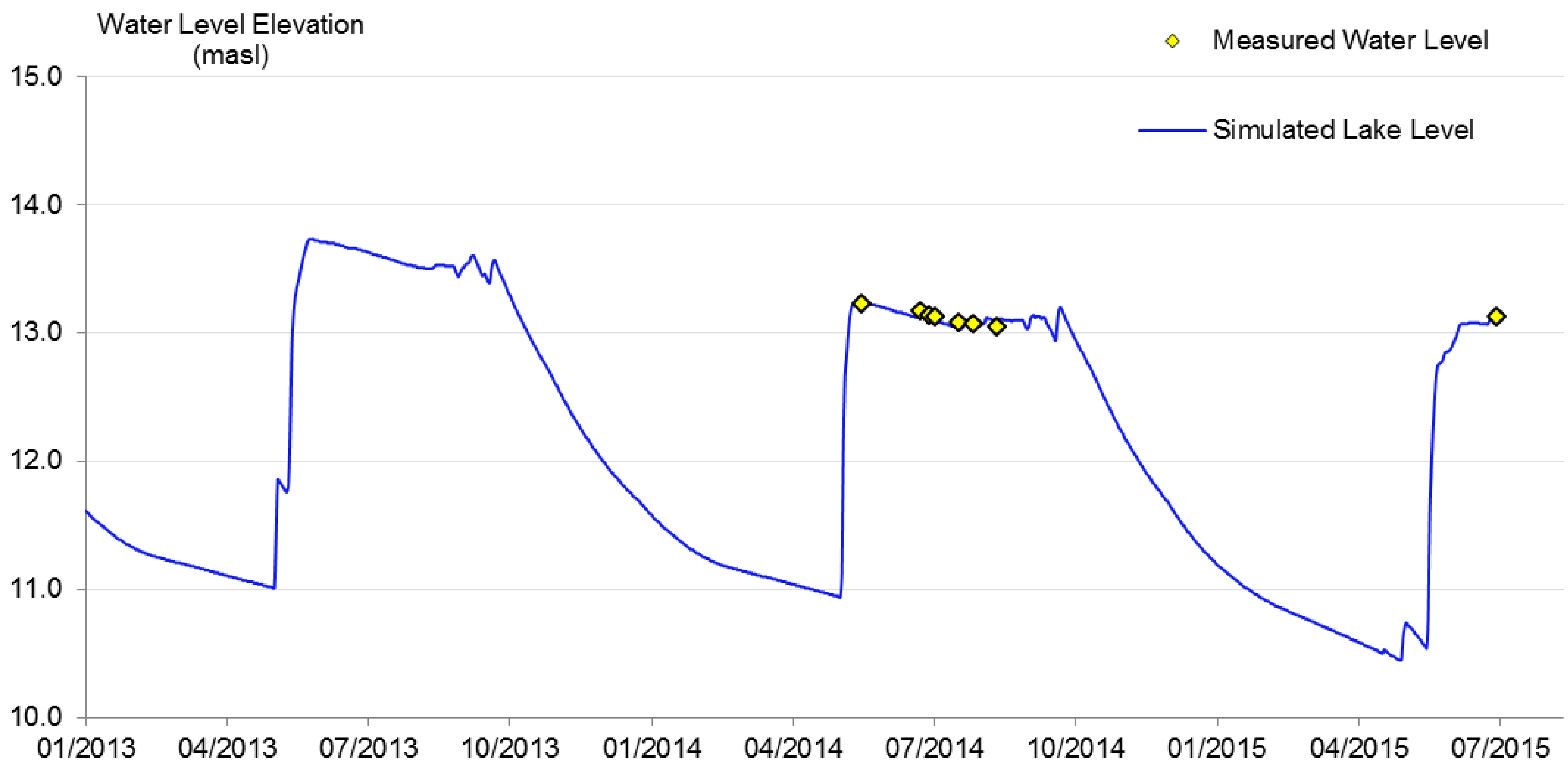
Graphical Results of the Nipissar Lake Level Calibration Period (June 4 2014 to July 13 2015)

Figure 11



PROJECT: 1534002

DATE: February 2016

Golder Associates

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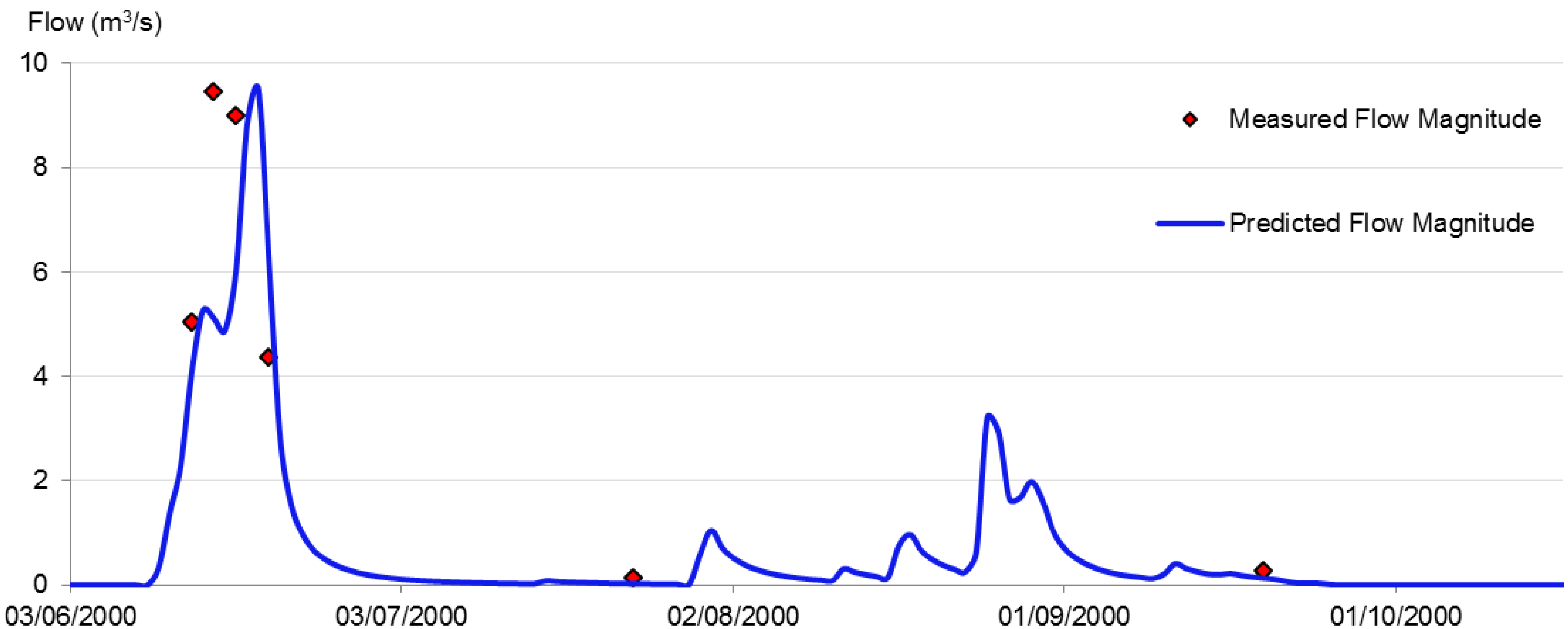
Graphical Results of the Char River Flow Calibration Period (June 14 2000 to September 9 2000)

Figure 12



PROJECT: 1534002
DATE: February 2016

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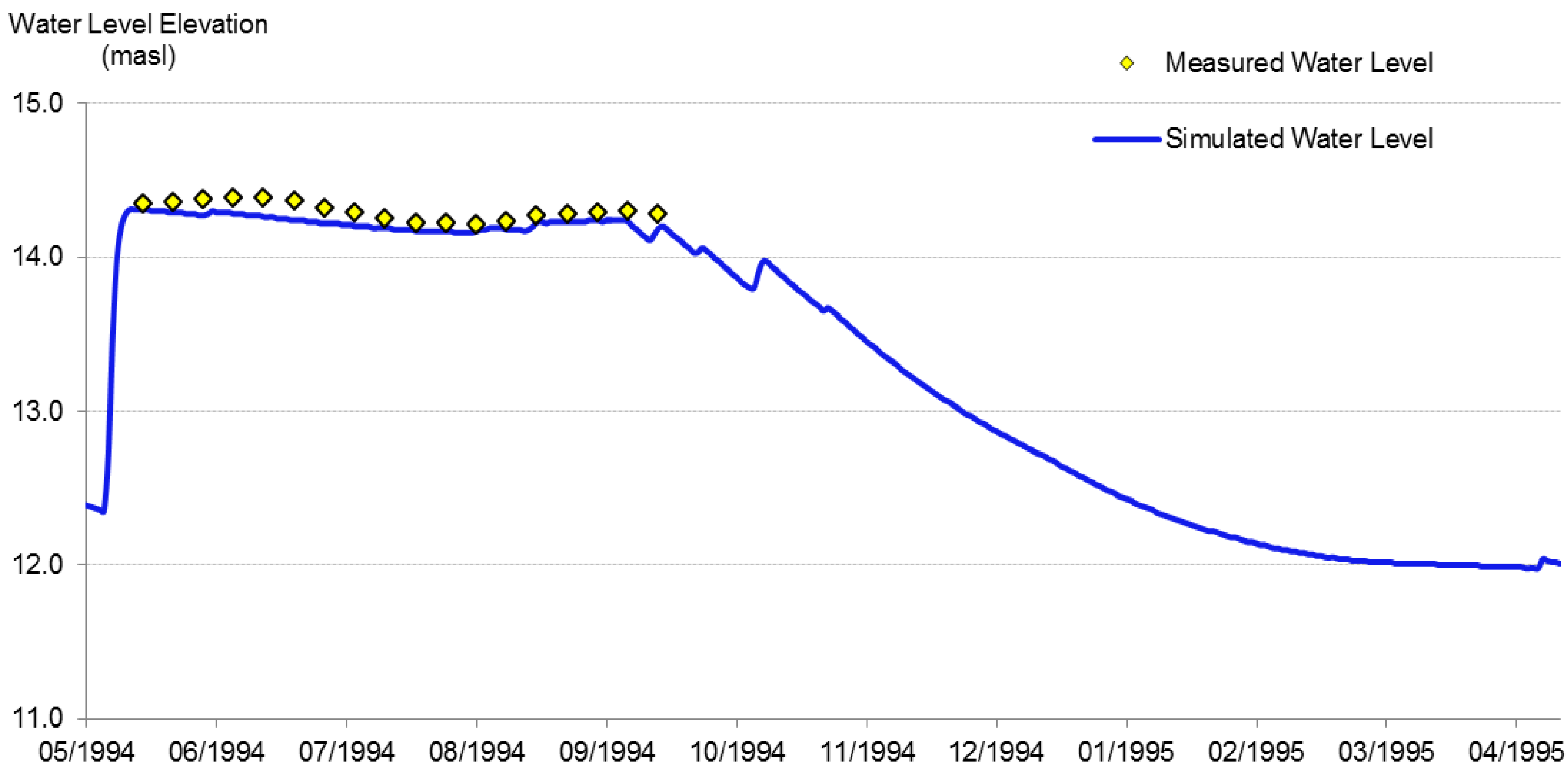
Graphical Results of the Nipissar Lake Level Validation Period (June 8 1994 to October 5 1994)

Figure 13



PROJECT: 1534002

DATE: February 2016

Golder Associates

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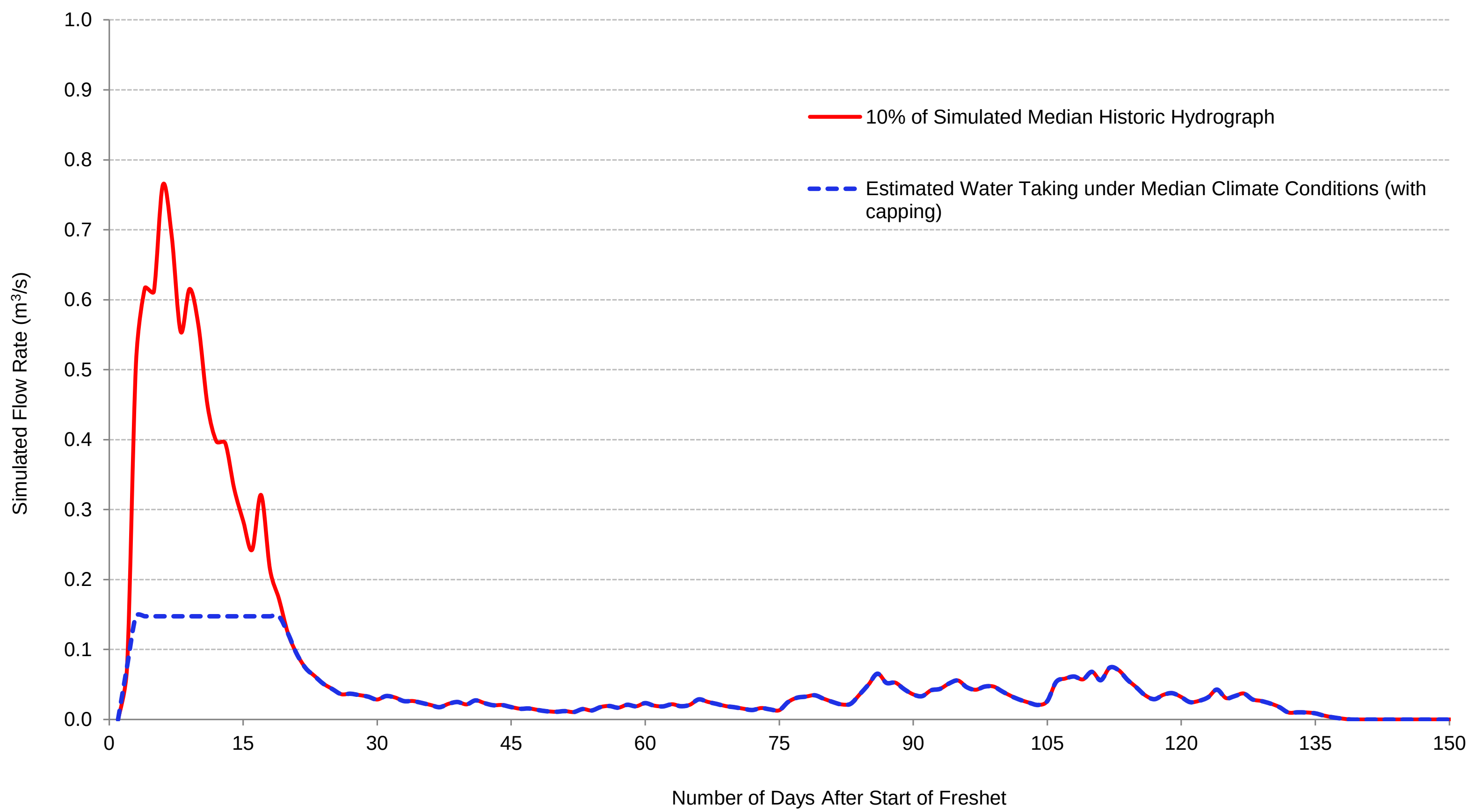
Option 1 Water Taking Based on Median Historic Char River Hydrograph	Figure 14



PROJECT: 1534002
DATE: February 2016

Golder Associates

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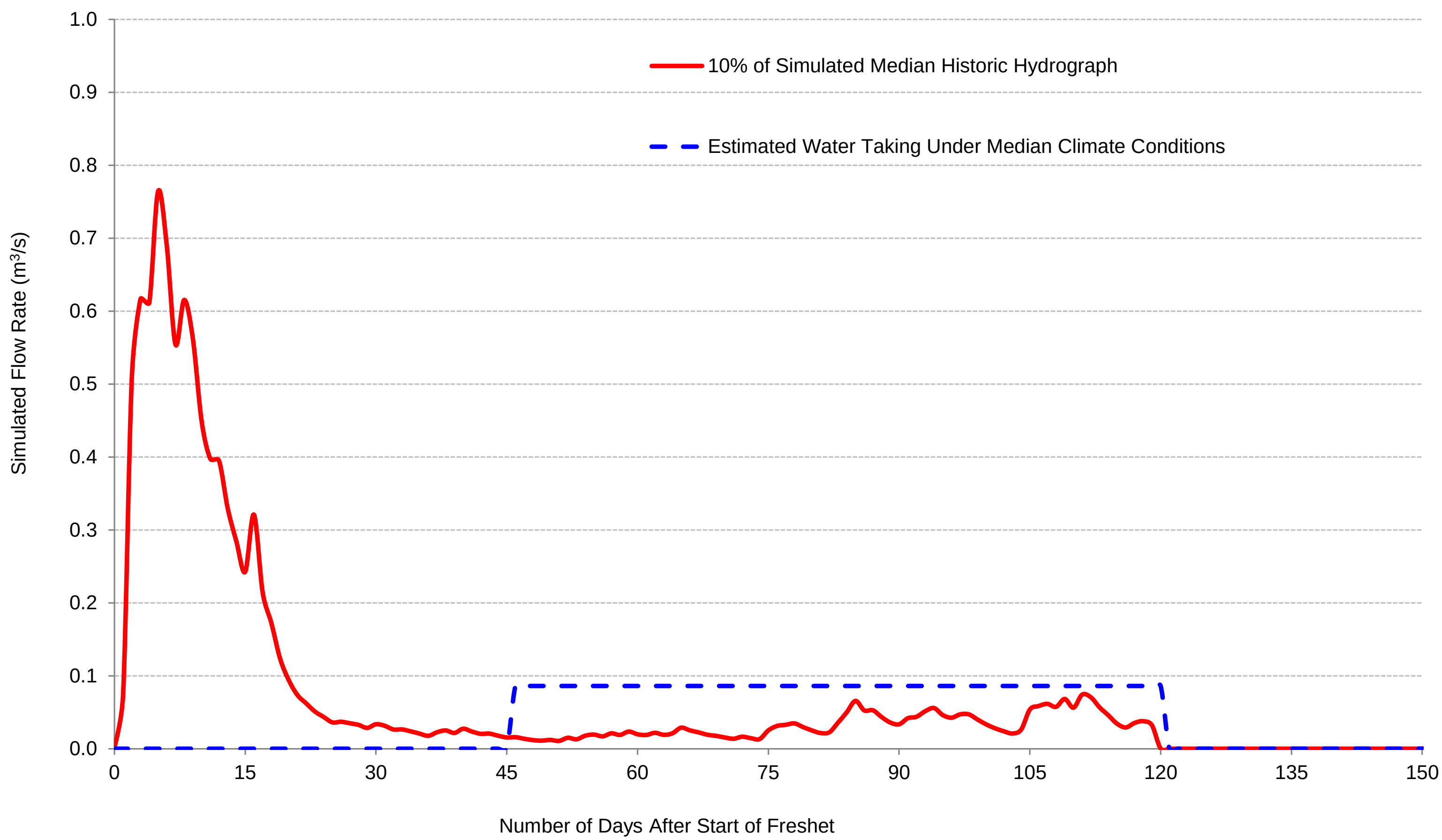
Option 2 Water Taking Based on Median Historic Char River Hydrograph	Figure 15



PROJECT: 1534002
DATE: February 2016

Golder Associates

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APPENDIX A

Predicted Water Supply Deficits Tables

Table A1: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Longest Winter Period (268 Days) under Historic Climate Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		**4300**		**4800**		**5300**		**5800**	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	271	170	344	191	527	229	709	253	892	270	1074	283	1257	292	1439	300	1622	306	1804	311
75	100	187	117	260	145	443	193	625	223	808	245	990	261	1173	273	1355	282	1538	290	1720	297
60	100	155	97	228	126	410	178	593	212	775	235	958	252	1140	265	1323	276	1505	284	1688	291
50	100	126	79	199	111	382	166	564	202	747	226	929	245	1112	259	1294	270	1477	279	1659	286
40	100	65	41	138	77	320	139	503	180	685	208	868	228	1050	244	1233	257	1415	267	1598	276
25	100	0	0	66	37	249	108	431	154	614	186	796	210	979	228	1161	242	1344	254	1526	263
0	100	0	0	0	0	0	0	0	0	0	0	65	17	247	58	430	90	612	116	795	137
100	75	170	106	243	135	425	185	608	217	790	239	973	256	1155	269	1338	279	1520	287	1703	294
75	75	86	53	159	88	341	148	524	187	706	214	889	234	1071	249	1254	261	1436	271	1619	279
60	75	53	33	126	70	308	134	491	175	673	204	856	225	1038	241	1221	254	1403	265	1586	273
50	75	25	15	98	54	280	122	463	165	645	195	828	218	1010	235	1193	248	1375	259	1558	269
40	75	0	0	36	20	219	95	401	143	584	177	766	202	949	221	1131	236	1314	248	1496	258
25	75	0	0	0	0	147	64	329	118	512	155	694	183	877	204	1059	221	1242	234	1424	246
0	75	0	0	0	0	0	0	0	0	0	0	0	0	146	34	328	68	511	96	693	120
100	60	153	96	226	126	409	178	591	211	774	235	956	252	1139	265	1321	275	1504	284	1686	291
75	60	69	43	142	79	325	141	507	181	690	209	872	230	1055	245	1237	258	1420	268	1602	276
60	60	37	23	110	61	292	127	475	170	657	199	840	221	1022	238	1205	251	1387	262	1570	271
50	60	8	5	81	45	264	115	446	159	629	191	811	214	994	231	1176	245	1359	256	1541	266
40	60	0	0	20	11	202	88	385	137	567	172	750	197	932	217	1115	232	1297	245	1480	255
25	60	0	0	0	0	131	57	313	112	496	150	678	179	861	200	1043	217	1226	231	1408	243
0	60	0	0	0	0	0	0	0	0	0	0	0	0	129	30	312	65	494	93	677	117
100	50	133	83	206	114	388	169	571	204	753	228	936	246	1118	260	1301	271	1483	280	1666	287
75	50	49	30	122	68	304	132	487	174	669	203	852	224	1034	241	1217	253	1399	264	1582	273
60	50	16	10	89	49	272	118	454	162	637	193	819	216	1002	233	1184	247	1367	258	1549	267
50	50	0	0	61	34	243	106	426	152	608	184	791	208	973	226	1156	241	1338	252	1521	262
40	50	0	0	0	0	182	79	364	130	547	166	729	192	912	212	1094	228	1277	241	1459	252
25	50	0	0	0	0	110	48	293	104	475	144	658	173	840	195	1023	213	1205	227	1388	239
0	50	0	0	0	0	0	0	0	0	0	0	0	0	109	25	291	61	474	89	656	113
100	40	116	72	189	105	371	161	554	198	736	223	919	242	1101	256	1284	267	1466	277	1649	284
75	40	32	20	105	58	287	125	470	168	652	198	835	220	1017	237	1200	250	1382	261	1565	270
60	40	0	0	72	40	255	111	437	156	620	188	802	211	985	229	1167	243	1350	255	1532	264
50	40	0	0	44	24	226	98	409	146	591	179	774	204	956	222	1139	237	1321	249	1504	259
40	40	0	0	0	0	165	72	347	124	530	161	712	187	895	208	1077	224	1260	238	1442	249
25	40	0	0	0	0	93	40	276	98	458	139	641	169	823	191	1006	209	1188	224	1371	236
0	40	0	0	0	0	0	0	0	0	0	0	0	0	92	21	274	57	457	86	639	110
100	25	37	23	110	61	292	127	475	170	657	199	840	221	1022	238	1205	251	1387	262	1570	271
75	25	0	0	26	14	208	91	391	140	573	174	756	199	938	218	1121	233	1303	246	1486	256
60	25	0	0	0	0	176	76	358	128	541	164	723	190	906	211	1088	227	1271	240	1453	251
50	25	0	0	0	0	147	64	330	118	512	155	695	183	877	204	1060	221	1242	234	1425	246
40	25	0	0	0	0	86	37	268	96	451	137	633	167	816	190	998	208	1181	223	1363	235
25	25	0	0	0	0	14	6	197	70	379	115	562	148	744	173	927	193	1109	209	1292	223
0	25	0	0	0	0	0	0	0	0	0	0	0	0	13	3	195	41	378	71	560	97
100	0	0	0	0	0	173	75	355	127	538	163	720	190	903	210	1085	226	1268	239	1450	250
75	0	0	0	0	0	89	39	271	97	454	138	636	167	819	190	1001	209	1184	223	1366	236
60	0	0	0	0	0	56	24	239	85	421	128	604	159	786	183	969	202	1151	217	1334	230
50	0	0	0	0	0	28	12	210	75	393	119	575	151	758	176	940	196	1123	212	1305	225
40	0	0	0	0	0	0	0	149	53	331	100	514	135	696	162	879	183	1061	200	1244	214
25	0	0	0	0	0	0	0	77	28	260	79	442	116	625	145	807	168	990	187	1172	202
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	16	258	49	441	76

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A2: Predicted Water Supply Deficits and Potential Number of Days Without Water during the L1:75 ongest Winter Period (255 Days) under Historic Climate Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		**4800**		**5300**		**5800**	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	251	157	324	180	506	220	689	246	871	264	1054	277	1236	287	1419	296	1601	302	1784	308
75	100	171	107	244	135	426	185	609	217	791	240	974	256	1156	269	1339	279	1521	287	1704	294
60	100	140	87	213	118	395	172	578	206	760	230	943	248	1125	262	1308	272	1490	281	1673	288
50	100	113	70	186	103	368	160	551	197	733	222	916	241	1098	255	1281	267	1463	276	1646	284
40	100	54	34	127	71	310	135	492	176	675	204	857	226	1040	242	1222	255	1405	265	1587	274
25	100	0	0	59	33	242	105	424	151	607	184	789	208	972	226	1154	240	1337	252	1519	262
0	100	0	0	0	0	0	0	0	0	0	0	93	25	276	64	458	95	641	121	823	142
100	75	135	85	208	116	391	170	573	205	756	229	938	247	1121	261	1303	272	1486	280	1668	288
75	75	55	35	128	71	311	135	493	176	676	205	858	226	1041	242	1223	255	1406	265	1588	274
60	75	24	15	97	54	280	122	462	165	645	195	827	218	1010	235	1192	248	1375	259	1557	268
50	75	0	0	70	39	253	110	435	155	618	187	800	211	983	229	1165	243	1348	254	1530	264
40	75	0	0	12	7	194	84	377	135	559	169	742	195	924	215	1107	231	1289	243	1472	254
25	75	0	0	0	0	126	55	309	110	491	149	674	177	856	199	1039	216	1221	230	1404	242
0	75	0	0	0	0	0	0	0	0	0	0	0	0	160	37	343	71	525	99	708	122
100	60	117	73	190	106	372	162	555	198	737	223	920	242	1102	256	1285	268	1467	277	1650	284
75	60	37	23	110	61	293	127	475	170	658	199	840	221	1023	238	1205	251	1388	262	1570	271
60	60	6	4	79	44	261	114	444	159	626	190	809	213	991	231	1174	245	1356	256	1539	265
50	60	0	0	52	29	234	102	417	149	599	182	782	206	964	224	1147	239	1329	251	1512	261
40	60	0	0	0	0	176	77	358	128	541	164	723	190	906	211	1088	227	1271	240	1453	251
25	60	0	0	0	0	108	47	290	104	473	143	655	172	838	195	1020	213	1203	227	1385	239
0	60	0	0	0	0	0	0	0	0	0	0	0	0	142	33	324	68	507	96	689	119
100	50	93	58	166	92	349	152	531	190	714	216	896	236	1079	251	1261	263	1444	272	1626	280
75	50	14	8	87	48	269	117	452	161	634	192	817	215	999	232	1182	246	1364	257	1547	267
60	50	0	0	55	31	238	103	420	150	603	183	785	207	968	225	1150	240	1333	251	1515	261
50	50	0	0	28	16	211	92	393	141	576	175	758	200	941	219	1123	234	1306	246	1488	257
40	50	0	0	0	0	152	66	335	120	517	157	700	184	882	205	1065	222	1247	235	1430	247
25	50	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	223	1362	235
0	50	0	0	0	0	0	0	0	0	0	0	0	0	118	28	301	63	483	91	666	115
100	40	74	46	147	82	330	143	512	183	695	211	877	231	1060	246	1242	259	1425	269	1607	277
75	40	0	0	67	37	250	109	432	154	615	186	797	210	980	228	1162	242	1345	254	1527	263
60	40	0	0	36	20	219	95	401	143	584	177	766	202	949	221	1131	236	1314	248	1496	258
50	40	0	0	9	5	192	83	374	134	557	169	739	195	922	214	1104	230	1287	243	1469	253
40	40	0	0	0	0	133	58	316	113	498	151	681	179	863	201	1046	218	1228	232	1411	243
25	40	0	0	0	0	65	28	248	88	430	130	613	161	795	185	978	204	1160	219	1343	231
0	40	0	0	0	0	0	0	0	0	0	0	0	0	99	23	282	59	464	88	647	111
100	25	0	0	58	32	240	104	423	151	605	183	788	207	970	226	1153	240	1335	252	1518	262
75	25	0	0	0	0	160	70	343	122	525	159	708	186	890	207	1073	223	1255	237	1438	248
60	25	0	0	0	0	129	56	312	111	494	150	677	178	859	200	1042	217	1224	231	1407	243
50	25	0	0	0	0	102	44	285	102	467	142	650	171	832	194	1015	211	1197	226	1380	238
40	25	0	0	0	0	44	19	226	81	409	124	591	156	774	180	956	199	1139	215	1321	228
25	25	0	0	0	0	0	0	158	56	340	103	523	138	705	164	888	185	1070	202	1253	216
0	25	0	0	0	0	0	0	0	0	0	0	0	0	10	2	192	40	375	71	557	96
100	0	0	0	0	0	105	46	287	103	470	142	652	172	835	194	1017	212	1200	226	1382	238
75	0	0	0	0	0	25	11	207	74	390	118	572	151	755	176	937	195	1120	211	1302	225
60	0	0	0	0	0	0	0	176	63	359	109	541	142	724	168	906	189	1089	205	1271	219
50	0	0	0	0	0	0	0	149	53	332	101	514	135	697	162	879	183	1062	200	1244	215
40	0	0	0	0	0	0	0	91	32	273	83	456	120	638	148	821	171	1003	189	1186	204
25	0	0	0	0	0	0	0	23	8	205	62	388	102	570	133	753	157	935	176	1118	193
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	12	239	45	422	73

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A3: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:60 Longest Winter Period (248 days) under Historic Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]
100	100	239	149	312	173	494	215	677	242	859	260	1042	274	1224	285	1407	293	1589	300	1772	306
75	100	161	101	234	130	417	181	599	214	782	237	964	254	1147	267	1329	277	1512	285	1694	292
60	100	131	82	204	113	387	168	569	203	752	228	934	246	1117	260	1299	271	1482	280	1664	287
50	100	105	66	178	99	360	157	543	194	725	220	908	239	1090	254	1273	265	1455	275	1638	282
40	100	48	30	121	67	304	132	486	174	669	203	851	224	1034	240	1216	253	1399	264	1581	273
25	100	0	0	55	31	237	103	420	150	602	183	785	207	967	225	1150	240	1332	251	1515	261
0	100	0	0	0	0	0	0	0	0	0	0	109	29	292	68	474	99	657	124	839	145
100	75	116	72	189	105	371	161	554	198	736	223	919	242	1101	256	1284	267	1466	277	1649	284
75	75	38	24	111	62	294	128	476	170	659	200	841	221	1024	238	1206	251	1389	262	1571	271
60	75	8	5	81	45	263	114	446	159	628	190	811	213	993	231	1176	245	1358	256	1541	266
50	75	0	0	55	30	237	103	420	150	602	182	785	207	967	225	1150	240	1332	251	1515	261
40	75	0	0	0	0	180	78	363	130	545	165	728	192	910	212	1093	228	1275	241	1458	251
25	75	0	0	0	0	114	50	297	106	479	145	662	174	844	196	1027	214	1209	228	1392	240
0	75	0	0	0	0	0	0	0	0	0	0	0	0	169	39	351	73	534	101	716	123
100	60	96	60	169	94	352	153	534	191	717	217	899	237	1082	252	1264	263	1447	273	1629	281
75	60	19	12	92	51	274	119	457	163	639	194	822	216	1004	234	1187	247	1369	258	1552	268
60	60	0	0	61	34	244	106	426	152	609	184	791	208	974	226	1156	241	1339	253	1521	262
50	60	0	0	35	20	218	95	400	143	583	177	765	201	948	220	1130	235	1313	248	1495	258
40	60	0	0	0	0	161	70	343	123	526	159	708	186	891	207	1073	224	1256	237	1438	248
25	60	0	0	0	0	95	41	277	99	460	139	642	169	825	192	1007	210	1190	224	1372	237
0	60	0	0	0	0	0	0	0	0	0	0	0	0	149	35	332	69	514	97	697	120
100	50	71	44	144	80	327	142	509	182	692	210	874	230	1057	246	1239	258	1422	268	1604	277
75	50	0	0	66	37	249	108	431	154	614	186	796	210	979	228	1161	242	1344	254	1526	263
60	50	0	0	36	20	219	95	401	143	584	177	766	202	949	221	1131	236	1314	248	1496	258
50	50	0	0	10	6	193	84	375	134	558	169	740	195	923	215	1105	230	1288	243	1470	253
40	50	0	0	0	0	136	59	318	114	501	152	683	180	866	201	1048	218	1231	232	1413	244
25	50	0	0	0	0	70	30	252	90	435	132	617	162	800	186	982	205	1165	220	1347	232
0	50	0	0	0	0	0	0	0	0	0	0	0	0	124	29	306	64	489	92	671	116
100	40	51	32	124	69	306	133	489	174	671	203	854	225	1036	241	1219	254	1401	264	1584	273
75	40	0	0	46	26	228	99	411	147	593	180	776	204	958	223	1141	238	1323	250	1506	260
60	40	0	0	16	9	198	86	381	136	563	171	746	196	928	216	1111	231	1293	244	1476	254
50	40	0	0	0	0	172	75	355	127	537	163	720	189	902	210	1085	226	1267	239	1450	250
40	40	0	0	0	0	115	50	298	106	480	146	663	174	845	197	1028	214	1210	228	1393	240
25	40	0	0	0	0	49	21	232	83	414	125	597	157	779	181	962	200	1144	216	1327	229
0	40	0	0	0	0	0	0	0	0	0	0	0	0	103	24	286	60	468	88	651	112
100	25	0	0	28	16	210	92	393	140	575	174	758	199	940	219	1123	234	1305	246	1488	257
75	25	0	0	0	0	133	58	315	113	498	151	680	179	863	201	1045	218	1228	232	1410	243
60	25	0	0	0	0	103	45	285	102	468	142	650	171	833	194	1015	211	1198	226	1380	238
50	25	0	0	0	0	76	33	259	92	441	134	624	164	806	188	989	206	1171	221	1354	233
40	25	0	0	0	0	20	9	202	72	385	117	567	149	750	174	932	194	1115	210	1297	224
25	25	0	0	0	0	0	0	136	49	318	97	501	132	683	159	866	180	1048	198	1231	212
0	25	0	0	0	0	0	0	0	0	0	0	0	0	8	2	190	40	373	70	555	96
100	0	0	0	0	0	66	29	248	89	431	131	613	161	796	185	978	204	1161	219	1343	232
75	0	0	0	0	0	0	0	171	61	353	107	536	141	718	167	901	188	1083	204	1266	218
60	0	0	0	0	0	0	0	141	50	323	98	506	133	688	160	871	181	1053	199	1236	213
50	0	0	0	0	0	0	0	114	41	297	90	479	126	662	154	844	176	1027	194	1209	209
40	0	0	0	0	0	0	0	58	21	240	73	423	111	605	141	788	164	970	183	1153	199
25	0	0	0	0	0	0	0	0	0	174	53	356	94	539	125	721	150	904	171	1086	187
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	10	228	43	411	71

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A4: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:50 Longest Winter Period (245 days) under Historic Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	234	146	307	171	490	213	672	240	855	259	1037	273	1220	284	1402	292	1585	299	1767	305
75	100	158	98	231	128	413	180	596	213	778	236	961	253	1143	266	1326	276	1508	285	1691	291
60	100	128	80	201	111	383	167	566	202	748	227	931	245	1113	259	1296	270	1478	279	1661	286
50	100	102	64	175	97	357	155	540	193	722	219	905	238	1087	253	1270	265	1452	274	1635	282
40	100	46	29	119	66	301	131	484	173	666	202	849	223	1031	240	1214	253	1396	263	1579	272
25	100	0	0	53	30	236	103	418	149	601	182	783	206	966	225	1148	239	1331	251	1513	261
0	100	0	0	0	0	0	0	0	0	0	0	116	30	298	69	481	100	663	125	846	146
100	75	108	67	181	100	363	158	546	195	728	221	911	240	1093	254	1276	266	1458	275	1641	283
75	75	31	19	104	58	287	125	469	168	652	197	834	219	1017	236	1199	250	1382	261	1564	270
60	75	1	1	74	41	257	112	439	157	622	188	804	212	987	229	1169	244	1352	255	1534	265
50	75	0	0	48	27	231	100	413	148	596	181	778	205	961	223	1143	238	1326	250	1508	260
40	75	0	0	0	0	175	76	357	128	540	164	722	190	905	210	1087	227	1270	240	1452	250
25	75	0	0	0	0	109	48	292	104	474	144	657	173	839	195	1022	213	1204	227	1387	239
0	75	0	0	0	0	0	0	0	0	0	0	0	0	172	40	354	74	537	101	719	124
100	60	88	55	161	89	343	149	526	188	708	215	891	234	1073	250	1256	262	1438	271	1621	279
75	60	11	7	84	47	267	116	449	160	632	191	814	214	997	232	1179	246	1362	257	1544	266
60	60	0	0	54	30	237	103	419	150	602	182	784	206	967	225	1149	239	1332	251	1514	261
50	60	0	0	28	16	211	92	393	141	576	175	758	200	941	219	1123	234	1306	246	1488	257
40	60	0	0	0	0	155	67	337	120	520	158	702	185	885	206	1067	222	1250	236	1432	247
25	60	0	0	0	0	89	39	272	97	454	138	637	168	819	191	1002	209	1184	223	1367	236
0	60	0	0	0	0	0	0	0	0	0	0	0	0	152	35	334	70	517	98	699	121
100	50	62	39	135	75	318	138	500	179	683	207	865	228	1048	244	1230	256	1413	267	1595	275
75	50	0	0	58	32	241	105	423	151	606	184	788	207	971	226	1153	240	1336	252	1518	262
60	50	0	0	28	16	211	92	393	141	576	175	758	200	941	219	1123	234	1306	246	1488	257
50	50	0	0	3	1	185	81	368	131	550	167	733	193	915	213	1098	229	1280	242	1463	252
40	50	0	0	0	0	129	56	312	111	494	150	677	178	859	200	1042	217	1224	231	1407	243
25	50	0	0	0	0	64	28	246	88	429	130	611	161	794	185	976	203	1159	219	1341	231
0	50	0	0	0	0	0	0	0	0	0	0	0	0	126	29	309	64	491	93	674	116
100	40	41	26	114	63	296	129	479	171	661	200	844	222	1026	239	1209	252	1391	263	1574	271
75	40	0	0	37	21	220	96	402	144	585	177	767	202	950	221	1132	236	1315	248	1497	258
60	40	0	0	7	4	190	83	372	133	555	168	737	194	920	214	1102	230	1285	242	1467	253
50	40	0	0	0	0	164	71	347	124	529	160	712	187	894	208	1077	224	1259	238	1442	249
40	40	0	0	0	0	108	47	290	104	473	143	655	172	838	195	1020	213	1203	227	1385	239
25	40	0	0	0	0	43	19	225	80	408	124	590	155	773	180	955	199	1138	215	1320	228
0	40	0	0	0	0	0	0	0	0	0	0	0	0	105	24	288	60	470	89	653	113
100	25	0	0	16	9	198	86	381	136	563	171	746	196	928	216	1111	231	1293	244	1476	254
75	25	0	0	0	0	122	53	304	109	487	147	669	176	852	198	1034	215	1217	230	1399	241
60	25	0	0	0	0	92	40	274	98	457	138	639	168	822	191	1004	209	1187	224	1369	236
50	25	0	0	0	0	66	29	249	89	431	131	614	161	796	185	979	204	1161	219	1344	232
40	25	0	0	0	0	10	4	192	69	375	114	557	147	740	172	922	192	1105	208	1287	222
25	25	0	0	0	0	0	0	127	45	310	94	492	129	675	157	857	179	1040	196	1222	211
0	25	0	0	0	0	0	0	0	0	0	0	0	0	7	2	190	39	372	70	555	96
100	0	0	0	0	0	50	22	233	83	415	126	598	157	780	181	963	201	1145	216	1328	229
75	0	0	0	0	0	0	0	156	56	339	103	521	137	704	164	886	185	1069	202	1251	216
60	0	0	0	0	0	0	0	126	45	309	94	491	129	674	157	856	178	1039	196	1221	211
50	0	0	0	0	0	0	0	100	36	283	86	465	122	648	151	830	173	1013	191	1195	206
40	0	0	0	0	0	0	0	44	16	227	69	409	108	592	138	774	161	957	181	1139	196
25	0	0	0	0	0	0	0	0	0	161	49	344	90	526	122	709	148	891	168	1074	185
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	9	224	42	406	70

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

Legend	
1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A5: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:40 Longest Winter Period (242 days) under Historic Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	231	144	304	169	486	211	669	239	851	258	1034	272	1216	283	1399	291	1581	298	1764	304
75	100	155	97	228	127	410	178	593	212	775	235	958	252	1140	265	1323	276	1505	284	1688	291
60	100	125	78	198	110	381	165	563	201	746	226	928	244	1111	258	1293	269	1476	278	1658	286
50	100	100	62	173	96	355	154	538	192	720	218	903	238	1085	252	1268	264	1450	274	1633	281
40	100	44	27	117	65	299	130	482	172	664	201	847	223	1029	239	1212	252	1394	263	1577	272
25	100	0	0	52	29	235	102	417	149	600	182	782	206	965	224	1147	239	1330	251	1512	261
0	100	0	0	0	0	0	0	0	0	0	0	121	32	303	70	486	101	668	126	851	147
100	75	102	64	175	97	357	155	540	193	722	219	905	238	1087	253	1270	265	1452	274	1635	282
75	75	26	16	99	55	281	122	464	166	646	196	829	218	1011	235	1194	249	1376	260	1559	269
60	75	0	0	69	39	252	110	434	155	617	187	799	210	982	228	1164	243	1347	254	1529	264
50	75	0	0	44	24	226	98	409	146	591	179	774	204	956	222	1139	237	1321	249	1504	259
40	75	0	0	0	0	171	74	353	126	536	162	718	189	901	209	1083	226	1266	239	1448	250
25	75	0	0	0	0	106	46	288	103	471	143	653	172	836	194	1018	212	1201	227	1383	239
0	75	0	0	0	0	0	0	0	0	0	0	0	0	174	41	357	74	539	102	722	124
100	60	82	51	155	86	337	147	520	186	702	213	885	233	1067	248	1250	260	1432	270	1615	278
75	60	6	3	79	44	261	114	444	158	626	190	809	213	991	230	1174	244	1356	256	1539	265
60	60	0	0	49	27	231	101	414	148	596	181	779	205	961	224	1144	238	1326	250	1509	260
50	60	0	0	23	13	206	90	388	139	571	173	753	198	936	218	1118	233	1301	245	1483	256
40	60	0	0	0	0	150	65	333	119	515	156	698	184	880	205	1063	221	1245	235	1428	246
25	60	0	0	0	0	85	37	268	96	450	137	633	167	815	190	998	208	1180	223	1363	235
0	60	0	0	0	0	0	0	0	0	0	0	0	0	154	36	337	70	519	98	702	121
100	50	55	35	128	71	311	135	493	176	676	205	858	226	1041	242	1223	255	1406	265	1588	274
75	50	0	0	52	29	235	102	417	149	600	182	782	206	965	224	1147	239	1330	251	1512	261
60	50	0	0	23	13	205	89	388	139	570	173	753	198	935	218	1118	233	1300	245	1483	256
50	50	0	0	0	0	180	78	362	129	545	165	727	191	910	212	1092	228	1275	241	1457	251
40	50	0	0	0	0	124	54	307	110	489	148	672	177	854	199	1037	216	1219	230	1402	242
25	50	0	0	0	0	59	26	242	86	424	129	607	160	789	184	972	202	1154	218	1337	230
0	50	0	0	0	0	0	0	0	0	0	0	0	0	128	30	310	65	493	93	675	116
100	40	34	21	107	59	289	126	472	169	654	198	837	220	1019	237	1202	250	1384	261	1567	270
75	40	0	0	31	17	213	93	396	141	578	175	761	200	943	219	1126	235	1308	247	1491	257
60	40	0	0	1	1	184	80	366	131	549	166	731	192	914	213	1096	228	1279	241	1461	252
50	40	0	0	0	0	158	69	341	122	523	159	706	186	888	207	1071	223	1253	236	1436	248
40	40	0	0	0	0	103	45	285	102	468	142	650	171	833	194	1015	211	1198	226	1380	238
25	40	0	0	0	0	38	16	220	79	403	122	585	154	768	179	950	198	1133	214	1315	227
0	40	0	0	0	0	0	0	0	0	0	0	0	0	106	25	289	60	471	89	654	113
100	25	0	0	7	4	190	82	372	133	555	168	737	194	920	214	1102	230	1285	242	1467	253
75	25	0	0	0	0	114	49	296	106	479	145	661	174	844	196	1026	214	1209	228	1391	240
60	25	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	222	1362	235
50	25	0	0	0	0	58	25	241	86	423	128	606	159	788	183	971	202	1153	218	1336	230
40	25	0	0	0	0	3	1	185	66	368	111	550	145	733	170	915	191	1098	207	1280	221
25	25	0	0	0	0	0	0	121	43	303	92	486	128	668	155	851	177	1033	195	1216	210
0	25	0	0	0	0	0	0	0	0	0	0	0	0	7	2	189	39	372	70	554	96
100	0	0	0	0	0	39	17	221	79	404	122	586	154	769	179	951	198	1134	214	1316	227
75	0	0	0	0	0	0	0	145	52	328	99	510	134	693	161	875	182	1058	200	1240	214
60	0	0	0	0	0	0	0	116	41	298	90	481	126	663	154	846	176	1028	194	1211	209
50	0	0	0	0	0	0	0	90	32	272	83	455	120	637	148	820	171	1002	189	1185	204
40	0	0	0	0	0	0	0	34	12	217	66	399	105	582	135	764	159	947	179	1129	195
25	0	0	0	0	0	0	0	0	0	152	46	335	88	517	120	700	146	882	166	1065	184
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	8	221	42	403	70

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A6: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:25 Longest Winter Period (237 days) under Historic Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]
100	100	221	138	294	164	477	207	659	236	842	255	1024	270	1207	281	1389	289	1572	297	1754	302
75	100	147	92	220	122	403	175	585	209	768	233	950	250	1133	263	1315	274	1498	283	1680	290
60	100	118	74	191	106	374	163	556	199	739	224	921	242	1104	257	1286	268	1469	277	1651	285
50	100	93	58	166	92	349	152	531	190	714	216	896	236	1079	251	1261	263	1444	272	1626	280
40	100	39	24	112	62	295	128	477	170	660	200	842	222	1025	238	1207	251	1390	262	1572	271
25	100	0	0	49	27	231	101	414	148	596	181	779	205	961	224	1144	238	1326	250	1509	260
0	100	0	0	0	0	0	0	0	0	0	0	133	35	316	73	498	104	681	128	863	149
100	75	87	54	160	89	342	149	525	187	707	214	890	234	1072	249	1255	261	1437	271	1620	279
75	75	12	8	85	47	268	117	450	161	633	192	815	215	998	232	1180	246	1363	257	1545	266
60	75	0	0	57	31	239	104	422	151	604	183	787	207	969	225	1152	240	1334	252	1517	261
50	75	0	0	32	18	214	93	397	142	579	175	762	200	944	220	1127	235	1309	247	1492	257
40	75	0	0	0	0	160	69	342	122	525	159	707	186	890	207	1072	223	1255	237	1437	248
25	75	0	0	0	0	97	42	279	100	462	140	644	169	827	192	1009	210	1192	225	1374	237
0	75	0	0	0	0	0	0	0	0	0	0	0	0	181	42	363	76	546	103	728	126
100	60	65	41	138	77	321	139	503	180	686	208	868	228	1051	244	1233	257	1416	267	1598	276
75	60	0	0	64	36	247	107	429	153	612	185	794	209	977	227	1159	241	1342	253	1524	263
60	60	0	0	35	20	218	95	400	143	583	177	765	201	948	220	1130	235	1313	248	1495	258
50	60	0	0	10	6	193	84	375	134	558	169	740	195	923	215	1105	230	1288	243	1470	253
40	60	0	0	0	0	138	60	321	115	503	153	686	181	868	202	1051	219	1233	233	1416	244
25	60	0	0	0	0	75	33	258	92	440	133	623	164	805	187	988	206	1170	221	1353	233
0	60	0	0	0	0	0	0	0	0	0	0	0	0	160	37	342	71	525	99	707	122
100	50	38	24	111	62	293	128	476	170	658	200	841	221	1023	238	1206	251	1388	262	1571	271
75	50	0	0	37	20	219	95	402	143	584	177	767	202	949	221	1132	236	1314	248	1497	258
60	50	0	0	8	4	190	83	373	133	555	168	738	194	920	214	1103	230	1285	243	1468	253
50	50	0	0	0	0	165	72	348	124	530	161	713	188	895	208	1078	225	1260	238	1443	249
40	50	0	0	0	0	111	48	294	105	476	144	659	173	841	196	1024	213	1206	228	1389	239
25	50	0	0	0	0	48	21	230	82	413	125	595	157	778	181	960	200	1143	216	1325	228
0	50	0	0	0	0	0	0	0	0	0	0	0	0	132	31	315	66	497	94	680	117
100	40	15	10	88	49	271	118	453	162	636	193	818	215	1001	233	1183	247	1366	258	1548	267
75	40	0	0	14	8	197	86	379	135	562	170	744	196	927	216	1109	231	1292	244	1474	254
60	40	0	0	0	0	168	73	350	125	533	161	715	188	898	209	1080	225	1263	238	1445	249
50	40	0	0	0	0	143	62	325	116	508	154	690	182	873	203	1055	220	1238	234	1420	245
40	40	0	0	0	0	89	39	271	97	454	137	636	167	819	190	1001	209	1184	223	1366	236
25	40	0	0	0	0	25	11	208	74	390	118	573	151	755	176	938	195	1120	211	1303	225
0	40	0	0	0	0	0	0	0	0	0	0	0	0	110	26	292	61	475	90	657	113
100	25	0	0	0	0	166	72	349	125	531	161	714	188	896	208	1079	225	1261	238	1444	249
75	25	0	0	0	0	92	40	275	98	457	139	640	168	822	191	1005	209	1187	224	1370	236
60	25	0	0	0	0	63	28	246	88	428	130	611	161	793	184	976	203	1158	219	1341	231
50	25	0	0	0	0	38	17	221	79	403	122	586	154	768	179	951	198	1133	214	1316	227
40	25	0	0	0	0	0	0	167	59	349	106	532	140	714	166	897	187	1079	204	1262	218
25	25	0	0	0	0	0	0	103	37	286	87	468	123	651	151	833	174	1016	192	1198	207
0	25	0	0	0	0	0	0	0	0	0	0	0	0	5	1	188	39	370	70	553	95
100	0	0	0	0	0	8	4	191	68	373	113	556	146	738	172	921	192	1103	208	1286	222
75	0	0	0	0	0	0	0	117	42	299	91	482	127	664	154	847	176	1029	194	1212	209
60	0	0	0	0	0	0	0	88	31	270	82	453	119	635	148	818	170	1000	189	1183	204
50	0	0	0	0	0	0	0	63	22	245	74	428	113	610	142	793	165	975	184	1158	200
40	0	0	0	0	0	0	0	8	3	191	58	373	98	556	129	738	154	921	174	1103	190
25	0	0	0	0	0	0	0	0	0	128	39	310	82	493	115	675	141	858	162	1040	179
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	6	212	40	395	68

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A7: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Shortest Winter Period (216 days) under Historic Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]
100	100	189	118	262	145	444	193	627	224	809	245	992	261	1174	273	1357	283	1539	290	1722	297
75	100	121	76	194	108	376	164	559	200	741	225	924	243	1106	257	1289	269	1471	278	1654	285
60	100	95	59	168	93	350	152	533	190	715	217	898	236	1080	251	1263	263	1445	273	1628	281
50	100	72	45	145	80	327	142	510	182	692	210	875	230	1057	246	1240	258	1422	268	1605	277
40	100	22	14	95	53	278	121	460	164	643	195	825	217	1008	234	1190	248	1373	259	1555	268
25	100	0	0	37	21	220	96	402	144	585	177	767	202	950	221	1132	236	1315	248	1497	258
0	100	0	0	0	0	0	0	0	0	0	0	178	47	361	84	543	113	726	137	908	157
100	75	32	20	105	58	288	125	470	168	653	198	835	220	1018	237	1200	250	1383	261	1565	270
75	75	0	0	38	21	220	96	403	144	585	177	768	202	950	221	1133	236	1315	248	1498	258
60	75	0	0	11	6	194	84	376	134	559	169	741	195	924	215	1106	230	1289	243	1471	254
50	75	0	0	0	0	171	74	353	126	536	162	718	189	901	209	1083	226	1266	239	1448	250
40	75	0	0	0	0	121	53	304	108	486	147	669	176	851	198	1034	215	1216	229	1399	241
25	75	0	0	0	0	64	28	246	88	429	130	611	161	794	185	976	203	1159	219	1341	231
0	75	0	0	0	0	0	0	0	0	0	0	22	6	204	47	387	81	569	107	752	130
100	60	7	5	80	45	263	114	445	159	628	190	810	213	993	231	1175	245	1358	256	1540	266
75	60	0	0	13	7	195	85	378	135	560	170	743	195	925	215	1108	231	1290	243	1473	254
60	60	0	0	0	0	169	73	351	125	534	162	716	189	899	209	1081	225	1264	238	1446	249
50	60	0	0	0	0	146	64	329	117	511	155	694	183	876	204	1059	221	1241	234	1424	245
40	60	0	0	0	0	97	42	279	100	462	140	644	169	827	192	1009	210	1192	225	1374	237
25	60	0	0	0	0	39	17	221	79	404	122	586	154	769	179	951	198	1134	214	1316	227
0	60	0	0	0	0	0	0	0	0	0	0	0	0	179	42	362	75	544	103	727	125
100	50	0	0	49	27	231	100	414	148	596	181	779	205	961	224	1144	238	1326	250	1509	260
75	50	0	0	0	0	163	71	346	124	528	160	711	187	893	208	1076	224	1258	237	1441	248
60	50	0	0	0	0	137	60	320	114	502	152	685	180	867	202	1050	219	1232	232	1415	244
50	50	0	0	0	0	114	50	297	106	479	145	662	174	844	196	1027	214	1209	228	1392	240
40	50	0	0	0	0	65	28	247	88	430	130	612	161	795	185	977	204	1160	219	1342	231
25	50	0	0	0	0	7	3	189	68	372	113	554	146	737	171	919	192	1102	208	1284	221
0	50	0	0	0	0	0	0	0	0	0	0	0	0	148	34	330	69	513	97	695	120
100	40	0	0	23	13	205	89	388	138	570	173	753	198	935	217	1118	233	1300	245	1483	256
75	40	0	0	0	0	137	60	320	114	502	152	685	180	867	202	1050	219	1232	233	1415	244
60	40	0	0	0	0	111	48	293	105	476	144	658	173	841	196	1023	213	1206	228	1388	239
50	40	0	0	0	0	88	38	271	97	453	137	636	167	818	190	1001	208	1183	223	1366	235
40	40	0	0	0	0	39	17	221	79	404	122	586	154	769	179	951	198	1134	214	1316	227
25	40	0	0	0	0	0	0	163	58	346	105	528	139	711	165	893	186	1076	203	1258	217
0	40	0	0	0	0	0	0	0	0	0	0	0	0	121	28	304	63	486	92	669	115
100	25	0	0	0	0	84	36	266	95	449	136	631	166	814	189	996	208	1179	222	1361	235
75	25	0	0	0	0	16	7	199	71	381	115	564	148	746	173	929	193	1111	210	1294	223
60	25	0	0	0	0	0	0	172	61	355	107	537	141	720	167	902	188	1085	205	1267	218
50	25	0	0	0	0	0	0	149	53	332	101	514	135	697	162	879	183	1062	200	1244	215
40	25	0	0	0	0	0	0	100	36	282	86	465	122	647	151	830	173	1012	191	1195	206
25	25	0	0	0	0	0	0	42	15	225	68	407	107	590	137	772	161	955	180	1137	196
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183	38	365	69	548	94
100	0	0	0	0	0	0	0	83	30	265	80	448	118	630	147	813	169	995	188	1178	203
75	0	0	0	0	0	0	0	15	5	198	60	380	100	563	131	745	155	928	175	1110	191
60	0	0	0	0	0	0	0	0	0	171	52	354	93	536	125	719	150	901	170	1084	187
50	0	0	0	0	0	0	0	0	0	148	45	331	87	513	119	696	145	878	166	1061	183
40	0	0	0	0	0	0	0	0	0	99	30	281	74	464	108	646	135	829	156	1011	174
25	0	0	0	0	0	0	0	0	0	41	12	224	59	406	94	589	123	771	145	954	164
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	34	364	63

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A8: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Longest Winter Period (253 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	192	120	265	147	448	195	630	225	813	246	995	262	1178	274	1360	283	1543	291	1725	297
75	100	52	32	125	69	307	134	490	175	672	204	855	225	1037	241	1220	254	1402	265	1585	273
60	100	0	0	70	39	253	110	435	155	618	187	800	211	983	229	1165	243	1348	254	1530	264
50	100	0	0	23	13	206	89	388	139	571	173	753	198	936	218	1118	233	1301	245	1483	256
40	100	0	0	0	0	103	45	285	102	468	142	650	171	833	194	1015	212	1198	226	1380	238
25	100	0	0	0	0	0	0	166	59	348	105	531	140	713	166	896	187	1078	203	1261	217
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	7
100	75	90	56	163	91	345	150	528	189	710	215	893	235	1075	250	1258	262	1440	272	1623	280
75	75	0	0	23	13	205	89	388	138	570	173	753	198	935	217	1118	233	1300	245	1483	256
60	75	0	0	0	0	150	65	333	119	515	156	698	184	880	205	1063	221	1245	235	1428	246
50	75	0	0	0	0	103	45	286	102	468	142	651	171	833	194	1016	212	1198	226	1381	238
40	75	0	0	0	0	0	0	183	65	365	111	548	144	730	170	913	190	1095	207	1278	220
25	75	0	0	0	0	0	0	63	23	246	74	428	113	611	142	793	165	976	184	1158	200
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	60	74	46	147	81	329	143	512	183	694	210	877	231	1059	246	1242	259	1424	269	1607	277
75	60	0	0	6	4	189	82	371	133	554	168	736	194	919	214	1101	229	1284	242	1466	253
60	60	0	0	0	0	134	58	317	113	499	151	682	179	864	201	1047	218	1229	232	1412	243
50	60	0	0	0	0	87	38	269	96	452	137	634	167	817	190	999	208	1182	223	1364	235
40	60	0	0	0	0	0	0	167	60	349	106	532	140	714	166	897	187	1079	204	1262	218
25	60	0	0	0	0	0	0	47	17	229	70	412	108	594	138	777	162	959	181	1142	197
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	50	53	33	126	70	308	134	491	175	673	204	856	225	1038	241	1221	254	1403	265	1586	273
75	50	0	0	0	0	168	73	350	125	533	162	715	188	898	209	1080	225	1263	238	1445	249
60	50	0	0	0	0	113	49	296	106	478	145	661	174	843	196	1026	214	1208	228	1391	240
50	50	0	0	0	0	66	29	249	89	431	131	614	161	796	185	979	204	1161	219	1344	232
40	50	0	0	0	0	0	0	146	52	328	99	511	134	693	161	876	182	1058	200	1241	214
25	50	0	0	0	0	0	0	26	9	209	63	391	103	574	133	756	158	939	177	1121	193
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	40	36	22	109	60	291	127	474	169	656	199	839	221	1021	238	1204	251	1386	262	1569	270
75	40	0	0	0	0	151	66	333	119	516	156	698	184	881	205	1063	222	1246	235	1428	246
60	40	0	0	0	0	96	42	279	100	461	140	644	169	826	192	1009	210	1191	225	1374	237
50	40	0	0	0	0	49	21	231	83	414	125	596	157	779	181	961	200	1144	216	1326	229
40	40	0	0	0	0	0	0	129	46	311	94	494	130	676	157	859	179	1041	196	1224	211
25	40	0	0	0	0	0	0	9	3	191	58	374	98	556	129	739	154	921	174	1104	190
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	25	0	0	29	16	212	92	394	141	577	175	759	200	942	219	1124	234	1307	247	1489	257
75	25	0	0	0	0	71	31	254	91	436	132	619	163	801	186	984	205	1166	220	1349	233
60	25	0	0	0	0	17	7	199	71	382	116	564	148	747	174	929	194	1112	210	1294	223
50	25	0	0	0	0	0	0	152	54	335	101	517	136	700	163	882	184	1065	201	1247	215
40	25	0	0	0	0	0	0	49	18	232	70	414	109	597	139	779	162	962	181	1144	197
25	25	0	0	0	0	0	0	0	0	112	34	295	78	477	111	660	137	842	159	1025	177
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	92	40	274	98	457	138	639	168	822	191	1004	209	1187	224	1369	236
75	0	0	0	0	0	0	0	134	48	316	96	499	131	681	158	864	180	1046	197	1229	212
60	0	0	0	0	0	0	0	79	28	262	79	444	117	627	146	809	169	992	187	1174	202
50	0	0	0	0	0	0	0	32	11	214	65	397	104	579	135	762	159	944	178	1127	194
40	0	0	0	0	0	0	0	0	0	112	34	294	77	477	111	659	137	842	159	1024	177
25	0	0	0	0	0	0	0	0	0	0	0	174	46	357	83	539	112	722	136	904	156
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A9: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:75 Longest Winter Period (239 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		**4800**		**5300**		**5800**	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	178	111	251	140	434	189	616	220	799	242	981	258	1164	271	1346	280	1529	288	1711	295
75	100	46	29	119	66	301	131	484	173	666	202	849	223	1031	240	1214	253	1396	263	1579	272
60	100	0	0	67	37	250	109	432	154	615	186	797	210	980	228	1162	242	1345	254	1527	263
50	100	0	0	22	12	205	89	387	138	570	173	752	198	935	217	1117	233	1300	245	1482	256
40	100	0	0	0	0	108	47	291	104	473	143	656	173	838	195	1021	213	1203	227	1386	239
25	100	0	0	0	0	0	0	178	63	360	109	543	143	725	169	908	189	1090	206	1273	219
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	21
100	75	63	39	136	75	318	138	501	179	683	207	866	228	1048	244	1231	256	1413	267	1596	275
75	75	0	0	3	2	186	81	368	132	551	167	733	193	916	213	1098	229	1281	242	1463	252
60	75	0	0	0	0	134	58	317	113	499	151	682	179	864	201	1047	218	1229	232	1412	243
50	75	0	0	0	0	90	39	272	97	455	138	637	168	820	191	1002	209	1185	224	1367	236
40	75	0	0	0	0	0	0	175	63	358	108	540	142	723	168	905	189	1088	205	1270	219
25	75	0	0	0	0	0	0	62	22	245	74	427	112	610	142	792	165	975	184	1157	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
100	60	44	28	117	65	300	130	482	172	665	202	847	223	1030	240	1212	253	1395	263	1577	272
75	60	0	0	0	0	167	73	350	125	532	161	715	188	897	209	1080	225	1262	238	1445	249
60	60	0	0	0	0	116	50	298	107	481	146	663	175	846	197	1028	214	1211	228	1393	240
50	60	0	0	0	0	71	31	254	91	436	132	619	163	801	186	984	205	1166	220	1349	233
40	60	0	0	0	0	0	0	157	56	339	103	522	137	704	164	887	185	1069	202	1252	216
25	60	0	0	0	0	0	0	44	16	226	69	409	108	591	138	774	161	956	180	1139	196
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	50	21	13	94	52	277	120	459	164	642	194	824	217	1007	234	1189	248	1372	259	1554	268
75	50	0	0	0	0	144	63	327	117	509	154	692	182	874	203	1057	220	1239	234	1422	245
60	50	0	0	0	0	92	40	275	98	457	139	640	168	822	191	1005	209	1187	224	1370	236
50	50	0	0	0	0	48	21	230	82	413	125	595	157	778	181	960	200	1143	216	1325	228
40	50	0	0	0	0	0	0	133	48	316	96	498	131	681	158	863	180	1046	197	1228	212
25	50	0	0	0	0	0	0	20	7	203	61	385	101	568	132	750	156	933	176	1115	192
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	40	2	1	75	42	257	112	440	157	622	189	805	212	987	230	1170	244	1352	255	1535	265
75	40	0	0	0	0	125	54	307	110	490	148	672	177	855	199	1037	216	1220	230	1402	242
60	40	0	0	0	0	73	32	256	91	438	133	621	163	803	187	986	205	1168	220	1351	233
50	40	0	0	0	0	29	12	211	75	394	119	576	152	759	176	941	196	1124	212	1306	225
40	40	0	0	0	0	0	0	114	41	297	90	479	126	662	154	844	176	1027	194	1209	208
25	40	0	0	0	0	0	0	1	0	184	56	366	96	549	128	731	152	914	172	1096	189
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	25	0	0	0	0	168	73	350	125	533	161	715	188	898	209	1080	225	1263	238	1445	249
75	25	0	0	0	0	35	15	218	78	400	121	583	153	765	178	948	197	1130	213	1313	226
60	25	0	0	0	0	0	0	166	59	349	106	531	140	714	166	896	187	1079	204	1261	217
50	25	0	0	0	0	0	0	122	43	304	92	487	128	669	156	852	177	1034	195	1217	210
40	25	0	0	0	0	0	0	25	9	207	63	390	103	572	133	755	157	937	177	1120	193
25	25	0	0	0	0	0	0	0	0	94	28	277	73	459	107	642	134	824	155	1007	174
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	32	14	215	77	397	120	580	153	762	177	945	197	1127	213	1310	226
75	0	0	0	0	0	0	0	82	29	265	80	447	118	630	146	812	169	995	188	1177	203
60	0	0	0	0	0	0	0	31	11	213	65	396	104	578	134	761	158	943	178	1126	194
50	0	0	0	0	0	0	0	0	0	169	51	351	92	534	124	716	149	899	170	1081	186
40	0	0	0	0	0	0	0	0	0	72	22	254	67	437	102	619	129	802	151	984	170
25	0	0	0	0	0	0	0	0	0	0	0	141	37	324	75	506	105	689	130	871	150
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A10: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:60 Longest Winter Period (233 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]
100	100	172	108	245	136	428	186	610	218	793	240	975	257	1158	269	1340	279	1523	287	1705	294
75	100	43	27	116	64	298	130	481	172	663	201	846	223	1028	239	1211	252	1393	263	1576	272
60	100	0	0	66	36	248	108	431	154	613	186	796	209	978	227	1161	242	1343	253	1526	263
50	100	0	0	22	12	205	89	387	138	570	173	752	198	935	217	1117	233	1300	245	1482	256
40	100	0	0	0	0	110	48	293	105	475	144	658	173	840	195	1023	213	1205	227	1388	239
25	100	0	0	0	0	0	0	183	65	365	111	548	144	730	170	913	190	1095	207	1278	220
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	154	27
100	75	51	32	124	69	306	133	489	175	671	203	854	225	1036	241	1219	254	1401	264	1584	273
75	75	0	0	0	0	177	77	360	129	542	164	725	191	907	211	1090	227	1272	240	1455	251
60	75	0	0	0	0	127	55	310	111	492	149	675	178	857	199	1040	217	1222	231	1405	242
50	75	0	0	0	0	84	36	266	95	449	136	631	166	814	189	996	208	1179	222	1361	235
40	75	0	0	0	0	0	0	172	61	354	107	537	141	719	167	902	188	1084	205	1267	218
25	75	0	0	0	0	0	0	62	22	244	74	427	112	609	142	792	165	974	184	1157	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	6
100	60	32	20	105	58	287	125	470	168	652	198	835	220	1017	237	1200	250	1382	261	1565	270
75	60	0	0	0	0	158	69	341	122	523	159	706	186	888	207	1071	223	1253	236	1436	248
60	60	0	0	0	0	108	47	290	104	473	143	655	172	838	195	1020	213	1203	227	1385	239
50	60	0	0	0	0	64	28	247	88	429	130	612	161	794	185	977	204	1159	219	1342	231
40	60	0	0	0	0	0	0	153	54	335	102	518	136	700	163	883	184	1065	201	1248	215
25	60	0	0	0	0	0	0	42	15	225	68	407	107	590	137	772	161	955	180	1137	196
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	2
100	50	7	4	80	44	263	114	445	159	628	190	810	213	993	231	1175	245	1358	256	1540	266
75	50	0	0	0	0	134	58	316	113	499	151	681	179	864	201	1046	218	1229	232	1411	243
60	50	0	0	0	0	83	36	266	95	448	136	631	166	813	189	996	207	1178	222	1361	235
50	50	0	0	0	0	40	17	222	79	405	123	587	155	770	179	952	198	1135	214	1317	227
40	50	0	0	0	0	0	0	128	46	310	94	493	130	675	157	858	179	1040	196	1223	211
25	50	0	0	0	0	0	0	18	6	200	61	383	101	565	131	748	156	930	176	1113	192
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	40	0	0	60	33	242	105	425	152	607	184	790	208	972	226	1155	241	1337	252	1520	262
75	40	0	0	0	0	113	49	296	106	478	145	661	174	843	196	1026	214	1208	228	1391	240
60	40	0	0	0	0	63	27	246	88	428	130	611	161	793	184	976	203	1158	219	1341	231
50	40	0	0	0	0	20	9	202	72	385	117	567	149	750	174	932	194	1115	210	1297	224
40	40	0	0	0	0	0	0	108	38	290	88	473	124	655	152	838	175	1020	192	1203	207
25	40	0	0	0	0	0	0	0	0	180	55	363	95	545	127	728	152	910	172	1093	188
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	25	0	0	0	0	148	65	331	118	513	156	696	183	878	204	1061	221	1243	235	1426	246
75	25	0	0	0	0	19	8	202	72	384	116	567	149	749	174	932	194	1114	210	1297	224
60	25	0	0	0	0	0	0	152	54	334	101	517	136	699	163	882	184	1064	201	1247	215
50	25	0	0	0	0	0	0	108	39	291	88	473	125	656	152	838	175	1021	193	1203	207
40	25	0	0	0	0	0	0	14	5	196	59	379	100	561	131	744	155	926	175	1109	191
25	25	0	0	0	0	0	0	0	0	86	26	269	71	451	105	634	132	816	154	999	172
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	6	3	189	67	371	113	554	146	736	171	919	191	1101	208	1284	221
75	0	0	0	0	0	0	0	60	21	242	73	425	112	607	141	790	165	972	183	1155	199
60	0	0	0	0	0	0	0	10	3	192	58	375	99	557	130	740	154	922	174	1105	190
50	0	0	0	0	0	0	0	0	0	149	45	331	87	514	119	696	145	879	166	1061	183
40	0	0	0	0	0	0	0	0	0	54	16	237	62	419	98	602	125	784	148	967	167
25	0	0	0	0	0	0	0	0	0	0	0	127	33	309	72	492	102	674	127	857	148
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A11: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:50 Longest Winter Period (225 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	166	104	239	133	422	183	604	216	787	238	969	255	1152	268	1334	278	1517	286	1699	293
75	100	40	25	113	63	296	129	478	171	661	200	843	222	1026	239	1208	252	1391	262	1573	271
60	100	0	0	64	36	247	107	429	153	612	185	794	209	977	227	1159	242	1342	253	1524	263
50	100	0	0	22	12	205	89	387	138	570	173	752	198	935	217	1117	233	1300	245	1482	256
40	100	0	0	0	0	112	49	295	105	477	145	660	174	842	196	1025	214	1207	228	1390	240
25	100	0	0	0	0	5	2	188	67	370	112	553	145	735	171	918	191	1100	208	1283	221
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	187	32
100	75	40	25	113	63	295	128	478	171	660	200	843	222	1025	238	1208	252	1390	262	1573	271
75	75	0	0	0	0	169	74	352	126	534	162	717	189	899	209	1082	225	1264	239	1447	249
60	75	0	0	0	0	120	52	303	108	485	147	668	176	850	198	1033	215	1215	229	1398	241
50	75	0	0	0	0	78	34	261	93	443	134	626	165	808	188	991	206	1173	221	1356	234
40	75	0	0	0	0	0	0	169	60	351	106	534	140	716	167	899	187	1081	204	1264	218
25	75	0	0	0	0	0	0	61	22	244	74	426	112	609	142	791	165	974	184	1156	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	10
100	60	20	12	93	52	275	120	458	164	640	194	823	217	1005	234	1188	247	1370	259	1553	268
75	60	0	0	0	0	149	65	332	119	514	156	697	183	879	205	1062	221	1244	235	1427	246
60	60	0	0	0	0	100	44	283	101	465	141	648	171	830	193	1013	211	1195	226	1378	238
50	60	0	0	0	0	58	25	241	86	423	128	606	159	788	183	971	202	1153	218	1336	230
40	60	0	0	0	0	0	0	149	53	331	100	514	135	696	162	879	183	1061	200	1244	214
25	60	0	0	0	0	0	0	41	15	224	68	406	107	589	137	771	161	954	180	1136	196
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	7
100	50	0	0	67	37	250	109	432	154	615	186	797	210	980	228	1162	242	1345	254	1527	263
75	50	0	0	0	0	124	54	306	109	489	148	671	177	854	199	1036	216	1219	230	1401	242
60	50	0	0	0	0	75	32	257	92	440	133	622	164	805	187	987	206	1170	221	1352	233
50	50	0	0	0	0	32	14	215	77	397	120	580	153	762	177	945	197	1127	213	1310	226
40	50	0	0	0	0	0	0	123	44	305	93	488	128	670	156	853	178	1035	195	1218	210
25	50	0	0	0	0	0	0	15	6	198	60	380	100	563	131	745	155	928	175	1110	191
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	3
100	40	0	0	46	26	229	99	411	147	594	180	776	204	959	223	1141	238	1324	250	1506	260
75	40	0	0	0	0	103	45	285	102	468	142	650	171	833	194	1015	211	1198	226	1380	238
60	40	0	0	0	0	54	23	236	84	419	127	601	158	784	182	966	201	1149	217	1331	230
50	40	0	0	0	0	11	5	194	69	376	114	559	147	741	172	924	192	1106	209	1289	222
40	40	0	0	0	0	0	0	102	36	284	86	467	123	649	151	832	173	1014	191	1197	206
25	40	0	0	0	0	0	0	0	0	177	54	359	95	542	126	724	151	907	171	1089	188
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	25	0	0	0	0	130	57	313	112	495	150	678	178	860	200	1043	217	1225	231	1408	243
75	25	0	0	0	0	5	2	187	67	370	112	552	145	735	171	917	191	1100	207	1282	221
60	25	0	0	0	0	0	0	138	49	321	97	503	132	686	159	868	181	1051	198	1233	213
50	25	0	0	0	0	0	0	96	34	278	84	461	121	643	150	826	172	1008	190	1191	205
40	25	0	0	0	0	0	0	4	1	186	56	369	97	551	128	734	153	916	173	1099	189
25	25	0	0	0	0	0	0	0	0	79	24	261	69	444	103	626	130	809	153	991	171
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	165	59	347	105	530	139	712	166	895	186	1077	203	1260	217
75	0	0	0	0	0	0	0	39	14	221	67	404	106	586	136	769	160	951	180	1134	196
60	0	0	0	0	0	0	0	0	0	172	52	355	93	537	125	720	150	902	170	1085	187
50	0	0	0	0	0	0	0	0	0	130	39	313	82	495	115	678	141	860	162	1043	180
40	0	0	0	0	0	0	0	0	0	38	11	220	58	403	94	585	122	768	145	950	164
25	0	0	0	0	0	0	0	0	0	0	0	113	30	296	69	478	100	661	125	843	145
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A12: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:40 Longest Winter Period (222 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]
100	100	161	101	234	130	417	181	599	214	782	237	964	254	1147	267	1329	277	1512	285	1694	292
75	100	38	24	111	62	294	128	476	170	659	200	841	221	1024	238	1206	251	1389	262	1571	271
60	100	0	0	63	35	246	107	428	153	611	185	793	209	976	227	1158	241	1341	253	1523	263
50	100	0	0	22	12	204	89	387	138	569	173	752	198	934	217	1117	233	1299	245	1482	255
40	100	0	0	0	0	114	50	297	106	479	145	662	174	844	196	1027	214	1209	228	1392	240
25	100	0	0	0	0	9	4	192	69	374	113	557	147	739	172	922	192	1104	208	1287	222
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	6	216	37
100	75	30	19	103	57	286	124	468	167	651	197	833	219	1016	236	1198	250	1381	261	1563	270
75	75	0	0	0	0	163	71	345	123	528	160	710	187	893	208	1075	224	1258	237	1440	248
60	75	0	0	0	0	115	50	297	106	480	145	662	174	845	196	1027	214	1210	228	1392	240
50	75	0	0	0	0	73	32	256	91	438	133	621	163	803	187	986	205	1168	220	1351	233
40	75	0	0	0	0	0	0	166	59	348	106	531	140	713	166	896	187	1078	203	1261	217
25	75	0	0	0	0	0	0	61	22	243	74	426	112	608	141	791	165	973	184	1156	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	15
100	60	10	6	83	46	265	115	448	160	630	191	813	214	995	231	1178	245	1360	257	1543	266
75	60	0	0	0	0	142	62	324	116	507	154	689	181	872	203	1054	220	1237	233	1419	245
60	60	0	0	0	0	94	41	277	99	459	139	642	169	824	192	1007	210	1189	224	1372	236
50	60	0	0	0	0	53	23	235	84	418	127	600	158	783	182	965	201	1148	217	1330	229
40	60	0	0	0	0	0	0	145	52	328	99	510	134	693	161	875	182	1058	200	1240	214
25	60	0	0	0	0	0	0	40	14	223	67	405	107	588	137	770	160	953	180	1135	196
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	11
100	50	0	0	56	31	238	104	421	150	603	183	786	207	968	225	1151	240	1333	252	1516	261
75	50	0	0	0	0	115	50	298	106	480	146	663	174	845	197	1028	214	1210	228	1393	240
60	50	0	0	0	0	67	29	250	89	432	131	615	162	797	185	980	204	1162	219	1345	232
50	50	0	0	0	0	26	11	208	74	391	118	573	151	756	176	938	196	1121	211	1303	225
40	50	0	0	0	0	0	0	118	42	301	91	483	127	666	155	848	177	1031	195	1213	209
25	50	0	0	0	0	0	0	13	5	196	59	378	100	561	130	743	155	926	175	1108	191
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	6
100	40	0	0	34	19	217	94	399	143	582	176	764	201	947	220	1129	235	1312	247	1494	258
75	40	0	0	0	0	93	41	276	99	458	139	641	169	823	192	1006	210	1188	224	1371	236
60	40	0	0	0	0	46	20	228	81	411	124	593	156	776	180	958	200	1141	215	1323	228
50	40	0	0	0	0	4	2	187	67	369	112	552	145	734	171	917	191	1099	207	1282	221
40	40	0	0	0	0	0	0	97	34	279	85	462	121	644	150	827	172	1009	190	1192	205
25	40	0	0	0	0	0	0	0	0	174	53	357	94	539	125	722	150	904	171	1087	187
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	3
100	25	0	0	0	0	115	50	297	106	480	145	662	174	845	196	1027	214	1210	228	1392	240
75	25	0	0	0	0	0	0	174	62	357	108	539	142	722	168	904	188	1087	205	1269	219
60	25	0	0	0	0	0	0	126	45	309	94	491	129	674	157	856	178	1039	196	1221	211
50	25	0	0	0	0	0	0	85	30	268	81	450	118	633	147	815	170	998	188	1180	203
40	25	0	0	0	0	0	0	0	0	177	54	360	95	542	126	725	151	907	171	1090	188
25	25	0	0	0	0	0	0	0	0	72	22	255	67	437	102	620	129	802	151	985	170
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	144	51	326	99	509	134	691	161	874	182	1056	199	1239	214
75	0	0	0	0	0	0	0	21	7	203	62	386	102	568	132	751	156	933	176	1116	192
60	0	0	0	0	0	0	0	0	0	155	47	338	89	520	121	703	146	885	167	1068	184
50	0	0	0	0	0	0	0	0	0	114	35	296	78	479	111	661	138	844	159	1026	177
40	0	0	0	0	0	0	0	0	0	24	7	206	54	389	90	571	119	754	142	936	161
25	0	0	0	0	0	0	0	0	0	0	0	101	27	284	66	466	97	649	122	831	143
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A13: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:25 Longest Winter Period (215 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	155	97	228	127	411	179	593	212	776	235	958	252	1141	265	1323	276	1506	284	1688	291
75	100	36	22	109	60	291	127	474	169	656	199	839	221	1021	237	1204	251	1386	262	1569	270
60	100	0	0	62	34	244	106	427	152	609	185	792	208	974	227	1157	241	1339	253	1522	262
50	100	0	0	22	12	204	89	387	138	569	172	752	198	934	217	1117	233	1299	245	1482	255
40	100	0	0	0	0	116	51	299	107	481	146	664	175	846	197	1029	214	1211	229	1394	240
25	100	0	0	0	0	14	6	197	70	379	115	562	148	744	173	927	193	1109	209	1292	223
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	12	248	43
100	75	19	12	92	51	275	119	457	163	640	194	822	216	1005	234	1187	247	1370	258	1552	268
75	75	0	0	0	0	155	67	337	120	520	158	702	185	885	206	1067	222	1250	236	1432	247
60	75	0	0	0	0	108	47	291	104	473	143	656	173	838	195	1021	213	1203	227	1386	239
50	75	0	0	0	0	68	29	250	89	433	131	615	162	798	186	980	204	1163	219	1345	232
40	75	0	0	0	0	0	0	163	58	345	105	528	139	710	165	893	186	1075	203	1258	217
25	75	0	0	0	0	0	0	60	22	243	74	425	112	608	141	790	165	973	184	1155	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	112	19
100	60	0	0	71	39	253	110	436	156	618	187	801	211	983	229	1166	243	1348	254	1531	264
75	60	0	0	0	0	133	58	316	113	498	151	681	179	863	201	1046	218	1228	232	1411	243
60	60	0	0	0	0	87	38	269	96	452	137	634	167	817	190	999	208	1182	223	1364	235
50	60	0	0	0	0	46	20	229	82	411	125	594	156	776	181	959	200	1141	215	1324	228
40	60	0	0	0	0	0	0	141	50	324	98	506	133	689	160	871	181	1054	199	1236	213
25	60	0	0	0	0	0	0	39	14	221	67	404	106	586	136	769	160	951	179	1134	195
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	16
100	50	0	0	43	24	225	98	408	146	590	179	773	203	955	222	1138	237	1320	249	1503	259
75	50	0	0	0	0	106	46	288	103	471	143	653	172	836	194	1018	212	1201	227	1383	238
60	50	0	0	0	0	59	26	241	86	424	128	606	160	789	183	971	202	1154	218	1336	230
50	50	0	0	0	0	18	8	201	72	383	116	566	149	748	174	931	194	1113	210	1296	223
40	50	0	0	0	0	0	0	113	40	296	90	478	126	661	154	843	176	1026	194	1208	208
25	50	0	0	0	0	0	0	11	4	194	59	376	99	559	130	741	154	924	174	1106	191
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	11
100	40	0	0	20	11	203	88	385	138	568	172	750	197	933	217	1115	232	1298	245	1480	255
75	40	0	0	0	0	83	36	265	95	448	136	630	166	813	189	995	207	1178	222	1360	235
60	40	0	0	0	0	36	16	219	78	401	122	584	154	766	178	949	198	1131	213	1314	226
50	40	0	0	0	0	0	0	178	64	361	109	543	143	726	169	908	189	1091	206	1273	220
40	40	0	0	0	0	0	0	91	32	273	83	456	120	638	148	821	171	1003	189	1186	204
25	40	0	0	0	0	0	0	0	0	171	52	353	93	536	125	718	150	901	170	1083	187
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	7
100	25	0	0	0	0	97	42	279	100	462	140	644	170	827	192	1009	210	1192	225	1374	237
75	25	0	0	0	0	0	0	160	57	342	104	525	138	707	164	890	185	1072	202	1255	216
60	25	0	0	0	0	0	0	113	40	295	90	478	126	660	154	843	176	1025	193	1208	208
50	25	0	0	0	0	0	0	73	26	255	77	438	115	620	144	803	167	985	186	1168	201
40	25	0	0	0	0	0	0	0	0	167	51	350	92	532	124	715	149	897	169	1080	186
25	25	0	0	0	0	0	0	0	0	65	20	248	65	430	100	613	128	795	150	978	169
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	120	43	302	92	485	128	667	155	850	177	1032	195	1215	209
75	0	0	0	0	0	0	0	0	0	182	55	365	96	547	127	730	152	912	172	1095	189
60	0	0	0	0	0	0	0	0	0	136	41	318	84	501	116	683	142	866	163	1048	181
50	0	0	0	0	0	0	0	0	0	95	29	278	73	460	107	643	134	825	156	1008	174
40	0	0	0	0	0	0	0	0	0	8	2	190	50	373	87	555	116	738	139	920	159
25	0	0	0	0	0	0	0	0	0	0	0	88	23	270	63	453	94	635	120	818	141
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A14: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Shortest Winter Period (195 days) under 2050s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2, 4]	Number of Days In Water Deficit[2]
100	100	135	84	208	115	390	170	573	204	755	229	938	247	1120	260	1303	271	1485	280	1668	288
75	100	26	16	99	55	282	123	464	166	647	196	829	218	1012	235	1194	249	1377	260	1559	269
60	100	0	0	57	32	240	104	422	151	605	183	787	207	970	226	1152	240	1335	252	1517	262
50	100	0	0	21	12	203	88	386	138	568	172	751	198	933	217	1116	232	1298	245	1481	255
40	100	0	0	0	0	124	54	307	109	489	148	672	177	854	199	1037	216	1219	230	1402	242
25	100	0	0	0	0	32	14	214	77	397	120	579	152	762	177	944	197	1127	213	1309	226
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	185	35	368	63
100	75	0	0	52	29	235	102	417	149	600	182	782	206	965	224	1147	239	1330	251	1512	261
75	75	0	0	0	0	126	55	309	110	491	149	674	177	856	199	1039	216	1221	230	1404	242
60	75	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	222	1362	235
50	75	0	0	0	0	48	21	230	82	413	125	595	157	778	181	960	200	1143	216	1325	228
40	75	0	0	0	0	0	0	151	54	334	101	516	136	699	162	881	184	1064	201	1246	215
25	75	0	0	0	0	0	0	59	21	241	73	424	112	606	141	789	164	971	183	1154	199
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	6	212	37
100	60	0	0	27	15	210	91	392	140	575	174	757	199	940	219	1122	234	1305	246	1487	256
75	60	0	0	0	0	102	44	284	102	467	141	649	171	832	193	1014	211	1197	226	1379	238
60	60	0	0	0	0	60	26	242	86	425	129	607	160	790	184	972	203	1155	218	1337	231
50	60	0	0	0	0	23	10	206	73	388	118	571	150	753	175	936	195	1118	211	1301	224
40	60	0	0	0	0	0	0	126	45	309	94	491	129	674	157	856	178	1039	196	1221	211
25	60	0	0	0	0	0	0	34	12	217	66	399	105	582	135	764	159	947	179	1129	195
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	187	32
100	50	0	0	0	0	178	78	361	129	543	165	726	191	908	211	1091	227	1273	240	1456	251
75	50	0	0	0	0	70	30	253	90	435	132	618	163	800	186	983	205	1165	220	1348	232
60	50	0	0	0	0	28	12	210	75	393	119	575	151	758	176	940	196	1123	212	1305	225
50	50	0	0	0	0	0	0	174	62	357	108	539	142	722	168	904	188	1087	205	1269	219
40	50	0	0	0	0	0	0	95	34	277	84	460	121	642	149	825	172	1007	190	1190	205
25	50	0	0	0	0	0	0	3	1	185	56	368	97	550	128	733	153	915	173	1098	189
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156	27
100	40	0	0	0	0	152	66	335	120	517	157	700	184	882	205	1065	222	1247	235	1430	247
75	40	0	0	0	0	44	19	227	81	409	124	592	156	774	180	957	199	1139	215	1322	228
60	40	0	0	0	0	2	1	184	66	367	111	549	145	732	170	914	191	1097	207	1279	221
50	40	0	0	0	0	0	0	148	53	331	100	513	135	696	162	878	183	1061	200	1243	214
40	40	0	0	0	0	0	0	69	25	251	76	434	114	616	143	799	166	981	185	1164	201
25	40	0	0	0	0	0	0	0	0	159	48	342	90	524	122	707	147	889	168	1072	185
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	22
100	25	0	0	0	0	32	14	214	77	397	120	579	152	762	177	944	197	1127	213	1309	226
75	25	0	0	0	0	0	0	106	38	289	87	471	124	654	152	836	174	1019	192	1201	207
60	25	0	0	0	0	0	0	64	23	246	75	429	113	611	142	794	165	976	184	1159	200
50	25	0	0	0	0	0	0	27	10	210	64	392	103	575	134	757	158	940	177	1122	194
40	25	0	0	0	0	0	0	0	0	131	40	313	82	496	115	678	141	861	162	1043	180
25	25	0	0	0	0	0	0	0	0	39	12	221	58	404	94	586	122	769	145	951	164
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	2
100	0	0	0	0	0	0	0	32	11	214	65	397	104	579	135	762	159	944	178	1127	194
75	0	0	0	0	0	0	0	0	0	106	32	289	76	471	110	654	136	836	158	1019	176
60	0	0	0	0	0	0	0	0	0	64	19	247	65	429	100	612	127	794	150	977	168
50	0	0	0	0	0	0	0	0	0	28	8	210	55	393	91	575	120	758	143	940	162
40	0	0	0	0	0	0	0	0	0	0	0	131	34	313	73	496	103	678	128	861	148
25	0	0	0	0	0	0	0	0	0	0	0	39	10	221	51	404	84	586	111	769	133
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A15: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Longest Winter Period (248 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	182	114	255	142	437	190	620	221	802	243	985	259	1167	271	1350	281	1532	289	1715	296
75	100	56	35	129	71	311	135	494	176	676	205	859	226	1041	242	1224	255	1406	265	1589	274
60	100	16	10	89	49	271	118	454	162	636	193	819	215	1001	233	1184	247	1366	258	1549	267
50	100	0	0	37	21	220	96	402	144	585	177	767	202	950	221	1132	236	1315	248	1497	258
40	100	0	0	0	0	150	65	332	119	515	156	697	183	880	205	1062	221	1245	235	1427	246
25	100	0	0	0	0	28	12	210	75	393	119	575	151	758	176	940	196	1123	212	1305	225
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183	32
100	75	82	51	155	86	337	147	520	186	702	213	885	233	1067	248	1250	260	1432	270	1615	278
75	75	0	0	28	16	211	92	393	141	576	175	758	200	941	219	1123	234	1306	246	1488	257
60	75	0	0	0	0	171	74	354	126	536	162	719	189	901	210	1084	226	1266	239	1449	250
50	75	0	0	0	0	120	52	302	108	485	147	667	176	850	198	1032	215	1215	229	1397	241
40	75	0	0	0	0	50	22	232	83	415	126	597	157	780	181	962	200	1145	216	1327	229
25	75	0	0	0	0	0	0	110	39	293	89	475	125	658	153	840	175	1023	193	1205	208
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	14
100	60	61	38	134	75	317	138	499	178	682	207	864	227	1047	243	1229	256	1412	266	1594	275
75	60	0	0	8	4	190	83	373	133	555	168	738	194	920	214	1103	230	1285	243	1468	253
60	60	0	0	0	0	151	65	333	119	516	156	698	184	881	205	1063	221	1246	235	1428	246
50	60	0	0	0	0	99	43	282	101	464	141	647	170	829	193	1012	211	1194	225	1377	237
40	60	0	0	0	0	29	13	212	76	394	119	577	152	759	177	942	196	1124	212	1307	225
25	60	0	0	0	0	0	0	90	32	272	83	455	120	637	148	820	171	1002	189	1185	204
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	11
100	50	45	28	118	66	301	131	483	173	666	202	848	223	1031	240	1213	253	1396	263	1578	272
75	50	0	0	0	0	174	76	357	127	539	163	722	190	904	210	1087	226	1269	240	1452	250
60	50	0	0	0	0	135	58	317	113	500	151	682	179	865	201	1047	218	1230	232	1412	243
50	50	0	0	0	0	83	36	266	95	448	136	631	166	813	189	996	207	1178	222	1361	235
40	50	0	0	0	0	13	6	196	70	378	115	561	148	743	173	926	193	1108	209	1291	223
25	50	0	0	0	0	0	0	74	26	256	78	439	115	621	144	804	167	986	186	1169	202
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	8
100	40	19	12	92	51	275	119	457	163	640	194	822	216	1005	234	1187	247	1370	258	1552	268
75	40	0	0	0	0	148	65	331	118	513	156	696	183	878	204	1061	221	1243	235	1426	246
60	40	0	0	0	0	109	47	291	104	474	143	656	173	839	195	1021	213	1204	227	1386	239
50	40	0	0	0	0	57	25	240	86	422	128	605	159	787	183	970	202	1152	217	1335	230
40	40	0	0	0	0	0	0	170	61	352	107	535	141	717	167	900	187	1082	204	1265	218
25	40	0	0	0	0	0	0	48	17	230	70	413	109	595	138	778	162	960	181	1143	197
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	3
100	25	0	0	3	2	186	81	368	132	551	167	733	193	916	213	1098	229	1281	242	1463	252
75	25	0	0	0	0	60	26	242	86	425	129	607	160	790	184	972	203	1155	218	1337	231
60	25	0	0	0	0	20	9	202	72	385	117	567	149	750	174	932	194	1115	210	1297	224
50	25	0	0	0	0	0	0	151	54	334	101	516	136	699	162	881	184	1064	201	1246	215
40	25	0	0	0	0	0	0	81	29	263	80	446	117	628	146	811	169	993	187	1176	203
25	25	0	0	0	0	0	0	0	0	142	43	324	85	507	118	689	144	872	164	1054	182
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	68	30	251	89	433	131	616	162	798	186	981	204	1163	219	1346	232
75	0	0	0	0	0	0	0	124	44	307	93	489	129	672	156	854	178	1037	196	1219	210
60	0	0	0	0	0	0	0	84	30	267	81	449	118	632	147	814	170	997	188	1179	203
50	0	0	0	0	0	0	0	33	12	216	65	398	105	581	135	763	159	946	178	1128	195
40	0	0	0	0	0	0	0	0	0	145	44	328	86	510	119	693	144	875	165	1058	182
25	0	0	0	0	0	0	0	0	0	24	7	206	54	389	90	571	119	754	142	936	161
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A16: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:75 Longest Winter Period (231 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	166	104	239	133	422	183	604	216	787	238	969	255	1152	268	1334	278	1517	286	1699	293
75	100	49	30	122	68	304	132	487	174	669	203	852	224	1034	241	1217	253	1399	264	1582	273
60	100	12	7	85	47	267	116	450	161	632	192	815	214	997	232	1180	246	1362	257	1545	266
50	100	0	0	37	21	219	95	402	144	584	177	767	202	949	221	1132	236	1314	248	1497	258
40	100	0	0	0	0	154	67	337	120	519	157	702	185	884	206	1067	222	1249	236	1432	247
25	100	0	0	0	0	41	18	223	80	406	123	588	155	771	179	953	199	1136	214	1318	227
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	17	274	47
100	75	51	32	124	69	307	133	489	175	672	204	854	225	1037	241	1219	254	1402	264	1584	273
75	75	0	0	7	4	189	82	372	133	554	168	737	194	919	214	1102	230	1284	242	1467	253
60	75	0	0	0	0	152	66	335	120	517	157	700	184	882	205	1065	222	1247	235	1430	247
50	75	0	0	0	0	105	45	287	103	470	142	652	172	835	194	1017	212	1200	226	1382	238
40	75	0	0	0	0	39	17	222	79	404	122	587	154	769	179	952	198	1134	214	1317	227
25	75	0	0	0	0	0	0	108	39	291	88	473	125	656	153	838	175	1021	193	1203	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	27
100	60	28	17	101	56	283	123	466	166	648	196	831	219	1013	236	1196	249	1378	260	1561	269
75	60	0	0	0	0	166	72	348	124	531	161	713	188	896	208	1078	225	1261	238	1443	249
60	60	0	0	0	0	129	56	311	111	494	150	676	178	859	200	1041	217	1224	231	1406	242
50	60	0	0	0	0	81	35	264	94	446	135	629	165	811	189	994	207	1176	222	1359	234
40	60	0	0	0	0	16	7	198	71	381	115	563	148	746	173	928	193	1111	210	1293	223
25	60	0	0	0	0	0	0	85	30	267	81	450	118	632	147	815	170	997	188	1180	203
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135	23
100	50	9	6	82	46	265	115	447	160	630	191	812	214	995	231	1177	245	1360	257	1542	266
75	50	0	0	0	0	148	64	330	118	513	155	695	183	878	204	1060	221	1243	234	1425	246
60	50	0	0	0	0	110	48	293	105	475	144	658	173	840	195	1023	213	1205	227	1388	239
50	50	0	0	0	0	63	27	245	88	428	130	610	161	793	184	975	203	1158	218	1340	231
40	50	0	0	0	0	0	0	180	64	362	110	545	143	727	169	910	190	1092	206	1275	220
25	50	0	0	0	0	0	0	67	24	249	75	432	114	614	143	797	166	979	185	1162	200
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	20
100	40	0	0	53	29	235	102	418	149	600	182	783	206	965	224	1148	239	1330	251	1513	261
75	40	0	0	0	0	118	51	300	107	483	146	665	175	848	197	1030	215	1213	229	1395	241
60	40	0	0	0	0	81	35	263	94	446	135	628	165	811	189	993	207	1176	222	1358	234
50	40	0	0	0	0	33	14	215	77	398	121	580	153	763	177	945	197	1128	213	1310	226
40	40	0	0	0	0	0	0	150	54	333	101	515	136	698	162	880	183	1063	200	1245	215
25	40	0	0	0	0	0	0	37	13	219	66	402	106	584	136	767	160	949	179	1132	195
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87	15
100	25	0	0	0	0	133	58	316	113	498	151	681	179	863	201	1046	218	1228	232	1411	243
75	25	0	0	0	0	16	7	198	71	381	115	563	148	746	173	928	193	1111	210	1293	223
60	25	0	0	0	0	0	0	161	58	344	104	526	138	709	165	891	186	1074	203	1256	217
50	25	0	0	0	0	0	0	114	41	296	90	479	126	661	154	844	176	1026	194	1209	208
40	25	0	0	0	0	0	0	48	17	231	70	413	109	596	139	778	162	961	181	1143	197
25	25	0	0	0	0	0	0	0	0	117	36	300	79	482	112	665	139	847	160	1030	178
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	181	65	363	110	546	144	728	169	911	190	1093	206	1276	220
75	0	0	0	0	0	0	0	63	23	246	74	428	113	611	142	793	165	976	184	1158	200
60	0	0	0	0	0	0	0	26	9	209	63	391	103	574	133	756	158	939	177	1121	193
50	0	0	0	0	0	0	0	0	0	161	49	343	90	526	122	708	148	891	168	1073	185
40	0	0	0	0	0	0	0	0	0	96	29	278	73	461	107	643	134	826	156	1008	174
25	0	0	0	0	0	0	0	0	0	0	0	165	43	347	81	530	110	712	134	895	154
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A17: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:60 Longest Winter Period (225 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m³)																			
		1600		1800		2300		2800		3300		3800		4300		4800		**5300**		**5800**	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	161	101	234	130	416	181	599	214	781	237	964	254	1146	267	1329	277	1511	285	1694	292
75	100	46	29	119	66	302	131	484	173	667	202	849	224	1032	240	1214	253	1397	264	1579	272
60	100	10	6	83	46	266	116	448	160	631	191	813	214	996	232	1178	245	1361	257	1543	266
50	100	0	0	37	20	219	95	402	144	584	177	767	202	949	221	1132	236	1314	248	1497	258
40	100	0	0	0	0	156	68	338	121	521	158	703	185	886	206	1068	223	1251	236	1433	247
25	100	0	0	0	0	45	20	228	81	410	124	593	156	775	180	958	200	1140	215	1323	228
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	23	304	52
100	75	41	26	114	63	297	129	479	171	662	200	844	222	1027	239	1209	252	1392	263	1574	271
75	75	0	0	0	0	182	79	365	130	547	166	730	192	912	212	1095	228	1277	241	1460	252
60	75	0	0	0	0	146	63	328	117	511	155	693	182	876	204	1058	221	1241	234	1423	245
50	75	0	0	0	0	99	43	282	101	464	141	647	170	829	193	1012	211	1194	225	1377	237
40	75	0	0	0	0	36	16	218	78	401	121	583	153	766	178	948	198	1131	213	1313	226
25	75	0	0	0	0	0	0	108	38	290	88	473	124	655	152	838	175	1020	193	1203	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	184	32
100	60	17	10	90	50	272	118	455	162	637	193	820	216	1002	233	1185	247	1367	258	1550	267
75	60	0	0	0	0	158	69	340	121	523	158	705	186	888	206	1070	223	1253	236	1435	247
60	60	0	0	0	0	121	53	304	109	486	147	669	176	851	198	1034	215	1216	230	1399	241
50	60	0	0	0	0	75	33	257	92	440	133	622	164	805	187	987	206	1170	221	1352	233
40	60	0	0	0	0	11	5	194	69	376	114	559	147	741	172	924	192	1106	209	1289	222
25	60	0	0	0	0	0	0	83	30	266	81	448	118	631	147	813	169	996	188	1178	203
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	28
100	50	0	0	70	39	253	110	435	156	618	187	800	211	983	229	1165	243	1348	254	1530	264
75	50	0	0	0	0	138	60	321	115	503	153	686	181	868	202	1051	219	1233	233	1416	244
60	50	0	0	0	0	102	44	285	102	467	142	650	171	832	194	1015	211	1197	226	1380	238
50	50	0	0	0	0	56	24	238	85	421	128	603	159	786	183	968	202	1151	217	1333	230
40	50	0	0	0	0	0	0	175	62	357	108	540	142	722	168	905	188	1087	205	1270	219
25	50	0	0	0	0	0	0	64	23	247	75	429	113	612	142	794	165	977	184	1159	200
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141	24
100	40	0	0	39	22	222	96	404	144	587	178	769	202	952	221	1134	236	1317	248	1499	259
75	40	0	0	0	0	107	47	290	104	472	143	655	172	837	195	1020	212	1202	227	1385	239
60	40	0	0	0	0	71	31	254	91	436	132	619	163	801	186	984	205	1166	220	1349	233
50	40	0	0	0	0	25	11	207	74	390	118	572	151	755	176	937	195	1120	211	1302	225
40	40	0	0	0	0	0	0	143	51	326	99	508	134	691	161	873	182	1056	199	1238	214
25	40	0	0	0	0	0	0	33	12	216	65	398	105	581	135	763	159	946	178	1128	194
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	109	19
100	25	0	0	0	0	116	50	298	106	481	146	663	175	846	197	1028	214	1211	228	1393	240
75	25	0	0	0	0	1	0	184	66	366	111	549	144	731	170	914	190	1096	207	1279	220
60	25	0	0	0	0	0	0	147	53	330	100	512	135	695	162	877	183	1060	200	1242	214
50	25	0	0	0	0	0	0	101	36	283	86	466	123	648	151	831	173	1013	191	1196	206
40	25	0	0	0	0	0	0	37	13	220	67	402	106	585	136	767	160	950	179	1132	195
25	25	0	0	0	0	0	0	0	0	109	33	292	77	474	110	657	137	839	158	1022	176
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
100	0	0	0	0	0	0	0	157	56	340	103	522	137	705	164	887	185	1070	202	1252	216
75	0	0	0	0	0	0	0	43	15	225	68	408	107	590	137	773	161	955	180	1138	196
60	0	0	0	0	0	0	0	6	2	189	57	371	98	554	129	736	153	919	173	1101	190
50	0	0	0	0	0	0	0	0	0	142	43	325	86	507	118	690	144	872	165	1055	182
40	0	0	0	0	0	0	0	0	0	79	24	261	69	444	103	626	130	809	153	991	171
25	0	0	0	0	0	0	0	0	0	0	0	151	40	333	78	516	107	698	132	881	152
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A18: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:50 Longest Winter Period (220 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2,4]	Number of Days In Water Deficit [2]
100	100	157	98	230	128	413	179	595	213	778	236	960	253	1143	266	1325	276	1508	284	1690	291
75	100	45	28	118	65	300	131	483	172	665	202	848	223	1030	240	1213	253	1395	263	1578	272
60	100	9	6	82	46	265	115	447	160	630	191	812	214	995	231	1177	245	1360	257	1542	266
50	100	0	0	37	20	219	95	402	143	584	177	767	202	949	221	1132	236	1314	248	1497	258
40	100	0	0	0	0	157	68	339	121	522	158	704	185	887	206	1069	223	1252	236	1434	247
25	100	0	0	0	0	48	21	231	82	413	125	596	157	778	181	961	200	1143	216	1326	229
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145	27	327	56
100	75	33	21	106	59	289	126	471	168	654	198	836	220	1019	237	1201	250	1384	261	1566	270
75	75	0	0	0	0	177	77	359	128	542	164	724	191	907	211	1089	227	1272	240	1454	251
60	75	0	0	0	0	141	61	324	116	506	153	689	181	871	203	1054	220	1236	233	1419	245
50	75	0	0	0	0	96	42	278	99	461	140	643	169	826	192	1008	210	1191	225	1373	237
40	75	0	0	0	0	33	14	216	77	398	121	581	153	763	177	946	197	1128	213	1311	226
25	75	0	0	0	0	0	0	107	38	290	88	472	124	655	152	837	174	1020	192	1202	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	4	204	35
100	60	8	5	81	45	264	115	446	159	629	190	811	213	994	231	1176	245	1359	256	1541	266
75	60	0	0	0	0	151	66	334	119	516	156	699	184	881	205	1064	222	1246	235	1429	246
60	60	0	0	0	0	116	50	298	107	481	146	663	175	846	197	1028	214	1211	228	1393	240
50	60	0	0	0	0	70	31	253	90	435	132	618	163	800	186	983	205	1165	220	1348	232
40	60	0	0	0	0	8	3	190	68	373	113	555	146	738	172	920	192	1103	208	1285	222
25	60	0	0	0	0	0	0	82	29	265	80	447	118	630	146	812	169	995	188	1177	203
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	178	31
100	50	0	0	61	34	244	106	426	152	609	185	791	208	974	226	1156	241	1339	253	1521	262
75	50	0	0	0	0	132	57	314	112	497	150	679	179	862	200	1044	218	1227	231	1409	243
60	50	0	0	0	0	96	42	279	100	461	140	644	169	826	192	1009	210	1191	225	1374	237
50	50	0	0	0	0	51	22	233	83	416	126	598	157	781	182	963	201	1146	216	1328	229
40	50	0	0	0	0	0	0	171	61	353	107	536	141	718	167	901	188	1083	204	1266	218
25	50	0	0	0	0	0	0	62	22	245	74	427	112	610	142	792	165	975	184	1157	200
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	27
100	40	0	0	29	16	212	92	394	141	577	175	759	200	942	219	1124	234	1307	247	1489	257
75	40	0	0	0	0	100	43	282	101	465	141	647	170	830	193	1012	211	1195	225	1377	237
60	40	0	0	0	0	64	28	247	88	429	130	612	161	794	185	977	203	1159	219	1342	231
50	40	0	0	0	0	18	8	201	72	383	116	566	149	748	174	931	194	1113	210	1296	223
40	40	0	0	0	0	0	0	138	49	321	97	503	132	686	160	868	181	1051	198	1233	213
25	40	0	0	0	0	0	0	30	11	213	64	395	104	578	134	760	158	943	178	1125	194
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	22
100	25	0	0	0	0	102	44	285	102	467	142	650	171	832	194	1015	211	1197	226	1380	238
75	25	0	0	0	0	0	0	172	62	355	108	537	141	720	167	902	188	1085	205	1267	219
60	25	0	0	0	0	0	0	137	49	319	97	502	132	684	159	867	181	1049	198	1232	212
50	25	0	0	0	0	0	0	91	33	274	83	456	120	639	149	821	171	1004	189	1186	205
40	25	0	0	0	0	0	0	29	10	211	64	394	104	576	134	759	158	941	178	1124	194
25	25	0	0	0	0	0	0	0	0	103	31	286	75	468	109	651	136	833	157	1016	175
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	3
100	0	0	0	0	0	0	0	139	50	322	98	504	133	687	160	869	181	1052	198	1234	213
75	0	0	0	0	0	0	0	27	10	210	63	392	103	575	134	757	158	940	177	1122	193
60	0	0	0	0	0	0	0	0	0	174	53	357	94	539	125	722	150	904	171	1087	187
50	0	0	0	0	0	0	0	0	0	128	39	311	82	493	115	676	141	858	162	1041	179
40	0	0	0	0	0	0	0	0	0	66	20	249	65	431	100	614	128	796	150	979	169
25	0	0	0	0	0	0	0	0	0	0	0	140	37	323	75	505	105	688	130	870	150
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A19: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:40 Longest Winter Period (215 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]	Water Supply Deficit (ML) [2, 4]	Number of Days In Water Deficit [2]
100	100	152	95	225	125	407	177	590	211	772	234	955	251	1137	264	1320	275	1502	283	1685	290
75	100	42	27	115	64	298	130	480	172	663	201	845	222	1028	239	1210	252	1393	263	1575	272
60	100	8	5	81	45	263	115	446	159	628	190	811	213	993	231	1176	245	1358	256	1541	266
50	100	0	0	37	20	219	95	402	143	584	177	767	202	949	221	1132	236	1314	248	1497	258
40	100	0	0	0	0	158	69	341	122	523	159	706	186	888	207	1071	223	1253	236	1436	248
25	100	0	0	0	0	53	23	235	84	418	127	600	158	783	182	965	201	1148	217	1330	229
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	33	358	62
100	75	23	14	96	53	279	121	461	165	644	195	826	217	1009	235	1191	248	1374	259	1556	268
75	75	0	0	0	0	169	74	352	126	534	162	717	189	899	209	1082	225	1264	239	1447	249
60	75	0	0	0	0	135	59	317	113	500	151	682	180	865	201	1047	218	1230	232	1412	244
50	75	0	0	0	0	90	39	273	97	455	138	638	168	820	191	1003	209	1185	224	1368	236
40	75	0	0	0	0	30	13	212	76	395	120	577	152	760	177	942	196	1125	212	1307	225
25	75	0	0	0	0	0	0	107	38	289	88	472	124	654	152	837	174	1019	192	1202	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	9	229	40
100	60	0	0	70	39	252	110	435	155	617	187	800	211	982	228	1165	243	1347	254	1530	264
75	60	0	0	0	0	143	62	326	116	508	154	691	182	873	203	1056	220	1238	234	1421	245
60	60	0	0	0	0	109	47	291	104	474	143	656	173	839	195	1021	213	1204	227	1386	239
50	60	0	0	0	0	64	28	247	88	429	130	612	161	794	185	977	203	1159	219	1342	231
40	60	0	0	0	0	3	1	186	66	368	112	551	145	733	171	916	191	1098	207	1281	221
25	60	0	0	0	0	0	0	80	29	263	80	445	117	628	146	810	169	993	187	1175	203
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	4	203	35
100	50	0	0	49	27	232	101	414	148	597	181	779	205	962	224	1144	238	1327	250	1509	260
75	50	0	0	0	0	123	53	305	109	488	148	670	176	853	198	1035	216	1218	230	1400	241
60	50	0	0	0	0	88	38	270	97	453	137	635	167	818	190	1000	208	1183	223	1365	235
50	50	0	0	0	0	44	19	226	81	409	124	591	156	774	180	956	199	1139	215	1321	228
40	50	0	0	0	0	0	0	165	59	348	105	530	140	713	166	895	187	1078	203	1260	217
25	50	0	0	0	0	0	0	60	21	242	73	425	112	607	141	790	165	972	183	1155	199
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	31
100	40	0	0	16	9	198	86	381	136	563	171	746	196	928	216	1111	231	1293	244	1476	254
75	40	0	0	0	0	89	39	272	97	454	138	637	168	819	191	1002	209	1184	223	1367	236
60	40	0	0	0	0	55	24	237	85	420	127	602	158	785	182	967	201	1150	217	1332	230
50	40	0	0	0	0	10	4	193	69	375	114	558	147	740	172	923	192	1105	209	1288	222
40	40	0	0	0	0	0	0	132	47	314	95	497	131	679	158	862	180	1044	197	1227	212
25	40	0	0	0	0	0	0	26	9	209	63	391	103	574	133	756	158	939	177	1121	193
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	149	26
100	25	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	223	1362	235
75	25	0	0	0	0	0	0	158	56	340	103	523	138	705	164	888	185	1070	202	1253	216
60	25	0	0	0	0	0	0	123	44	306	93	488	128	671	156	853	178	1036	195	1218	210
50	25	0	0	0	0	0	0	79	28	261	79	444	117	626	146	809	168	991	187	1174	202
40	25	0	0	0	0	0	0	18	6	200	61	383	101	565	131	748	156	930	176	1113	192
25	25	0	0	0	0	0	0	0	0	95	29	277	73	460	107	642	134	825	156	1007	174
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	6
100	0	0	0	0	0	0	0	116	41	298	90	481	127	663	154	846	176	1028	194	1211	209
75	0	0	0	0	0	0	0	6	2	189	57	371	98	554	129	736	153	919	173	1101	190
60	0	0	0	0	0	0	0	0	0	154	47	337	89	519	121	702	146	884	167	1067	184
50	0	0	0	0	0	0	0	0	0	110	33	292	77	475	110	657	137	840	158	1022	176
40	0	0	0	0	0	0	0	0	0	49	15	232	61	414	96	597	124	779	147	962	166
25	0	0	0	0	0	0	0	0	0	0	0	126	33	309	72	491	102	674	127	856	148
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A20: Predicted Water Supply Deficits and Potential Number of Days Without Water during the 1:25 Longest Winter Period (212 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	149	93	222	123	405	176	587	210	770	233	952	251	1135	264	1317	274	1500	283	1682	290
75	100	41	26	114	64	297	129	479	171	662	201	844	222	1027	239	1209	252	1392	263	1574	271
60	100	7	5	80	45	263	114	445	159	628	190	810	213	993	231	1175	245	1358	256	1540	266
50	100	0	0	36	20	219	95	401	143	584	177	766	202	949	221	1131	236	1314	248	1496	258
40	100	0	0	0	0	159	69	341	122	524	159	706	186	889	207	1071	223	1254	237	1436	248
25	100	0	0	0	0	55	24	237	85	420	127	602	159	785	183	967	202	1150	217	1332	230
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	190	36	373	64
100	75	18	11	91	51	274	119	456	163	639	194	821	216	1004	233	1186	247	1369	258	1551	267
75	75	0	0	0	0	166	72	348	124	531	161	713	188	896	208	1078	225	1261	238	1443	249
60	75	0	0	0	0	132	57	314	112	497	151	679	179	862	200	1044	218	1227	231	1409	243
50	75	0	0	0	0	88	38	270	97	453	137	635	167	818	190	1000	208	1183	223	1365	235
40	75	0	0	0	0	28	12	210	75	393	119	575	151	758	176	940	196	1123	212	1305	225
25	75	0	0	0	0	0	0	106	38	289	88	471	124	654	152	836	174	1019	192	1201	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	11	242	42
100	60	0	0	64	36	247	107	429	153	612	185	794	209	977	227	1159	242	1342	253	1524	263
75	60	0	0	0	0	139	60	322	115	504	153	687	181	869	202	1052	219	1234	233	1417	244
60	60	0	0	0	0	105	46	288	103	470	142	653	172	835	194	1018	212	1200	226	1383	238
50	60	0	0	0	0	61	27	244	87	426	129	609	160	791	184	974	203	1156	218	1339	231
40	60	0	0	0	0	1	1	184	66	366	111	549	144	731	170	914	190	1096	207	1279	220
25	60	0	0	0	0	0	0	80	28	262	79	445	117	627	146	810	169	992	187	1175	203
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	6	215	37
100	50	0	0	44	24	226	98	409	146	591	179	774	204	956	222	1139	237	1321	249	1504	259
75	50	0	0	0	0	118	51	301	107	483	146	666	175	848	197	1031	215	1213	229	1396	241
60	50	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	222	1362	235
50	50	0	0	0	0	40	17	223	80	405	123	588	155	770	179	953	198	1135	214	1318	227
40	50	0	0	0	0	0	0	163	58	345	105	528	139	710	165	893	186	1075	203	1258	217
25	50	0	0	0	0	0	0	59	21	241	73	424	111	606	141	789	164	971	183	1154	199
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	2	194	33
100	40	0	0	10	5	192	83	375	134	557	169	740	195	922	214	1105	230	1287	243	1470	253
75	40	0	0	0	0	84	37	267	95	449	136	632	166	814	189	997	208	1179	222	1362	235
60	40	0	0	0	0	50	22	233	83	415	126	598	157	780	181	963	201	1145	216	1328	229
50	40	0	0	0	0	6	3	189	67	371	112	554	146	736	171	919	191	1101	208	1284	221
40	40	0	0	0	0	0	0	129	46	311	94	494	130	676	157	859	179	1041	196	1224	211
25	40	0	0	0	0	0	0	25	9	207	63	390	103	572	133	755	157	937	177	1120	193
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	28
100	25	0	0	0	0	76	33	258	92	441	134	623	164	806	187	988	206	1171	221	1353	233
75	25	0	0	0	0	0	0	151	54	333	101	516	136	698	162	881	183	1063	201	1246	215
60	25	0	0	0	0	0	0	116	42	299	91	481	127	664	154	846	176	1029	194	1211	209
50	25	0	0	0	0	0	0	73	26	255	77	438	115	620	144	803	167	985	186	1168	201
40	25	0	0	0	0	0	0	13	5	195	59	378	99	560	130	743	155	925	175	1108	191
25	25	0	0	0	0	0	0	0	0	91	28	274	72	456	106	639	133	821	155	1004	173
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	8
100	0	0	0	0	0	0	0	104	37	287	87	469	124	652	152	834	174	1017	192	1199	207
75	0	0	0	0	0	0	0	0	0	179	54	361	95	544	127	726	151	909	172	1091	188
60	0	0	0	0	0	0	0	0	0	145	44	327	86	510	119	692	144	875	165	1057	182
50	0	0	0	0	0	0	0	0	0	101	31	284	75	466	108	649	135	831	157	1014	175
40	0	0	0	0	0	0	0	0	0	41	12	224	59	406	94	589	123	771	145	954	164
25	0	0	0	0	0	0	0	0	0	0	0	119	31	302	70	484	101	667	126	849	146
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

Table A21: Predicted Water Supply Deficits and Potential Number of Days Without Water during the Shortest Winter Period (188 days) under 2080s Climatic Regime

Percentage Probability of Exceedance		Daily Consumption Rate (m^3)																			
		1600		1800		2300		2800		3300		3800		4300		4800		5300		5800	
Snow Accumulation[1,3]	Rainfall Runoff[1]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]	Water Supply Deficit (ML)[2,4]	Number of Days In Water Deficit[2]
100	100	128	80	201	111	383	167	566	202	748	227	931	245	1113	259	1296	270	1478	279	1661	286
75	100	32	20	105	58	287	125	470	168	652	198	835	220	1017	237	1200	250	1382	261	1565	270
60	100	2	1	75	41	257	112	440	157	622	189	805	212	987	230	1170	244	1352	255	1535	265
50	100	0	0	36	20	218	95	401	143	583	177	766	202	948	221	1131	236	1313	248	1496	258
40	100	0	0	0	0	165	72	348	124	530	161	713	188	895	208	1078	224	1260	238	1443	249
25	100	0	0	0	0	73	32	255	91	438	133	620	163	803	187	985	205	1168	220	1350	233
0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	134	28	317	60	499	86
100	75	0	0	49	27	232	101	414	148	597	181	779	205	962	224	1144	238	1327	250	1509	260
75	75	0	0	0	0	136	59	318	114	501	152	683	180	866	201	1048	218	1231	232	1413	244
60	75	0	0	0	0	106	46	288	103	471	143	653	172	836	194	1018	212	1201	227	1383	238
50	75	0	0	0	0	67	29	249	89	432	131	614	162	797	185	979	204	1162	219	1344	232
40	75	0	0	0	0	14	6	196	70	379	115	561	148	744	173	926	193	1109	209	1291	223
25	75	0	0	0	0	0	0	104	37	286	87	469	123	651	151	834	174	1016	192	1199	207
0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	31	348	60
100	60	0	0	18	10	201	87	383	137	566	171	748	197	931	216	1113	232	1296	244	1478	255
75	60	0	0	0	0	105	46	287	103	470	142	652	172	835	194	1017	212	1200	226	1382	238
60	60	0	0	0	0	75	32	257	92	440	133	622	164	805	187	987	206	1170	221	1352	233
50	60	0	0	0	0	36	16	218	78	401	121	583	154	766	178	948	198	1131	213	1313	226
40	60	0	0	0	0	0	0	165	59	348	105	530	139	713	166	895	186	1078	203	1260	217
25	60	0	0	0	0	0	0	73	26	255	77	438	115	620	144	803	167	985	186	1168	201
0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	134	25	317	55
100	50	0	0	0	0	176	77	359	128	541	164	724	190	906	211	1089	227	1271	240	1454	251
75	50	0	0	0	0	81	35	263	94	446	135	628	165	811	189	993	207	1176	222	1358	234
60	50	0	0	0	0	50	22	233	83	415	126	598	157	780	181	963	201	1145	216	1328	229
50	50	0	0	0	0	12	5	194	69	377	114	559	147	742	172	924	193	1107	209	1289	222
40	50	0	0	0	0	0	0	141	50	323	98	506	133	688	160	871	181	1053	199	1236	213
25	50	0	0	0	0	0	0	49	17	231	70	414	109	596	139	779	162	961	181	1144	197
0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	21	292	50
100	40	0	0	0	0	137	60	319	114	502	152	684	180	867	202	1049	219	1232	232	1414	244
75	40	0	0	0	0	41	18	224	80	406	123	589	155	771	179	954	199	1136	214	1319	227
60	40	0	0	0	0	11	5	194	69	376	114	559	147	741	172	924	192	1106	209	1289	222
50	40	0	0	0	0	0	0	155	55	337	102	520	137	702	163	885	184	1067	201	1250	215
40	40	0	0	0	0	0	0	101	36	284	86	466	123	649	151	831	173	1014	191	1196	206
25	40	0	0	0	0	0	0	9	3	192	58	374	98	557	129	739	154	922	174	1104	190
0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71	13	253	44
100	25	0	0	0	0	3	1	185	66	368	111	550	145	733	170	915	191	1098	207	1280	221
75	25	0	0	0	0	0	0	90	32	272	82	455	120	637	148	820	171	1002	189	1185	204
60	25	0	0	0	0	0	0	59	21	242	73	424	112	607	141	789	164	972	183	1154	199
50	25	0	0	0	0	0	0	20	7	203	61	385	101	568	132	750	156	933	176	1115	192
40	25	0	0	0	0	0	0	0	0	150	45	332	87	515	120	697	145	880	166	1062	183
25	25	0	0	0	0	0	0	0	0	57	17	240	63	422	98	605	126	787	149	970	167
0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	20
100	0	0	0	0	0	0	0	7	2	189	57	372	98	554	129	737	154	919	173	1102	190
75	0	0	0	0	0	0	0	0	0	94	28	276	73	459	107	641	134	824	155	1006	173
60	0	0	0	0	0	0	0	0	0	64	19	246	65	429	100	611	127	794	150	976	168
50	0	0	0	0	0	0	0	0	0	25	7	207	55	390	91	572	119	755	142	937	162
40	0	0	0	0	0	0	0	0	0	0	0	154	41	336	78	519	108	701	132	884	152
25	0	0	0	0	0	0	0	0	0	0	0	62	16	244	57	427	89	609	115	792	136
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Based on distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation
3. Probabilities of winter length are derived from the probabilities of freeze and thaw dates (Table 20)
4. Water deficits do not consider potential error in the calibrated water balance model.

1234	Winter Water Consumption Exceeds Maximum Available Active Winter Storage
4567	Total Annual Supplementation Exceeds Maximum Available Active Winter Storage
	Low Risk Water Supply Deficit
	High Risk Water Supply Deficit
	Extreme Risk Water Supply Deficit

APPENDIX B

Technical Memorandum - Char River Theoretical Rating Curve Based On Field Data

TECHNICAL MEMORANDUM

TO Nicole Lanchuske, Project Officer

DATE February 16, 2016

CC Project File

FROM Chris Davidson; Nathan Schmidt

PROJECT No. 1534002

CHAR RIVER THEORETICAL RATING CURVE BASED ON FIELD DATA

1.0 INTRODUCTION

This Technical Memorandum details the background, objectives, methodology, and results for the development of the theoretical flow rating curve for the Char River near Rankin Inlet, Nunavut.

2.0 BACKGROUND

The community of Rankin Inlet (*Kangiqtiniq*) currently depends on Nipissar Lake to provide its year-round municipal water supply (see Figure A in attachments). Given that the Nipissar Lake watershed is frozen over for approximately eight to nine months each year, raw water supplies at the outset of winter need to be sufficient to service the community over the winter until snowmelt runoff replenishes the reservoir during the following freshet. A water supply pipeline from the nearby Char River, downstream of Lower Landing Lake (also referred to as First Landing Lake), to augment water supplies in Nipissar Lake was consequently constructed; however, concerns regarding the viability of this secondary supply source have been expressed in light of sustainable flow and water depth objectives imposed by the Nunavut Water Board (NWB) and the Canada Department of Fisheries and Oceans (DFO).

Although cross-sectional data were collected at thirteen cross-sections along the Char River in 2014 (AMEC 2014), no continuous flow or water level data have been collected to provide a characterisation of baseline flows or levels for the river. In the absence of flow and water level data for the Char River, the DFO and NWB objectives are currently set to limit withdrawals to 10% of instantaneous flow and to maintain a minimum flow depth of 0.5 m.

3.0 OBJECTIVE

IMG-Golder was retained by the Government of Nunavut in July 2015 in order to undertake water balance studies for the Char River and a potential secondary water supply supplementation source, Lower Landing Lake, located immediately upstream of the lower reach of the Char River.

As part of this work, it was requested that IMG-Golder prepare a theoretical rating curve of the Char River using available cross-sectional data to provide a temporary characterisation of baseline flows and water levels until such time that monitoring data become available.

The objective of this work was to develop a theoretical rating curve for the Char River at the water intake location, situated slightly downstream of Lower Landing Lake.

4.0 METHODOLOGY

In order to produce rating curves, a hydraulic model of the Char River between First Landing Lake and Hudson Bay was created in HEC-RAS. HEC-RAS software, created by the U.S. Army Corps of Engineers, allows one-dimensional modelling of stream systems using Manning's flow equation. Users apply river cross-sectional information, streambed roughness, bridge dimensions, boundary conditions, and a set of flows, allowing the model to estimate resulting water levels throughout the modelled reach.

4.1 Cross-Sectional Information

Cross-sectional information for the Char River was obtained from the "*Rankin Inlet – Char River Channel Topographic Survey*" technical memorandum (AMEC 2014) provided to IMG-Golder with the original request for quotation. The provided data comprises 13 surveyed cross-sections along a 1400 metres (m) length of the Char River between Lower Landing Lake and Hudson Bay (Attachment A). These surveyed cross-sections range in width from 22 m to 173 m, with an average of 14 station-elevation points defining each cross-section. The collected data depict a reasonably well-defined floodplain (with banks of 1 to 3 m in height), but do not define a low-flow channel. It is therefore currently unclear whether such a feature was accidentally omitted from the survey or whether a low-flow channel is absent altogether. Existing aerial imagery from Google Earth does not clearly show a low flow channel; but its presence/absence will be confirmed during a field visit scheduled between July 10 and 13.

Cross-sectional information for all 13 cross-sections was entered into HEC-RAS as station-elevation points taken across each cross-section. The station number for each point (i.e., distance along the cross-section) was determined using the northing and easting provided in AMEC (2014).

The Char River water taking location is shown on the AMEC drawing as being situated between cross-section 12 and cross-section 13. In order to provide a rating curve at the water taking location, an additional cross-section (12.5*) was created at approximately the pump house location. The cross-section channel geometry was surveyed during the Golder 2015 flow measurements. The Golder survey was conducted with adequate detail to estimate the flow/level relationship under low-flow conditions at cross-section 12.5*. This surveyed channel cross-section was matched to the interpolated overbank cross-section using the left bank elevation.

4.2 Hudson Bay Tide Levels

Hudson Bay is subject to tides; during high tide, the water level in Hudson Bay is expected to cause a backwater effect in the Char River, filling a portion of the channel for distance upstream and reducing channel capacity. This can cause a temporary backwater effect leading to increased water levels for a short distance upstream. As such, it is important to consider tidal effects in the hydraulic model. In particular, it is important to determine whether or not the pumping location is above the potential tidal effects in the Char River.

A maximum tidal range of 4.64 m has been reported for Rankin Inlet (TF 2015); however a more typical maximum spring tidal range may be 4.5 m as reported by DFO (2015) for 2015. Applying the latter value to the cross-sectional data provided in AMEC (2015) indicates that maximum high spring tides may encroach into Char River up to an estimated elevation of 2.25 masl (not accounting for meteorological effects).

For the purposes of the modelling exercise the 2.25 masl high tide value was used to define the downstream boundary condition for Char River within HEC-RAS. This elevation is between 6.6 m and 9.0 m below the channel invert elevation for the assumed pumping location (for cross-section 12 and cross-section 13, respectively).

4.3 Streambed Roughness

An empirically-derived Manning's value was assigned to represent streambed roughness at each cross-section. Manning's roughness values are assigned to simulate energy loss within the watercourse. In order to calibrate the hydraulic model to the flow measurement collected by Golder in July 2015, a Manning's roughness value of 0.06 was assigned to all surfaces, which is in general agreement with the literature value for unlined open rock channels (MTO 1997).

4.4 Bridge Dimensions

The aerial imagery provided in AMEC (2014) shows a single bridge crossing of the Char River immediately upstream (west) of cross-section 9 (See Attachment A). While the elevation details for the bridge are not specifically identified, the survey information for cross-section 9 appears to show the road and footing elevations for a single span bridge (Figure 1). In the absence of more specific information, the cross-sectional data were therefore used to estimate a solid deck bridge, with a superstructure 29.5 m long and 1.9 m deep, with a deck elevation of 12.1 masl. The width of the bridge was estimated from aerial photos to be approximately 5 m. The bridge was assumed to be located 1 m upstream of cross-section 9. In order to provide a representation of the bridge in HEC-RAS, a second cross-section (cross-section 9.5) was created 1 m upstream of the upstream of the bridge face, using the same cross-section data as cross-section 9.

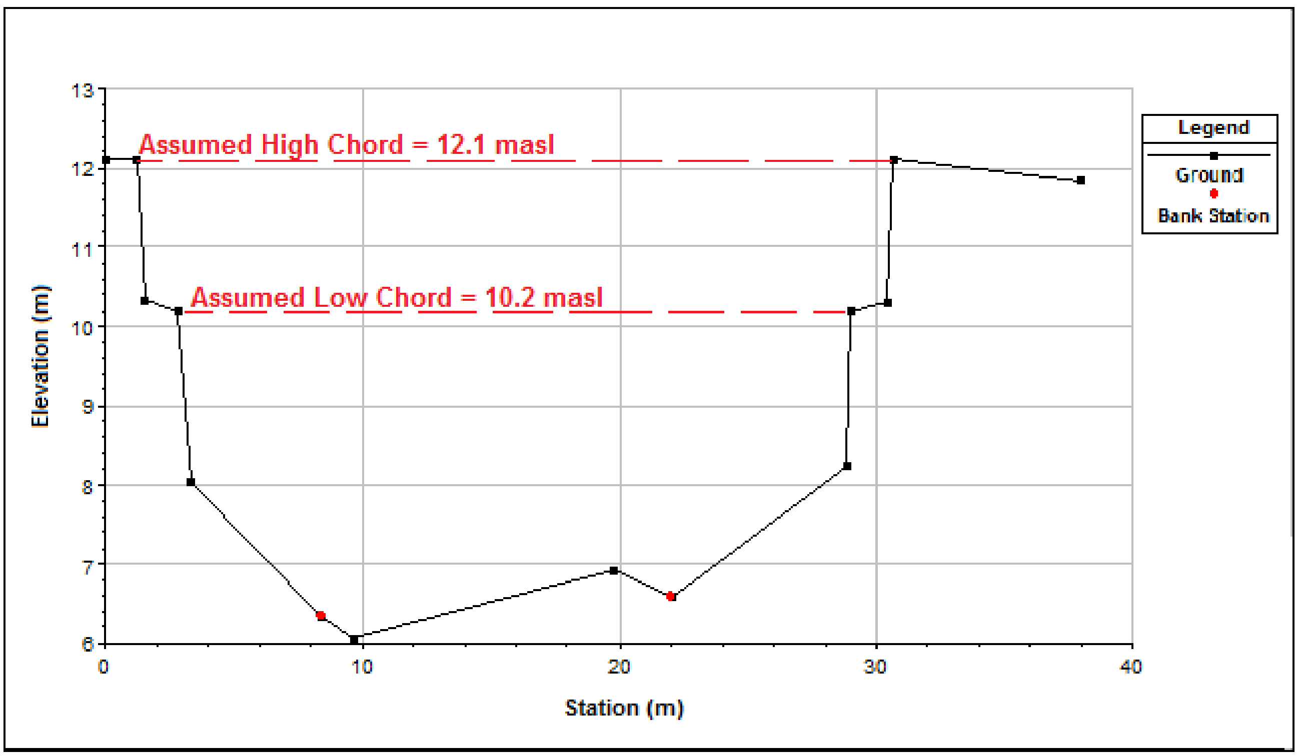

Figure 1: Assumed Bridge Dimensions on Cross-Section 9

4.5 Flows

Flow measurements for the Char River are not available to define the range of flows for the HEC-RAS model; as such, the analysis described below relies on indirect methods of flow estimation.

Flow ranges for the Char River were estimated using flow records for a nearby station. Based on available Water Survey of Canada (WSC) mapping, the nearest WSC flow gauge is located on the Diana River, approximately 18 km west of Rankin Inlet (ID# 06NC001 Diana River near Rankin Inlet). The catchment area for the Diana River WSC station (1460 km^2 based on WSC data) is roughly 20 times larger than the Char River catchment (estimated as 69.8 km^2 based on coarse topographic mapping). Mean daily flow data are available for this station from January 1989 to December 1995, although the station is now inactive.

Mean daily flows for the Diana River station were obtained from WSC, and the data were prorated to the Char River by the ratio of drainage area using the following equation:

$$Q_2 = Q_1 * (A_2/A_1)^B$$

Where:

- Q_2 is the flow rate to be estimated at the point of interest (m^3/s);
- Q_1 is the flow rate in the gauged watershed (m^3/s);
- A_2 is the watershed area contributing to the point of interest (estimated as 69.8 km^2 for the Char River based on initial coarse mapping);
- A_1 is the watershed area contributing to the reference watercourse at the gauge location (given as 1460 km^2 for the Diana River WSC gauge); and
- B is an empirical exponent equal to 1.00 for mean daily flow estimates.

The range of prorated flows for the Char River is shown on Figure 2 below. Generally, the mean daily flows range from 0 m^3/s to 4.9 m^3/s. It should be noted that actual peak flows in the Char River may be marginally greater in magnitude and shorter in duration owing to the smaller watershed associated with the Char River (approximately 5% of that for the Diana River gauge). To account for this possibility, the range of flows used in HEC-RAS for Char River was therefore expanded up to 10 m^3/s.

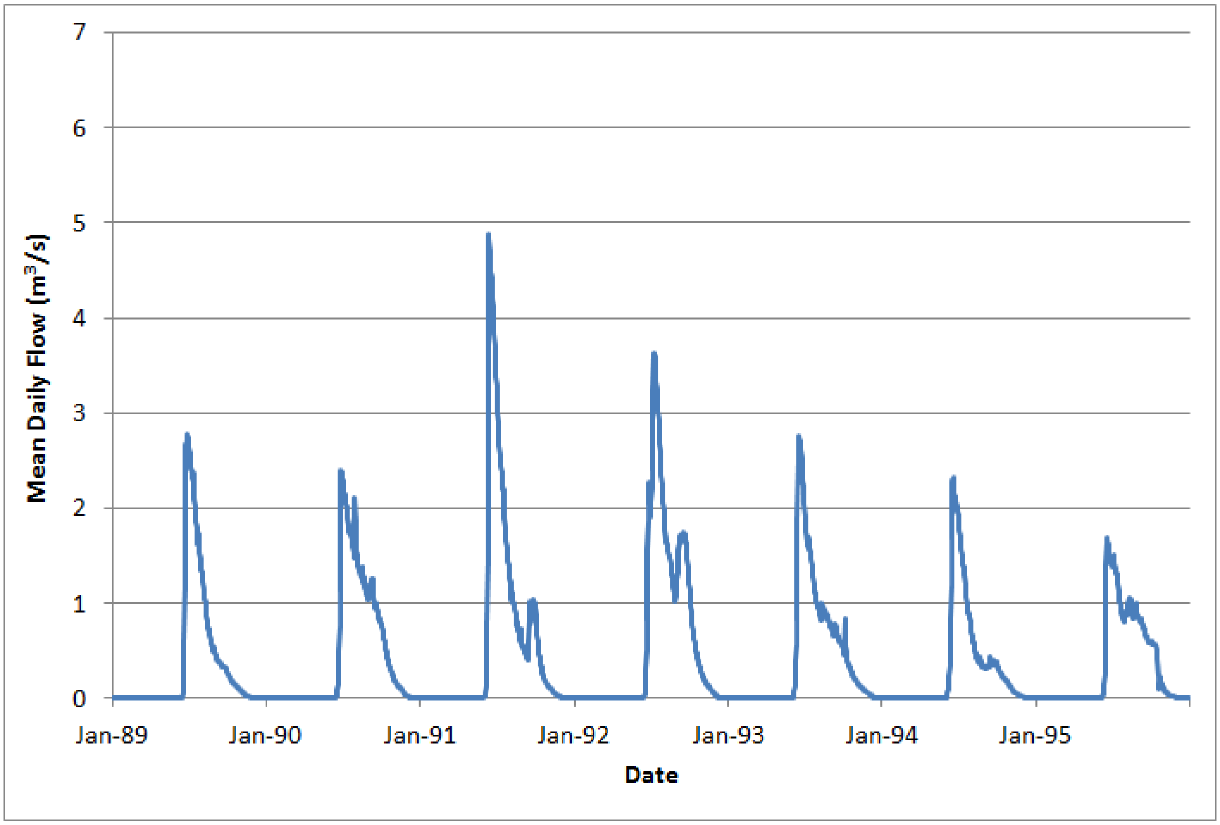

Figure 2: Prorated Flows for the Char River, 1989 to 1995

5.0 RESULTS AND DISCUSSION

5.1 Streamflow Profile

The HEC-RAS model was run for the selected range of flows; a graphical summary of the results (in the form of a stream profile) is shown on Figure 3 below. For the flows examined, water depths throughout the watercourse generally behaved similarly at each cross-section; the exceptions being cross-sections 1 to 5 which can experience backwater effects during high tides and cross-sections 9.5 and 10 which experience a small backwater effect as flows are constricted at the bridge. Full tabular results and graphical cross-sections are provided in Attachment B.

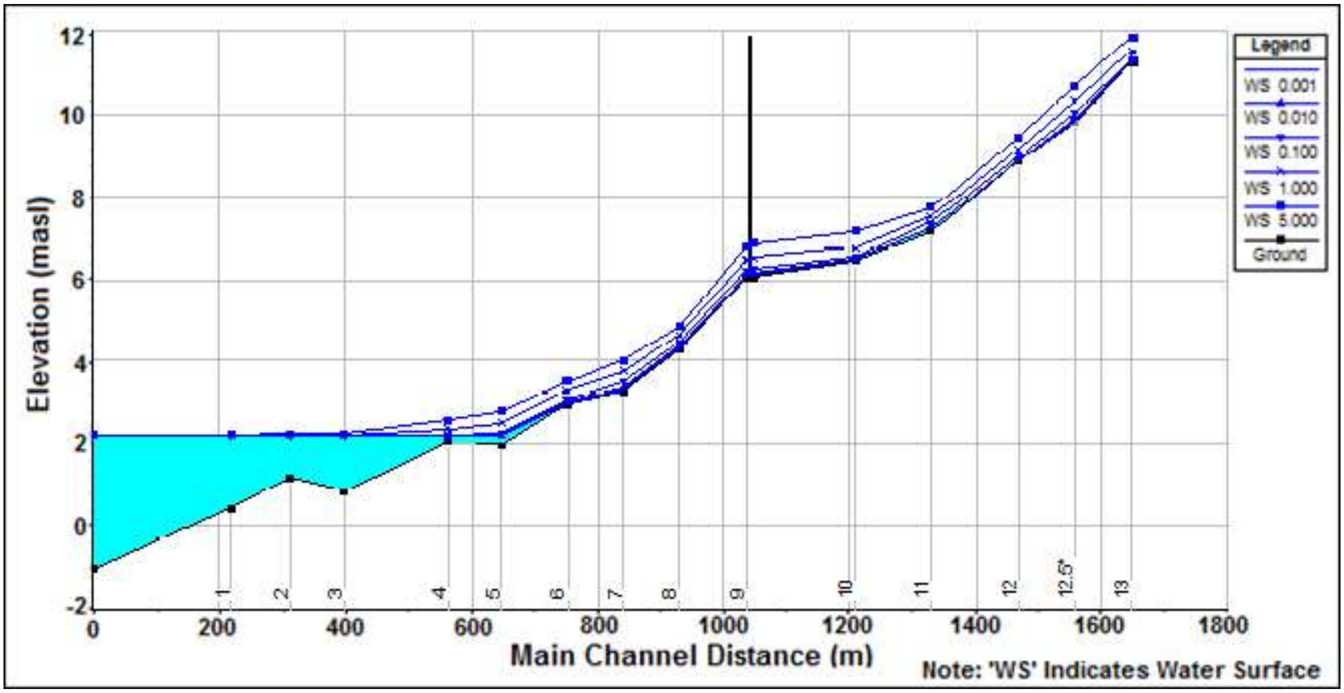

Figure 3: The Char River HEC-RAS Results Profile

5.2 Theoretical Rating Curves

Based on AMEC (2014) and Golder field measurements, the pumping station is located at cross-Section 12.5*. The rating curve for this cross-section is represented by two curve equations; one for high flows and one for low flows. This curve is plotted on Figure 4 below. In addition, theoretical rating curve equations (relating staff gauge water level to flow rate) are provided. The equations are:

$$Q = 7.19\ WL^{3.98}$$, when the staff gauge water level ≤ 0.6 m; and

$$Q = 5.62\ WL^{3.45}$$, when the staff gauge water level >0.6 m.

Where:

- Q is the flow rate (m^3/s); and
- WL is the water level on the staff gauge at the pump house (m).

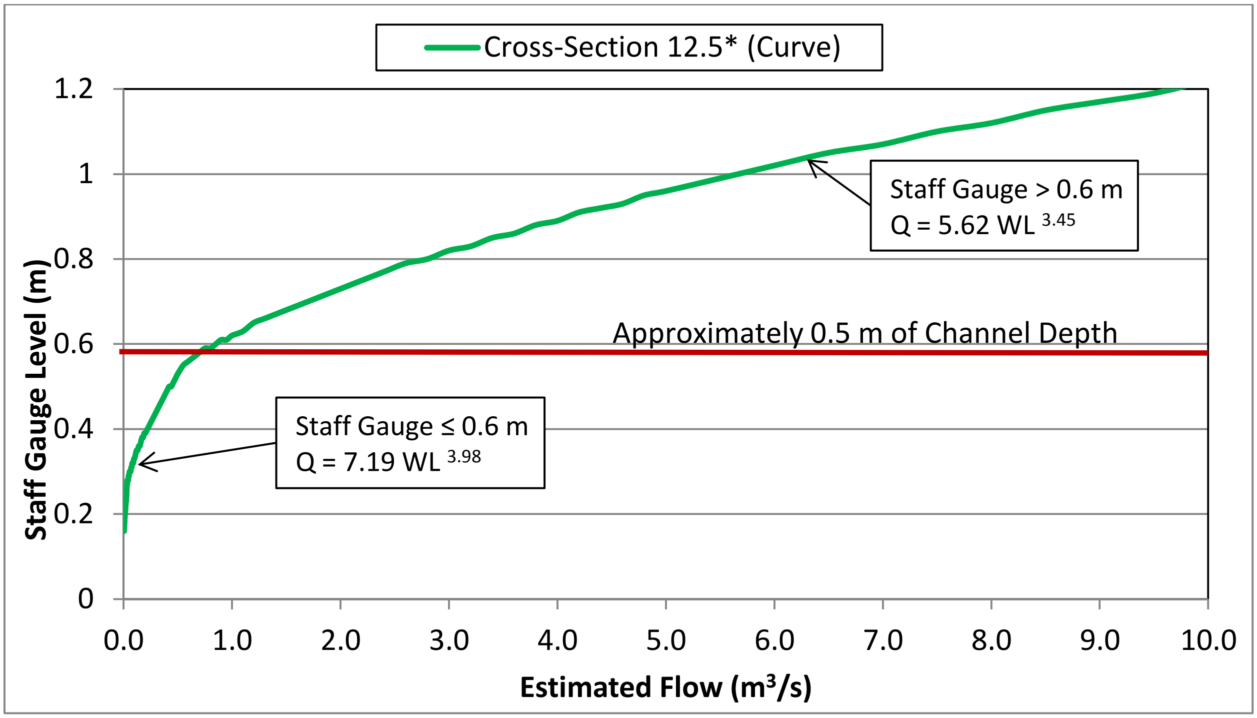

Figure 4: Char River Theoretical Rating Curve

According to the cross-Section 12.5* rating curve and the flow record (prorated from the Diana River gauge), the water level at cross-Section 12.5* will be above 0.5 m for over 50 days each year. Based on the rating curve depicted in Figure 4, a water depth of 0.5 m at cross-section 12.5* would result in a flow rate of approximately 0.7 m^3/s.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Assumptions and Limitations

The analysis described above is based on the following assumptions and limitations:

- Cross-sectional data provided in AMEC (2014) and Golder field measurements are assumed to be accurate, up-to-date and representative of channel morphology;
- The lower boundary condition of the model was based on a high spring tide condition provided by DFO (2015);
- The channel roughness coefficient, based on literature values for an unlined rock channel, are assumed to be representative; and
- A range of flows was assumed based on seven years of prorated flows from a nearby WSC gauge.

6.2 Conclusions

Based on the preceding information and subject to the assumptions and limitations documented herein:

- The lower portion of the Char River (cross-Sections 1 to 5) is affected by backwater effects from high tide in Hudson Bay;
- The mid portion of the Char River (cross-Sections 9.5 and 10) is affected by backwater effects from the bridge crossing; and
- Based on the available cross-sectional data, the 0.5 m minimum flow depth objective recommended by NWB appears to be met at the water taking location on average, over 50 days each year. The 10% DFO flow allowance corresponding to this water depth is approximately 0.07 m^3/s.

6.3 Recommendations

Based on the preceding conclusions, the following recommendations are made:

- Additional flow and water level measurements should continue to be obtained for the Char River during periods of flow in the river in order to further validate and, if necessary, recalibrate the HEC-RAS model; and
- Any additionally available information regarding the characteristics of the Char River, including local knowledge of flooding, water levels, historically high and low flows, freeze up/thaw timing should be shared with the project team.

7.0 CLOSURE

If you have any questions or require additional information, please do not hesitate to contact us at your convenience.

LICENSED PROFESSIONAL ENGINEER
C.R.B. DAVIDSON
100073957
February 16, 2016
PROVINCE OF ONTARIO

for Rankin Inlet Rating Curve Memo

REGISTERED PROFESSIONAL ENGINEER
12 FEB 2016
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THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
GEOLOGISTS and GEOPHYSICISTS
OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 049
GOLDER
ASSOCIATES LTD.

CD/NS/mp

N:\Active\2015\3 Proj\1534002 Gov of Nunavut_Water Balance & Water Supply Forecast_Rankin Inlet\06. Reporting\1. Tech Memos\1. Theoretical Rating Curve\Final\1534002 TM 2016Feb16 Char River Rating Curve Memo.docx

Attachements:

Figure A - General Location Plan
Attachment A - Survey Figure Excerpted From AMEC 2014
Attachment B1 - HEC-RAS Modelling Results
Attachment B2 – HEC RAS Sections

REFERENCES

AMEC (2014) Rankin Inlet – Char River Channel Topographic Survey, provided to IMG-Golder as part of the RFQ package.

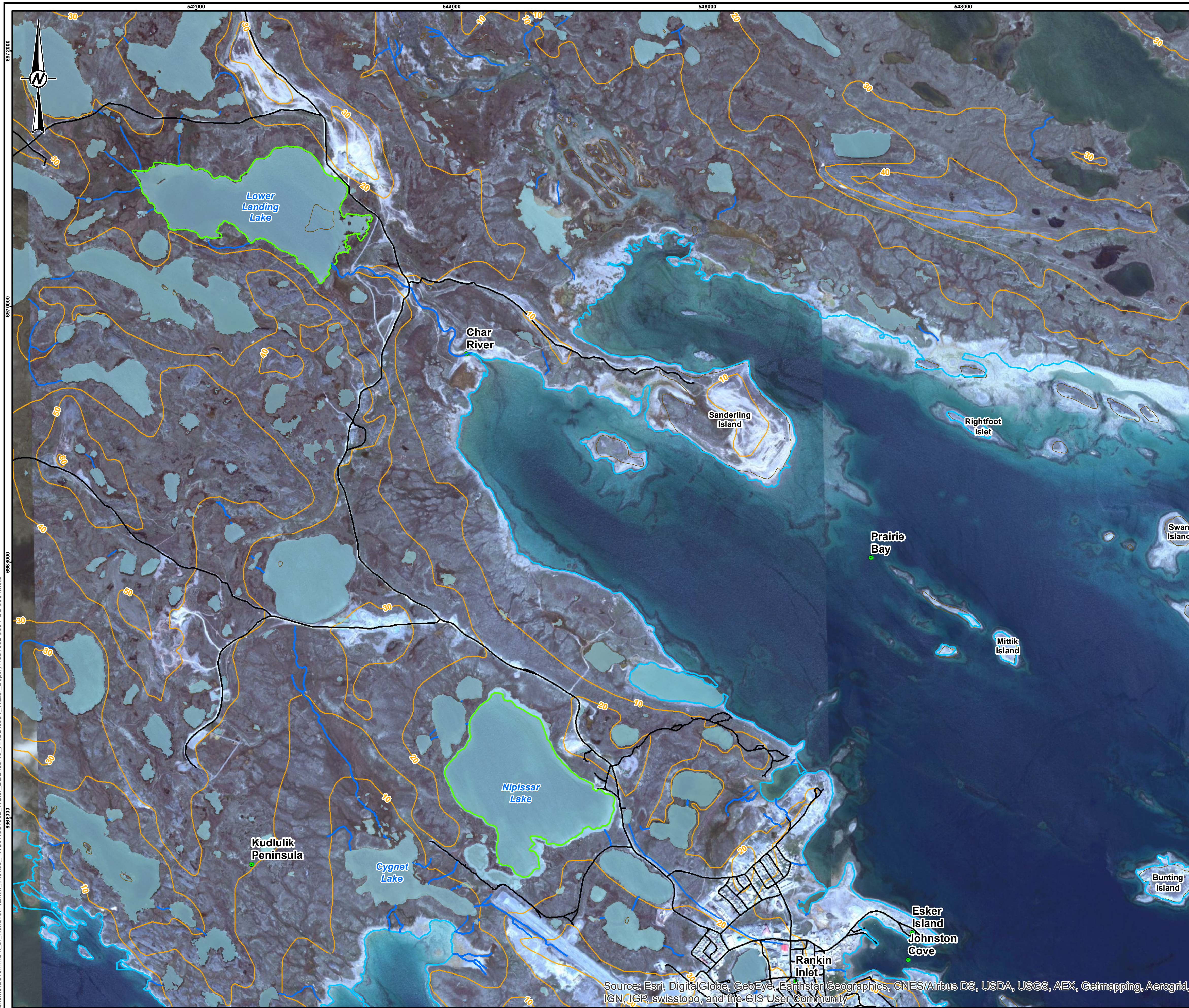
DFO (2015) Rankin Inlet 2015 Tide Tables, Downloaded from "*http://www.tides.gc.ca/eng/data/table/2015/wlev_sec/5100*" on July 6, 2015.

TF (2015) Tide Times for Rankin Inlet, Downloaded from "*http://www.tide-forecast.com/locations/Rankin-Inlet-Nunavut/tides/latest*" on July 6, 2015.

MTO (1997) Drainage Management Manual, Ontario Ministry of Transportation (MTO) Drainage and Hydrology Section, Transportation Engineering Branch, Quality and Standards Division.

FIGURE A

General Location Plan



LEGEND

- Topographic Elevation Contour
- Road
- Watercourse
- Shoreline
- Waterbody

0 0.5 1 1.5 2 2.5

1:30,000 Kilometres

REFERENCE(S)

BASE DATA DOWNLOADED FROM GOVERNRMENT OF CANADA WEBSITE, 20150707. UTM NAD83 Z15
WATERCOURSES, SHORELINE AND LAKES PROVIDED BY CGS, 20150626.

CLIENT
GOVERNMENT OF NUNAVUT

PROJECT
CHAR RIVER AND LOWER LANDING LAKE STUDIES

TITLE
GENERAL LOCATION PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-07-07
DESIGNED	KD
PREPARED	KD
REVIEWED	CD
APPROVED	GR

PROJECT NO.	CONTROL	REV.	FIGURE
1534002	0001	0.0	1

25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

ATTACHMENT A

Survey Figure Excerpted From AMEC 2014

Legend

PS Pump Station

Section

N S

Department of Community and Government Serivces Government of Nunavut

AMEC Environment & Infrastructure A Division of AMEC Americas Ltd.

50 Troop Avenue, Ste. 300
Darthmouth, NS B3B 1Z1
Tel 902-468-2848 Fax 902-468-1314

amec

PROJECT No:	TV141028
DATUM:	NAD83
PROJECTION:	UTM Zone 15 North
SCALE:	100 50 0 100 Metres 1:4,800

TITLE: **PLAN VIEW CHAR RIVER WITH SECTIONS**

PROJECT: **TOPOGRAPHICAL SURVEY CHAR RIVER**

DWN BY:	JT
CHK'D BY:	KV
DATE:	Oct, 2014
REV NO:	
FIGURE:	1

Path: G:\GIS\PROJECTS\TV141028_Topographical_Survey_Char_River\MXD\20141021_Section_Fig.mxd User: jonathan.thornton, Date: 22/10/2014

Source: AMEC 2014/ESRI Imagery

ATTACHMENT B1

HEC-RAS Modelling Results

HEC-RAS Plan: Char-Rating Curve; River: Char River; Reach: 1

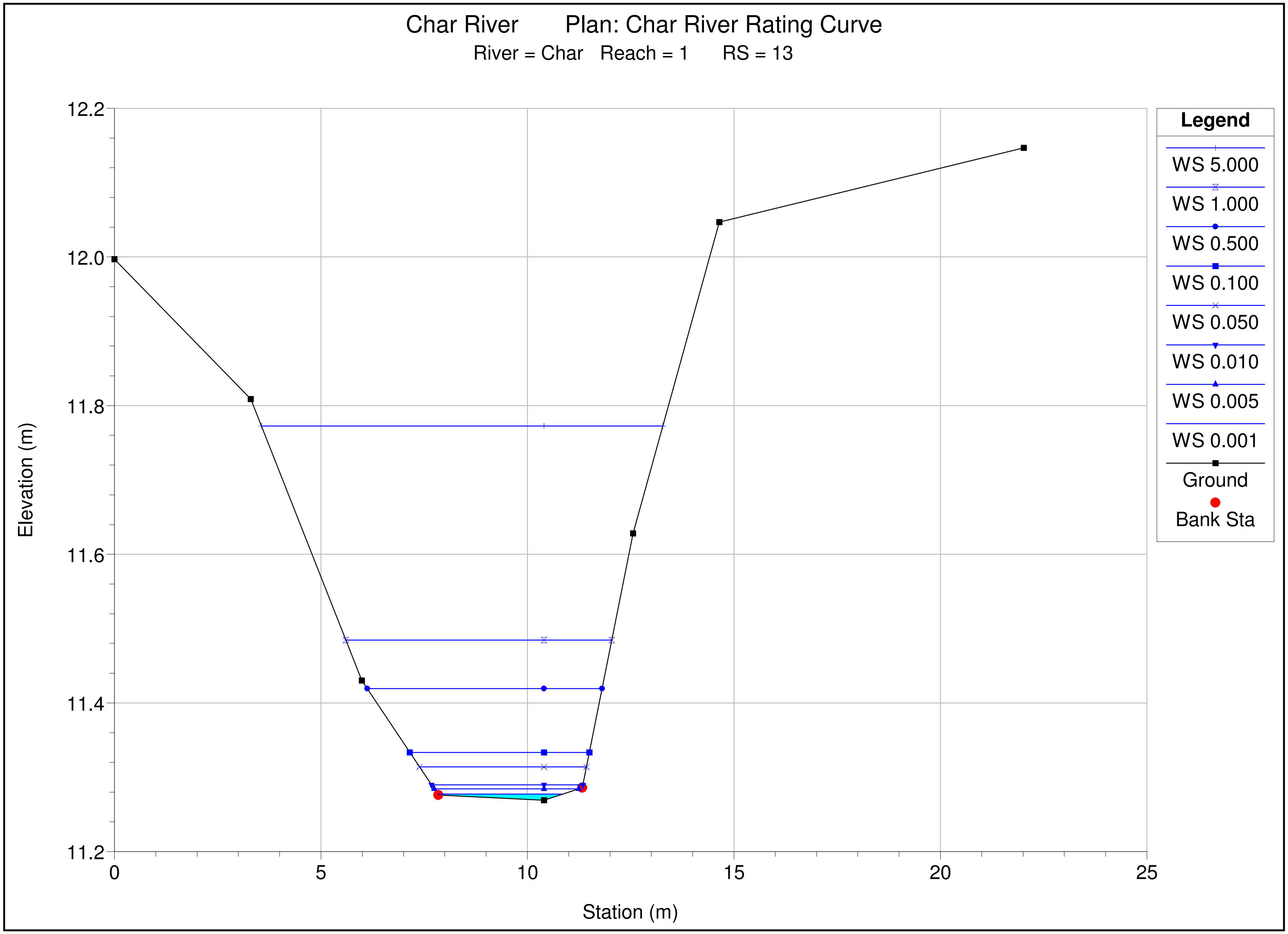
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	13	0.001	0	11.27	11.2772	11.27	11.28	0.011462	0.07	0.01	3.01	0.35
1	13	0.005	0	11.27	11.2845	11.28	11.29	0.012112	0.13	0.04	3.5	0.41
1	13	0.01	0.01	11.27	11.2898	11.28	11.29	0.012775	0.18	0.06	3.66	0.45
1	13	0.05	0.05	11.27	11.3139	11.3	11.32	0.013894	0.34	0.15	4.04	0.55
1	13	0.1	0.1	11.27	11.3333	11.32	11.34	0.014086	0.45	0.23	4.34	0.59
1	13	0.5	0.5	11.27	11.4192	11.39	11.45	0.014457	0.83	0.66	5.69	0.7
1	13	1	1	11.27	11.4846	11.46	11.53	0.013951	1.05	1.06	6.44	0.73
1	13	5	5	11.27	11.7726	11.73	11.89	0.011824	1.71	3.37	9.72	0.77
1	13	10	10	11.27	11.9805	11.94	12.15	0.010811	2.06	5.81	14.03	0.78
1	12	0.001	0	8.89	8.9082	8.9	8.91	0.015396	0.13	0.01	0.9	0.45
1	12	0.005	0	8.89	8.9228	8.91	8.92	0.014218	0.19	0.03	1.67	0.48
1	12	0.01	0.01	8.89	8.9328	8.92	8.94	0.013351	0.22	0.05	2.19	0.48
1	12	0.05	0.05	8.89	8.9688	8.95	8.97	0.012095	0.32	0.16	4.08	0.51
1	12	0.1	0.1	8.89	8.9923	8.97	9	0.011819	0.37	0.27	5.31	0.53
1	12	0.5	0.5	8.89	9.077	9.04	9.1	0.011477	0.62	0.8	7.09	0.59
1	12	1	1	8.89	9.1386	9.09	9.17	0.012006	0.79	1.27	8.26	0.64
1	12	5	5	8.89	9.3571	9.32	9.46	0.015159	1.45	3.46	11.03	0.81
1	12	10	10	8.89	9.5027	9.48	9.7	0.017348	1.99	5.12	11.75	0.92
1	11	0.001	0	7.17	7.2095	7.2	7.21	0.009007	0.16	0.01	0.34	0.38
1	11	0.005	0	7.17	7.2386	7.22	7.24	0.009973	0.25	0.02	0.61	0.44
1	11	0.01	0.01	7.17	7.2612	7.24	7.26	0.010715	0.24	0.04	1.4	0.45
1	11	0.05	0.05	7.17	7.3065	7.28	7.31	0.011753	0.34	0.15	3.33	0.51
1	11	0.1	0.1	7.17	7.3328	7.31	7.34	0.012003	0.4	0.25	4.46	0.54
1	11	0.5	0.5	7.17	7.4267	7.39	7.44	0.012355	0.5	1	13.08	0.58
1	11	1	1	7.17	7.4693	7.43	7.49	0.012156	0.61	1.65	16.19	0.6
1	11	5	5	7.17	7.6478	7.58	7.7	0.009907	1.06	4.97	21.8	0.64
1	11	10	10	7.17	7.7921	7.71	7.87	0.008456	1.29	8.58	28.6	0.63
1	10	0.001	0	6.45	6.4675	6.46	6.47	0.003416	0.05	0.02	2.89	0.2
1	10	0.005	0	6.45	6.4797	6.47	6.48	0.002705	0.07	0.07	5.52	0.2
1	10	0.01	0.01	6.45	6.4884	6.47	6.49	0.002256	0.08	0.13	7.41	0.19
1	10	0.05	0.05	6.45	6.5214	6.49	6.52	0.001409	0.11	0.46	11.97	0.17
1	10	0.1	0.1	6.45	6.5472	6.5	6.55	0.001202	0.12	0.82	15.64	0.17
1	10	0.5	0.5	6.45	6.6435	6.54	6.65	0.000826	0.17	2.87	24.12	0.16
1	10	1	1	6.45	6.7159	6.57	6.72	0.000681	0.22	4.63	24.48	0.16
1	10	5	5	6.45	7.0593	6.69	7.07	0.000538	0.38	13.31	25.97	0.17
1	10	10	10	6.45	7.3009	6.79	7.31	0.000606	0.52	19.69	26.91	0.19
1	9.5	0.001	0	6.06	6.1036	6.08	6.1	0.001028	0.06	0.02	0.71	0.13
1	9.5	0.005	0	6.06	6.1345	6.1	6.14	0.001552	0.11	0.05	1.21	0.18
1	9.5	0.01	0.01	6.06	6.1539	6.11	6.15	0.001827	0.14	0.07	1.52	0.2
1	9.5	0.05	0.05	6.06	6.2208	6.15	6.22	0.002644	0.24	0.21	2.59	0.27
1	9.5	0.1	0.1	6.06	6.2622	6.19	6.27	0.003132	0.3	0.33	3.25	0.3
1	9.5	0.5	0.5	6.06	6.4087	6.3	6.42	0.004134	0.52	0.97	5.49	0.38
1	9.5	1	1	6.06	6.5021	6.38	6.52	0.004693	0.65	1.55	6.84	0.43
1	9.5	5	5	6.06	6.854	6.68	6.9	0.005659	0.99	5.21	14.7	0.51
1	9.5	10	10	6.06	7.0595	6.87	7.13	0.005373	1.22	8.63	17.71	0.53
1	9.25		Bridge									
1	9	0.001	0	6.06	6.0868	6.08	6.09	0.012969	0.16	0.01	0.44	0.44
1	9	0.005	0	6.06	6.1096	6.1	6.11	0.013084	0.24	0.02	0.81	0.49
1	9	0.01	0.01	6.06	6.1246	6.11	6.13	0.013165	0.29	0.03	1.05	0.51
1	9	0.05	0.05	6.06	6.1783	6.15	6.19	0.013454	0.44	0.11	1.91	0.57
1	9	0.1	0.1	6.06	6.2133	6.19	6.23	0.013617	0.53	0.19	2.47	0.6
1	9	0.5	0.5	6.06	6.3378	6.3	6.37	0.014476	0.8	0.62	4.46	0.69
1	9	1	1	6.06	6.4144	6.38	6.47	0.015145	1	1.01	5.57	0.74
1	9	5	5	6.06	6.6939	6.68	6.82	0.018967	1.61	3.18	10.66	0.91
1	9	10	10	6.06	6.8671	6.87	7.05	0.020651	1.92	5.4	15.03	0.98
1	8	0.001	0	4.3	4.3282	4.32	4.33	0.021047	0.2	0	0.38	0.56
1	8	0.005	0	4.3	4.3502	4.34	4.35	0.020594	0.3	0.02	0.7	0.61
1	8	0.01	0.01	4.3	4.3647	4.35	4.37	0.020435	0.35	0.03	0.91	0.64
1	8	0.05	0.05	4.3	4.4173	4.4	4.43	0.01983	0.52	0.1	1.67	0.7
1	8	0.1	0.1	4.3	4.4521	4.43	4.47	0.019441	0.62	0.16	2.17	0.72
1	8	0.5	0.5	4.3	4.5692	4.55	4.59	0.018354	0.64	0.76	8.99	0.71
1	8	1	1	4.3	4.6215	4.6	4.65	0.018115	0.74	1.32	12.48	0.74
1	8	5	5	4.3	4.8032	4.77	4.86	0.016371	1.06	4.68	24.18	0.78
1	8	10	10	4.3	4.9276	4.88	5	0.014729	1.23	8.14	31.48	0.77
1	7	0.001	0	3.28	3.3215	3.3	3.32	0.001844	0.08	0.01	0.65	0.18
1	7	0.005	0	3.28	3.352	3.32	3.35	0.00218	0.12	0.04	1.15	0.21
1	7	0.01	0.01	3.28	3.3724	3.33	3.37	0.002225	0.15	0.07	1.49	0.22
1	7	0.05	0.05	3.28	3.4441	3.38	3.45	0.002468	0.23	0.22	2.67	0.26
1	7	0.1	0.1	3.28	3.4923	3.41	3.5	0.002596	0.27	0.36	3.63	0.28
1	7	0.5	0.5	3.28	3.6441	3.52	3.65	0.002979	0.32	1.57	13.89	0.3
1	7	1	1	3.28	3.7064	3.6	3.71	0.002993	0.39	2.54	16.39	0.32
1	7	5	5	3.28	3.931	3.76	3.96	0.003735	0.76	6.62	19.62	0.41
1	7	10	10	3.28	4.0716	3.89	4.13	0.004776	1.07	9.49	21.17	0.49
1	6	0.001	0	2.98	2.993	2.99	3	0.091082	0.27	0	0.53	1.05
1	6	0.005	0	2.98	3.0148	3.01	3.02	0.014717	0.21	0.02	1.36	0.49
1	6	0.01	0.01	2.98	3.0253	3.01	3.03	0.014908	0.25	0.04	1.75	0.52
1	6	0.05	0.05	2.98	3.063	3.05	3.07	0.015447	0.37	0.13	3.18	0.58
1	6	0.1	0.1	2.98	3.0873	3.07	3.1	0.01544	0.45	0.22	3.95	0.61

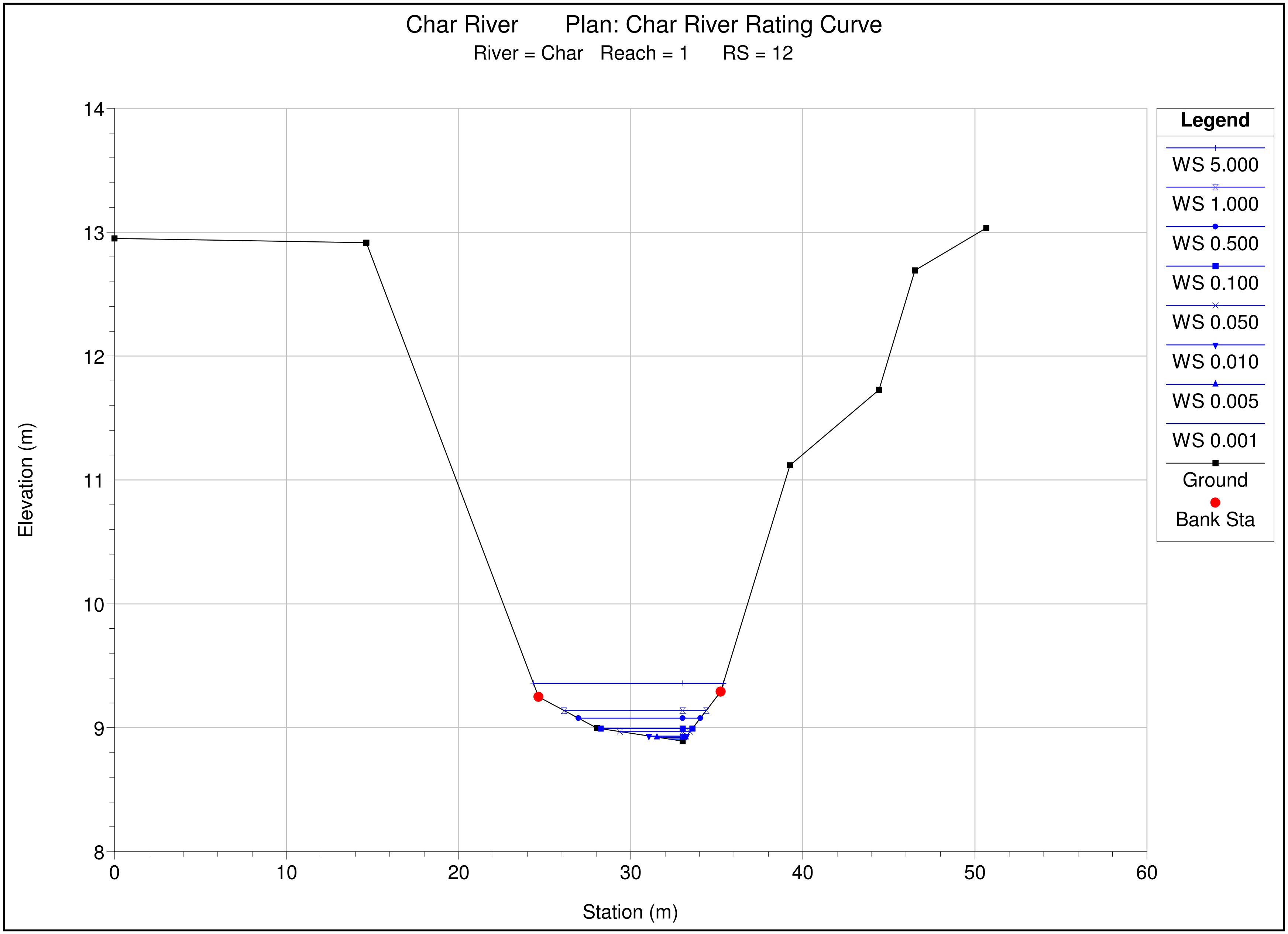
HEC-RAS Plan: Char-Rating Curve; River: Char River; Reach: 1

1	6	0.5	0.5	2.98	3.186	3.15	3.21	0.014175	0.66	0.76	7.34	0.65
1	6	1	1	2.98	3.2584	3.21	3.28	0.013452	0.64	1.56	14.98	0.63
1	6	5	5	2.98	3.446	3.38	3.48	0.009759	0.81	6.14	32.67	0.6
1	6	10	10	2.98	3.5731	3.47	3.62	0.007011	0.96	10.45	34.32	0.55
1	5	0.001	0	2.01	2.25	2.03	2.25	0	0	0.68	5.66	0
1	5	0.005	0	2.01	2.2501	2.04	2.25	0.000001	0.01	0.68	5.66	0.01
1	5	0.01	0.01	2.01	2.2503	2.05	2.25	0.000006	0.01	0.68	5.67	0.01
1	5	0.05	0.05	2.01	2.2559	2.09	2.26	0.000129	0.07	0.72	5.81	0.06
1	5	0.1	0.1	2.01	2.2695	2.11	2.27	0.000387	0.13	0.8	6.14	0.11
1	5	0.5	0.5	2.01	2.3726	2.22	2.38	0.001626	0.32	1.58	9.11	0.24
1	5	1	1	2.01	2.4512	2.28	2.46	0.002106	0.43	2.37	10.87	0.28
1	5	5	5	2.01	2.7289	2.52	2.77	0.003734	0.86	6.03	15.31	0.42
1	5	10	10	2.01	2.8745	2.68	2.95	0.005582	1.23	8.41	17.38	0.53
1	4	0.001	0	2.05	2.25	2.01	2.25	0	0	1.99	14.71	0
1	4	0.005	0	2.05	2.25	2.03	2.25	0	0	1.99	14.71	0
1	4	0.01	0.01	2.05	2.2501	2.04	2.25	0.000001	0.01	2	14.71	0
1	4	0.05	0.05	2.05	2.2511	2.07	2.25	0.000014	0.03	2.01	14.75	0.02
1	4	0.1	0.1	2.05	2.2542	2.1	2.25	0.000053	0.05	2.06	14.86	0.04
1	4	0.5	0.5	2.05	2.2956	2.15	2.3	0.000601	0.2	2.7	16.39	0.15
1	4	1	1	2.05	2.3387	2.18	2.34	0.001174	0.31	3.46	18.69	0.21
1	4	5	5	2.05	2.5187	2.35	2.53	0.00311	0.64	9.13	50.94	0.36
1	4	10	10	2.05	2.6305	2.49	2.65	0.003288	0.79	16.08	73.36	0.39
1	3	0.001	0	0.87	2.25	0.89	2.25	0	0	13.71	22.74	0
1	3	0.005	0	0.87	2.25	0.91	2.25	0	0	13.71	22.74	0
1	3	0.01	0.01	0.87	2.25	0.92	2.25	0	0	13.71	22.74	0
1	3	0.05	0.05	0.87	2.25	0.97	2.25	0	0.01	13.71	22.74	0
1	3	0.1	0.1	0.87	2.25	1	2.25	0	0.01	13.71	22.74	0
1	3	0.5	0.5	0.87	2.2502	1.12	2.25	0.000003	0.05	13.71	22.75	0.01
1	3	1	1	0.87	2.2507	1.21	2.25	0.000013	0.1	13.72	22.75	0.03
1	3	5	5	0.87	2.2663	1.58	2.27	0.000293	0.49	14.08	22.87	0.14
1	3	10	10	0.87	2.308	1.85	2.34	0.000975	0.92	15.04	23.18	0.26
1	2	0.001	0	1.2	2.25	1.21	2.25	0	0	27.62	36.68	0
1	2	0.005	0	1.2	2.25	1.23	2.25	0	0	27.62	36.68	0
1	2	0.01	0.01	1.2	2.25	1.24	2.25	0	0	27.62	36.68	0
1	2	0.05	0.05	1.2	2.25	1.26	2.25	0	0	27.62	36.68	0
1	2	0.1	0.1	1.2	2.25	1.27	2.25	0	0	27.62	36.68	0
1	2	0.5	0.5	1.2	2.2501	1.31	2.25	0.000001	0.02	27.62	36.68	0.01
1	2	1	1	1.2	2.2502	1.34	2.25	0.000003	0.04	27.62	36.68	0.01
1	2	5	5	1.2	2.2553	1.48	2.26	0.000068	0.21	27.81	36.73	0.07
1	2	10	10	1.2	2.2704	1.63	2.28	0.000255	0.4	28.37	36.87	0.13
1	1	0.001	0	0.43	2.25	0.45	2.25	0	0	38.32	38.89	0
1	1	0.005	0	0.43	2.25	0.46	2.25	0	0	38.32	38.89	0
1	1	0.01	0.01	0.43	2.25	0.46	2.25	0	0	38.32	38.89	0
1	1	0.05	0.05	0.43	2.25	0.49	2.25	0	0	38.32	38.89	0
1	1	0.1	0.1	0.43	2.25	0.51	2.25	0	0	38.32	38.89	0
1	1	0.5	0.5	0.43	2.2501	0.61	2.25	0	0.02	38.32	38.89	0
1	1	1	1	0.43	2.2501	0.68	2.25	0.000001	0.03	38.33	38.89	0.01
1	1	5	5	0.43	2.2518	0.98	2.25	0.000023	0.17	38.39	38.91	0.04
1	1	10	10	0.43	2.2571	1.2	2.26	0.000089	0.33	38.6	38.98	0.08

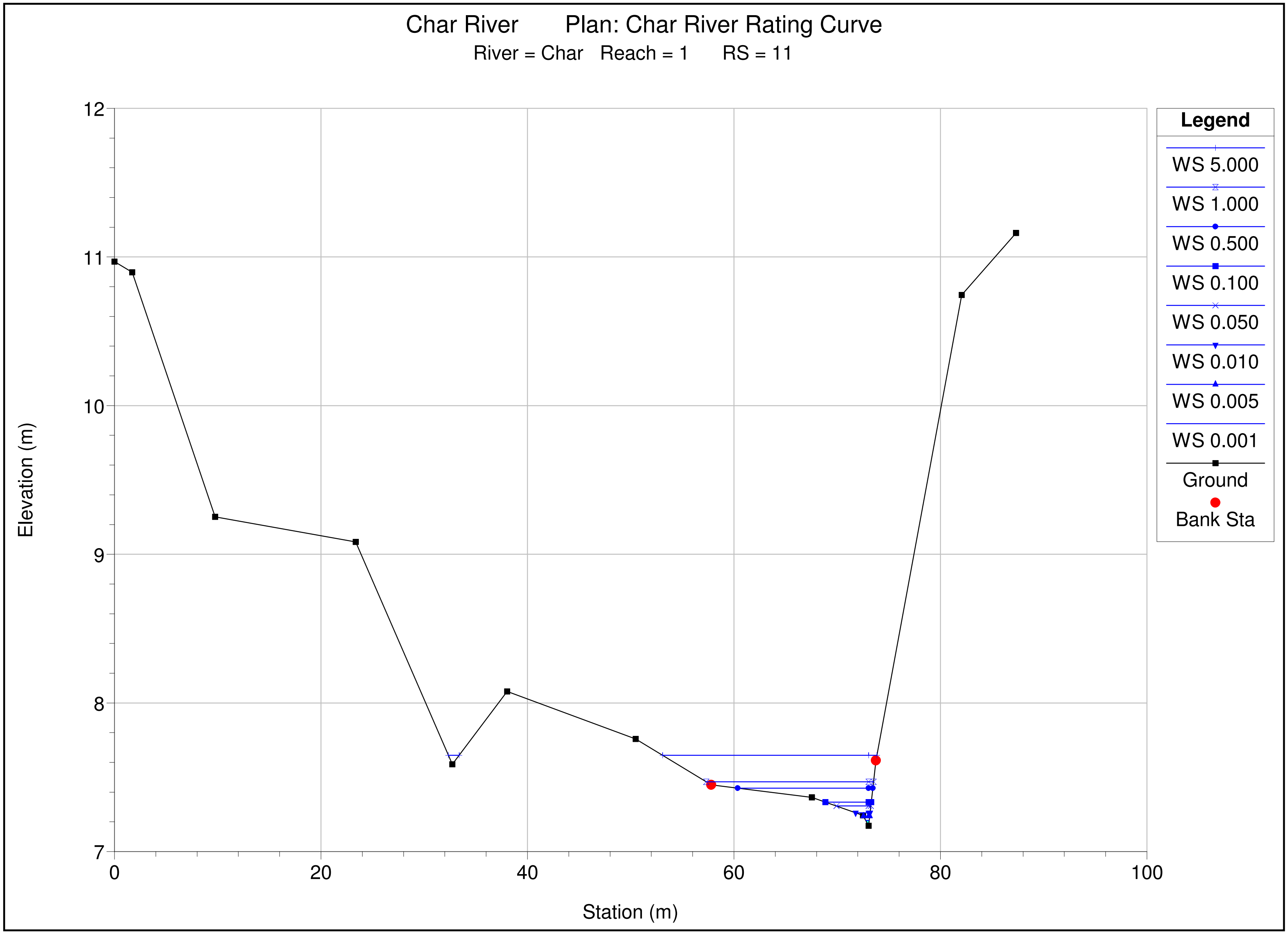
ATTACHMENT B2

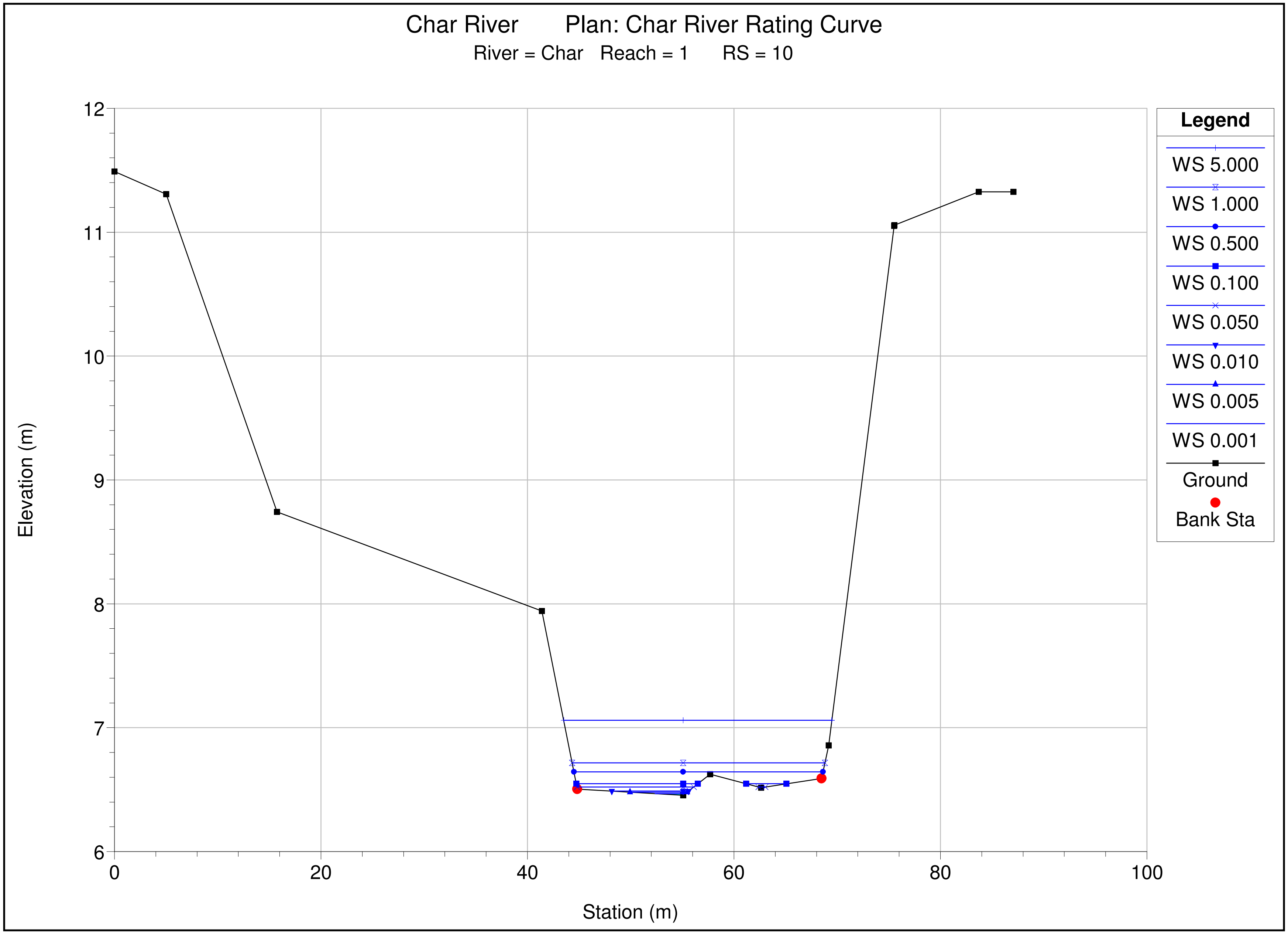
HEC-RAS Sections


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 13
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
12.2
12.0
11.8
11.6
11.4
11.2
0
5
10
15
20
25

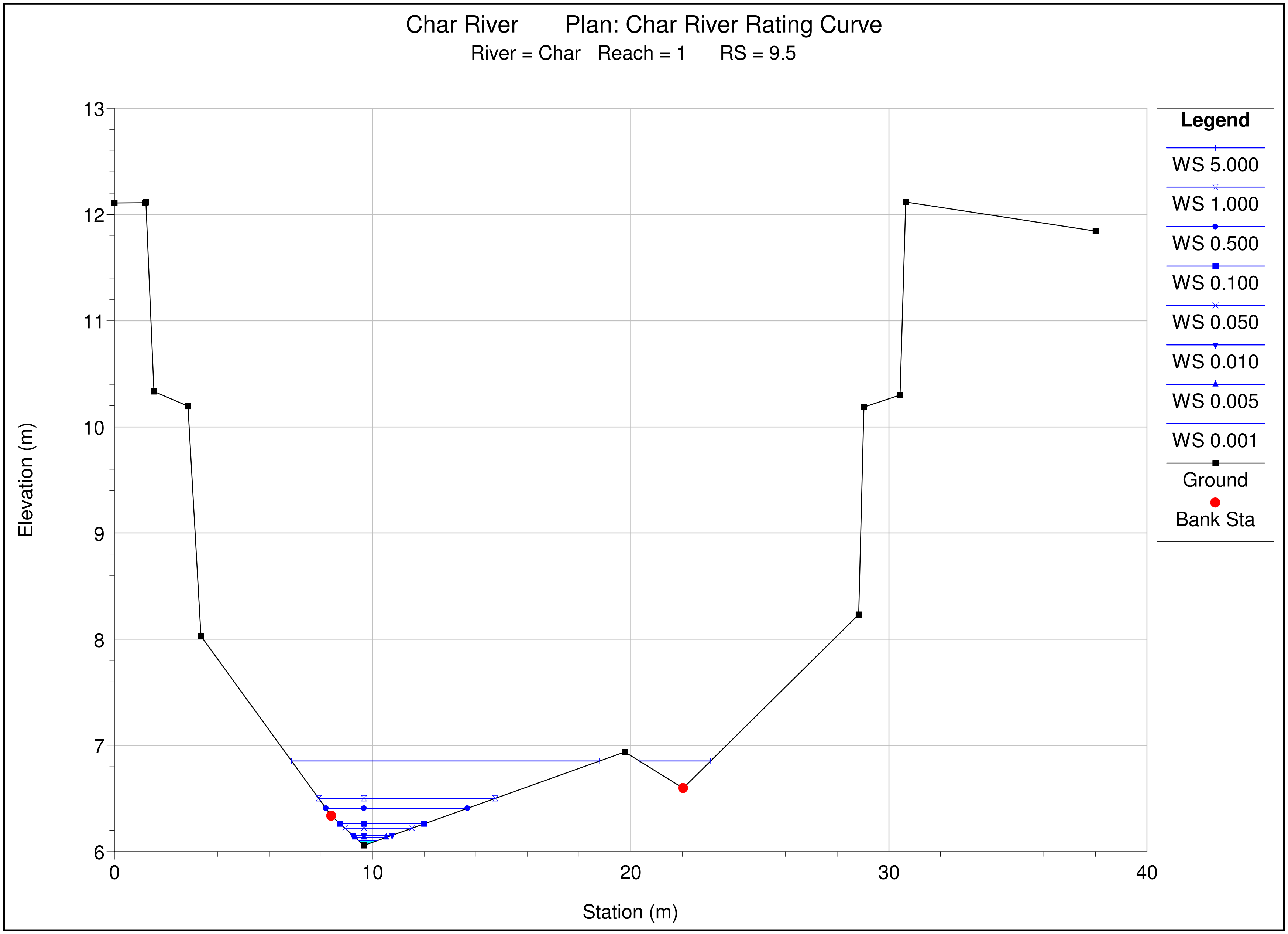


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 12
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
14
13
12
11
10
9
8
0
10
20
30
40
50
60

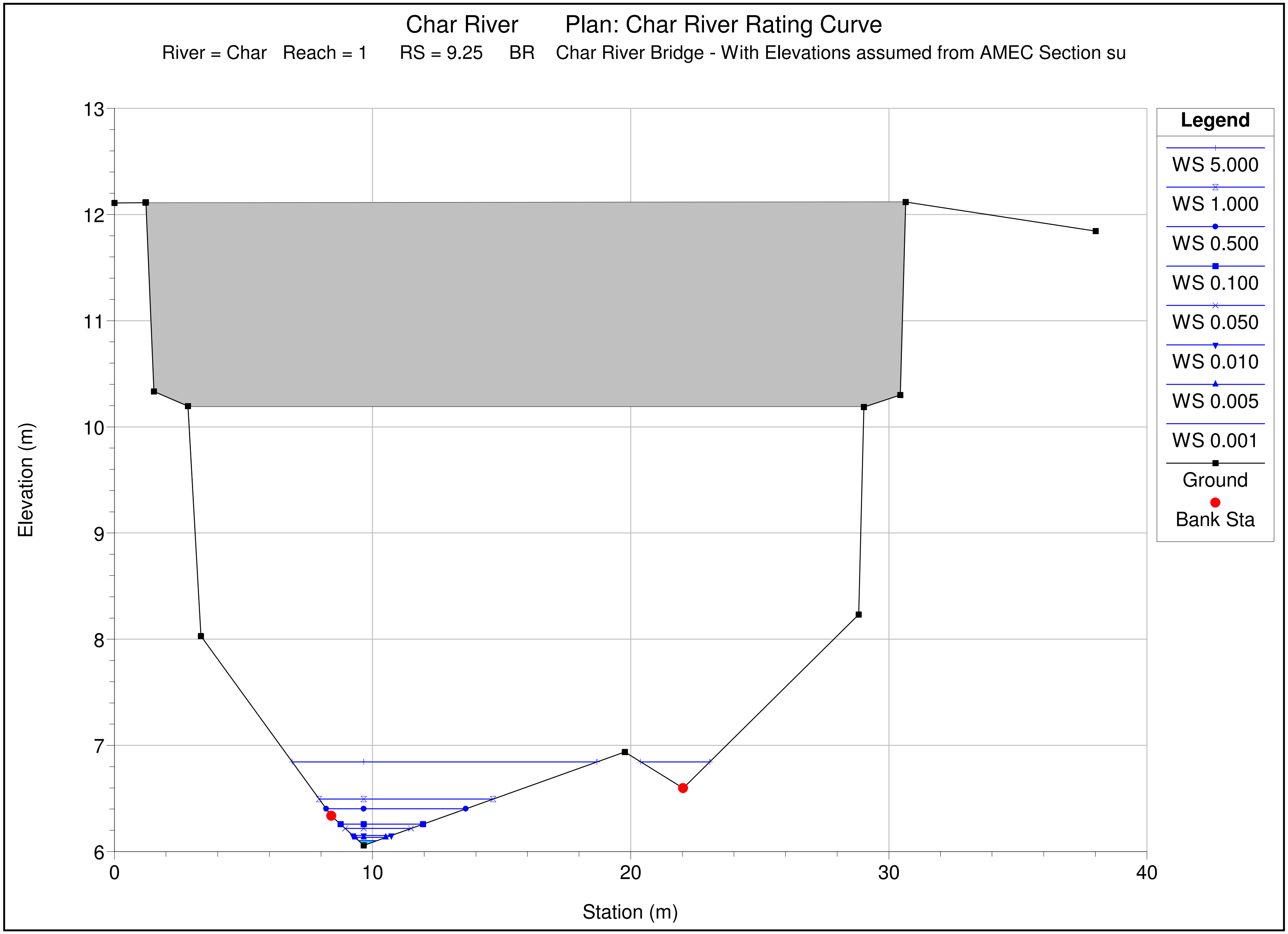

Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 11
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
12
11
10
9
8
7
0
20
40
60
80
100



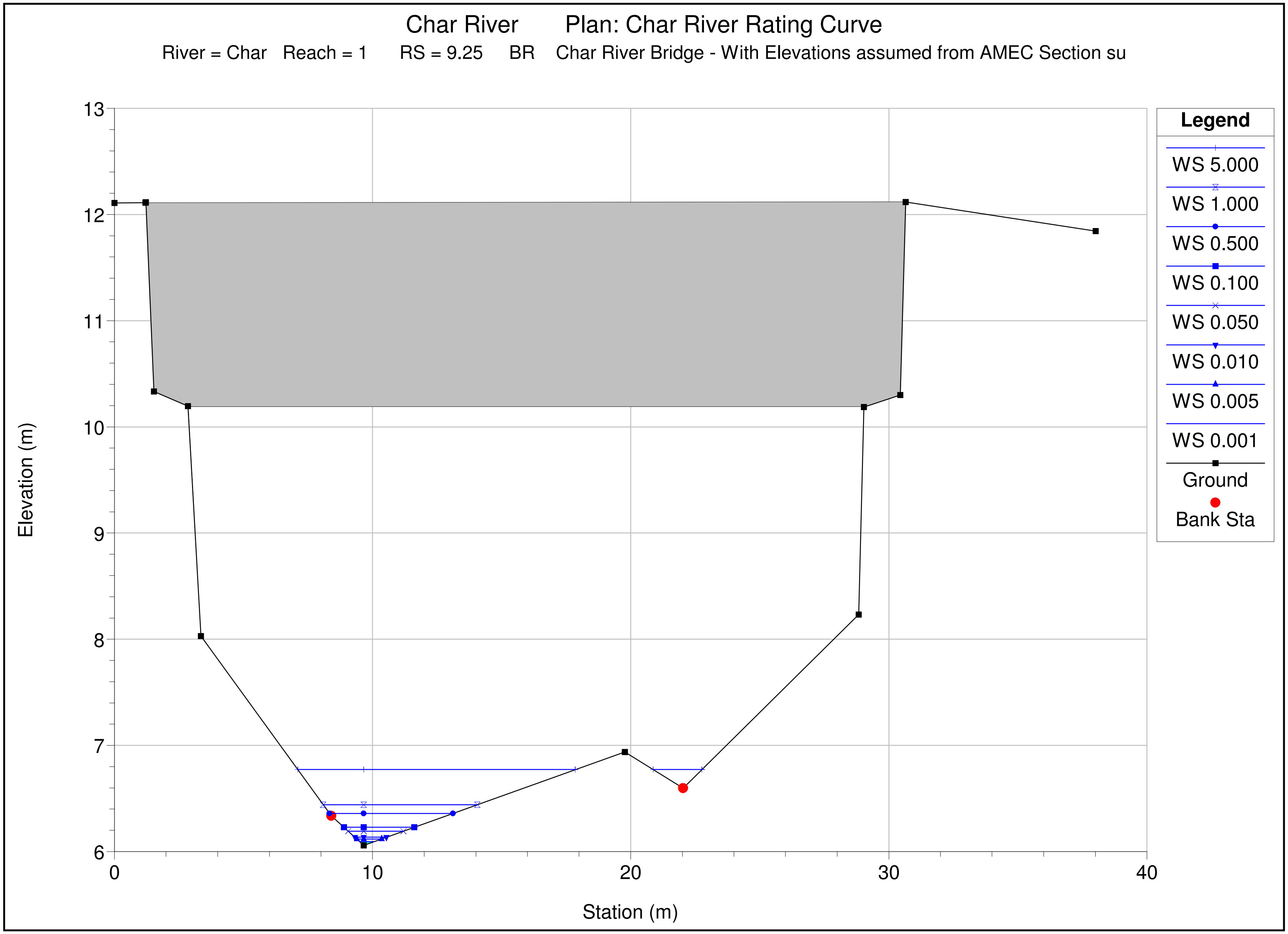
Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 10
Elevation (m)
Station (m)
12
11
10
9
8
7
6
0
20
40
60
80
100
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta

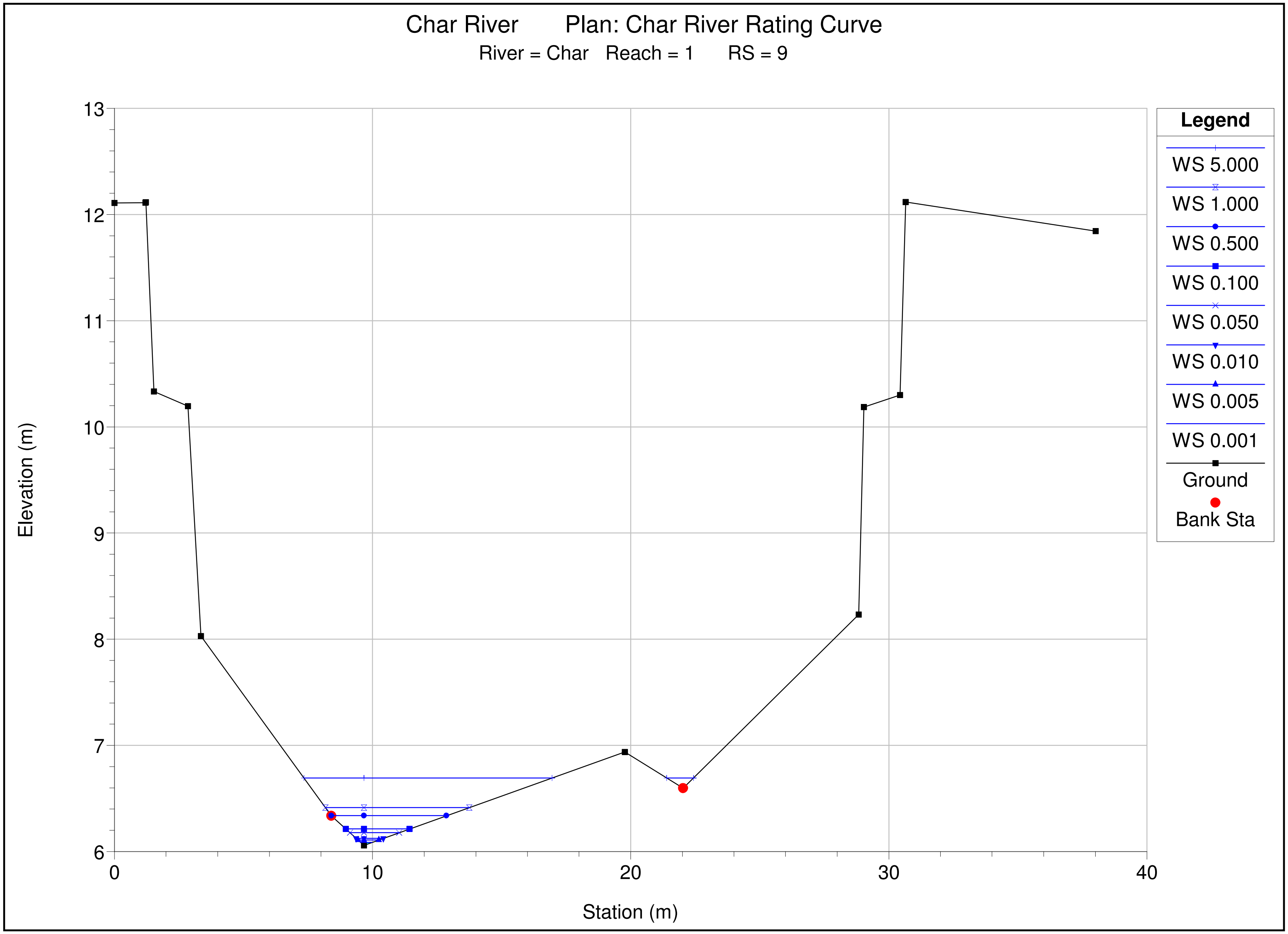


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 9.5
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
13
12
11
10
9
8
7
6
0
10
20
30
40

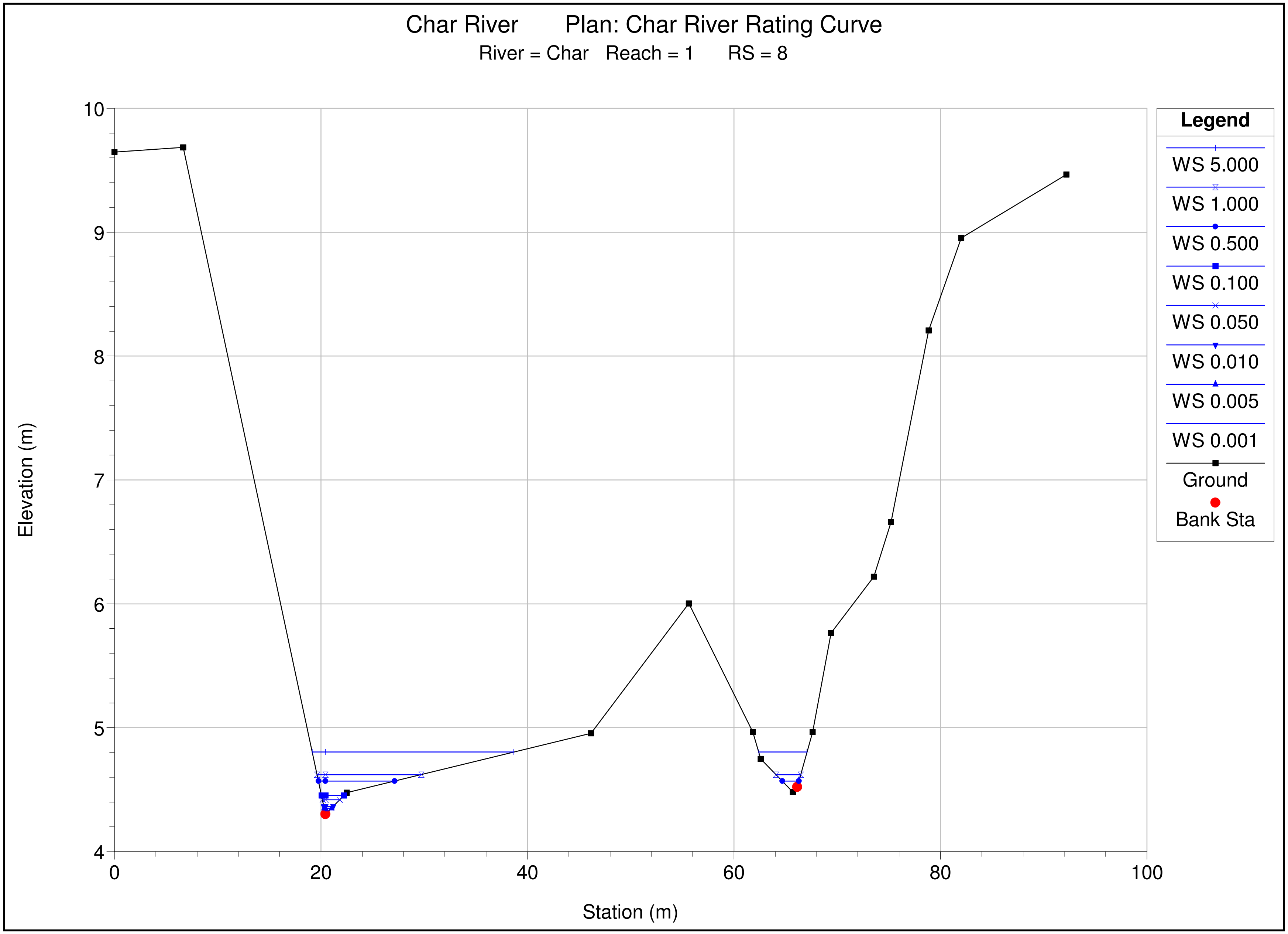


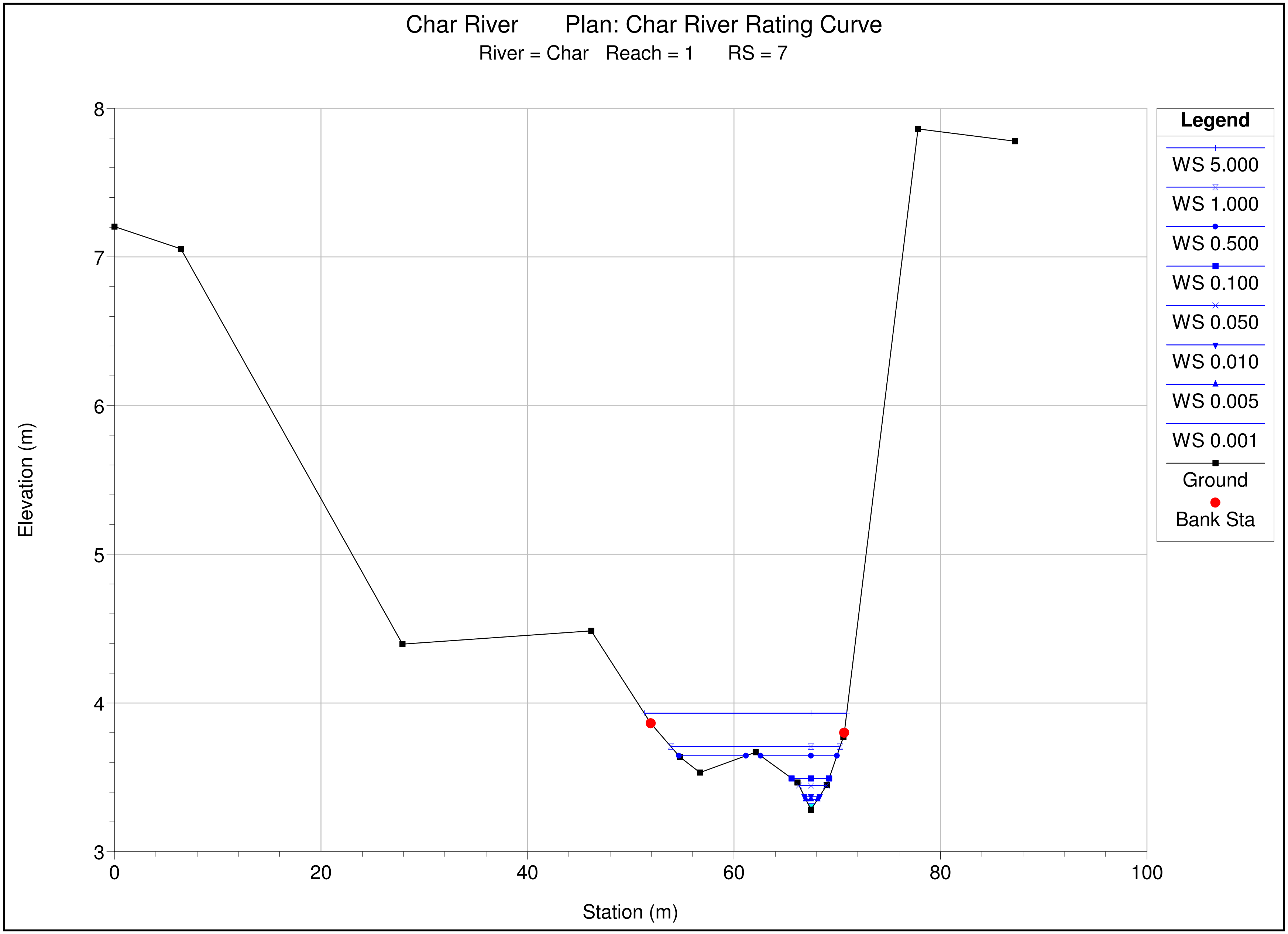
Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 9.25 BR Char River Bridge - With Elevations assumed from AMEC Section su
Elevation (m)
Station (m)
13
12
11
10
9
8
7
6
0
10
20
30
40
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 9.25 BR Char River Bridge - With Elevations assumed from AMEC Section su
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
13
12
11
10
9
8
7
6
0
10
20
30
40

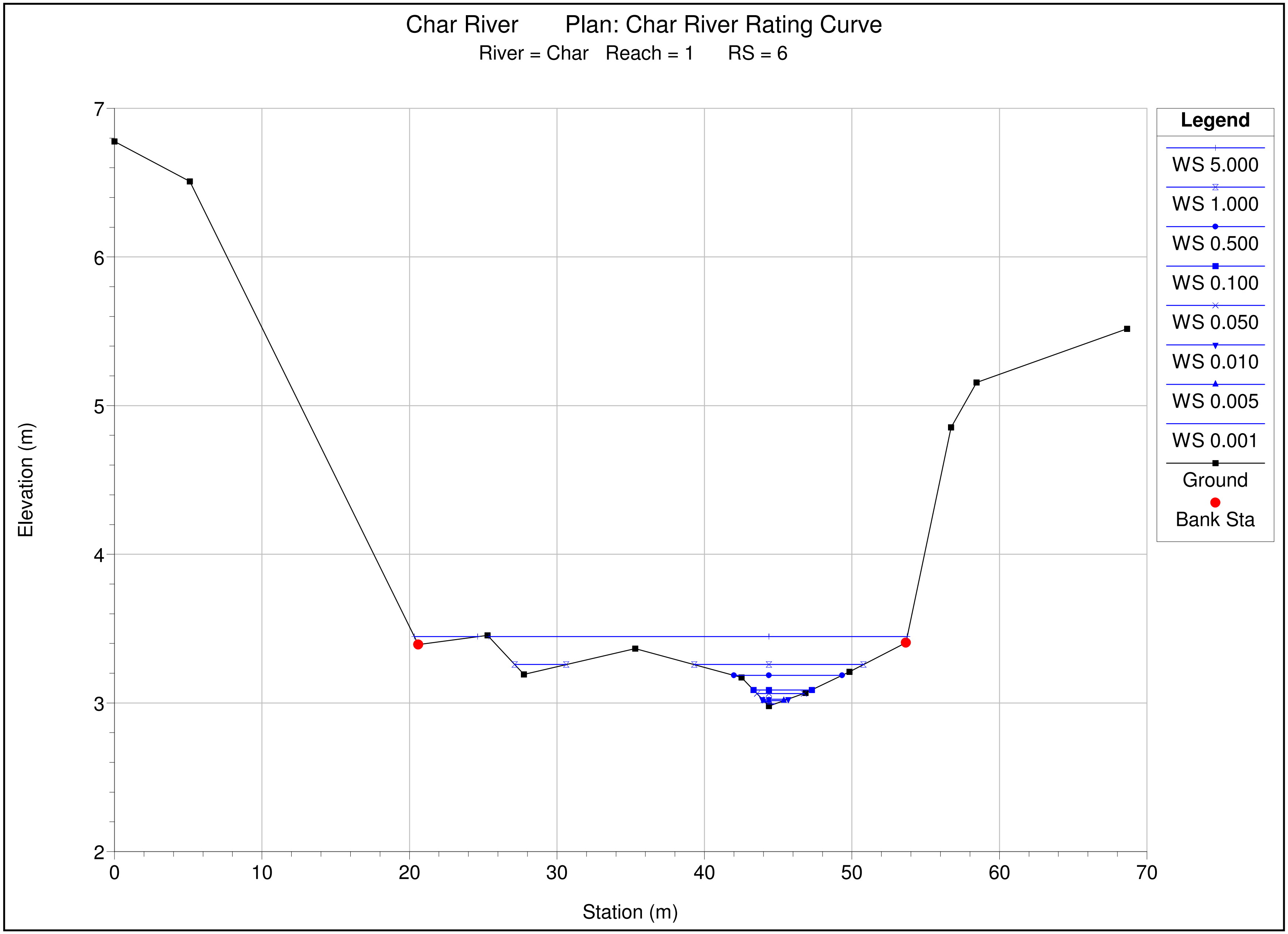


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 9
Elevation (m)
Station (m)
13
12
11
10
9
8
7
6
0
10
20
30
40
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta

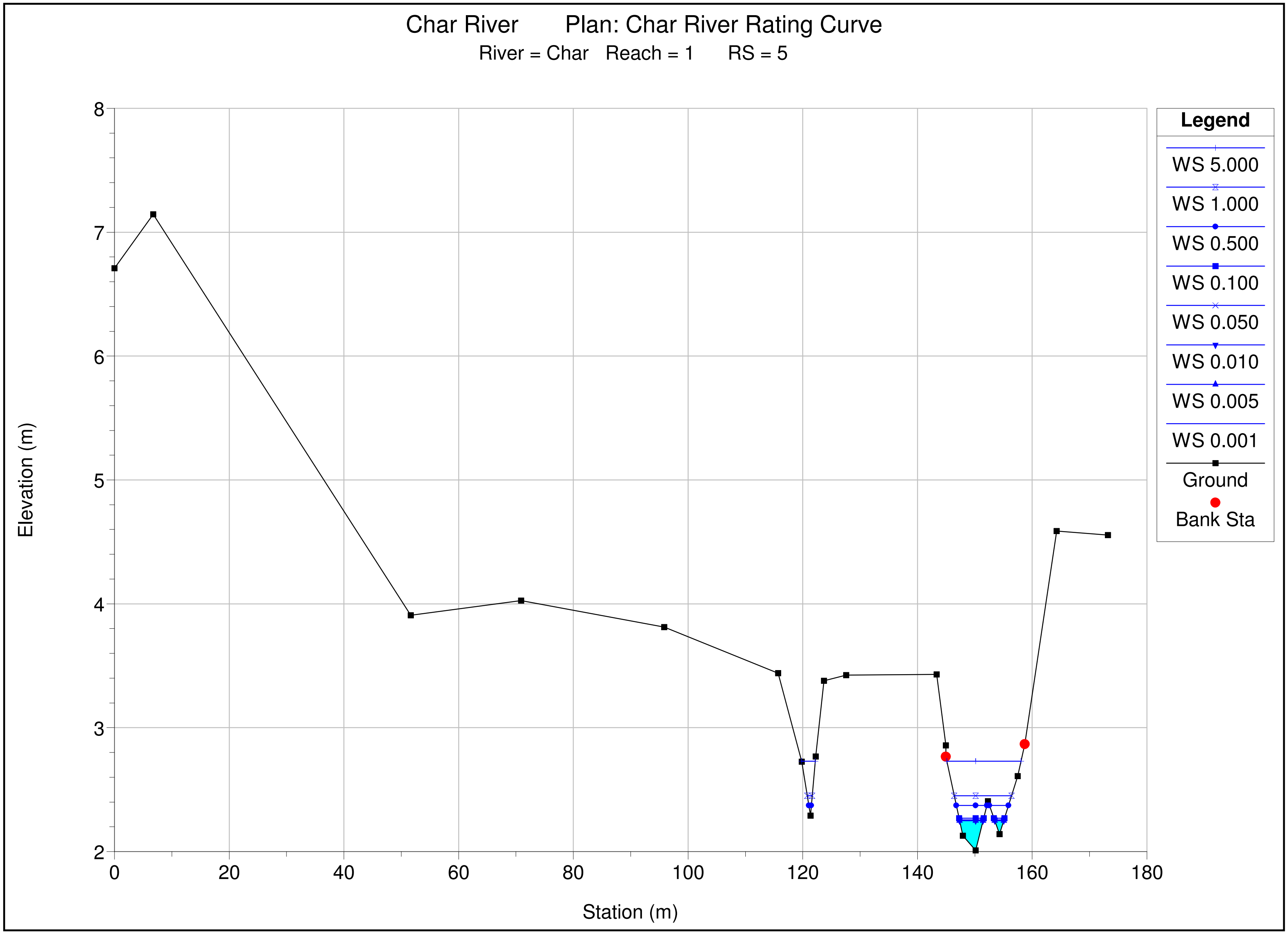

Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 8
Elevation (m)
Station (m)
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
10
9
8
7
6
5
4
0
20
40
60
80
100

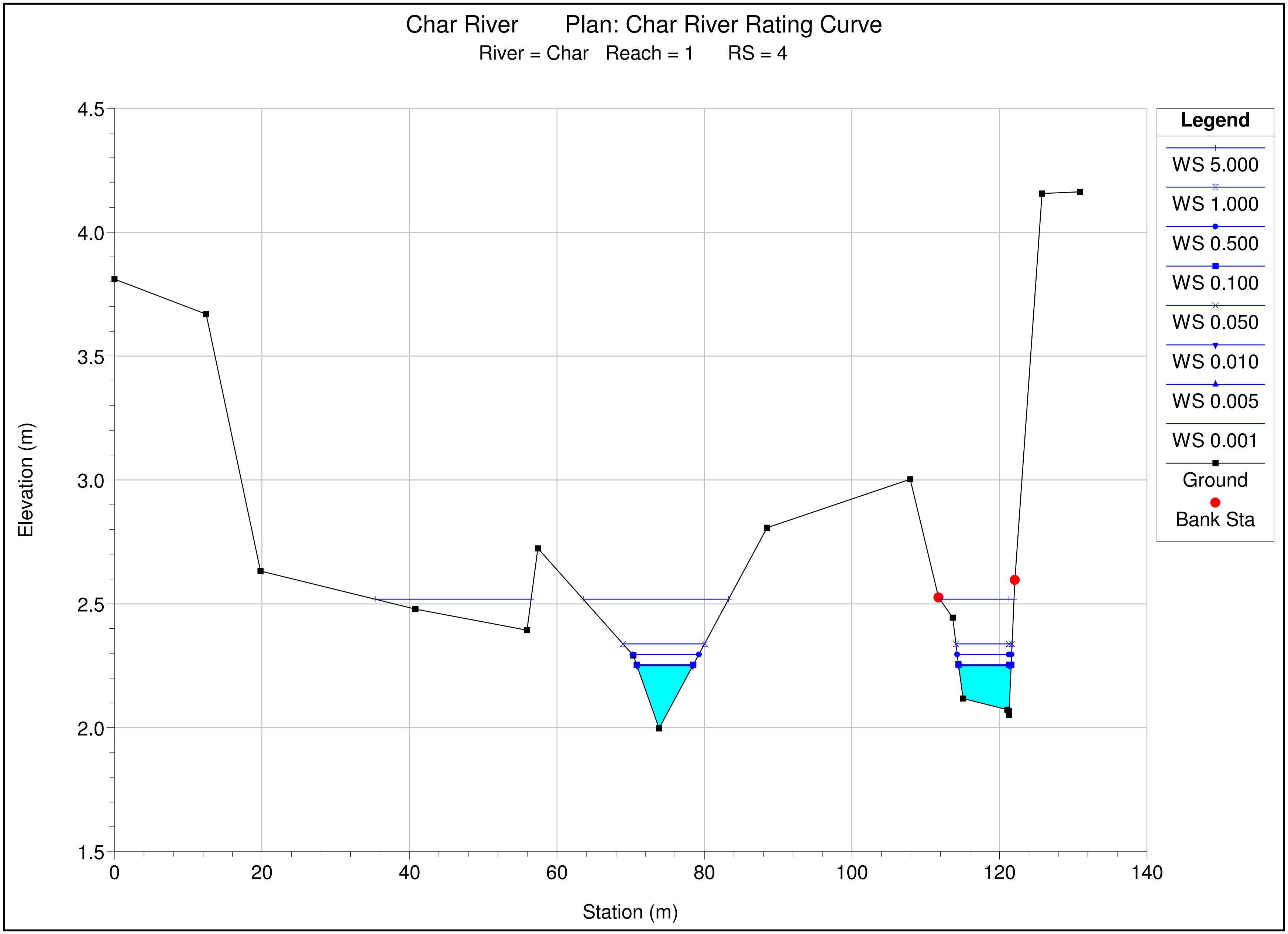


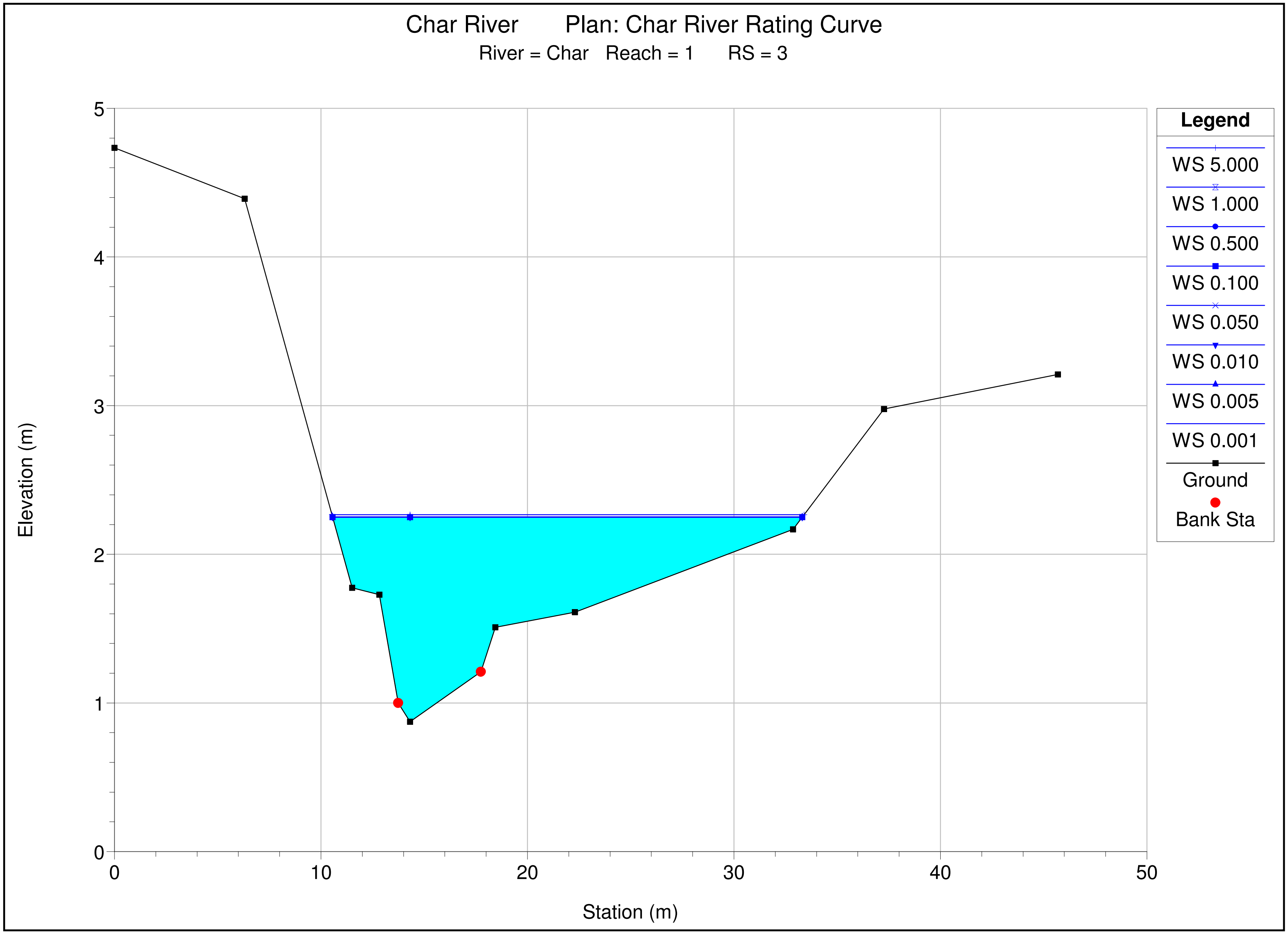
Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 7
Elevation (m)
Station (m)
8
7
6
5
4
3
0
20
40
60
80
100
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta

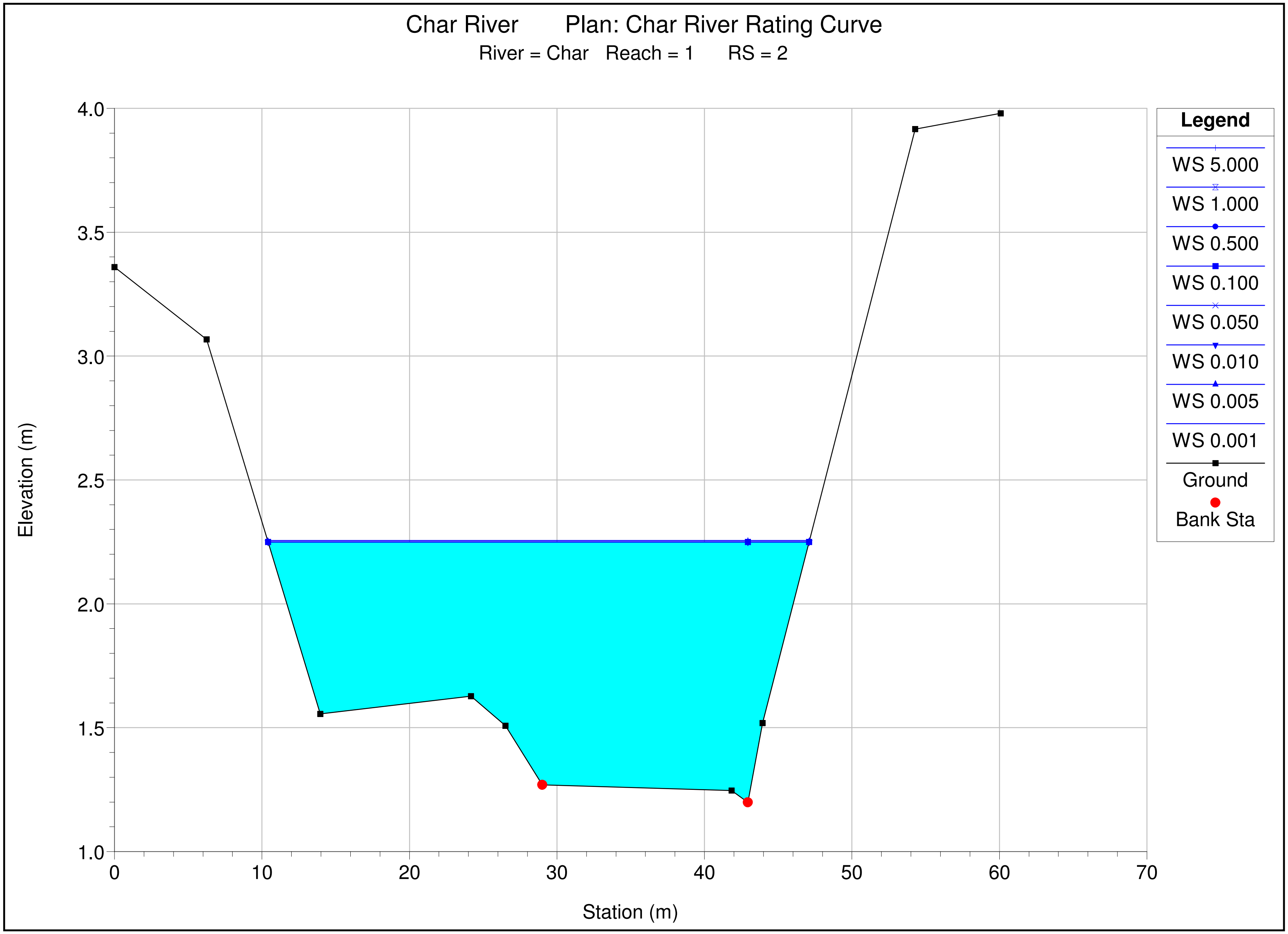


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 6
Elevation (m)
Station (m)
7
6
5
4
3
2
0
10
20
30
40
50
60
70
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta

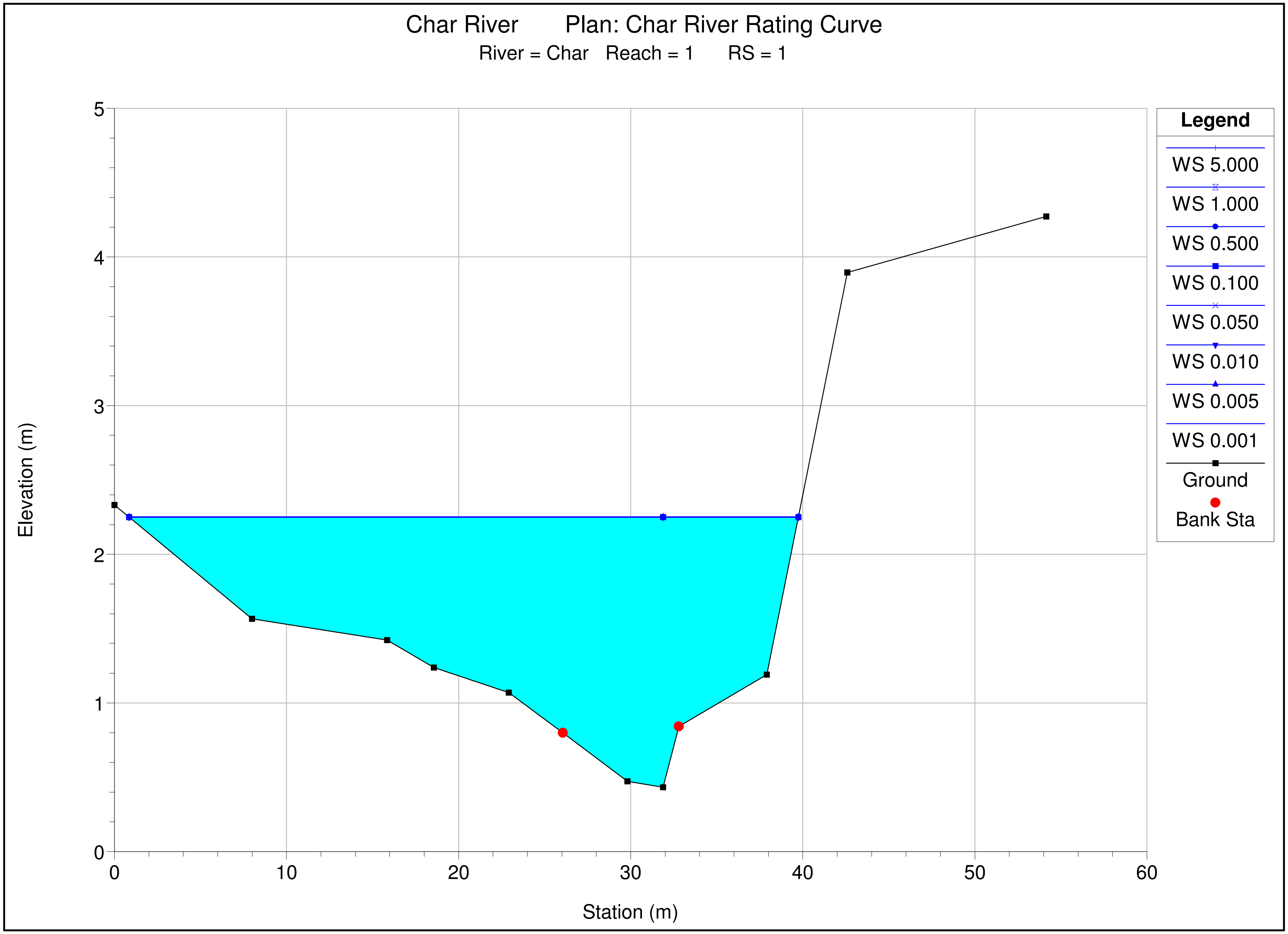

Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 5
Elevation (m)
Station (m)
8
7
6
5
4
3
2
0
20
40
60
80
100
120
140
160
180
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 4
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
0
20
40
60
80
100
120
140
Station (m)


Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 3
Elevation (m)
Station (m)
0
1
2
3
4
5
0
10
20
30
40
50
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta



Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 2
Elevation (m)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
10
20
30
40
50
60
70
Station (m)
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta



Char River Plan: Char River Rating Curve
River = Char Reach = 1 RS = 1
Legend
WS 5.000
WS 1.000
WS 0.500
WS 0.100
WS 0.050
WS 0.010
WS 0.005
WS 0.001
Ground
Bank Sta
Elevation (m)
Station (m)
0
1
2
3
4
5
0
10
20
30
40
50
60

APPENDIX C

Estimated Pumping Rates For Median, Wet and Dry Char River Hydrographs and Climate Change Scenarios

Table 0 Table C0: Estimated Water Taking Rates for the Median Char River Flow Hydrograph Under Historic Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	100	100	271	0.027	0.062	892	0.458	0.202	1622	0.764	0.368
	75	75	86	0.007	0.020	706	0.263	0.160	1436	0.764	0.326
	50	50	0	-	-	608	0.188	0.138	1338	0.764	0.304
	25	25	0	-	-	379	0.050	0.086	1109	0.764	0.252
	0	0	0	-	-	0	-	-	258	0.025	0.059
50	100	100	234	0.022	0.037	855	0.409	0.134	1585	0.764	0.248
	75	75	31	0.003	0.005	652	0.220	0.102	1382	0.764	0.216
	50	50	0	-	-	550	0.148	0.086	1280	0.764	0.200
	25	25	0	-	-	310	0.033	0.048	1040	0.764	0.163
	0	0	0	-	-	0	-	-	224	0.020	0.035
0	100	100	189	0.017	0.021	809	0.358	0.091	1539	0.764	0.173
	75	75	0	-	-	585	0.171	0.066	1315	0.764	0.148
	50	50	0	-	-	479	0.101	0.054	1209	0.764	0.136
	25	25	0	-	-	225	0.021	0.025	955	0.555	0.107
	0	0	0	-	-	0	-	-	182	0.016	0.020

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potantial error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 50% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 50% probability occurrence Char River hydrograph.

Table C1: Estimated Water Taking Rates for the Char River Wet Flow Hydrograph Under Historic Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	100	100	271	0.024	0.077	892	0.458	0.252	1,622	1.029	0.458
	75	75	86	0.007	0.024	706	0.175	0.199	1,436	1.029	0.405
	50	50	0	-	-	608	0.112	0.172	1,338	0.917	0.378
	25	25	0	-	-	379	0.038	0.107	1,109	0.503	0.313
	0	0	0	-	-	0	-	-	258	0.023	0.073
50	100	100	234	0.021	0.042	855	0.279	0.155	1,585	1.029	0.287
	75	75	31	0.003	0.006	652	0.140	0.118	1,382	1.029	0.250
	50	50	0	-	-	550	0.082	0.099	1,280	0.736	0.231
	25	25	0	-	-	310	0.029	0.056	1,040	0.432	0.188
	0	0	0	-	-	0	-	-	224	0.020	0.041
0	100	100	189	0.016	0.024	809	0.246	0.101	1,539	1.029	0.192
	75	75	0	-	-	585	0.099	0.073	1,315	0.810	0.164
	50	50	0	-	-	479	0.058	0.060	1,209	0.627	0.150
	25	25	0	-	-	225	0.020	0.028	955	0.358	0.119
	0	0	0	-	-	0	-	-	182	0.016	0.023

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 25% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 25% probability occurrence Char River hydrograph.

Table C2: Estimated Water Taking Rates for the Char River Dry Flow Hydrograph Under Historic Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	**100**	**100**	271	**0.032**	**0.052**	892	0.589	0.172	**1,622**	**0.589**	**0.313**
	75	**75**	86	**0.007**	**0.017**	706	**0.373**	**0.136**	**1,436**	**0.589**	**0.277**
	50	**50**	0	**-**	**-**	608	**0.260**	**0.117**	**1,338**	**0.589**	**0.258**
	25	**25**	0	**-**	**-**	379	**0.084**	**0.073**	**1,109**	**0.589**	**0.214**
	0	**0**	0	**-**	**-**	0	**-**	**-**	**258**	**0.029**	**0.050**
50	**100**	**100**	234	**0.024**	**0.033**	855	**0.589**	**0.119**	**1,585**	**0.589**	**0.221**
	75	**75**	31	**0.003**	**0.004**	652	**0.306**	**0.091**	**1,382**	**0.589**	**0.193**
	50	**50**	0	**-**	**-**	550	**0.207**	**0.077**	**1,280**	**0.589**	**0.178**
	25	**25**	0	**-**	**-**	310	**0.045**	**0.043**	**1,040**	**0.589**	**0.145**
	0	**0**	0	**-**	**-**	0	**-**	**-**	**224**	**0.023**	**0.031**
0	**100**	**100**	189	**0.018**	**0.020**	809	**0.589**	**0.084**	**1,539**	**0.589**	**0.159**
	75	**75**	0	**-**	**-**	585	**0.240**	**0.060**	**1,315**	**0.589**	**0.136**
	50	**50**	0	**-**	**-**	479	**0.152**	**0.049**	**1,209**	**0.589**	**0.125**
	25	**25**	0	**-**	**-**	225	**0.023**	**0.023**	**955**	**0.589**	**0.099**
	0	**0**	0	**-**	**-**	0	**-**	**-**	**182**	**0.017**	**0.019**

Notes:

1. Based on the normal distribution of historic meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potantial error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 75% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 75% probability occurrence Char River hydrograph.

Table C3: Estimated Water Taking Rates for the Median Char River Flow Hydrograph Under 2050s Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	100	100	192	0.017	0.034	**813**	0.333	0.143	**1,543**	**0.814**	**0.271**
	75	75	0	-	-	570	0.146	0.100	**1,300**	**0.814**	**0.228**
	50	50	0	-	-	431	0.063	0.076	**1,161**	**0.814**	**0.204**
	25	25	0	-	-	112	0.010	0.020	842	0.361	0.148
	0	0	0	-	-	0	-	-	0	-	-
50	100	100	166	0.014	0.021	787	0.310	0.099	**1,517**	**0.814**	**0.191**
	75	75	0	-	-	534	0.122	0.067	**1,264**	**0.814**	**0.159**
	50	50	0	-	-	397	0.051	0.050	**1,127**	**0.814**	**0.142**
	25	25	0	-	-	79	0.007	0.010	809	0.329	0.102
	0	0	0	-	-	0	-	-	0	-	-
0	100	100	135	0.012	0.013	755	0.283	0.070	**1,485**	**0.814**	**0.139**
	75	75	0	-	-	491	0.095	0.046	1,221	**0.814**	**0.114**
	50	50	0	-	-	357	0.041	0.033	1,087	**0.814**	**0.101**
	25	25	0	-	-	39	0.003	0.004	769	0.294	0.072
	0	0	0	-	-	0	-	-	0	-	-

Notes:

1. Based on the normal distribution of 2050s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 50% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 50% probability occurrence Char River hydrograph.

Table C4: Estimated Water Taking Rates for the Char River Wet Weather Flow Hydrograph Under 2050s Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	**100**	**100**	192	**0.017**	**0.040**	**813**	**0.252**	**0.168**	**1,543**	**1.020**	**0.319**
	75	**75**	0	**-**	**-**	570	**0.093**	**0.118**	**1,300**	**0.797**	**0.269**
	50	**50**	0	**-**	**-**	431	**0.047**	**0.089**	**1,161**	**0.572**	**0.240**
	25	**25**	0	**-**	**-**	112	**0.010**	**0.023**	842	**0.273**	**0.174**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
50	**100**	**100**	166	**0.014**	**0.023**	787	**0.233**	**0.111**	**1,517**	**1.020**	**0.214**
	75	**75**	0	**-**	**-**	534	**0.076**	**0.075**	**1,264**	**0.722**	**0.178**
	50	**50**	0	**-**	**-**	397	**0.041**	**0.056**	**1,127**	**0.528**	**0.159**
	25	**25**	0	**-**	**-**	79	**0.007**	**0.011**	809	**0.249**	**0.114**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
0	**100**	**100**	135	**0.012**	**0.014**	755	**0.211**	**0.077**	**1,485**	**1.020**	**0.151**
	75	**75**	0	**-**	**-**	491	**0.062**	**0.050**	1,221	**0.655**	**0.124**
	50	**50**	0	**-**	**-**	357	**0.035**	**0.036**	1,087	**0.486**	**0.110**
	25	**25**	0	**-**	**-**	39	**0.003**	**0.004**	769	**0.221**	**0.078**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**

Notes:

1. Based on the normal distribution of 2050s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 25% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 25% probability occurrence Char River hydrograph.

Table C5: Estimated Water Taking Rates for the Char River Dry Weather Flow Hydrograph Under 2050s Climate Conditions

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	100	100	192	0.018	0.030	813	0.606	0.125	1,543	0.606	0.238
	75	75	0	-	-	570	0.217	0.088	1,300	0.606	0.201
	50	50	0	-	-	431	0.114	0.067	1,161	0.606	0.179
	25	25	0	-	-	112	0.010	0.017	842	0.582	0.130
	0	0	0	-	-	0	-	-	0	-	-
50	100	100	166	0.015	0.019	787	0.538	0.090	1,517	0.606	0.174
	75	75	0	-	-	534	0.188	0.061	1,264	0.606	0.145
	50	50	0	-	-	397	0.091	0.046	1,127	0.606	0.129
	25	25	0	-	-	79	0.007	0.009	809	0.606	0.093
	0	0	0	-	-	0	-	-	0	-	-
0	100	100	135	0.012	0.012	755	0.436	0.066	1,485	0.606	0.129
	75	75	0	-	-	491	0.156	0.043	1,221	0.606	0.106
	50	50	0	-	-	357	0.066	0.031	1,087	0.606	0.095
	25	25	0	-	-	39	0.003	0.003	769	0.466	0.067
	0	0	0	-	-	0	-	-	0	-	-

Notes:

1. Based on the normal distribution of 2050s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 75% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 75% probability occurrence Char River hydrograph.

Table C6: Estimated Water Taking Rates for the Median Char River Flow Hydrograph Under 2080s Climate Regime

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	**100**	**100**	182	**0.016**	**0.030**	802	**0.336**	**0.131**	**1,532**	**0.788**	**0.250**
	75	**75**	0	**-**	**-**	576	**0.158**	**0.094**	**1,306**	**0.788**	**0.213**
	50	**50**	0	**-**	**-**	448	**0.076**	**0.073**	**1,178**	**0.788**	**0.192**
	25	**25**	0	**-**	**-**	142	**0.012**	**0.023**	872	**0.410**	**0.142**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
50	**100**	**100**	157	**0.014**	**0.019**	778	**0.314**	**0.092**	**1,508**	**0.788**	**0.178**
	75	**75**	0	**-**	**-**	542	**0.135**	**0.064**	**1,272**	**0.788**	**0.150**
	50	**50**	0	**-**	**-**	416	**0.060**	**0.049**	**1,146**	**0.788**	**0.135**
	25	**25**	0	**-**	**-**	103	**0.009**	**0.012**	833	**0.368**	**0.098**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
0	**100**	**100**	128	**0.011**	**0.011**	748	**0.288**	**0.066**	**1,478**	**0.788**	**0.131**
	75	**75**	0	**-**	**-**	501	**0.108**	**0.044**	1,231	**0.788**	**0.109**
	50	**50**	0	**-**	**-**	377	**0.047**	**0.033**	1,107	**0.788**	**0.098**
	25	**25**	0	**-**	**-**	57	**0.005**	**0.005**	787	**0.322**	**0.070**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**

Notes:

1. Based on the normal distribution of 2080s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 50% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 50% probability occurrence Char River hydrograph.

Table C7: Estimated Water Taking Rates for the Char River Wet Weather Flow Hydrograph Under 2080s Climate Regime

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	**Snow Accumulation**	**Rainfall Runoff**	**Total Water Taking (ML) [1,2,3]**	**Option 1 (m3/s) [5,6,7]**	**Option 2 (m3/s) [5,8,9]**	**Total Water Taking (ML) [1,2,3]**	**Option 1 (m3/s) [5,6,7]**	**Option 2 (m3/s) [5,8,9]**	**Total Water Taking (ML) [1,2,3]**	**Option 1 (m3/s) [5,6,7]**	**Option 2 (m3/s) [5,8,9]**
100	**100**	**100**	182	**0.016**	**0.035**	802	**0.258**	**0.152**	**1,532**	**0.977**	**0.291**
	75	**75**	0	**-**	**-**	576	**0.106**	**0.109**	**1,306**	**0.977**	**0.248**
	50	**50**	0	**-**	**-**	448	**0.053**	**0.085**	**1,178**	**0.639**	**0.224**
	25	**25**	0	**-**	**-**	142	**0.012**	**0.027**	872	**0.311**	**0.165**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
50	**100**	**100**	157	**0.013**	**0.021**	778	**0.241**	**0.102**	**1,508**	**0.977**	**0.198**
	75	**75**	0	**-**	**-**	542	**0.087**	**0.071**	**1,272**	**0.880**	**0.167**
	50	**50**	0	**-**	**-**	416	**0.046**	**0.055**	**1,146**	**0.593**	**0.151**
	25	**25**	0	**-**	**-**	103	**0.009**	**0.014**	833	**0.281**	**0.110**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**
0	**100**	**100**	128	**0.011**	**0.012**	748	**0.219**	**0.072**	**1,478**	**0.977**	**0.141**
	75	**75**	0	**-**	**-**	501	**0.069**	**0.048**	1,231	**0.729**	**0.118**
	50	**50**	0	**-**	**-**	377	**0.039**	**0.036**	1,107	**0.540**	**0.106**
	25	**25**	0	**-**	**-**	57	**0.005**	**0.005**	787	**0.247**	**0.075**
	0	**0**	0	**-**	**-**	0	**-**	**-**	0	**-**	**-**

Notes:

1. Based on the normal distribution of 2080s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 25% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 25% probability occurrence Char River hydrograph.

Table C8: Estimated Water Taking Rates for the Char River Dry Weather Flow Hydrograph Under 2080s Climate Regime

Percentage Probability of Exceedance			Daily Consumption (m^3)								
			1600			3300			5300		
Winter Length [4]	Snow Accumulation	Rainfall Runoff	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]	Total Water Taking (ML) [1,2,3]	Option 1 (m3/s) [5,6,7]	Option 2 (m3/s) [5,8,9]
100	100	100	182	0.017	0.026	802	0.500	0.116	1,532	0.625	0.222
	75	75	0	-	-	576	0.214	0.083	1,306	0.625	0.189
	50	50	0	-	-	448	0.119	0.065	1,178	0.625	0.170
	25	25	0	-	-	142	0.012	0.021	872	0.625	0.126
	0	0	0	-	-	0	-	-	0	-	-
50	100	100	157	0.014	0.017	778	0.448	0.084	1,508	0.625	0.163
	75	75	0	-	-	542	0.187	0.059	1,272	0.625	0.138
	50	50	0	-	-	416	0.098	0.045	1,146	0.625	0.124
	25	25	0	-	-	103	0.009	0.011	833	0.625	0.090
	0	0	0	-	-	0	-	-	0	-	-
0	100	100	128	0.011	0.011	748	0.401	0.062	1,478	0.625	0.122
	75	75	0	-	-	501	0.156	0.041	1,231	0.625	0.102
	50	50	0	-	-	377	0.073	0.031	1,107	0.625	0.092
	25	25	0	-	-	57	0.005	0.005	787	0.466	0.065
	0	0	0	-	-	0	-	-	0	-	-

Notes:

1. Based on the normal distribution of 2080s meteorological conditions examined.
2. Assumes a portion of water is unavailable for consumption due to ice formation.
3. Water deficits do not consider potential error in the calibrated water balance model.
4. Probabilities of winter length are derived from the probabilities of freeze and thaw dates, as shown in Table 17, 20 and 23.
5. Pumping rates based on a 75% probability occurrence hydrograph of Char River.
6. The timing of the water taking may not correspond to periods of available storage in Nipissar Lake and water may be lost over the Nipissar Lake spillway.
7. Option 1 water taking assumes pumping occurs over the entire thaw season.
8. Pumping rates assume 24 hour pumping duration per day.
9. Option 2 water taking assumes pumping occurs following spring freshet to estimated freeze-up.
10. Red Bold values denote cases where the winter consumption rate exceeds the active storage capacity of the lake (i.e. daily consumption rate x number of winter days > than active lake storage).
11. Blue Bold values denote cases where the total water taking required exceeds 10% of the hydrograph and therefore the total supplementation can not be met under the 75% probability occurrence Char River hydrograph.

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