Rook I Project

Environmental Impact Statement

Annex IV.3: Geomorphology Characterization Report

GEOMORPHOLOGY CHARACTERIZATION REPORT FOR THE ROOK I PROJECT

Prepared for:

NexGen Energy Ltd.

Prepared by:

Golder Associates Ltd.

March 2022

Executive Summary

The geomorphology baseline study was completed as part of the hydrology program to support the Environmental Assessment (EA) for the Rook I Project (Project). The study incorporated existing, publicly available desktop geomorphology information such as surficial geology and glacial landforms as well as results from field studies to characterize baseline geomorphology of waterbodies and watercourses that may be most influenced by proposed Project activities. The study focused on the area of Patterson Lake and the Clearwater River between Patterson and Forrest lakes, as these are the areas expected to be most influenced by proposed Project activities. The objectives of the baseline study were twofold: 1) to characterize existing geomorphology of Patterson Lake's shorelines and the Clearwater River channel downstream of the Patterson Lake outlet; and 2) to identify areas that may be vulnerable to increased erosion due to proposed Project activities.

The field survey sites included the following locations:

- the shoreline near the sand bar/spit formation that divides the Patterson Lake – North Arm into two basins;
- two shoreline locations in Patterson Lake – South Arm; and
- multiple channel cross-sections between Patterson Lake (upstream) and Forrest Lake (downstream).

The field surveys included observations of landform, shoreline slope, bank and bed materials, and vegetation, as well as photographic documentation. Information collected during the field surveys was used to classify erosion susceptibility at the field survey sites. Erosion susceptibility at other portions of the Patterson Lake shoreline was assessed using a combination of field survey, geospatial data, and aerial imagery. Channel erosion susceptibility in the Clearwater River below Patterson Lake was also assessed based on field observations.

The results from the baseline characterization of Patterson Lake showed that several shoreline segments along Patterson Lake were observed to be subject to modification by ongoing sediment transport processes. These processes include accretion (i.e., gradual build-up of sediment) resulting from longshore drift, with historical shoreline alignments different than current shoreline locations visible in the aerial imagery, as well as likely ice-thrust modification of sedimentary shorelines. The active sediment transport areas are expected to be most sensitive to possible changes in the lake hydrologic regime. The localized bank erosion sites observed along the lake shoreline in sections with ice-thrust berms were also identified as sensitive areas.

The corresponding results from the baseline characterization of Clearwater River identified a single channel upstream and multiple meandering channels farther downstream, with typical channel cross-section geometries (i.e., deep banks on the outside of the meander) and fluvial morphology (i.e., point bars). The river has an active sediment transport regime, capable of transporting mostly small size materials (i.e., fine to medium sand), as indicated by the delta feature at its mouth into Forrest Lake.

Overall, this baseline geomorphological characterization has established that there are portions of both the Patterson Lake shoreline and the Clearwater River channel below Patterson Lake that are subject to active sediment transport regimes and may be susceptible to future erosion. The potential for future changes to erosion-sedimentation processes at these areas of erosion susceptibility would depend on changes to the water surface

elevation of Patterson Lake. The magnitude, direction, and duration of any future changes in lake levels and the corresponding influence on baseline sediment transport regimes in the areas of interest would be evaluated as part of the EA.

If referencing this report, please use for the following citation:

Golder (Golder Associates Ltd.). 2022. Geomorphology Characterization Report for the Rook I Project. Prepared for NexGen Energy Ltd.

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Abbreviations and Units of Measure

Acronym	Definition
EA	Environmental Assessment
GIS	geographic information system
LiDAR	Light Detection and Ranging
LSA	local study area
NexGen	NexGen Energy Ltd.
NHC	Northwest Hydraulics Consultants Ltd.
Project	Rook I Project
RSA	regional study area
TLU	traditional land use

Units	Definition
°	degree (angle)
%	percent
<	less than
>	more than
≥	more than or equal to
km	kilometre
km^2	square kilometre
m	metre
m/s	metres per second
masl	metres above sea level

1.0 INTRODUCTION

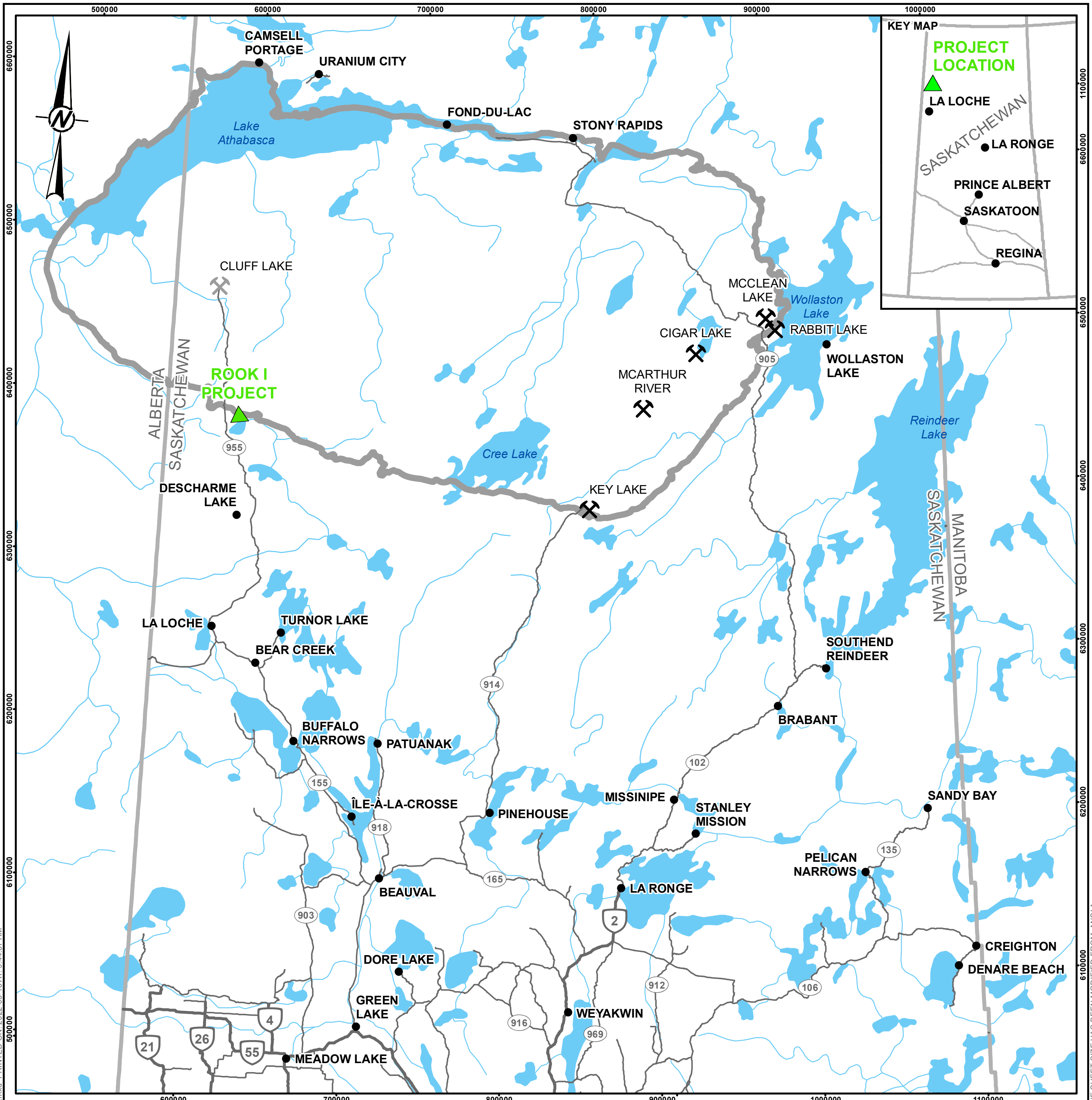
The Rook I Project (Project) is a proposed new uranium mining and milling operation that is 100% owned by NexGen Energy Ltd. (NexGen). The Project would be located in northwestern Saskatchewan, approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon (Figure 1). The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake, and along the upper Clearwater River system (Figure 2). Access to the Project would be from an existing road off Highway 955. The Project would include underground and surface facilities to support the extraction and processing of uranium ore from the Arrow deposit, a land-based, basement-hosted, high-grade uranium deposit.

The geomorphology baseline report represents a component of a comprehensive baseline program that documents the natural and socio-economic environments in the anticipated area of the Project. The hydrology baseline program, of which the geomorphology baseline study is a part, was undertaken to provide context from which Project environmental hydrological effects could be assessed in the Environmental Impact Statement.

Since exploration at the Project commenced in 2013, NexGen has engaged regularly and established relationships with local First Nation and Métis Groups (collectively referred to as Indigenous Groups) and northern communities, specifically those closest and with greatest access to the proposed Project. NexGen respects the rights of Indigenous Peoples and the unique relationship Indigenous Peoples have with the environment, and recognizes the importance of full and open discussion with interested or potentially affected Indigenous communities regarding the development, operation, and decommissioning of the proposed Project. Engagement activities to date, as well as future planned engagement activities, reflect the value NexGen places on meaningful engagement with Indigenous Groups and northern communities who could be potentially affected by the proposed Project. Engagement mechanisms have included, but are not limited to: meetings with leadership, workshops and community information sessions, Project site tours, establishing Joint Working Groups to support the gathering and incorporation of Indigenous and Local Knowledge throughout the Environmental Assessment (EA) process, and providing funding for Traditional Land Use (TLU) Studies[1] to understand how the proposed Project may interact with the Indigenous communities' traditional use of the anticipated area of the Project.

Feedback received during engagement activities was documented for contribution to the Environmental Impact Statement for the Project; examples of feedback received include discussion of concerns, interests, potential adverse effects, mitigation, and design alternatives. Many baseline studies were initiated in advance of formal engagement on the EA for the Project; however, engagement during the execution of baseline studies has helped inform the understanding of baseline conditions and confirmed components of the natural and socio-economic environments that required study. A summary of feedback related to the hydrology baseline program is presented in Appendix A of the Hydrology Baseline Road Map (Annex IV).

[1] Traditional Land Use (TLU) Studies include all land use studies developed by the Project's affected Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies, henceforth referred collectively as TLU Studies.



LEGEND

- POPULATED PLACE
- URANIUM MINING FACILITY (ACTIVE)
- URANIUM MINING FACILITY (DECOMMISSIONED)
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- ATHABASCA BASIN BOUNDARY
- PROJECT LOCATION

0 100 200

1:3,500,000 KILOMETRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

LOCATION OF THE ROOK I PROJECT, SASKATCHEWAN

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	SS
PREPARED	NO/AK
REVIEWED	JMC
APPROVED	MM

PROJECT NO.	PHASE	REV.	FIGURE
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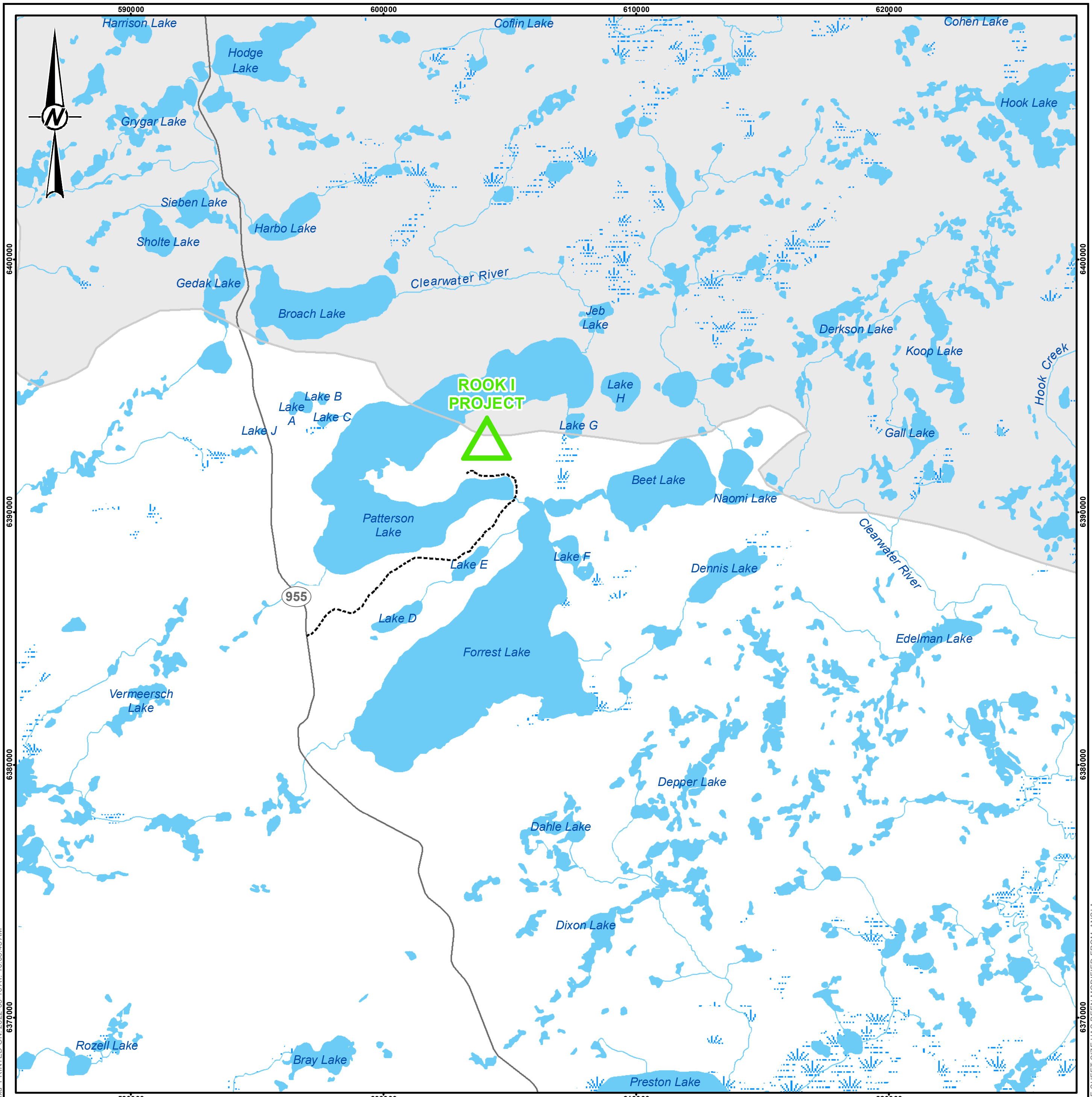

LEGEND

- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- ATHABASCA BASIN
- PROJECT LOCATION
- EXISTING ACCESS ROAD

0 5,000 10,000

1:225,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

REGIONAL AREA OF THE ROOK I PROJECT

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	JMC
PREPARED	NO/AK
REVIEWED	JMC
APPROVED	MM

PROJECT NO.	PHASE	REV.	FIGURE
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2.0 STUDY OBJECTIVES

The geomorphology baseline study was completed in conjunction with the hydrology baseline program. The specific objectives of the geomorphology baseline study were to:

- Summarize any existing geomorphology information collected near the proposed Project.
- Characterize existing geomorphology of waterbody shorelines that could be influenced by the Project, including the shoreline of Patterson Lake.
- Characterize existing geomorphology of watercourse channels that could be influenced by the Project, including the Clearwater River below Patterson Lake from the outlet of Patterson Lake to the inlet into Forrest Lake.
- Identify areas that may be vulnerable to increased erosion due to proposed Project activities.
- Acquire accurate baseline information that can support the Project EA.

3.0 STUDY AREAS

The baseline study areas considered in the hydrology baseline program include the following (Figure 3):

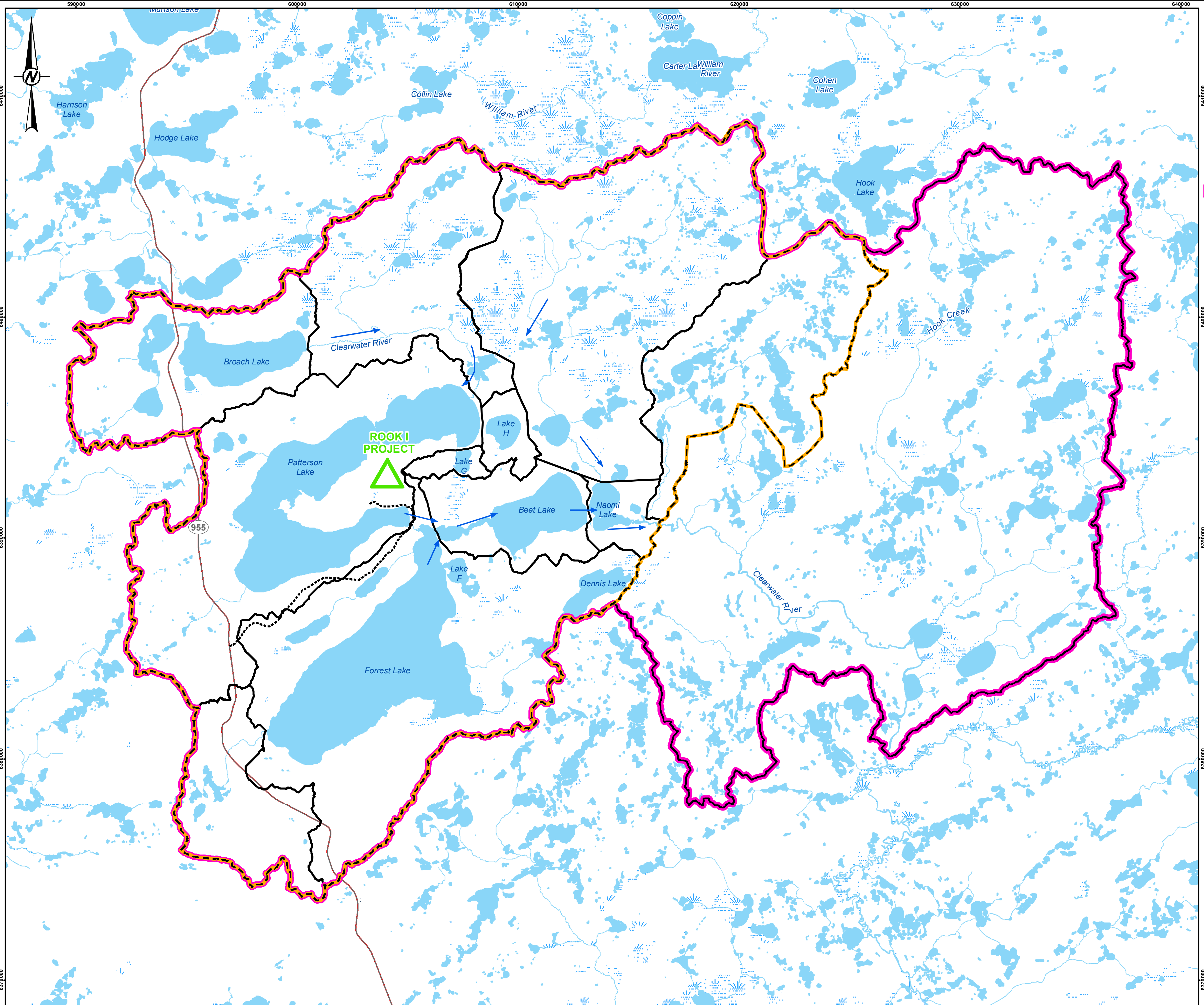
- local study area (LSA): the Clearwater River watershed to Naomi Lake outlet; and
- regional study area (RSA): the Clearwater River watershed above the confluence with the Mirror River.

The proposed Project would be located adjacent to Patterson Lake, which is in the upper portion of the Clearwater River system. The Clearwater River Upper Reach flows from Broach Lake through a series of lakes including Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake (listed in order from upstream to downstream). From Naomi Lake, the Clearwater River flows 20 km southeast before reaching the Mirror River confluence. Below the Mirror River confluence, the river deepens with higher flow volumes from the Mirror River, and the channel form changes to meandering within a well-defined river valley. Farther downstream, the Clearwater River flows through Lloyd Lake, which is immediately upstream of the Clearwater River Provincial Park; the downstream end of the park is at the Saskatchewan-Alberta border.

In general, the hydrological baseline studies focused on the Clearwater River watershed upstream of the Patterson Lake outlet and along the main lake chain downstream, including Forrest Lake, Beet Lake, Naomi Lake, and the reaches of the Clearwater River separating the lakes. Based on the potential effects of the Project and hydrologic characteristics of the region, the LSA is defined as the Clearwater River watershed to the Naomi Lake outlet (Figure 3). The Clearwater River watershed above the Naomi Lake outlet drains an area of 685 km^2. Seven waterbody monitoring locations are included in the LSA.

The RSA for hydrology includes waterbodies and watercourses within the Clearwater River watershed above the Mirror River confluence, which includes the LSA. The Clearwater River watershed above the Mirror River confluence drains an area of 1,070 km^2. The spatial extent of the Clearwater River watershed above the Mirror River confluence is expected to provide an ecologically relevant RSA for the EA. The RSA spans an area that provides habitat requirements for a discernible population unit for large-bodied fish species where cumulative effects may occur.

The baseline geomorphological characterization targeted Patterson Lake and the Clearwater River between Patterson and Forrest lakes as this waterbody and watercourse are expected to be most influenced geomorphologically by proposed Project activities. Patterson Lake can be divided into the North Arm and South Arm, oriented approximately southwest to northeast as shown in Figure 4. The North Arm can be further separated into the West Basin and East Basin separated by a narrow and shallow sand bar with spit formations forming on either side. Outflow from Patterson Lake is out of the east end of the South Arm via the Clearwater River.



LEGEND

- FLOW DIRECTION
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND

PROJECT FEATURES

- EXISTING ACCESS ROAD
- PROJECT LOCATION
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

0 3,500 7,000

1:175,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. WATERSHEDS DELINEATED BY GOLDER USING GREENKENUE SOFTWARE BASED ON CANADIAN DIGITAL ELEVATION DATA AND NATIONAL HYDROGRAPHIC NETWORK WATERCOURSES.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

HYDROLOGY BASELINE STUDY AREA

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	RP
PREPARED	PMT
REVIEWED	RWP
APPROVED	RA

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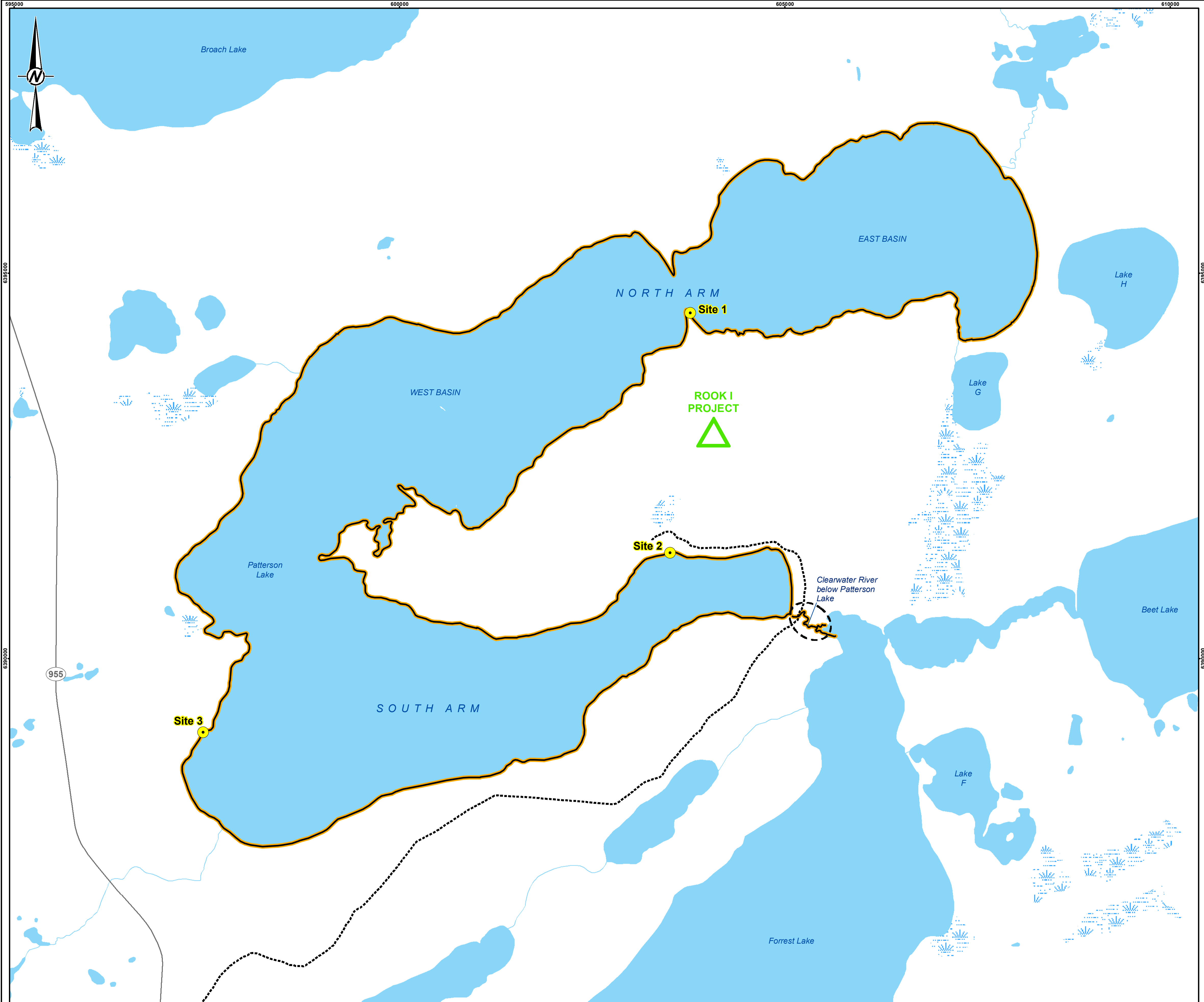

LEGEND

SECONDARY HIGHWAY
WATERCOURSE
WATERBODY
WETLAND

PROJECT FEATURES

EXISTING ACCESS ROAD
PROJECT LOCATION

GEOMORPHOLOGY STUDY AREA

SURVEY POINT LOCATION
SURVEY AREA

0 1,000 2,000
1:50,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
NexGen Energy Ltd.

PROJECT
ROOK I PROJECT

TITLE
GEOMORPHOLOGY BASELINE STUDY AREA

CONSULTANT
GOLDER

YYYY-MM-DD	2022-03-16
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PREPARED	LMS
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
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4.0 METHODS

The baseline geomorphological characterization used readily available desktop data and field data collected in October 2018.

4.1 Review of Existing Information

The desktop review focused on information relevant to local shoreline erosion and downstream fluvial geomorphology, including the following:

- **Meteorology data:** Wind speed and direction are the main meteorological parameters that affect lake shoreline erosion. Local wind data were measured at the NexGen Rook I Meteorological Station located near the existing exploration camp (Universal Transverse Mercator 12V 602795 E 6392291 N). Baseline meteorological monitoring data up to fall 2018 was used for field planning and initial analysis but later supplemented with data to September 2020. Wind speed and direction data were analyzed for the open-water period from May to October for a five-year period from 2016 to 2020. Windrose and direction frequency analysis were completed for the period with available data (i.e., 2016 to 2020). Local wind was reviewed to determine wind patterns at site for the open water season (i.e., May to October).
- **Surficial geology, terrain, and soils:** The review of surficial materials and soils for the area was completed using readily available data obtained from the Saskatchewan Mining and Petroleum GeoAtlas (MER 2018) and from the Department of Soil Science at the University of Saskatchewan (U of S 2018). These data were used to inform the geomorphological review for the lake shorelines and the outlet channels.
- **Available GIS data:** Aerial imagery, LiDAR data available in fall 2018, and other topographic data (NRCan 2018) were used to describe the site morphology along the lake shorelines and lake outlet channels. The LiDAR data provided by NexGen for the study area did not cover the entire shoreline of Patterson Lake nor provide sufficient resolution (i.e., typical vertical and horizontal is around 0.1 m) to be used in describing the shoreline geometry. Therefore, the LiDAR data were used as a guidance for describing the surrounding terrain and only for the portion of the shoreline with available data (i.e., east shores of Patterson Lake – South Arm, and partial areas of the south and east shores of Patterson Lake North Arm). The characterization of lake shorelines used other criteria such as shoreline geometry, inferred shoreline landforms, and vegetation type.
- **Previous studies:** Northwest Hydraulics Consultants Ltd. (NHC) completed a desktop hydrology and geomorphology analysis (NHC 2016) to review and compare options for potential treated effluent discharge points. The NHC analysis was based on desktop resources and provided background context but is not directly comparable to the current baseline study.

The baseline characterization study was largely completed based on the available information at the time of draft reporting. Baseline meteorological monitoring data up to fall 2018 was used for field planning and initial analysis but later supplemented with data to September 2020. Of the information listed above, only meteorological conditions are expected to have varied since 2019, and, as a result, the observations made in this study are not anticipated to be sensitive to surficial geology, terrain, and soils data or GIS data that may have become available since 2019.

4.2 Approach

4.2.1 Field Observations and Data Collection

Field surveys were completed between 28 September 2018 and 4 October 2018 and included the shoreline locations of Patterson Lake near the proposed mine infrastructure and the channel of Clearwater River below Patterson Lake extending to Forrest Lake.

The following methods were used for field data collection:

- The lakeshore survey area is comprised of the Patterson Lake shoreline. Three lakeshore survey sites were selected to be generally representative of larger sections of Patterson Lake and adjusted during the field visit to accommodate sites that were accessible. At each site, general characteristics of the shoreline were noted, including general bank slope, near-shore materials (i.e., materials below the water surface, in the shallow/wadable section of shore), and ice-thrust effects (e.g., ice-push berms at the shoreline, considered as evidence of thermal erosion at existing water level elevations). Photographs collected during the field surveys documented each homogenous shoreline section visited (Appendix A, Photographs). The locations of the three field survey sites are shown in Figure 4: Site 1 on the portion of Patterson Lake shoreline extending along the longshore drift feature in the vicinity of proposed mine infrastructure; Site 2 on the north shore of the South Arm; and Site 3 on the west shore of the South Arm. Weather conditions at the time of the field survey (i.e., snowfall and a continuous snow layer) prevented the field crew from fully observing the terrain on the shoreline banks at each site. However, sufficient data were collected to describe the lake shorelines and produce shoreline erosion susceptibility classifications for each site. Observations were verified during subsequent hydrometric field investigations in 2019 and 2020 when shoreline landforms were visually checked for ground truthing at randomized locations on the Patterson Lake shoreline.
- The geomorphology of the Clearwater River extending from the Patterson Lake outlet downstream to Forrest Lake was characterized based on measured cross-sectional profiles, water slope measurements, water level, bed and bank material, bank vegetation type, and active erosion or depositional areas. This reach of the Clearwater River is multi-threaded and has multiple channels for some of its length. Photographs collected during the field surveys document each homogenous channel section (Appendix A). The Clearwater River below Patterson Lake was surveyed from the Patterson Lake outlet to the Forrest Lake inlet (Figure 4). A total of 38 transects were surveyed from immediately upstream of the lake outlet, moving downstream at approximately 35 m intervals depending on channel morphology (Figure 13). The main outlet channel separates into two smaller channels (i.e., north channel and south channel) approximately 200 m upstream from Forrest Lake, carrying similar flow rates in each of the smaller channels. Both smaller channels were surveyed.

4.2.2 Erosion Susceptibility Assessment

Erosion susceptibility was assessed at a high level for the watercourse channels and waterbody shorelines located in the geomorphology baseline study area shown in Figure 4. A waterbody shoreline erosion susceptibility class system, ranking from “Very Low” to “Very High”, was developed using the geomorphological field data collected for shoreline characteristics. Erosion susceptibility was classified according to an erosion potential score (Table 1) derived as a function of bank and shoreline features, exposure characteristics, and attenuation characteristics. The details for determining waterbody shoreline erosion susceptibility are presented in Appendix B, Shoreline Erosion Susceptibility Calculations.

Table 1: Classification of Shoreline Erosion Susceptibility or Potential based on the Erosion Susceptibility Score

Erosion Susceptibility Class	Erosion Susceptibility Score
Very Low	<15
Low	15 to 20
Moderate	20 to 25
High	25 to 35
Very High	>35

< = less than; > = more than.

The Patterson Lake shoreline was delineated, as a desktop exercise, into areas with similar geomorphological characteristics using readily available data: satellite imagery, terrain elevation, and field observations. The main delineation criteria are summarized in Table 2.

Table 2: Lake Shoreline Delineation Criteria

Data Available	Delineation Criteria
Shoreline Exposure	Dominant wind, by quadrant Criterion looked at a combination of the most frequent wind direction and fetch length
Vegetation Type	Forested (i.e., trees) Shrubs Bare
Shoreline Landform including materials (inferred)	Sandy, beach Shallow, with berm Steep, rocky
Shoreline Geometry (i.e., shape)	Point (or headland) Straight (or irregular) Bay

The channels of the Clearwater River between the outlet of Patterson Lake and its outflow into Forrest Lake were evaluated using a channel assessment procedure adapted for northern environments that considers factors such as streambed and bank materials, channel slope, and development of ice formations.

5.0 RESULTS

The results of baseline geomorphological characterization desktop study and 2018 field study are presented in the subsections below.

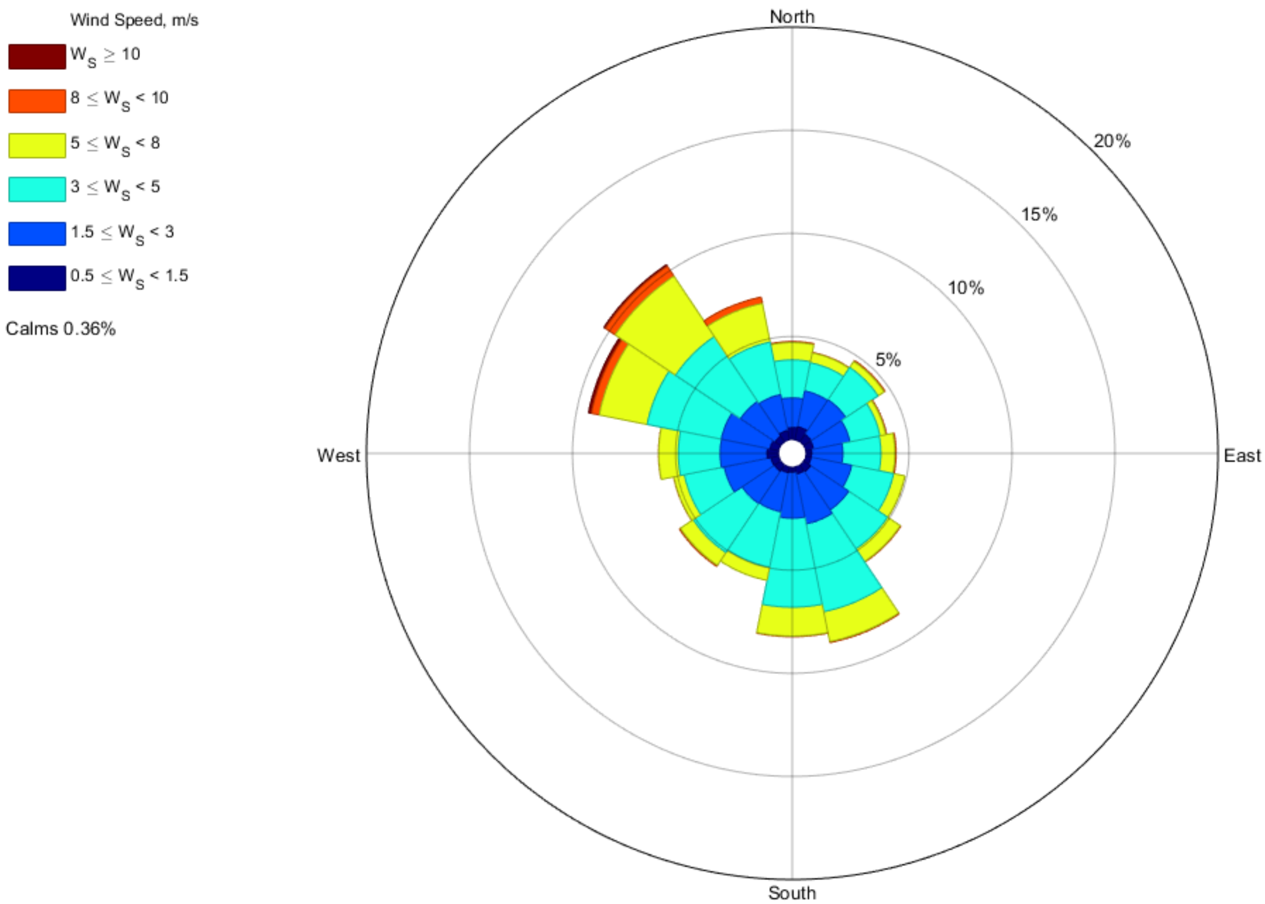
5.1 Review of Existing Information

5.1.1 Meteorological Observations

The main meteorological parameters that affect shoreline erosion potential are wind speed and wind direction. This is because wind blowing over open water generates waves. The uninterrupted length of the open water parallel to the direction the wind is blowing is referred to as the fetch. As wind speed and fetch increase, wave height typically increases; the height of the waves is related to the magnitude of persistent wind speed and the length of open water (i.e., fetch) over which the wind blows. As wave height increases, the erosive power of the waves increases. Water depth serves to modify this general relationship. Ice cover limits the generation of waves by winds by reducing the area of open water and, thus, the available fetch lengths. Wind-wave analysis is, therefore, typically limited to open water months (i.e., spring through fall).

Figure 5 presents the directions and the wind class frequency distribution measured during the period with available climate data. Prevailing winds were from the northwest and west-northwest as well as the south-southeast and south directions (Figure 5). Higher winds exceeding 5 m/s occurred 25% of the time and were most frequently from the west-northwest to north-northwest. The available wind data were sufficient to characterize the general range of wind speed and directions for the site.

Figure 5: Rook I Meteorological Station Wind Rose for the Open-Water Period, May 2016 to October 2020



> = more than.

5.1.2 Geology

5.1.2.1 Project Geology

The study area is located within the Athabasca Basin geological unit. The Athabasca Basin is a Paleoproterozoic-age, intracontinental, sedimentary basin covering a large portion of northwestern Saskatchewan and a smaller portion of northeastern Alberta. This basin consists of the Athabasca Group and is composed primarily of sandstones with local conglomeratic beds. The general geology of the region around the Project includes 30 m to 100 m thick glaciofluvial tills deposited by the retreating glaciers that overlie Cretaceous mudstones. The glaciofluvial tills are composed primarily of sand mixed with gravels, cobbles, and boulders. The glacial deposits, commonly referred to as overburden, have formed topographic features in the anticipated area of the Project such as drumlins, outwashes, hummocky terrain, and kettle lakes.

5.1.2.2 Local Surficial Geology, Terrain, and Soils

Terrain is a comprehensive term used to describe a tract of landscape and the associated natural physical features. Terrain maps typically show surficial materials, material texture, surface expression, relief, elevation, drainage, or material-modifying processes. The surficial geology for the study area was obtained from the Saskatchewan Mining and Petroleum GeoAtlas (MER 2018) and was used to inform the geomorphological analysis for the lake shorelines and the channels of Clearwater River below Patterson Lake.

The local surficial geology in the study area presents the main characteristics of the main geological unit, the Athabasca Basin, where the spatial and temporal patterns of deglaciation formed the main terrain landforms. The typical materials for this geological unit include sand mixed with gravels, cobbles, and boulders. The Patterson Lake watershed, together with the Broach Lake watershed (upstream) and parts of the Forrest Lake watershed (downstream), is located within a small geological unit of mainly glaciolacustrine plain deposits (Simpson 1997) with sand, silt, and clay accumulations deposited in glacial lakes. This geological unit borders glaciofluvial hummocky deposits to the east (i.e., downstream of Naomi Lake) and north, and morainal deposits to the west and south. The surficial materials in this area appear to be dominated by sediments deposited around the end of the last glaciation approximately 9,500 years ago, with a secondary component of fluvial and organic deposits that have accumulated in the last few thousand years.

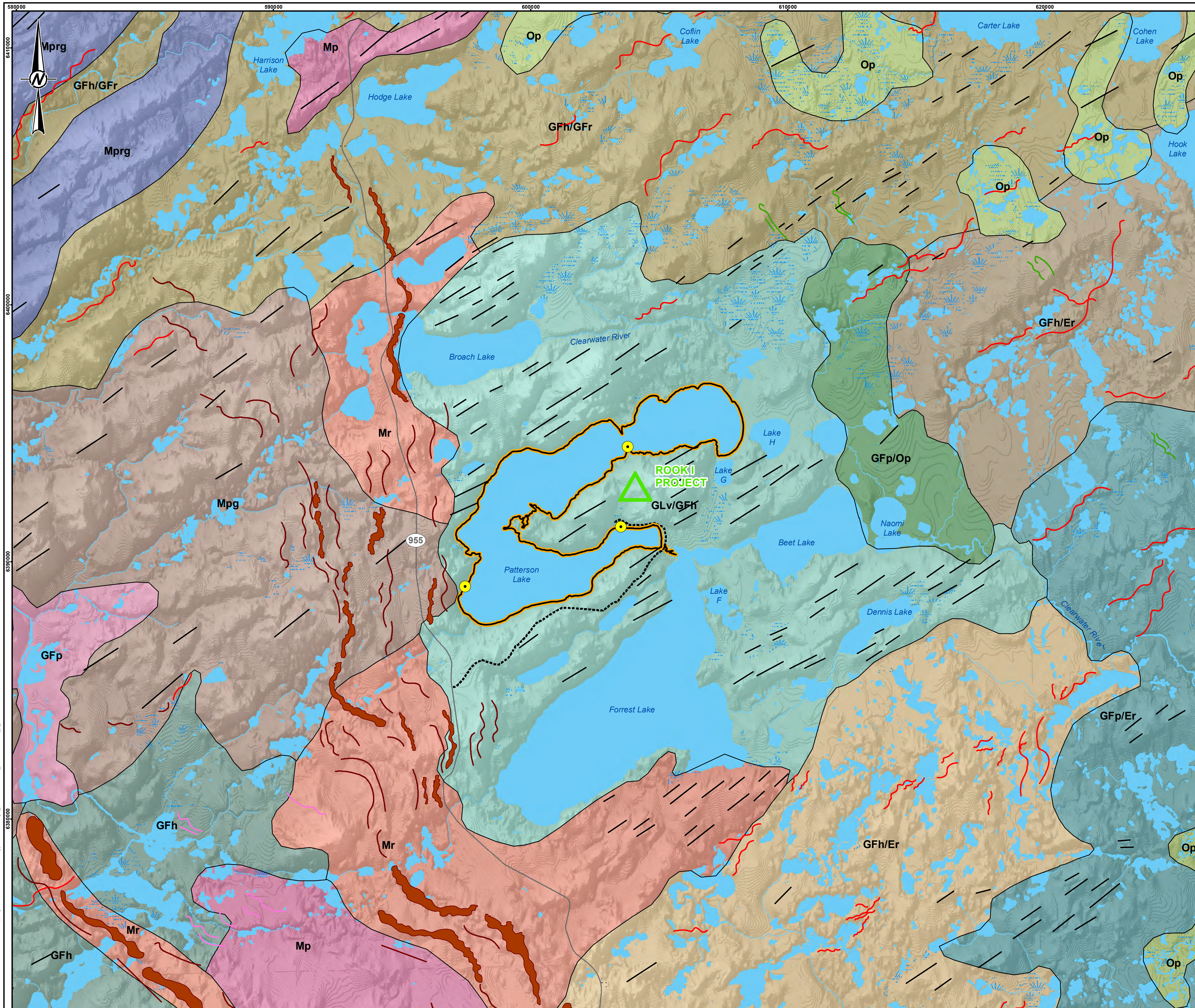
While glaciolacustrine and glaciofluvial materials are predominant in the area, they occur in association with other materials, especially where organic materials overlie the glacial and post-glacial sediments. Consequently, most map units describing terrain areas depict complexes of terrain with a mixture of types. The glacial landforms in the study area, from Norris et al. (2017), are shown in Figure 6. A summary of the terrain units within the surveyed watersheds is provided in Table 3.

Table 3: Surficial Geology within the Study Area

Terrain Symbol Unit (Dominant/Sub-dominant)	Description
GLv/GFh	Glaciolacustrine veneer and glaciofluvial hummocky landforms
GFh/GFr	Glaciofluvial hummocky landforms and ridges
GFp/Op	Glaciofluvial with outwash plain
Op	Outwash plains
Mr	Morainal ridged
Mpg	Morainal plain
GFh/Er	Glaciofluvial with hummocky landforms and eolian-ridged dunes
GFp/Er	Glaciofluvial with plains and eolian ridged dunes

Source: MER 2018.

Most of the surficial geology (more than 60%) in the vicinity of Patterson Lake, including its shoreline and banks, is made up of mineral soils (dominant Eluviated Dystric Brunisolic soils, with inclusions of Gleyed Eluviated Dystric Brunisolic and Gleysolic soils). These soils have developed in sandy glacial sediments under pine forests on undulating and rolling landscapes (i.e., more than 0.5% to 10% slopes) (Annex VI, Terrain and Soils Baseline Report). The areas dominated by a depressional landscape have Gleysolic soils and organic soils at the deepest part of the depression areas (Annex VI). Organic soils are present in the depressional areas with low slopes (i.e., less than 0.5%) and moderately decomposed organic materials (i.e., fen peat) overlying moderately coarse to coarse textured glaciofluvial deposits (i.e., loamy sand, sand, sandy loam). These areas include areas adjacent to watercourses, such as the Clearwater River below Patterson Lake, which also tend to occupy low lying areas in the landscape.



LEGEND

- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND

PROJECT FEATURES

- EXISTING ACCESS ROAD
- PROJECT LOCATION

GEOMORPHOLOGY STUDY AREA

- SURVEY POINT LOCATION
- SURVEY AREA

GLACIAL LANDFORMS

- CREVASSE-FILL RIDGE
- ESKER
- ICE-THRUST RIDGE
- LINEATION
- MINOR MORAINE RIDGE
- MAJOR MORAINE

SURFICIAL GEOLOGY

- GFh - GLACIOFLUVIAL HUMMOCKY
- GFh//Er - GLACIOFLUVIAL HUMMOCKY
- GFh//GFr - GLACIOFLUVIAL HUMMOCKY
- GFh/Er - GLACIOFLUVIAL HUMMOCKY
- GFp - GLACIOFLUVIAL OUTWASH PLAIN
- GFp/Er - GLACIOFLUVIAL
- GFp/Op - GLACIOFLUVIAL OUTWASH PLAIN
- GLv/GFh - GLACIOLACUSTRINE
- Mp - MORAINAL PLAIN
- Mpg - MORAINAL PLAIN
- Mprg, MORAINAL PLAIN
- Mr - MORAINAL RIDGED
- Op - ORGANIC

0 2,500 5,000

1:150,000 METRES

REFERENCE(S)

1. SURFICIAL GEOLOGY OBTAINED FROM GEOLOGICAL ATLAS OF SASKATCHEWAN VIEWER © 2016, GOVERNMENT OF SASKATCHEWAN.
2. GLACIAL LANDFORMS: SOPHIE L. NORRIS, MARTIN MARGOLD & DUANE G. FROESE (2017) GLACIAL LANDFORMS OF NORTHWEST SASKATCHEWAN, JOURNAL OF MAPS, 13:2, 600-607, DOI: 10.1080/17445647.2017.1342212.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

SURFICIAL GEOLOGY AND GLACIAL LANDFORMS IN THE STUDY AREA

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	DC
PREPARED	LMS
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
20138965	2000	0	6

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

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5.2 Patterson Lake

5.2.1 Field Observations and Data

Patterson Lake is a U-shaped lake composed of two arms (i.e., the North Arm and the South Arm) oriented approximately southwest to northeast (Figure 4). The North Arm can be classified as two basins (i.e., West Basin and East Basin), which are separated by a narrow, shallow sand bar (Figure 7). The narrow, shallow sand bar appears to connect two spit-like sediment features that extend from either side of the lake. The sand bar/spit formation is composed of predominantly sand-sized sediment. The North Arm is the longer of the two arms, at approximately 12 km, while the South Arm is approximately 8 km.

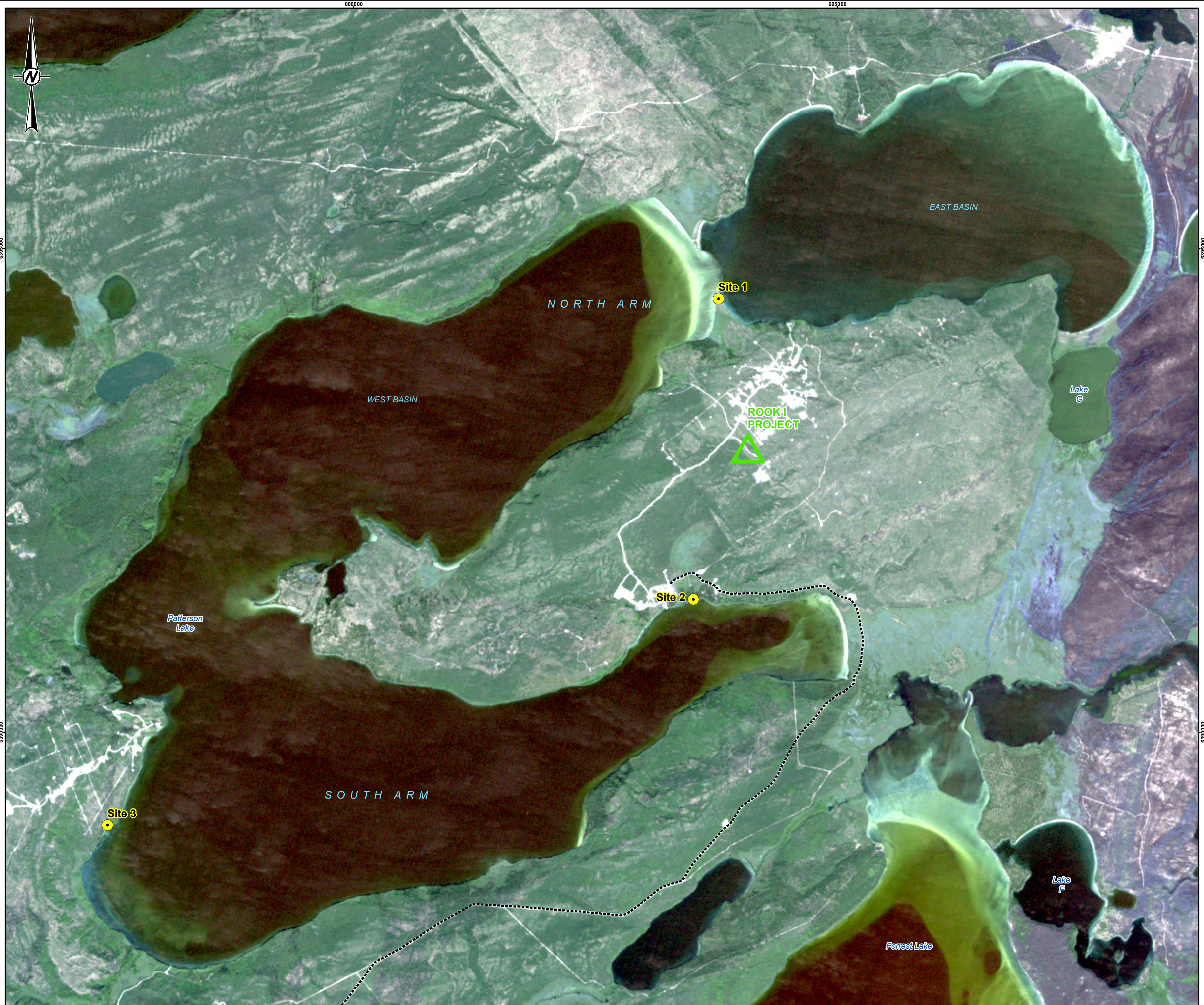
Three sites on the Patterson Lake shoreline were investigated during the site reconnaissance (Figure 7) to document shorelines in areas that were available for access. Weather conditions at the time of visit (i.e., snow cover) prevented detailed information from being collected. However, sufficient data were collected to describe the lake shorelines and produce shoreline erosion susceptibility classifications for each site.

The main observations for the three shoreline sites on Patterson Lake are summarized in Table 4.

Table 4: Patterson Lake Shoreline Sites Description

Site Number	Location	Site Description
Site 1	Southern shoreline of the North Arm at the narrows (Figure 8)	Site 1 is located along a sandy spit-like shoreline between the western and eastern basins of the North Arm. The shoreline is composed of a sand beach varying in width from approximately 1.5 m on the lakeward end of the spit, widening to 6 m shoreward. Elevated shoreline berms of sediments and organics were observed along the shoreline and were interpreted to be ice-thrust features. The height of the berms was measured at approximately 2 m above the top of bank. The bank height was measured at approximately 0.5 m to 0.7 m above the water level (498.510 masl) at the time of visit on 29 September 2018. The shoreline banks were steep (i.e., >45°) along the entire investigated shoreline section.
Site 2	Northeast shoreline of the South Arm (Figure 9)	Site 2 shoreline is composed of a mix of large cobble and boulder materials overlain with organic soils and a forest with mainly black spruce. Elevated shoreline berms were not observed at this location. The bank height was measured at approximately 0.5 m above the water level (498.510 masl) at the time of visit on 29 September 2018. The shoreline banks have a gentle slope (i.e., <25°) along the investigated shoreline section.
Site 3	Western shoreline of the South Arm (Figure 10)	Site 3 shoreline is composed of a mix of cobble and boulder materials overlain with organic soils and a forest with mainly conifers. Elevated shoreline berms were observed and measured to be approximately 3 m above the water level at the time of visit. These are interpreted to be ice-thrust features. The bank height was measured at approximately 0.5 m to 1.0 m above the water level (498.571 masl) on 1 October 2018. The shoreline banks are steep (i.e., >45°) along the investigated shoreline section.

> = more than; < = less than; masl = metres above sea level.



LEGEND

PROJECT FEATURES

EXISTING ACCESS ROAD

PROJECT LOCATION

SURVEY POINT LOCATION

0 1,000 2,000

1:40,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: SEPTEMBER 1, 2017.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE SHORELINE SURVEY LOCATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	DC
PREPARED	LMS/AK
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
20138965	2000	0	**7**

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

0 25mm

Figure 8: Typical Photograph of the Shoreline at Site 1

Note: Universal Transverse Mercator 12V 603680 E 63943657 N facing northwest.

Figure 9: Typical Photograph of the Shoreline at Site 2

Note: Universal Transverse Mercator 12V 597619 E 6389251 N facing northwest.

Figure 10: Typical Photograph of the Shoreline at Site 3

Note: Universal Transverse Mercator 12V 604460 E 6394250 N facing east.

5.2.2 Shoreline Erosion Susceptibility

The main parameters derived for each Patterson Lake shoreline field survey site that were used to estimate the shoreline erosion susceptibility potential are summarized in Table 5 and presented in detail in Appendix B.

Table 5: Shoreline Parameters and Erosion Susceptibility Classes for Patterson Lake

Site Name	Shoreline Orientation	Bank Slope (º)	Fetch Length (m)	Erosion Susceptibility Score	
				Score	Class
Site 1	NE, ENE	>45	4,300	45	Very High
Site 2	S	<25	850	23	Moderate
Site 3	ESE, SE	>45	3,300	27	High

> = more than; < = less than; N = north; E = east; S = south.

Site 1 was classed as having a Very High erosion susceptibility. Site 1 is located along the narrow section in the North Arm that divides the East Basin and West Basin. The organic bank materials and sandy shoreline materials combined with the exposed nature of the shoreline to a fetch length of approximately 4.5 km make this section of the shoreline highly susceptible to processes that can include erosion (i.e., removal of bank material) and/or deposition/accretion (i.e., sediment is added to the shoreline). Figure 11 shows the shoreline at Site 1 in more detail using satellite imagery available from May 2013 (ESRI Digital Globe 2013). Historical shoreline alignments were inferred based on visible striated patterns in the vegetation. The alignment of the striations indicates that the shoreline at this location is advancing towards the north-northeast as a result of sediment transport, most likely carried by longshore currents. Overall, the shoreline of Patterson Lake at Site 1 showed signs of ongoing and active sediment transport in the form of accretion of the point at the narrows.

Site 2 was classed as having a Moderate erosion susceptibility. Site 2 is located near the active hydrometric station on Patterson Lake, CR-WB-MS-02, and is also near the existing exploration camp. The fetch length at Site 2 is approximately 0.9 km. The shores were armoured with large cobbles and boulders, and the banks were interpreted as stable (i.e., no erosion signs). The shoreline banks are covered by mature pine trees. No signs of other shoreline processes were observed.

Site 3 was classed as having a High erosion susceptibility. Site 3 is located on the western shoreline of the Patterson Lake – South Arm near the site of a former hydrometric station that was used for the monitoring of lake water levels. The fetch length at Site 3 is approximately 8 km. At this location, a large ice-thrust berm, approximately 3 m high, was interpreted from observations of mounded sediment and organic material along the shoreline. The berm forms the edge of the lake. Bank erosion and bank failures were also observed along this section of shoreline. The main shoreline processes at this location were attributed to thermal erosion (i.e., ice-push berms) where lake ice is the dominant factor. The bank materials were observed to be large cobble and boulders.

The results of the Patterson Lake shoreline delineation are presented in Figure 12. The variability in Patterson Lake shoreline exposure, surficial geology, landform, and geometry are shown in the complexity and variety of shoreline types inferred in the delineation. Relatively long wind fetches (i.e., over 3 km) are typical for most of the shoreline. These characteristic fetch lengths, combined with the observed shoreline landform (i.e., profile) and surficial materials, are expected to be the main indicator of shoreline susceptibility to erosion, recognizing that shoreline sections with similar erosion potential are expected to exhibit similar responses to changes in the hydrological regime of the lake. To that end, the areas most susceptible to erosion due to wave action are shorelines composed of sand with long wind fetches, especially with exposure to the directions with the most intense winds including the south and northwest. The shoreline classification in Figure 12 indicates such shorelines can be found on the end of the peninsula separating the North Arm – West Basin and South Arm as well as on the north shore of the North Arm – East Basin. The shoreline classification mapping was verified during subsequent hydrometric field investigations in 2019 and 2020 when shoreline landforms were visually checked for ground truthing at randomized locations on the Patterson Lake shoreline.

LEGEND

- SURVEY POINT LOCATION
- HISTORICAL SHORELINE

0 40 80

1:2,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE HISTORICAL SHORELINE ALIGNMENTS

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	DC
PREPARED	LMS/AK
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
20138965	2000	0	11

5.3 Clearwater River below Patterson Lake

5.3.1 Field Observations and Data

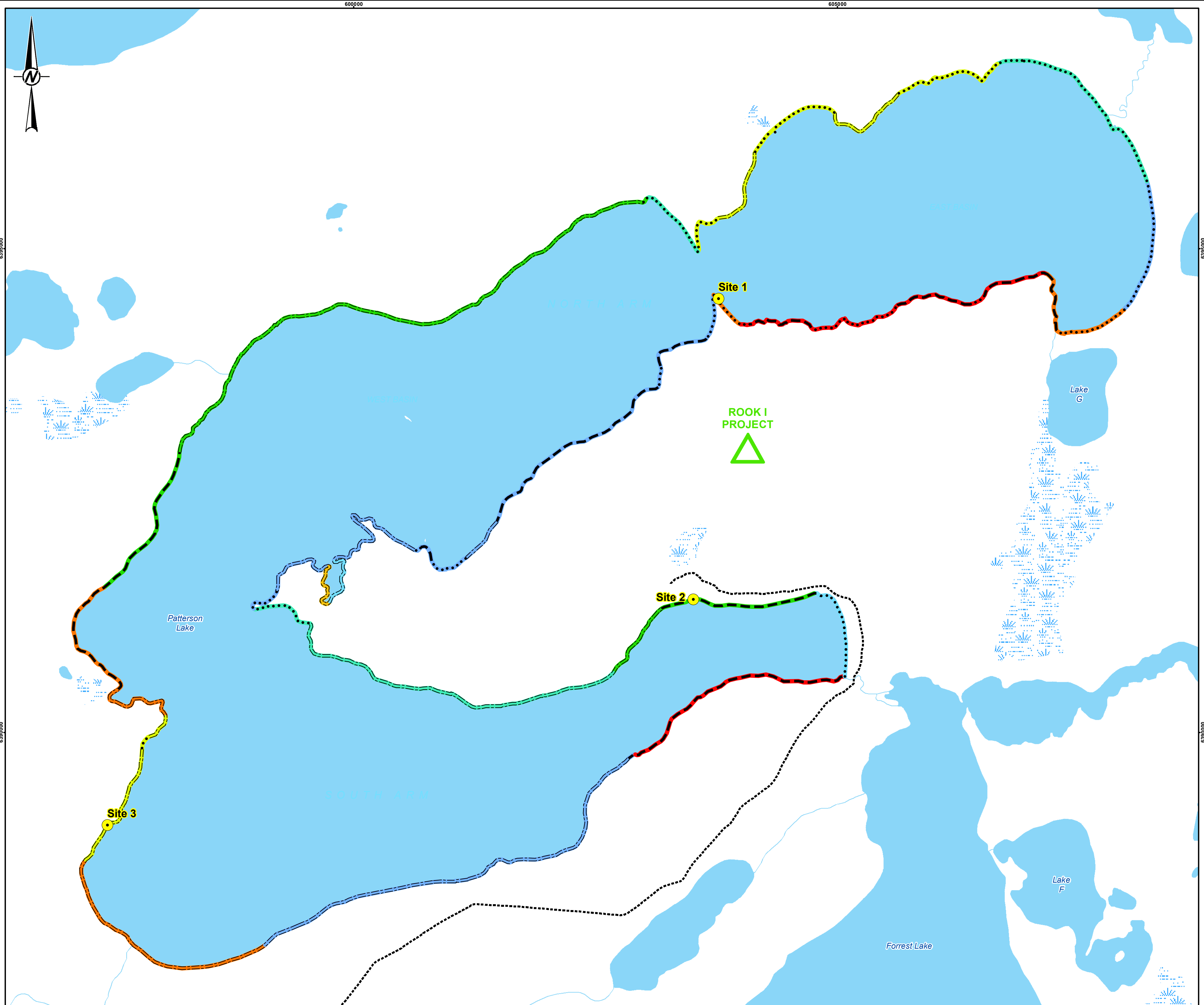
The Clearwater River flows through flat terrain, with surficial materials of hummocky glaciofluvial deposits covered by black spruce pine forests. Both banks of the channel have soils consisting of primarily organic materials fully covered by vegetation, which is predominantly black spruce. The channel is typically 5 m to 10 m wide with water depths less than 1.5 m deep relative to the surrounding terrain. The stream bed materials are primarily sand with sparse large boulders. The channel banks were observed to be a mixture of soils and organic materials. In straight run reaches, the bed was observed to be characterized by a typical ripple bed form pattern. This characterization is supported by comparison of hydraulic characteristics to the bed form charts presented in the *Handbook of Hydrology* (Maidment 1994) associated with fine to medium sand. The channel is made up of single and multi-threaded wandering meanders and its planform (i.e., shape when viewed from above) is sinuous (i.e., sinuosity coefficient of approximately 1.5), meaning that the curvilinear length along the stream is approximately 1.5 times longer than the straight line length. The river meanders show typical channel geometries:

- steeper banks occurring on the outside of bends; and
- some erosion and deeper than average (i.e., 1.5 m to 1.9 m) riverbed pools at the apex and downstream of the apex of the meanders.

The full channel cross-sections of the surveyed transects are presented in Appendix C, Transect Cross-Sections. The average slope gradient of the water surface in the Clearwater River from Patterson Lake outlet to Forrest Lake inlet was measured at 0.05%.

Ongoing bank erosion was observed on the outside bend for most channel meanders and was confirmed by channel geometry cross-section measurements (Appendix C) and vegetation observations such as mature trees leaning over the channel, or already fallen in the channel. A typical channel-transects comparison example in Figure 14 shows the differences in bank slope and maximum bank full depth between a transect measured in a straight portion of the channel (i.e., Transect 13), and a transect measured at a meander (i.e., Transect 14). The maximum bank full depth is approximately double in the meander section.

Where trees were observed to have fallen from the bank, they were observed to typically remain attached to the bank (Figure 15) and have the potential to promote local scour during high flow periods in the spring.



LEGEND

- WATERCOURSE
- WATERBODY
- WETLAND

PROJECT FEATURES

- EXISTING ACCESS ROAD
- PROJECT LOCATION

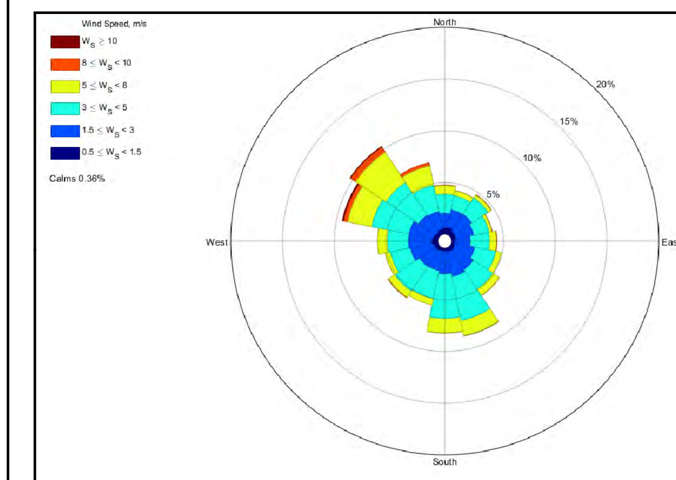
- SURVEY POINT LOCATION

DOMINANT WIND EXPOSURE (BY QUADRANT)

- NORTH
- NORTHEAST
- EAST
- SOUTHEAST
- SOUTH
- SOUTHWEST
- WEST
- NORTHWEST

SHORELINE LANDFORMS

- SANDY/BEACH
- SHALLOW WITH BERM
- STEEP/ROCKY



0 1,000 2,000

1:40,000 METRES

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE GEOMORPHOLOGICAL SHORELINE DELINEATION

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	DC
PREPARED	LMS
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
20138965	2000	0	12

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25mm

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LEGEND

PROJECT FEATURES

EXISTING ACCESS ROAD

FLOW DIRECTION

STREAM SURVEY TRANSECT

0 40 80

1:2,000 METRES

REFERENCE(S)
1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

CLEARWATER RIVER SURVEY LOCATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2022-03-16
DESIGNED	DC
PREPARED	LMS
REVIEWED	RP
APPROVED	RWP

PROJECT NO.	PHASE	REV.	FIGURE
20138965	2000	0	13

Figure 14: Channel Cross-Section Comparison, Clearwater River below Patterson Lake

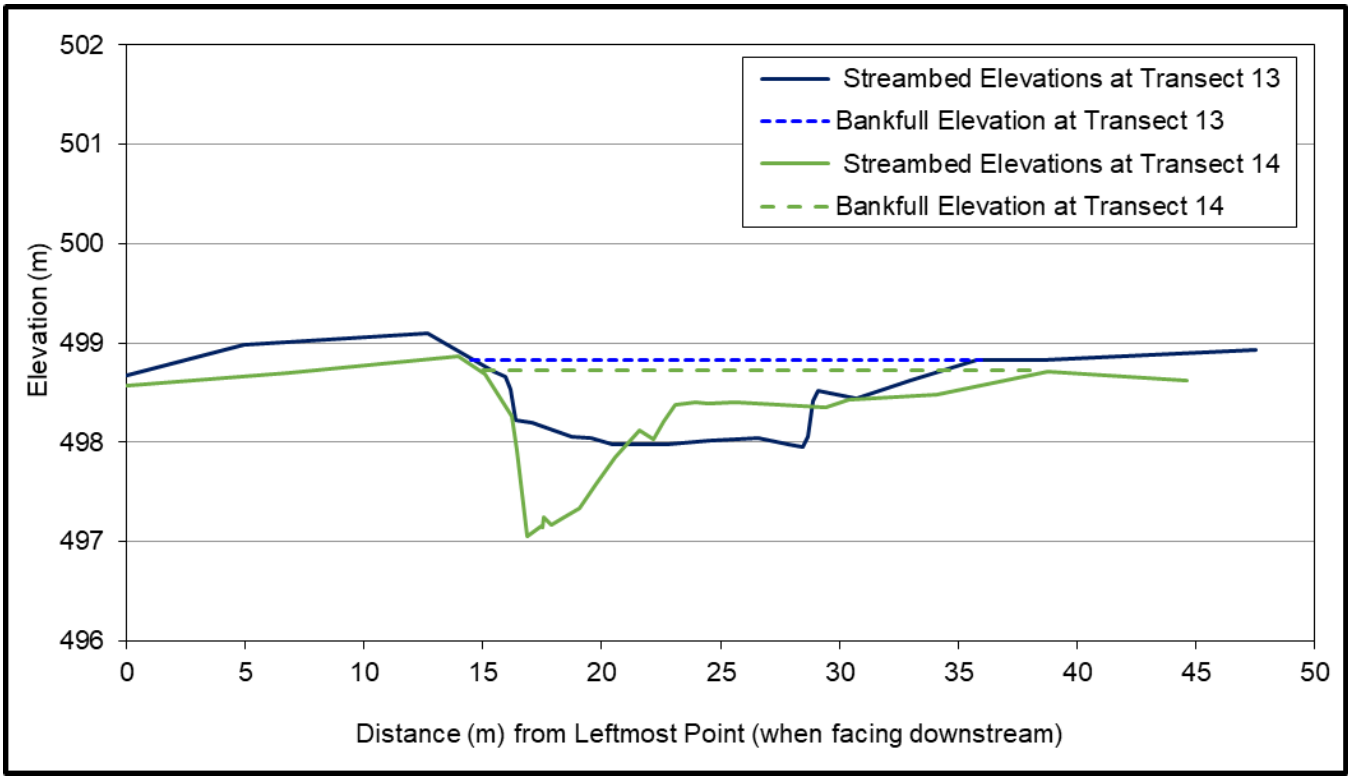

Figure 15: Typical Bank Erosion on Outside of Meander with Trees Leaning over the Channel

Note: Universal Transverse Mercator 12V 605322 E 6390403 N. View is from south to north, taken on day 3 October 2018.

5.3.2 Channel Erosion Susceptibility

Sediment transport along the channel was interpreted at a high level using available imagery and visual observations made during the field visit. Channel bed materials over the surveyed area were observed to be mostly sand. The main channel splits into two smaller channels approximately 200 m upstream of the Forrest Lake inflow. The imagery suggests that the north channel is the main active sediment transport pathway of the Clearwater River, with visible and recent sediment deposits at the mouth and formation of a delta. Field observations for sediment transport indicated that the bulk of the sediment volume is delivered during the spring high flows as transport was not observed during low flow conditions. Sediment transport on the south channel is present but at a lower rate compared to the north channel, with no recent sediments visible at the mouth. However, older delta deposits at the mouth of the south channel were interpreted from the aerial imagery to be similar in morphology to the active deposits at the mouth of the north channel (Figure 16 and Figure 17). This finding implies that Clearwater River may switch between north and south channel alignments in this section during flood events. Sediment transport measurements, suspended or as bed load, were collected as part of the hydrometric monitoring and are summarized in the terrain and soils baseline report (Annex VI).

Overall, the Clearwater River below Patterson Lake is susceptible to bank erosion (with soils and organics materials on its banks) and has active sediment transport (mostly sand-size materials) indicated by the active delta at its mouth.

Figure 16: Patterson Lake Channel Outflow (Clearwater River below Patterson Lake) into Forrest Lake

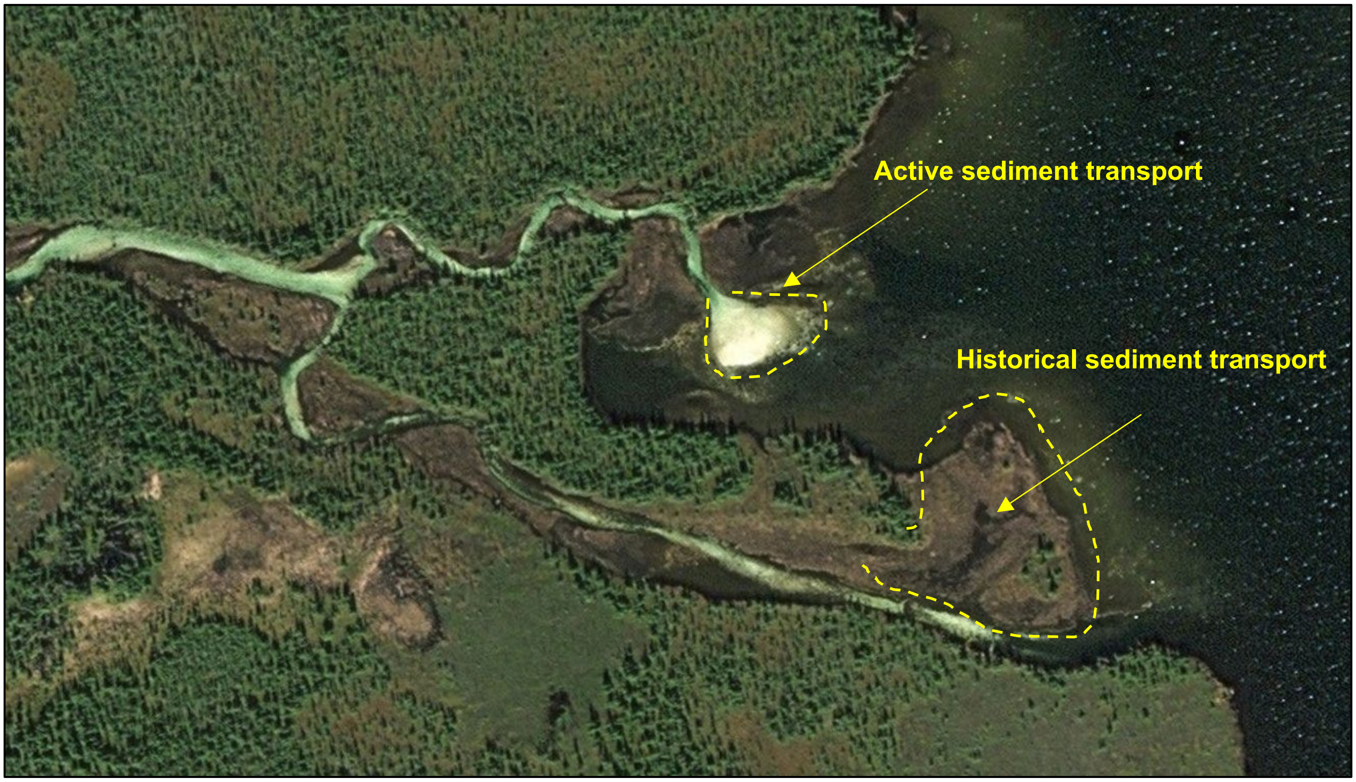

Figure 17: Patterson Lake Channel Outflow (Clearwater River below Patterson Lake) into Forrest Lake

Note: View is from east to west, the photo was taken from helicopter on 1 October 2019.

6.0 SUMMARY

A geomorphological baseline study was completed as part of the hydrology program to establish baseline conditions to support an Environmental Assessment (EA) of the Rook I Project (Project). The study consisted of a desktop geomorphological review, targeted field study, and preliminary analysis for erosion susceptibility. The baseline geomorphological characterization focused on Patterson Lake and the Clearwater River below Patterson Lake as these are areas expected to be most influenced by proposed Project activities.

The field survey sites visited on Patterson Lake included one location on the shoreline of Patterson Lake near the sand bar/spit formation that divides the Patterson Lake – North Arm into two basins, as well as two additional shoreline locations in the South Arm. The field survey of the Clearwater River included multiple channel cross-sections between Patterson Lake (upstream) and Forrest Lake (downstream). The field surveys included observations of landform, shoreline slope, bank and bed materials, and vegetation, as well as photographic documentation.

Information collected during the field survey was used to support classification of erosion susceptibility at the field survey sites as well as other portions of Patterson Lake shoreline and the Clearwater River below Patterson Lake. Several shoreline segments along Patterson Lake were observed to be subject to modification by ongoing sediment transport processes. These processes include accretion resulting from longshore drift, with historical shoreline alignments visible in the aerial imagery, as well as likely ice-thrust modification of sedimentary shorelines. These active sediment transport areas are expected to be most sensitive to possible changes in the lake hydrologic regime. The localized bank erosion sites observed along the lake shoreline in sections with ice-thrust berms were also identified as sensitive areas. The surveyed reach of the Clearwater River was observed to have a single to multi-thread meandering channel, with typical channel cross-section geometries (i.e., deep banks on the outside of the meander) and fluvial morphology (i.e., point bars). The river has an active sediment transport regime, capable of transporting mostly small size materials (i.e., fine to medium sand), as indicated by the delta feature at its mouth into Forrest Lake.

This baseline geomorphological characterization has established that there are portions of both the Patterson Lake shoreline and the Clearwater River below Patterson Lake that are subject to active sediment transport regimes and may be susceptible to future erosion. Actual future changes to sediment transport regimes and erosion of areas that have been identified as susceptible would depend on changes to the water surface elevation of Patterson Lake. Change to Patterson Lake water surface elevation would influence wave action and resultant shoreline erosion as well as deposition or accretion along different portions of the shoreline. Change to water level in Patterson Lake could also influence the flow regime in the Clearwater River below Patterson Lake, which may alter sediment transport regimes in the Clearwater River channel between Patterson Lake and Forrest Lake. The magnitude, direction, and duration of the changes in lake level and the resultant influence on baseline sediment transport regimes would be evaluated as part of the EA.

CLOSING

Golder is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations section following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

Golder Associates Ltd.

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Wat. Resources	22672	

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APPENDIX A

Photographs

1.0 PATTERSON LAKE OUTLET CHANNEL (CLEARWATER RIVER)

Figure A1: Patterson Lake Outlet Channel Transect 1 - Upstream of the Access Road Bridge Crossing

Figure A2: Patterson Lake Outlet Channel, Transect 11, View downstream

Figure A3: Patterson Lake Outlet Channel, Transect 12, View Downstream

Figure A4: Patterson Lake Outlet Channel, Transect 17, View Upstream

Figure A5: Patterson Lake Outlet Channel, Transect 21, View Upstream

Figure A6: Patterson Lake Outlet Channel, Transect 21, View Upstream

Figure A7: Patterson Lake Outlet Channel, Transect 22, View Downstream

Figure A8: Patterson Lake Outlet Channel, Transect 21, View Upstream

Figure A9: Patterson Lake Outlet Channel, Transect 34, View Upstream

Figure A10: Patterson Lake Outlet Channel, Transect 29, View Downstream

Figure A11: Patterson Lake Outlet Channel, Transect 29, View Upstream

Figure A12: Patterson Lake Outlet Channel, Transect 31, View Downstream

Figure A13: Patterson Lake Outlet Channel, Transect 36, View Downstream

Figure A14: Patterson Lake Outlet Channel, Transect 38, View Upstream

Figure A15: Patterson Lake Outlet Channel, Inlet into Forest Lake, View Upstream

2.0 PATTERSON LAKE SHORELINE

Figure A16: Patterson Lake Shoreline, Site 1, Facing Northwest

Figure A17: Patterson Lake Shoreline, Site 1, Facing Northeast

Figure A18: Patterson Lake Shoreline, Site 1, Facing Northwest

Figure A19: Patterson Lake Shoreline, Site 1, Facing Northeast

Figure A20: Patterson Lake Shoreline, Site 1

Figure A21: Patterson Lake Shoreline, Site 1, Facing North

Figure A22: Patterson Lake Shoreline, Site 2, Facing East

Figure A23: Patterson Lake Shoreline, Site 2, Facing Southeast

Figure A24: Patterson Lake Shoreline, Site 3, Facing Northwest

Figure A25: Patterson Lake Shoreline, Site 3

APPENDIX B

Shoreline Erosion Susceptibility Calculations

This Appendix presents the methods used to derive the erosion susceptibility class for the shoreline erosion assessment and the scores at each location for all parameters.

EROSION SUSCEPTIBILITY METHODS

To estimate the shoreline erosion susceptibility class, the parameters used were separated into three categories: bank and shoreline features, exposure characteristics, and attenuation characteristics, with each category having its own parameters (Table B1). The shoreline erosion susceptibility was classified into a five-class system, ranking from Very Low to Very High and the classification was based on a modified version of a tool developed to calculate Lakeshore erosion potential for Alberta Sustainable Resource Development.

Table B1: Final Score Calculation

Categories	Parameters
Bank and Shoreline Features	Bank Height Bank Vegetation Bank Stability Shoreline Geometry
Exposure Characteristics	Shore Orientation (wind direction) Fetch Length Depth at 6 m from shore Depth at 30 m from shore
Attenuation Characteristics	Aquatic Vegetation Bank Composition Bank Slope

For each parameter a score range and a number of class were assigned (Table B2). The class values for each parameter were determined based on field observations at site, including:

- bank height (collected at existing lake level at the time of survey)
- bank vegetation
- bank stability
- shoreline geometry
- shore orientation (wind directions scores and class were calculated based on wind data collected at NexGen Rook I Hill Meteorological Station and presented in the main report)
- fetch length (based on map measurements in GIS)
- lake depth at 6 and 30 m from shore (estimated from field data and aerial imageries)
- aquatic vegetation
- bank slope (calculated from cross-section profiles)

Table B2: Score Range and Classes for Shoreline Parameters

<table>
<tr><th colspan="2">Bank and Shoreline Features</th></tr>
<tr><th>Parameter</th><th>Score and Class</th></tr>
<tr><td>Bank Height (BH)</td><td>1 = <0.3 m
2 = 0.3-1.5 m
3 = 1.5-3.0 m
4 = 3.0-6.0 m
5 = >6.0 m</td></tr>
<tr><td>Bank Vegetation (BV)</td><td>0 = rocky outcrop with little or no vegetation
1 = mixed boulders and cobbles with mature vegetation
4 = bog peat and brush vegetation on top of boulders
7 = organic materials with no rocky materials</td></tr>
<tr><td>Bank Stability (BSt)</td><td>0 = bedrock or boulder with no vegetation
1 = boulders or bedrock with mature forests
2 = boulders and cobbles with discontinued vegetation
4 = boulders and cobbles with vegetation on top (brush and fen)
6 = soils with thermo-erosion processes
7 = organic materials with bog and fen peat and not rocky materials</td></tr>
<tr><td>Shoreline Geometry (SG)</td><td>1 = coves or bays
4 = irregular or straight shorelines
8 = headland or islands</td></tr>
<tr><th colspan="2">Exposure Characteristics</th></tr>
<tr><th>Parameter</th><th>Score and Class</th></tr>
<tr><td>Shore Orientation (SO)
(wind direction)</td><td>0 = ESE
1 = NNE, NE, ENE, E
2 = N, SE, NNW
3 = SW, WSW, W
4 = SSE, S, SSW, WNW, NW</td></tr>
<tr><td>Fetch Length (FL) (m)</td><td>0 = < 50 m
1 = 50 to 100 m
2 = 100 to 200 m
3 = 200 to 500 m
4 = 500 to 1000 m
5 = 1000 to 3000 m
6 = > 3000 m</td></tr>
<tr><td>Lake Depth (LD)
at 6 and 30 m
from shore</td><td>
<table>
<tr><th></th><th colspan="5">Depth at 6 m</th></tr>
<tr><th>Depth at 30 m</th><td>0.0</td><td>0.3</td><td>0.9</td><td>1.8</td><td>3.7</td></tr>
<tr><td>0.0</td><td>-1</td><td>-1</td><td>-1</td><td>-2</td><td>-2</td></tr>
<tr><td>0.3</td><td>0</td><td>-1</td><td>-1</td><td>-2</td><td>-2</td></tr>
<tr><td>0.9</td><td>0</td><td>0</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td>1.8</td><td>1</td><td>1</td><td>0</td><td>-1</td><td>-1</td></tr>
<tr><td>3.7</td><td>1</td><td>1</td><td>0</td><td>-1</td><td>-1</td></tr>
</table>
</td></tr>
</table>

Table B2: Score Range and Classes for Shoreline Parameters

Attenuation Characteristics	
Parameter	**Score and Class**
Aquatic Vegetation (AV)	0 = no vegetation, spares or submerged -1 = moderate -2 = dense or abundant
Bank Slope (BSp)	0 = < 5 degrees 1 = 5 to 25 degrees 2 = 25 to 45 degrees 4 = > 45 degrees
Modified Bank Composition (MBC)	Bank Composition Scores (BC) 0 = bedrock or boulder with no vegetation 1 = boulders or bedrock with mature forests 2 = boulders and cobbles with discontinued vegetation 3 = boulders and cobbles with vegetation on top (brush and fen) 4 = soils with thermo-erosion processes 5 = organic materials with bog and fen peat and not rocky materials

	Bank Slope Score			
Bank Composition Score	0	1	2	4
0	0	0	0	0
1	-1	0	0	3
2	-1	0	1	3
3	-1	0	1	4
4	0	-1	1	4
5	0	-1	2	4

For each of the three categories a single score was calculated, and the final score was determined from the three combined scores indicating the susceptibility erosion class. The method to calculate the final score and associated classed are presented in Table B3.

Table B3: Final Score Calculation

<table>
<tr><th>Category</th><th>Score Description and Formulas</th></tr>
<tr><td>Bank and Shoreline Features (BSF)</td><td>The sum of score of all parameters
BSF = BH + BV +BSt + SG</td></tr>
<tr><td>Exposure and Attenuation Characteristics (EAC)</td><td>The final score is the sum of the modified fetch length with the wind scores (MFLW) and the modified score of the bank composition modified score (BCMS)
EAC = MFLW + BCMS
where
MFLW = SO * (FL + LD + AV)
BCMS = BSp & MBC</td></tr>
<tr><td>Erosion Potential (EP)</td><td>EP = BSF + EAC
EP Class:
<table>
<tr><th>Erosion Potential Class</th><th>Erosion Potential Score</th></tr>
<tr><td>Very Low</td><td>< 15</td></tr>
<tr><td>Low</td><td>15 to 20</td></tr>
<tr><td>Moderate</td><td>20 to 25</td></tr>
<tr><td>High</td><td>25 to 35</td></tr>
<tr><td>Very High</td><td>> 35</td></tr>
</table>
</td></tr>
</table>

SCORES FOR CONTRIBUTING PARAMETERS

Table B4 presents the scores for each parameter measured at the transects surveyed at each location.

Table B4: Scores for each parameter

Parameter	Site 1	Site 2	Site 3
Score - Bank Height (BH)	3	1	3
Score - Bank Vegetation (BV)	7	1	1
Score - Bank Stability (BSt)	6	1	1
Score - Shoreline Geometry (SG)	8	4	4
Score - BSF Score	24	7	9
Score - Exposure Characteristics Shore Orientation (SO)	1	4	1
Score - Fetch Length (m) (FL)	6	4	6
Score - Lake Depth (LD)	-1	0	0
Score - MFLW Score	5	16	6
Score - Aquatic Vegetation (AV)	0	0	0
Score - Bank Slope (BSp)	4	1	4
Score - Bank Composition Scores (BC)	4	1	1
Score - Modified Bank Composition (MBC)	4	0	3
Score - BCMS Score	16	0	12
Score - Exposure and Attenuation Characteristics (EAC)	21	16	18
Score - Erosion Potential (EP)	45	23	27

APPENDIX C

Transect Cross-Sections

1.0 PATTERSON LAKE OUTLET CHANNEL (CLEARWATER RIVER)

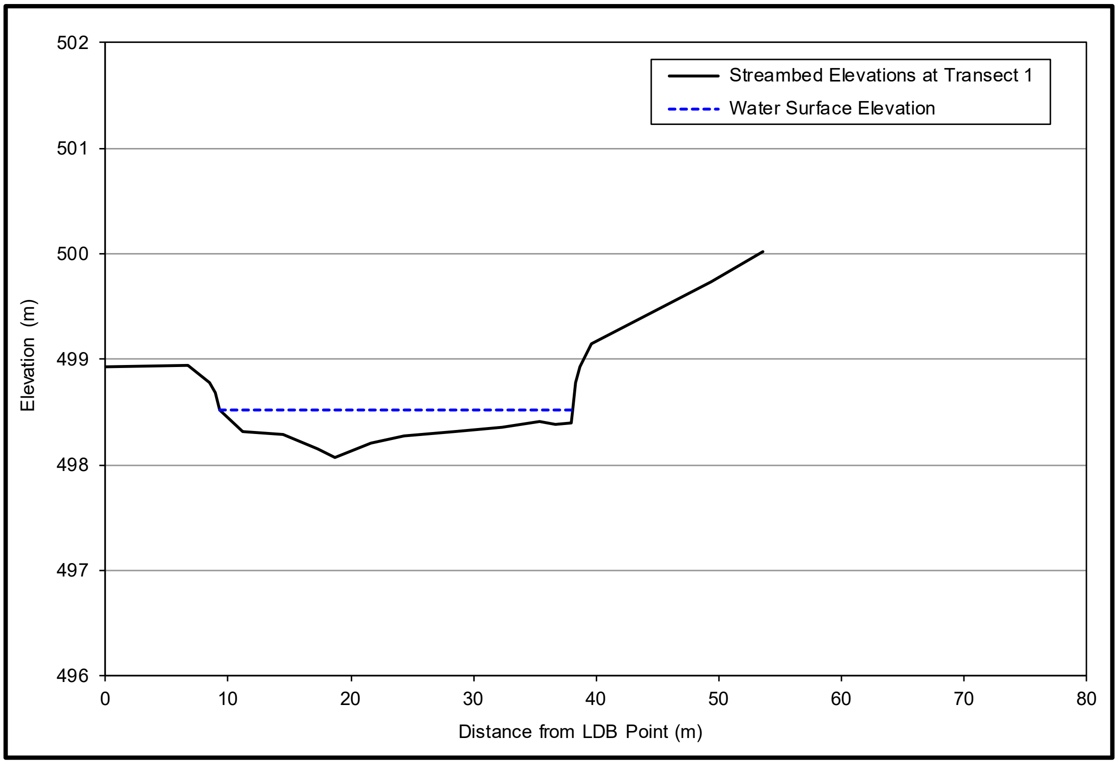

Figure C1: Patterson Lake Outlet Channel, Transect 1 Cross-Section

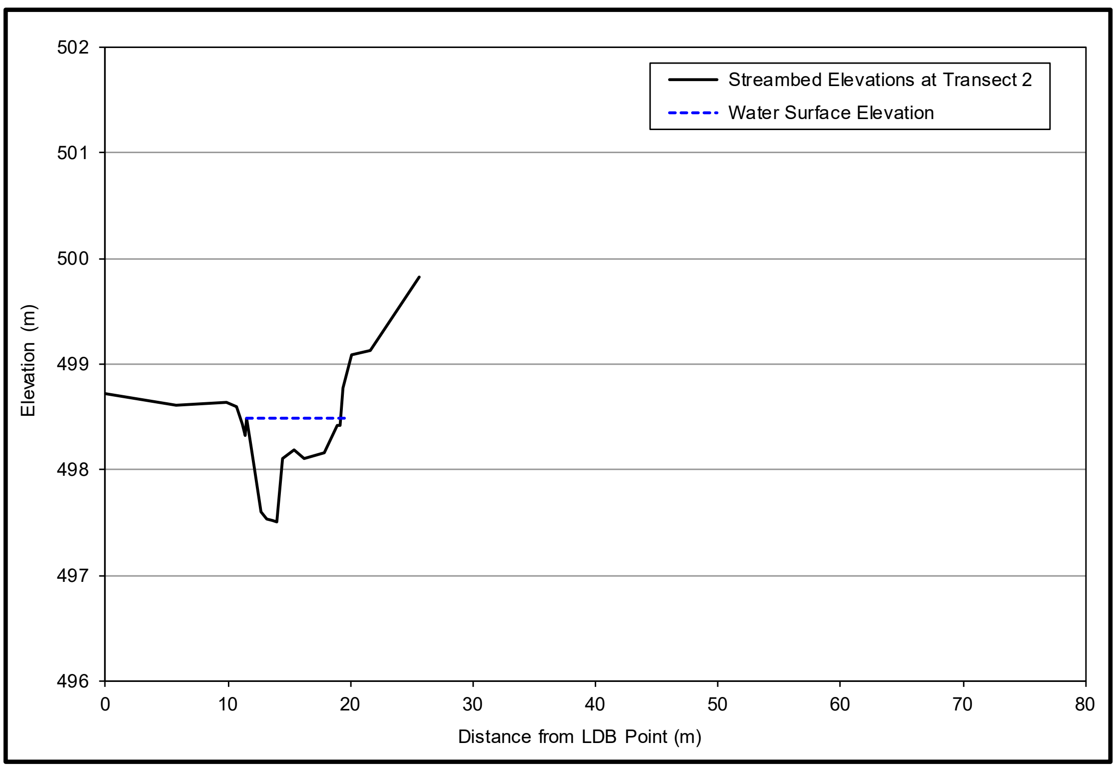

Figure C2: Patterson Lake Outlet Channel, Transect 2 Cross-Section

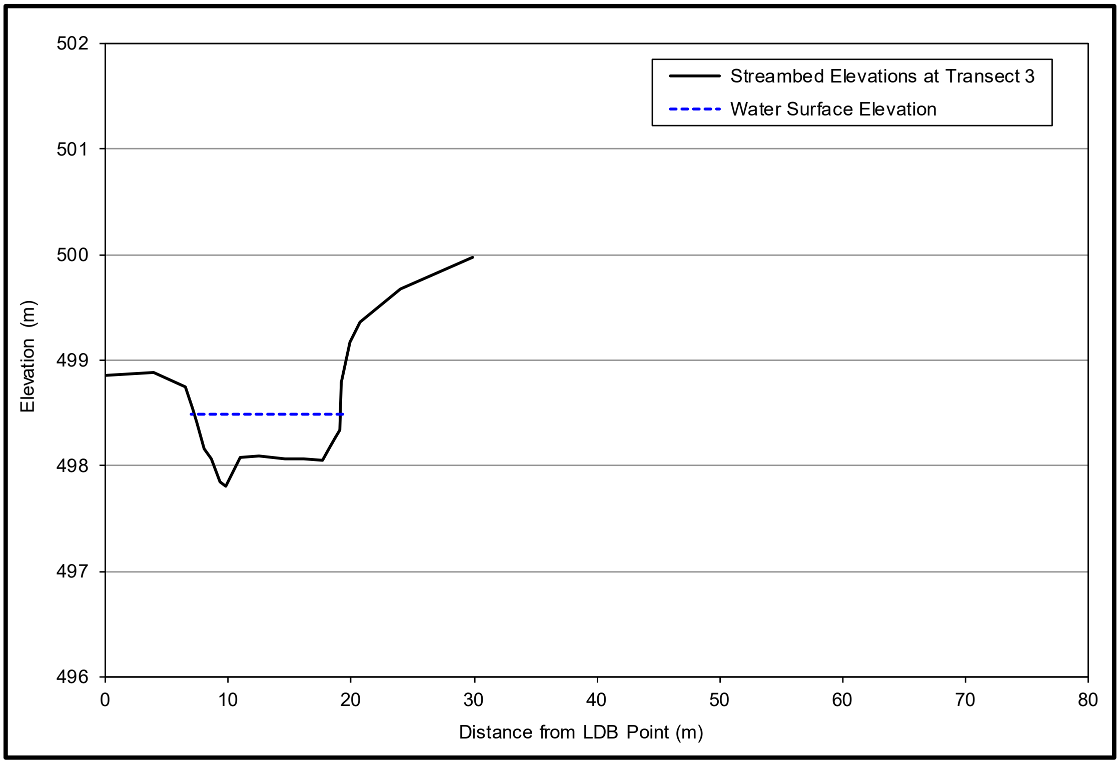

Figure C3: Patterson Lake Outlet Channel, Transect 3 Cross-Section

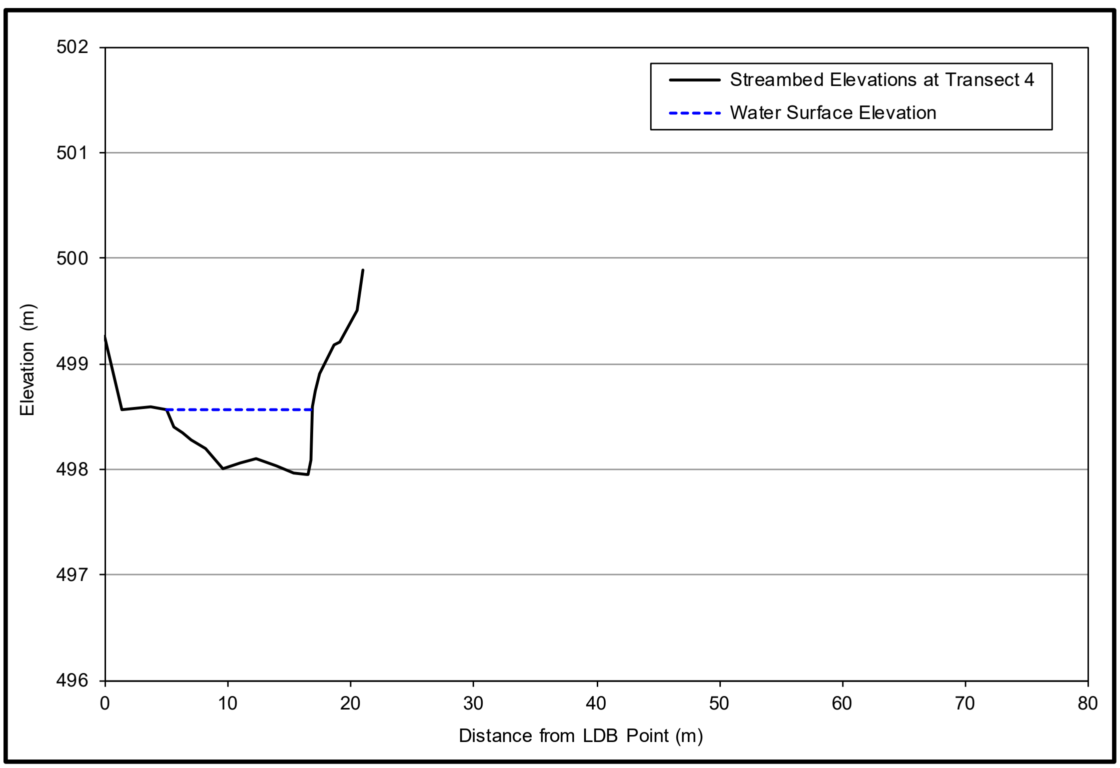

Figure C4: Patterson Lake Outlet Channel, Transect 4 Cross-Section

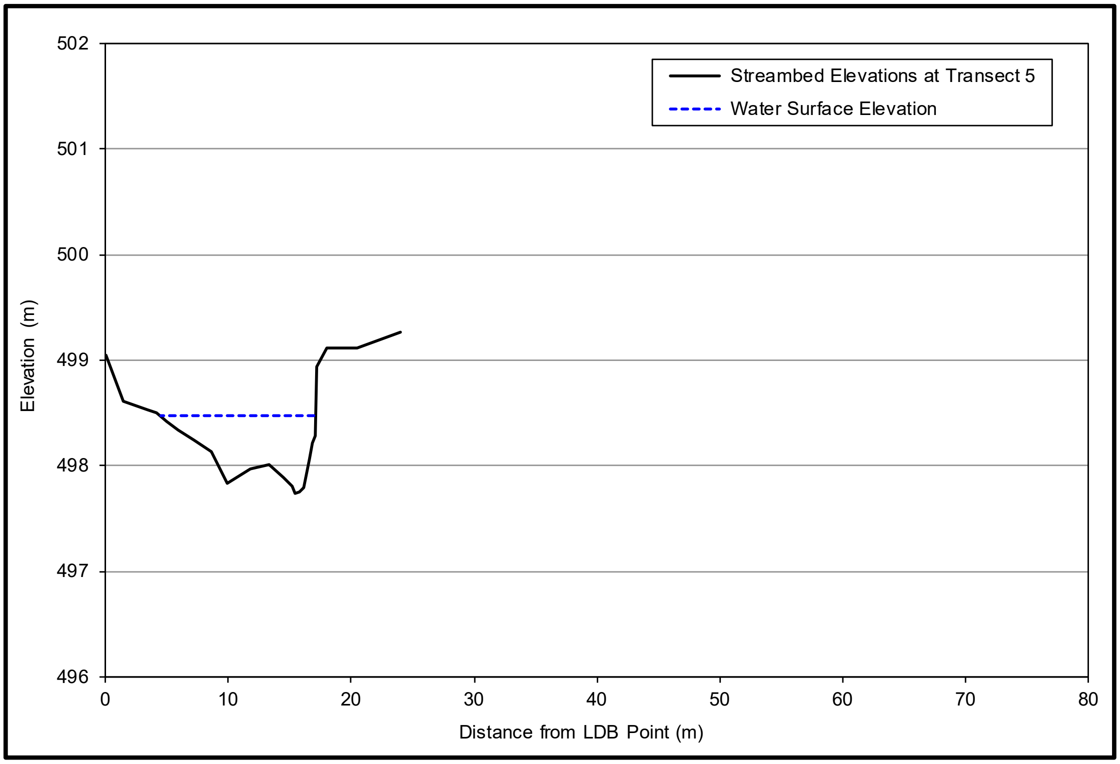

Figure C5: Patterson Lake Outlet Channel, Transect 5 Cross-Section

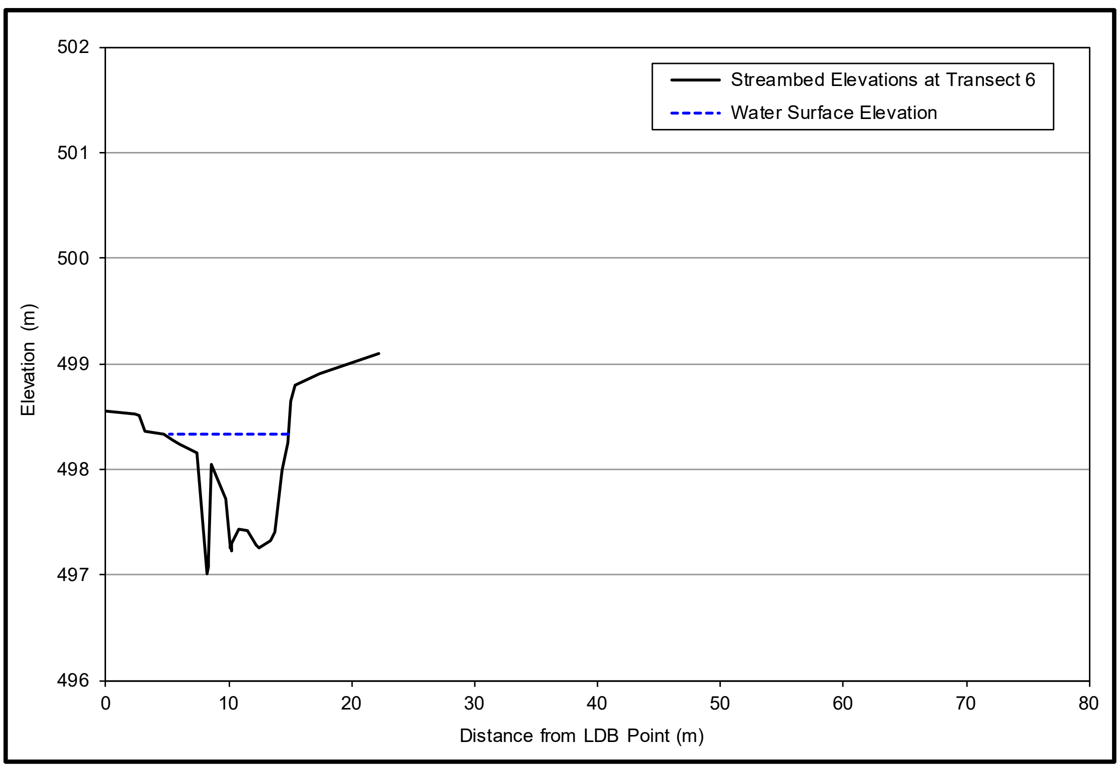

Figure C6: Patterson Lake Outlet Channel, Transect 6 Cross-Section

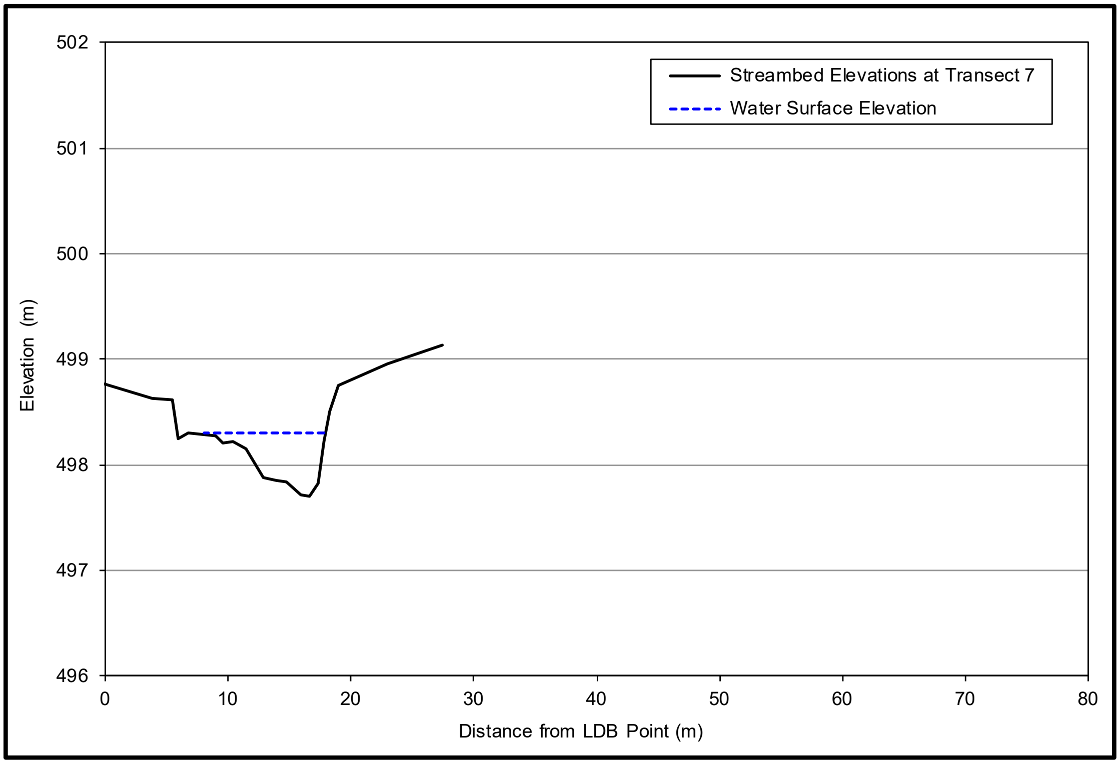

Figure C7: Patterson Lake Outlet Channel, Transect 7 Cross-Section

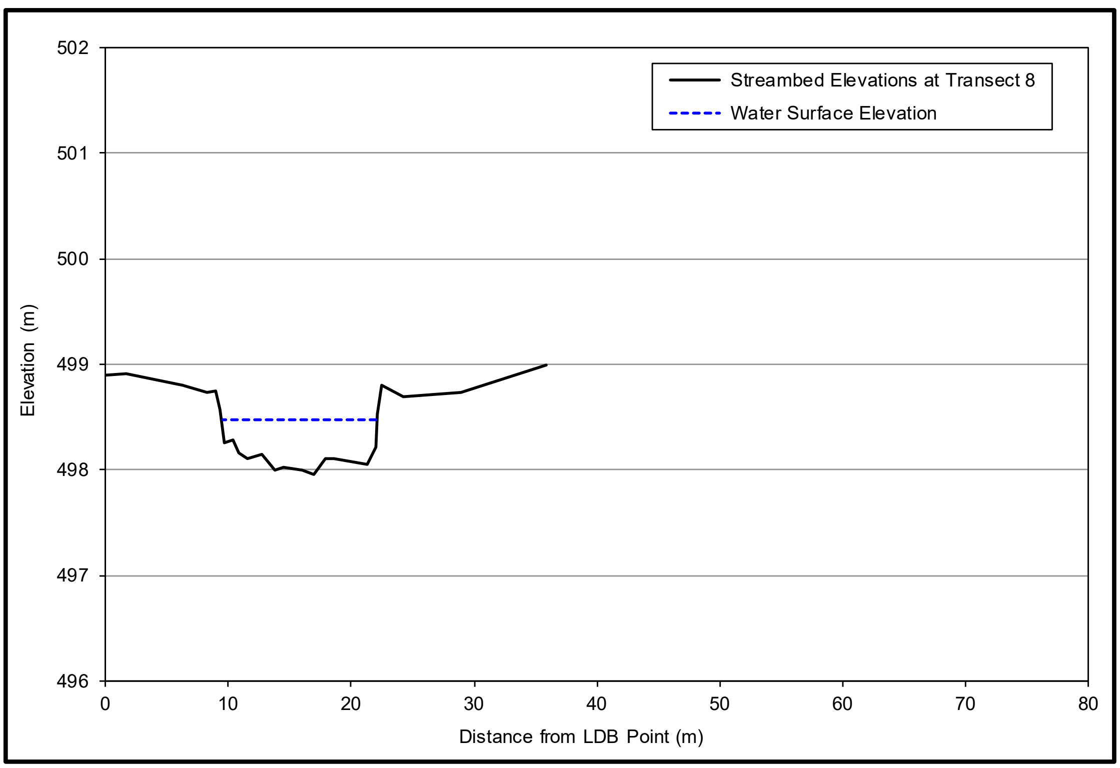

Figure C8: Patterson Lake Outlet Channel, Transect 8 Cross-Section

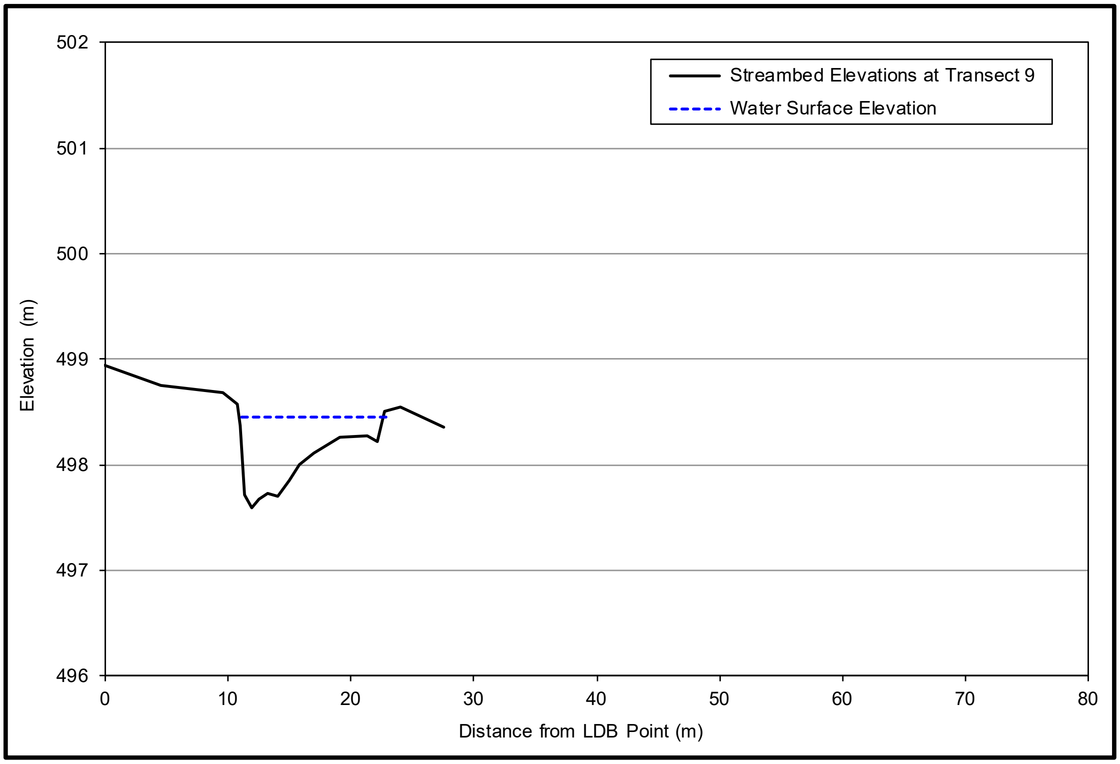

Figure C9: Patterson Lake Outlet Channel, Transect 9 Cross-Section

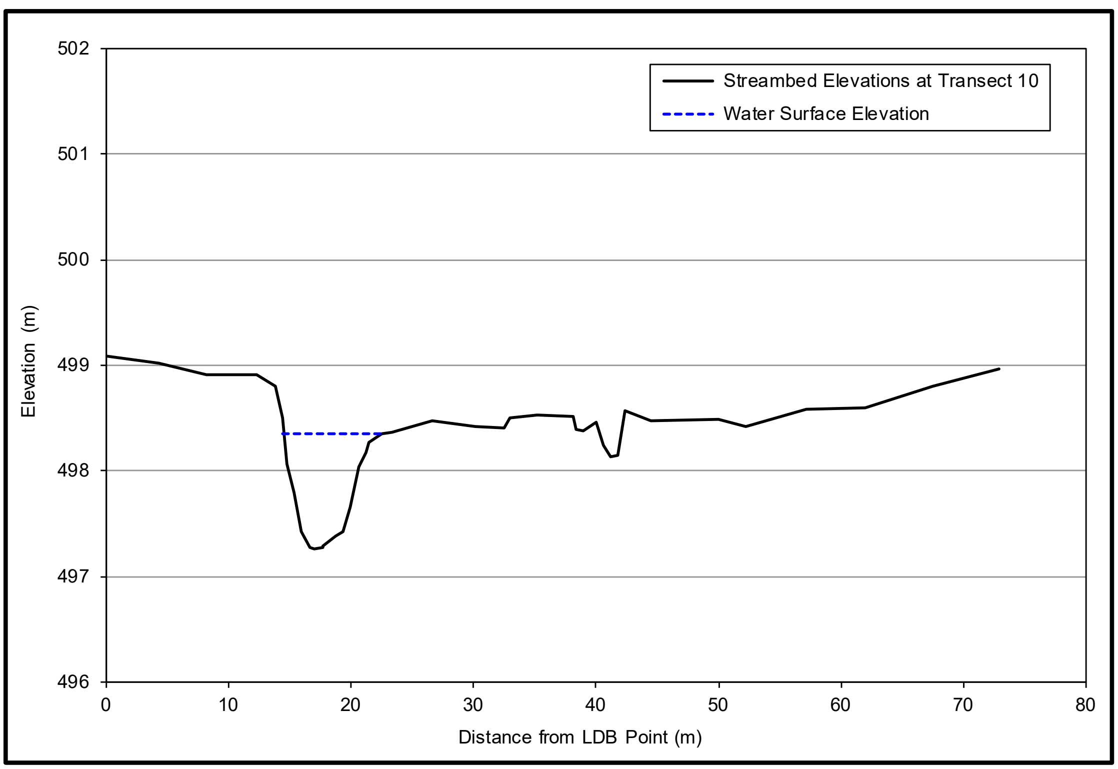

Figure C10: Patterson Lake Outlet Channel, Transect 10 Cross-Section

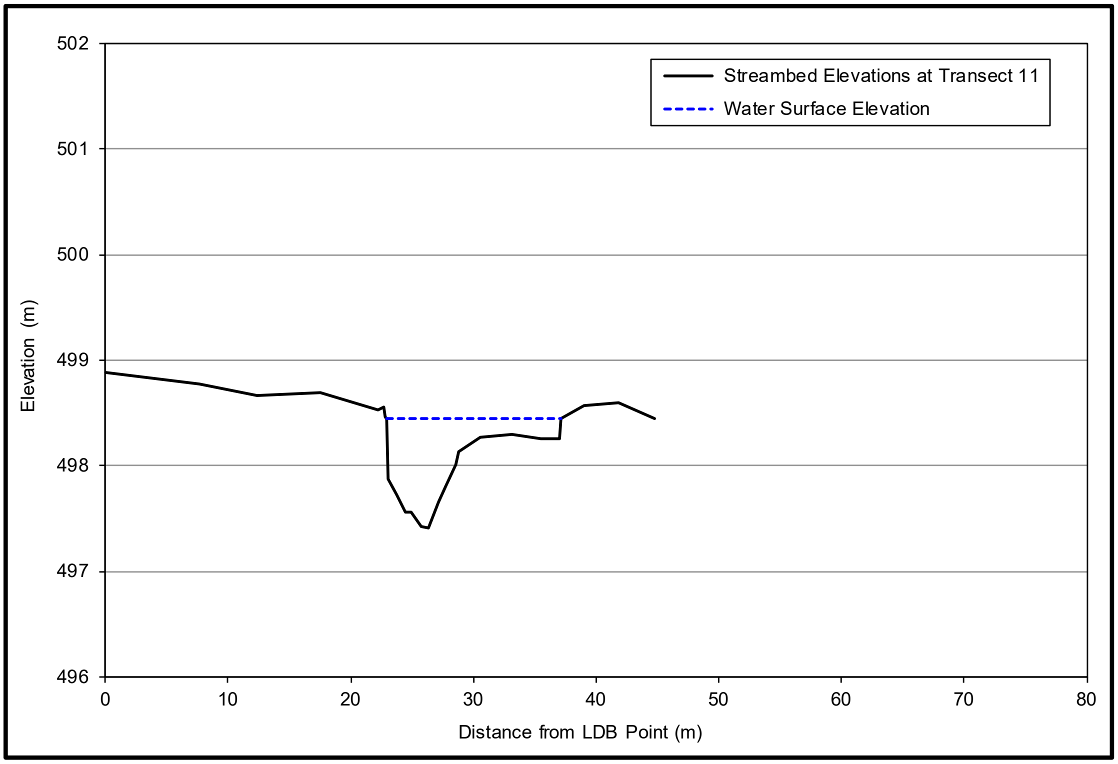

Figure C11: Patterson Lake Outlet Channel, Transect 11 Cross-Section

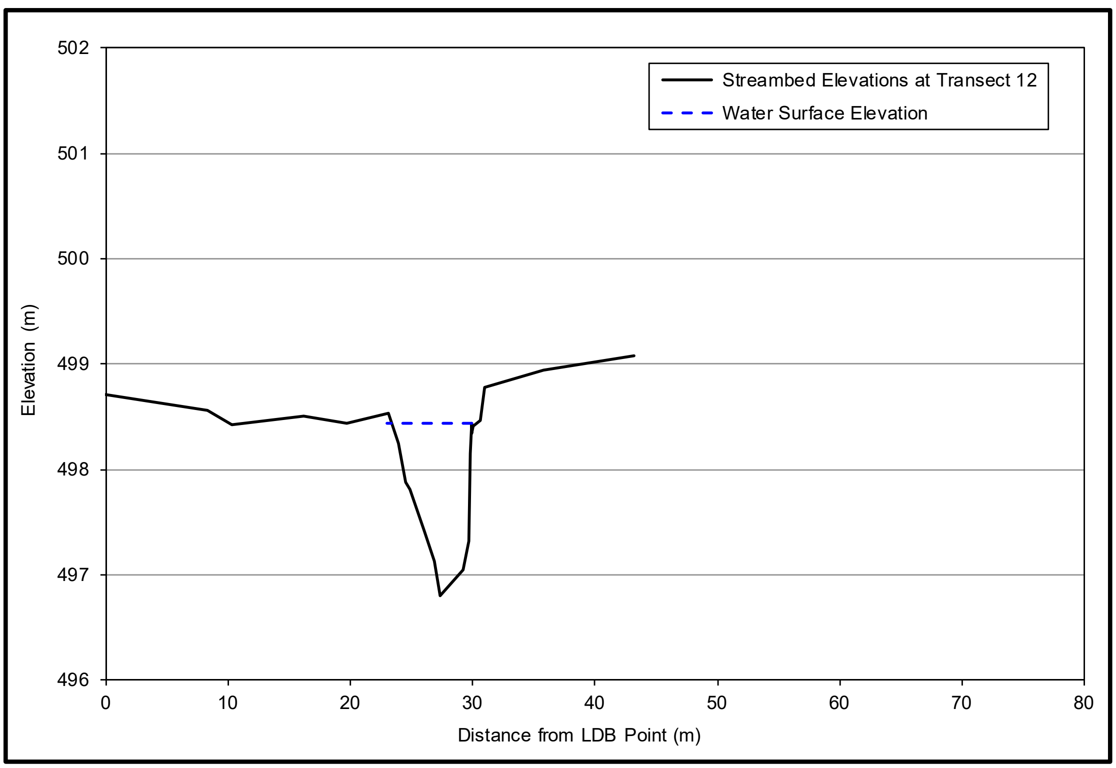

Figure C12: Patterson Lake Outlet Channel, Transect 12 Cross-Section

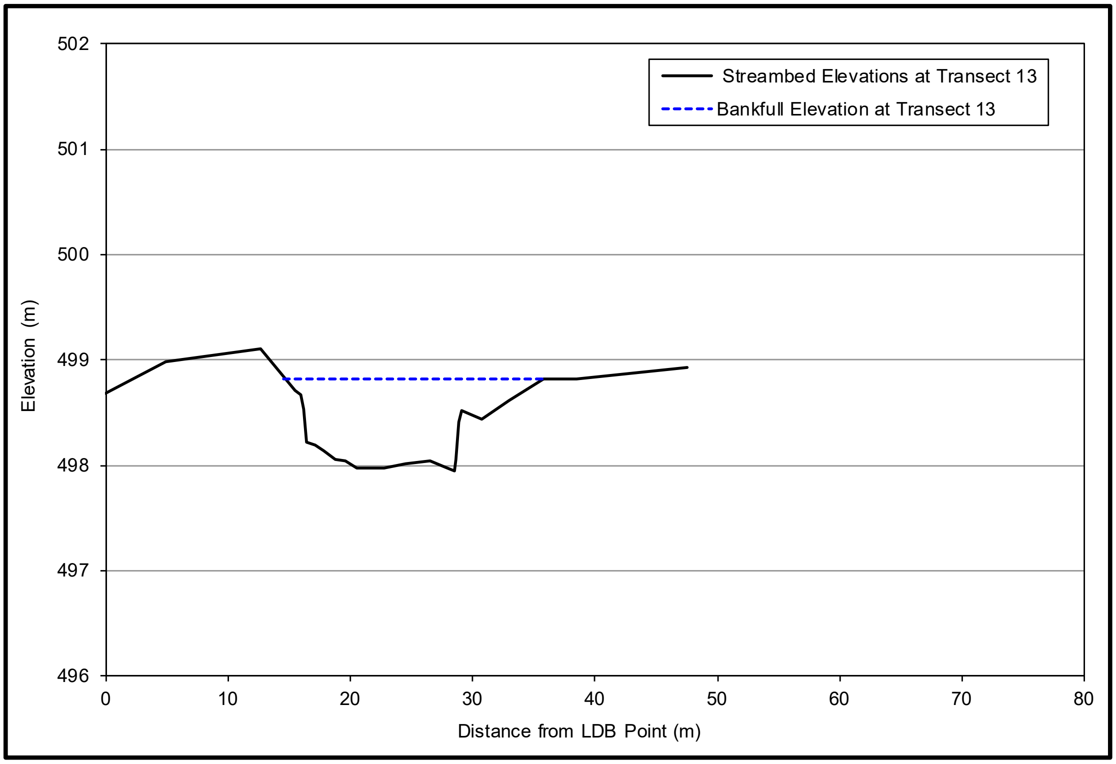

Figure 13: Patterson Lake Outlet Channel, Transect 13 Cross-Section

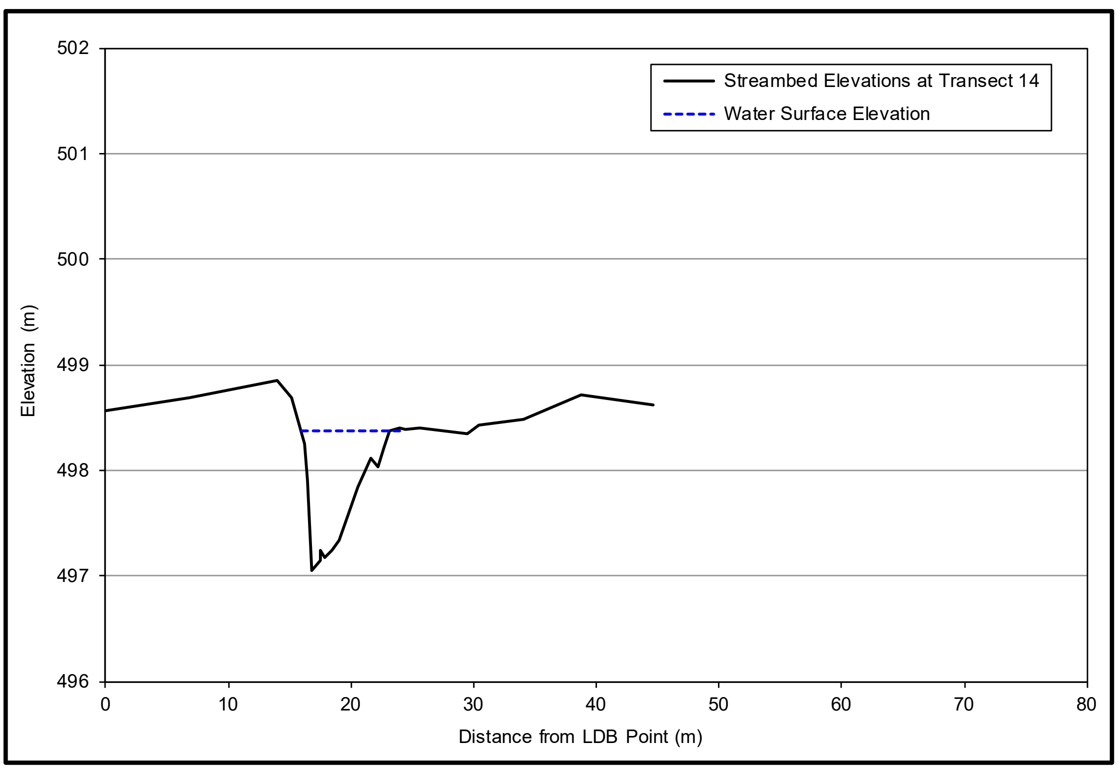

Figure C14: Patterson Lake Outlet Channel, Transect 14 Cross-Section

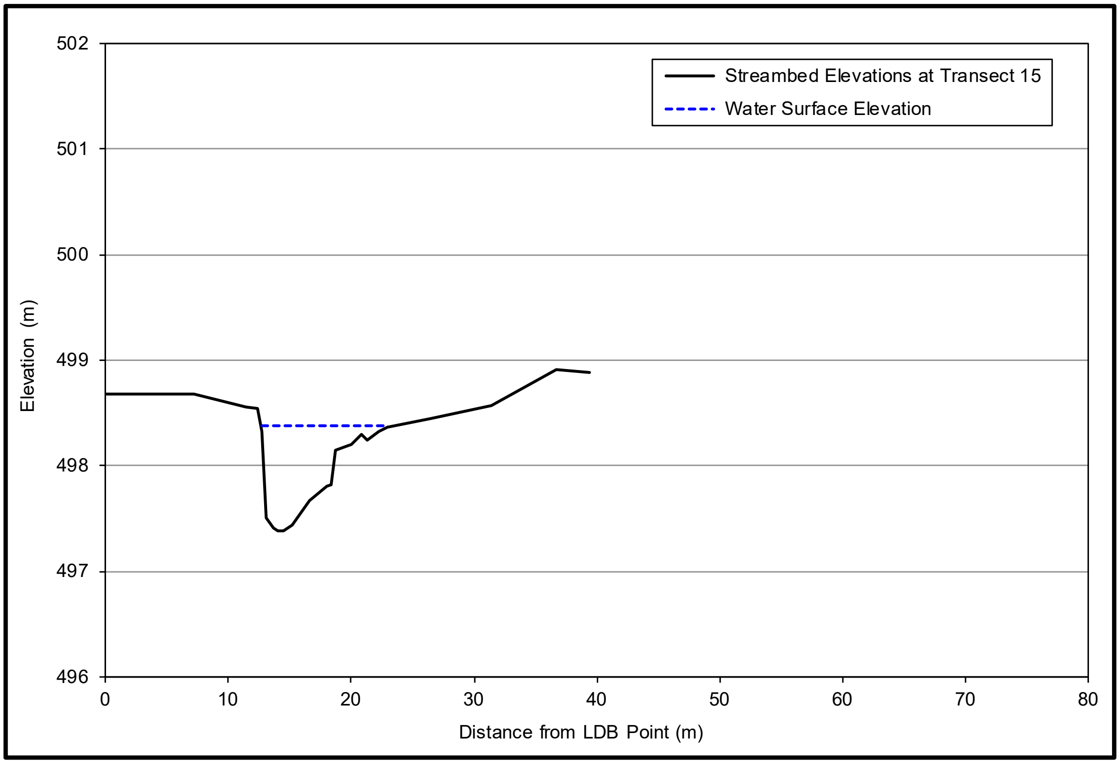

Figure C15: Patterson Lake Outlet Channel, Transect 15 Cross-Section

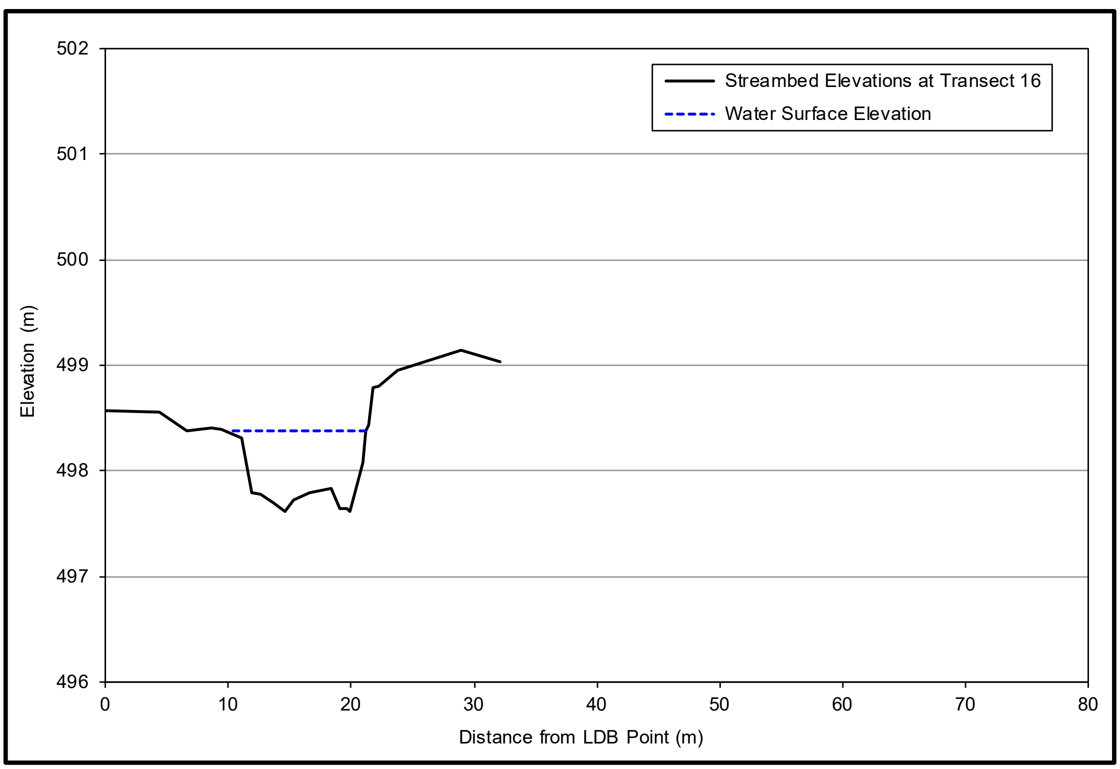

Figure C16: Patterson Lake Outlet Channel, Transect 16 Cross-Section

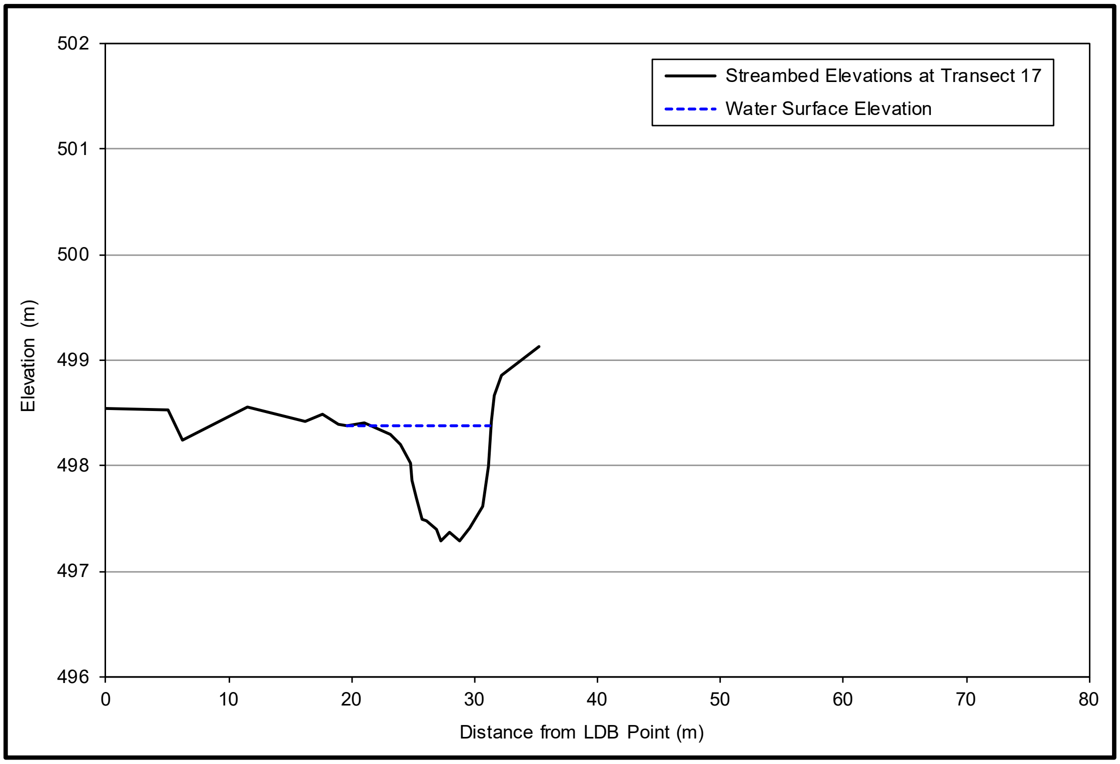

Figure C17: Patterson Lake Outlet Channel, Transect 17 Cross-Section

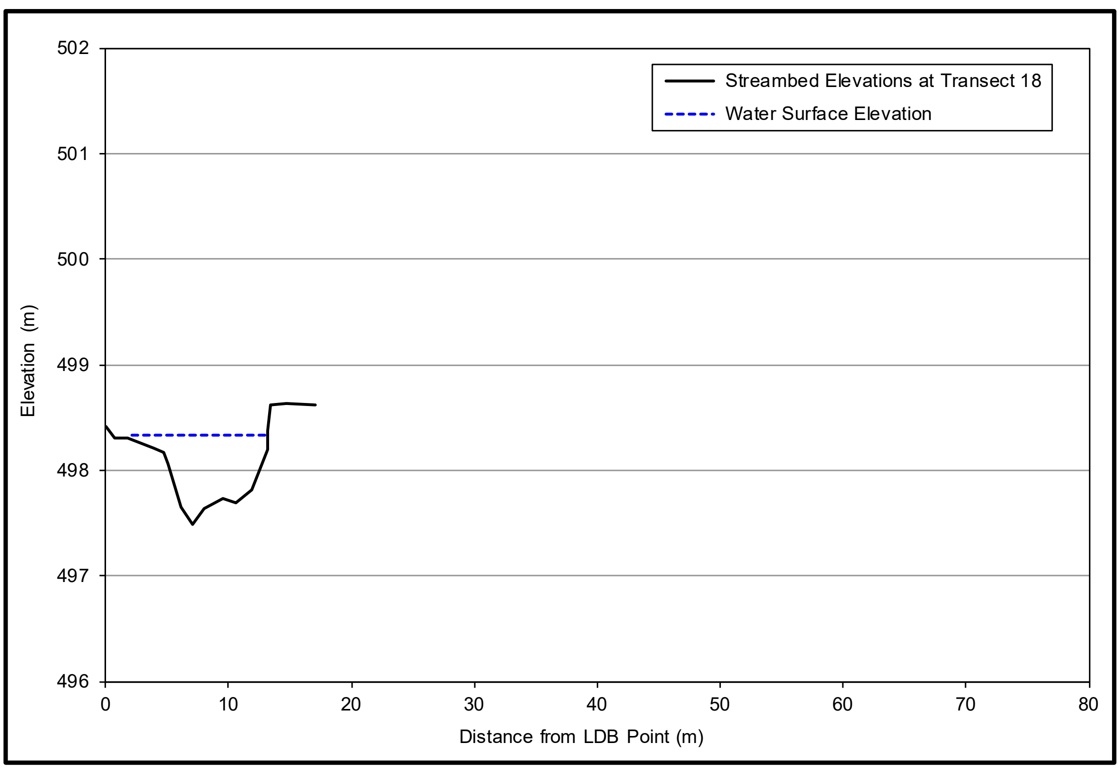

Figure C18: Patterson Lake Outlet Channel, Transect 18 Cross-Section

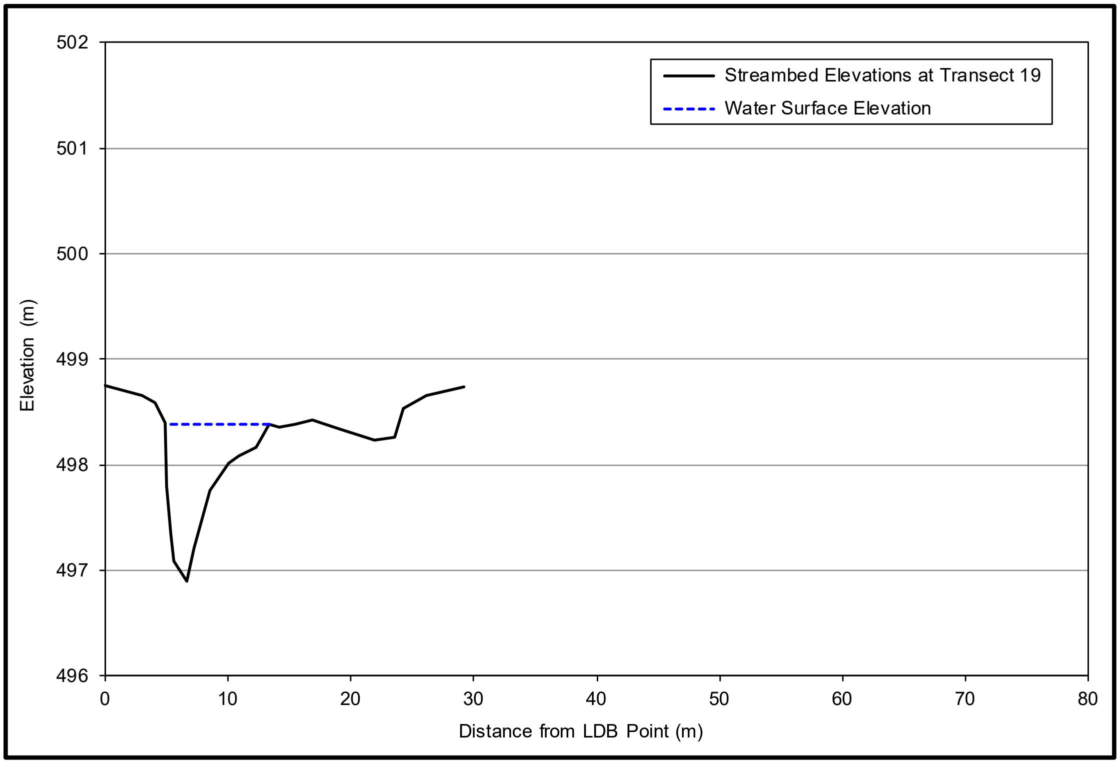

Figure C19: Patterson Lake Outlet Channel, Transect 19 Cross-Section

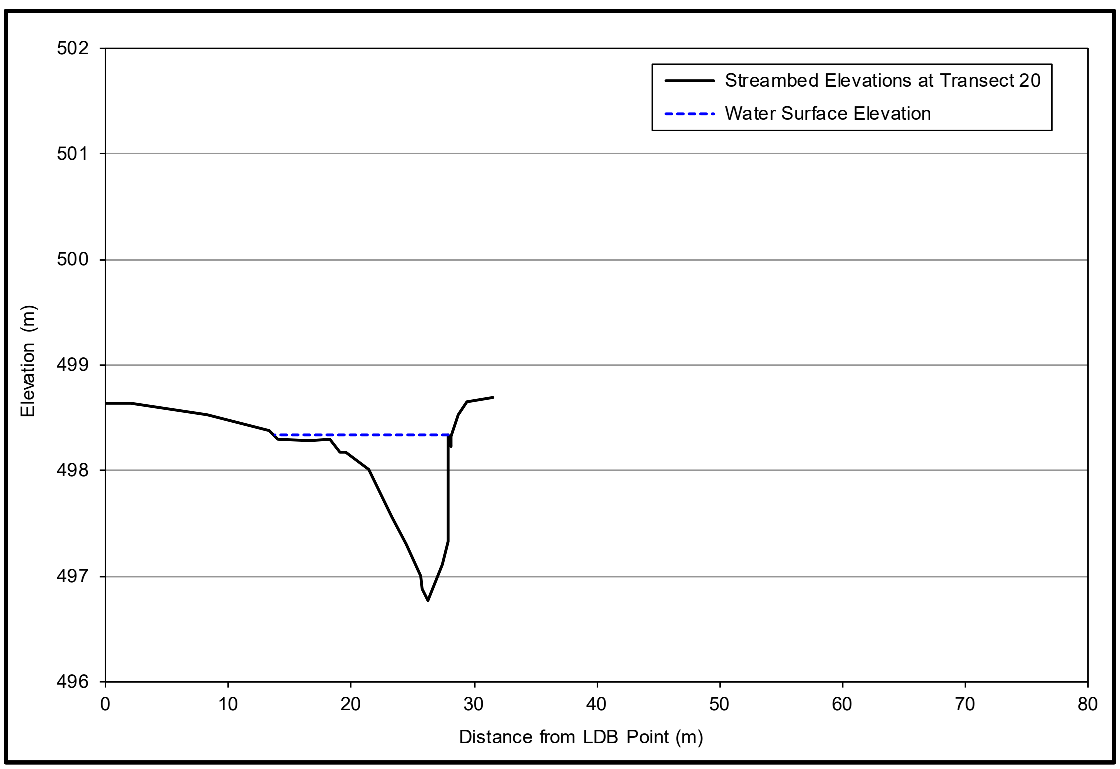

Figure C20: Patterson Lake Outlet Channel, Transect 20 Cross-Section

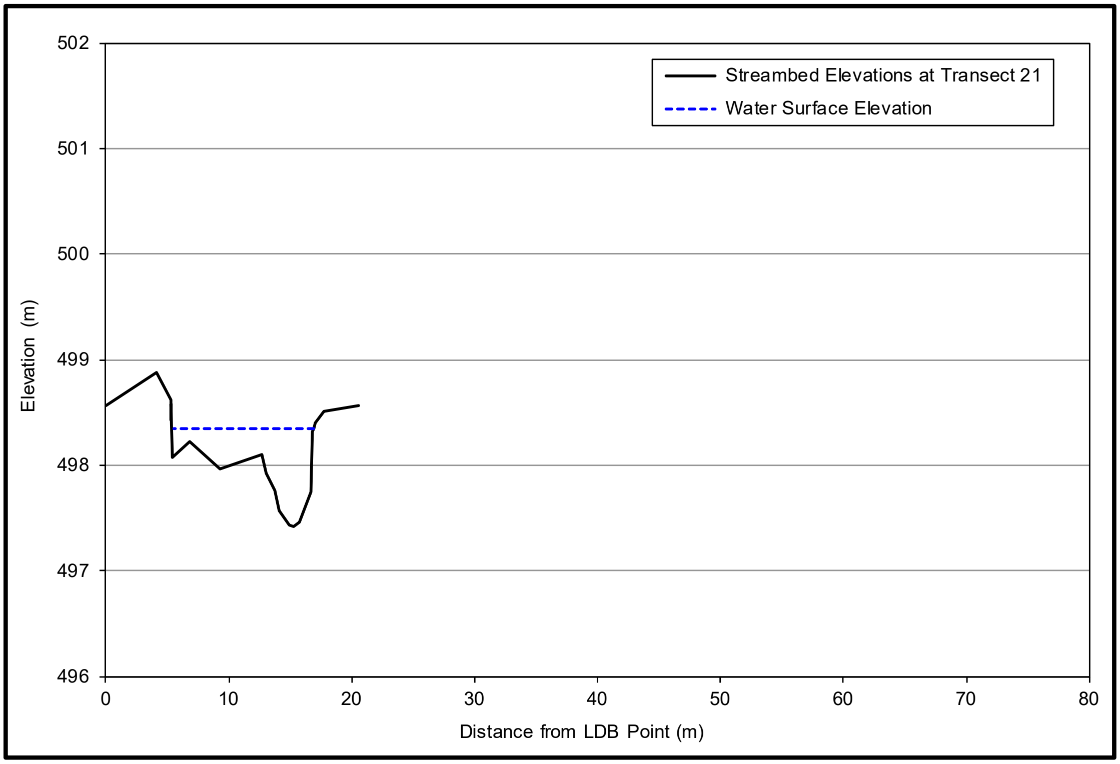

Figure C21: Patterson Lake Outlet Channel, Transect 21 Cross-Section

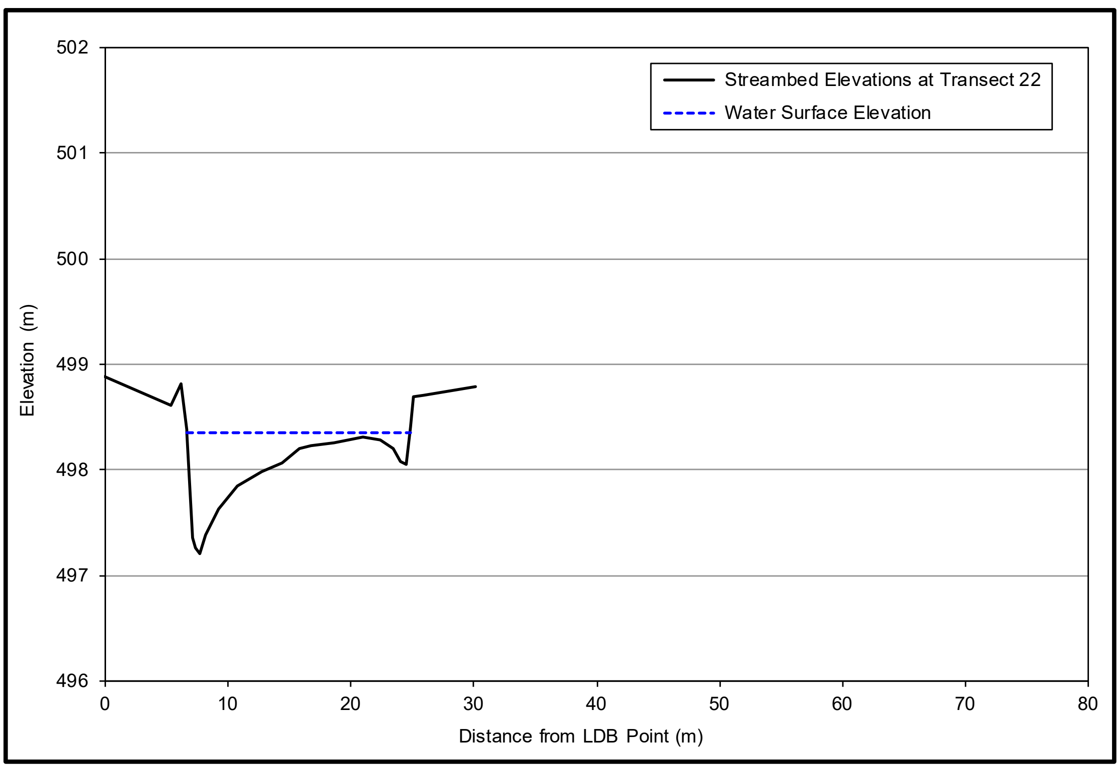

Figure C22: Patterson Lake Outlet Channel, Transect 22 Cross-Section

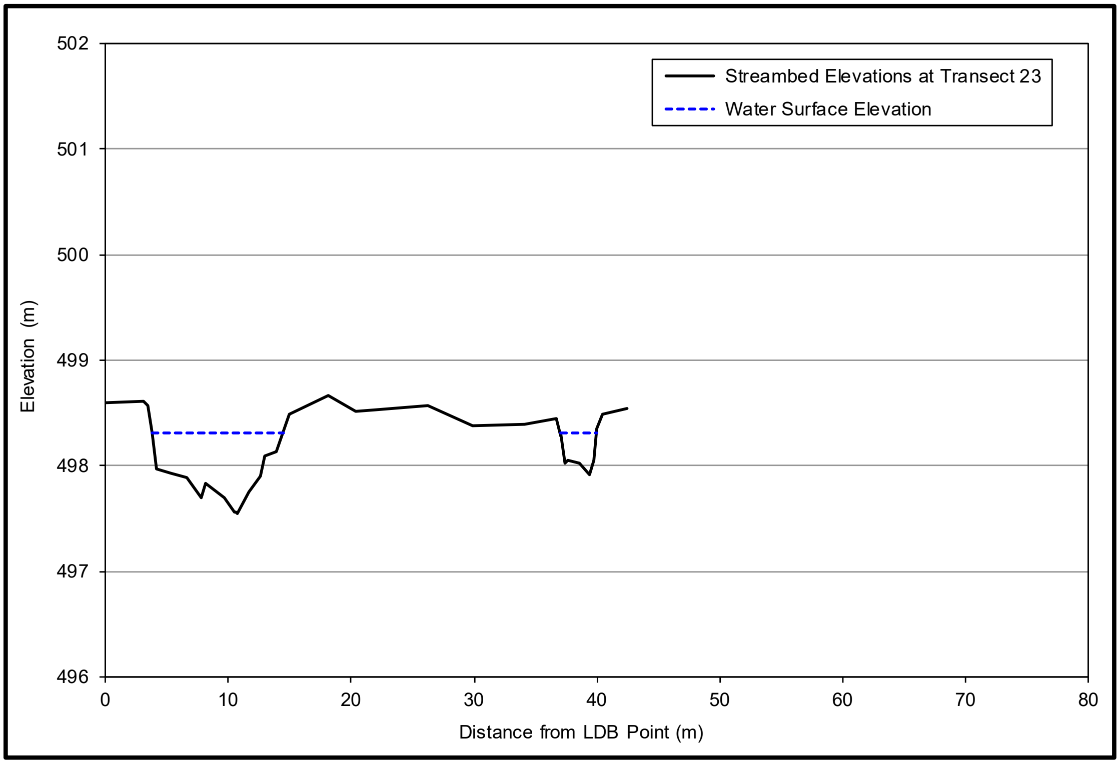

Figure C23: Patterson Lake Outlet Channel, Transect 23 Cross-Section

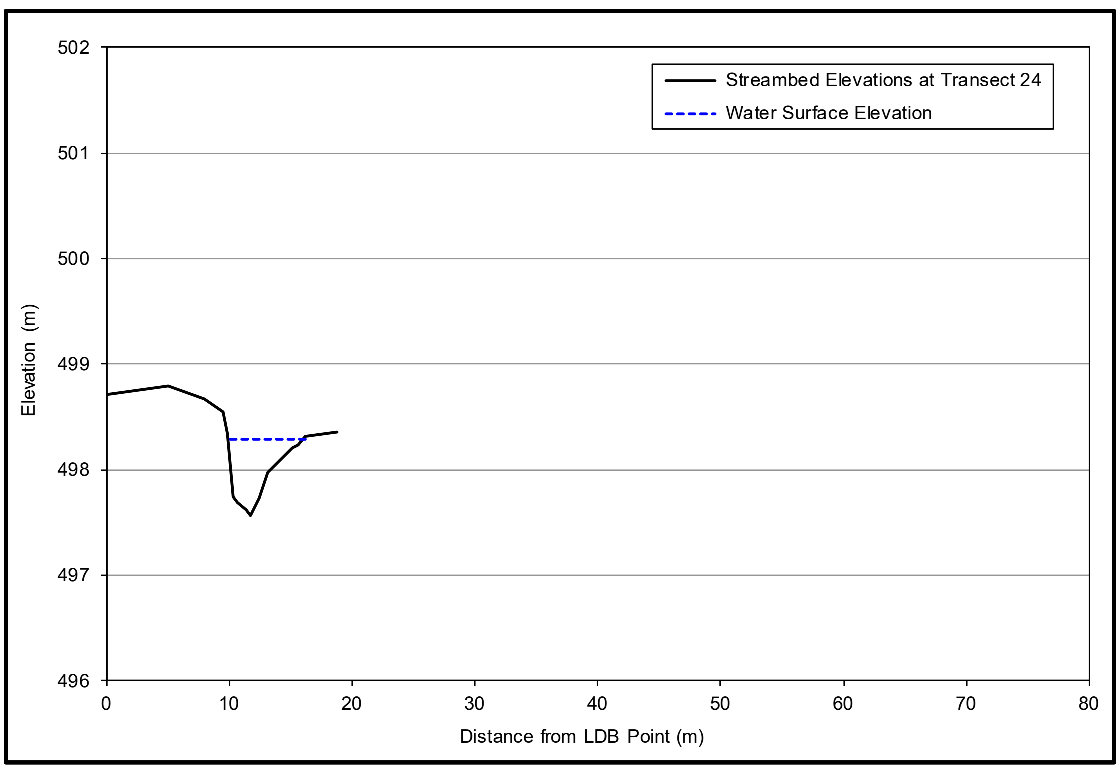

Figure C24: Patterson Lake Outlet Channel, Transect 24 Cross-Section

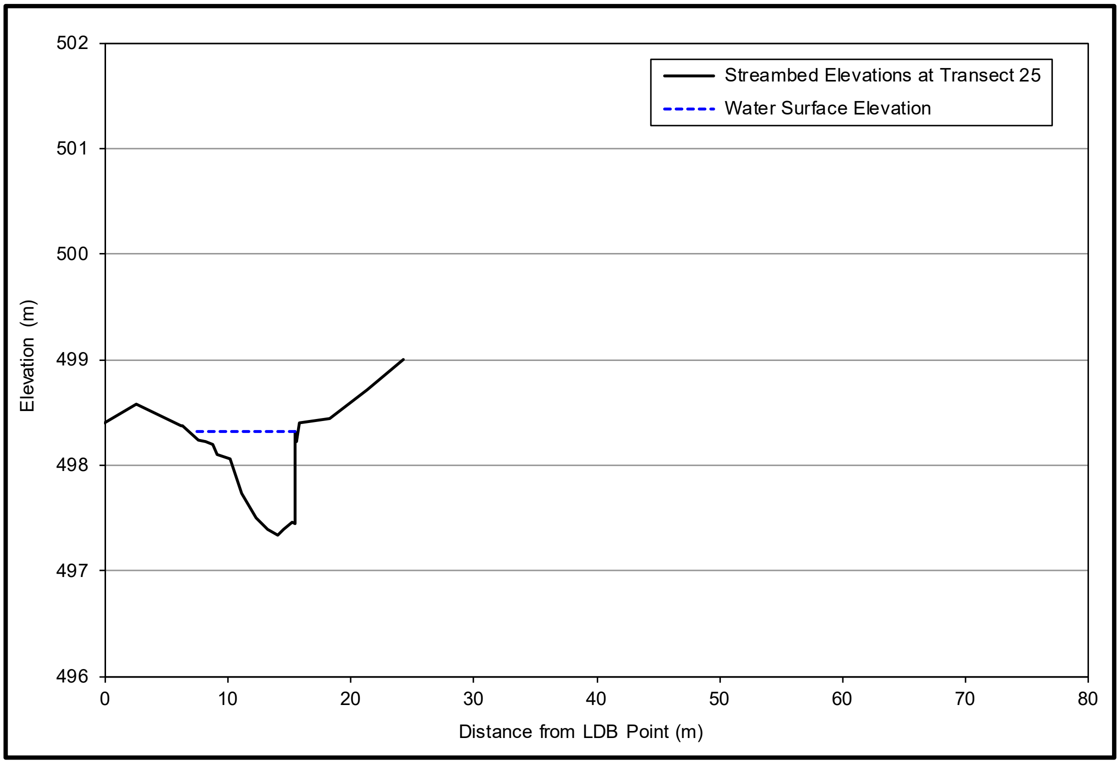

Figure C25: Patterson Lake Outlet Channel, Transect 25 Cross-Section

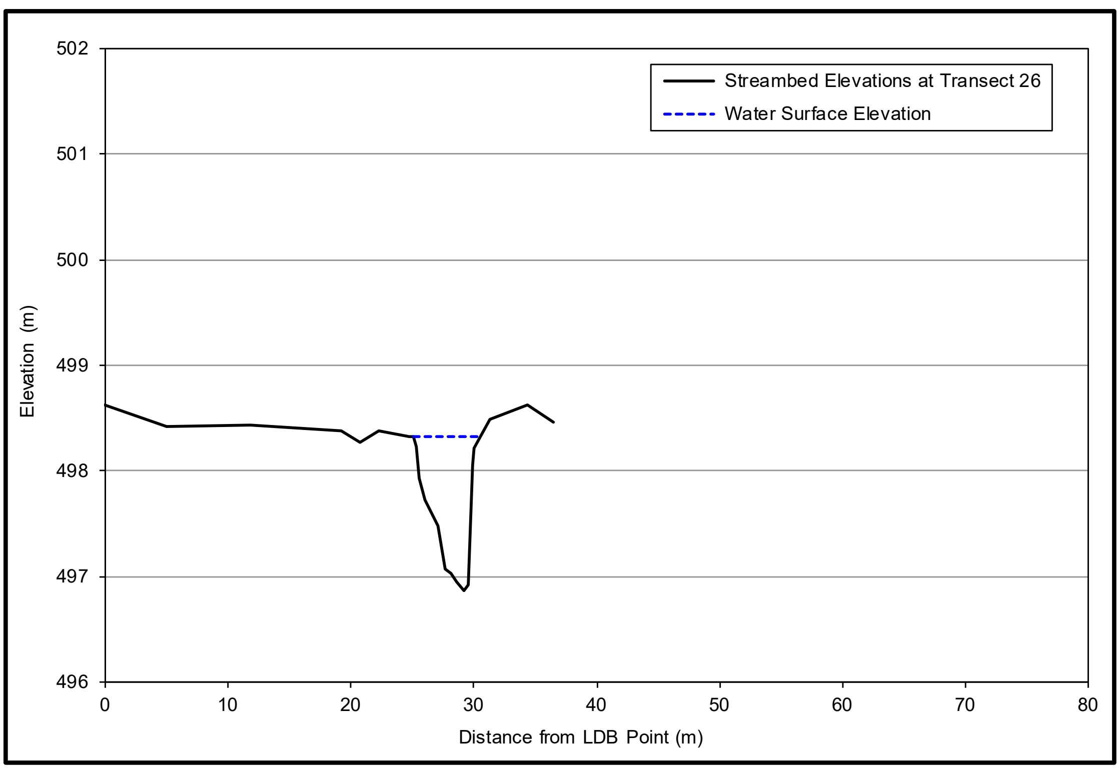

Figure C26: Patterson Lake Outlet Channel, Transect 26 Cross-Section

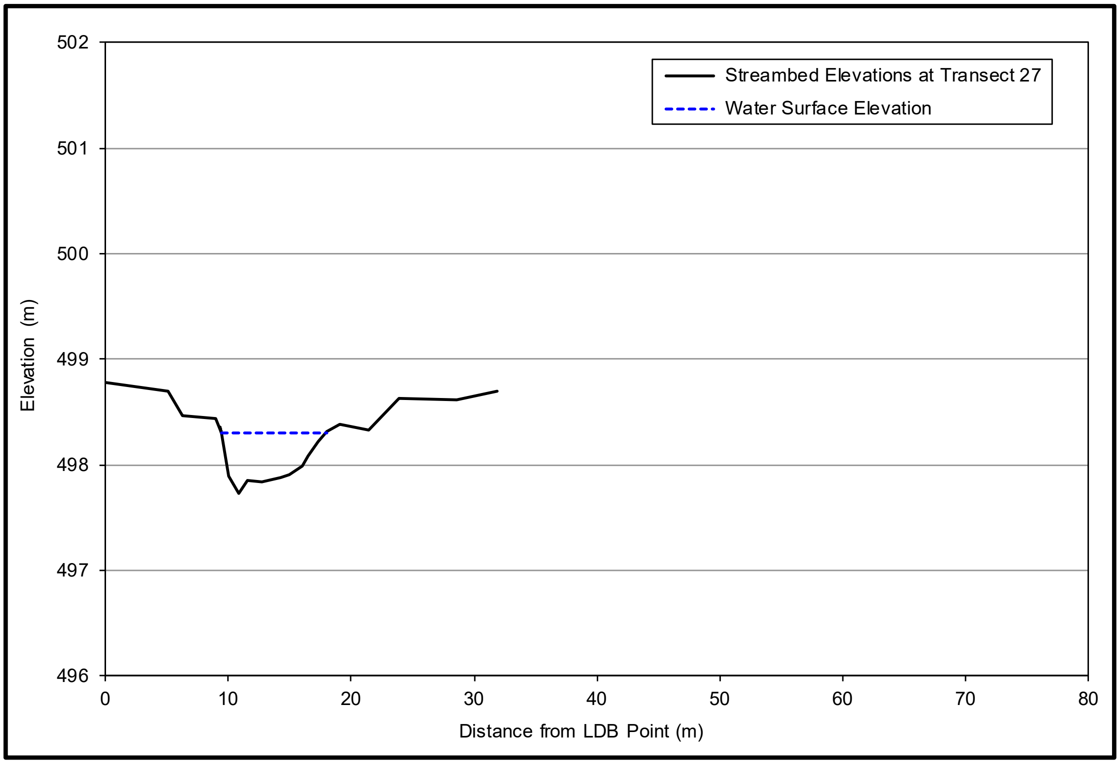

Figure C27: Patterson Lake Outlet Channel, Transect 27 Cross-Section

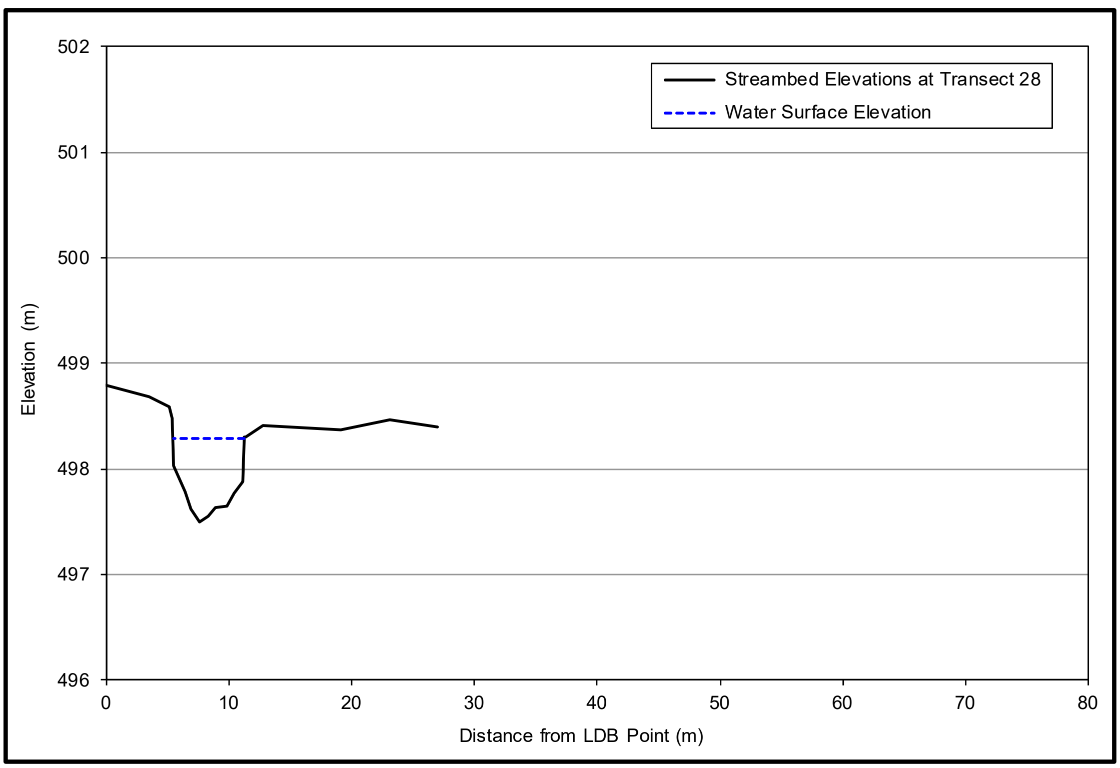

Figure C28: Patterson Lake Outlet Channel, Transect 28 Cross-Section

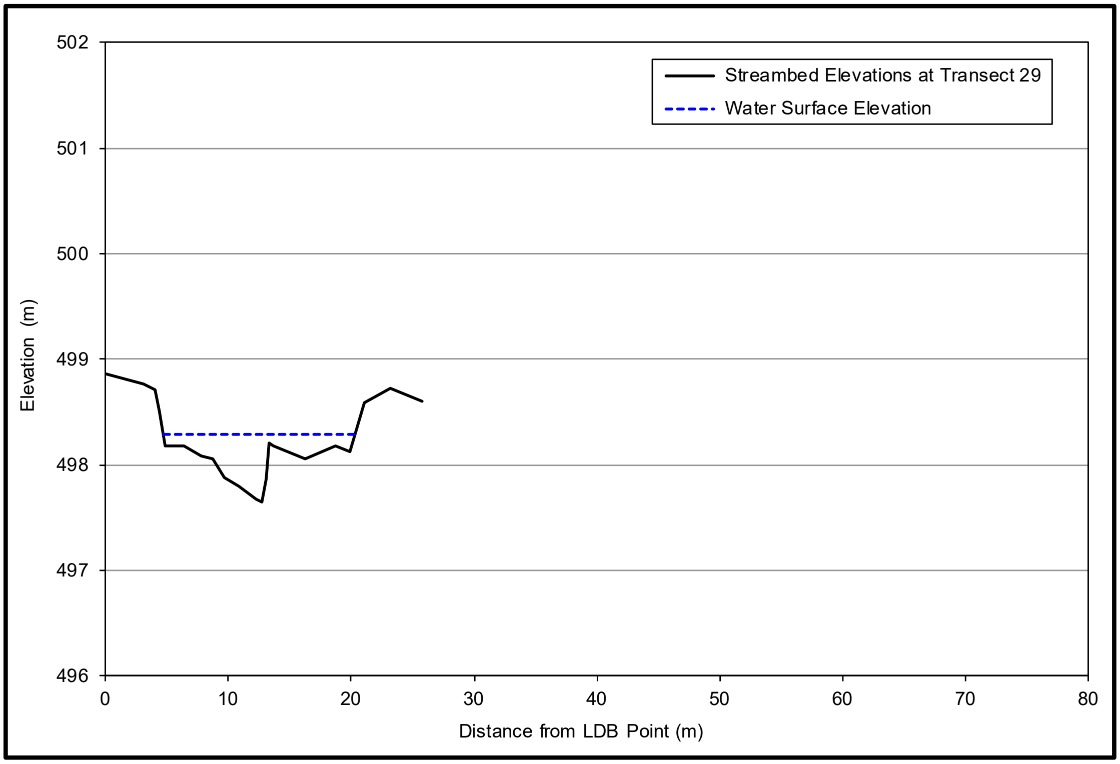

Figure C29: Patterson Lake Outlet Channel, Transect 29 Cross-Section

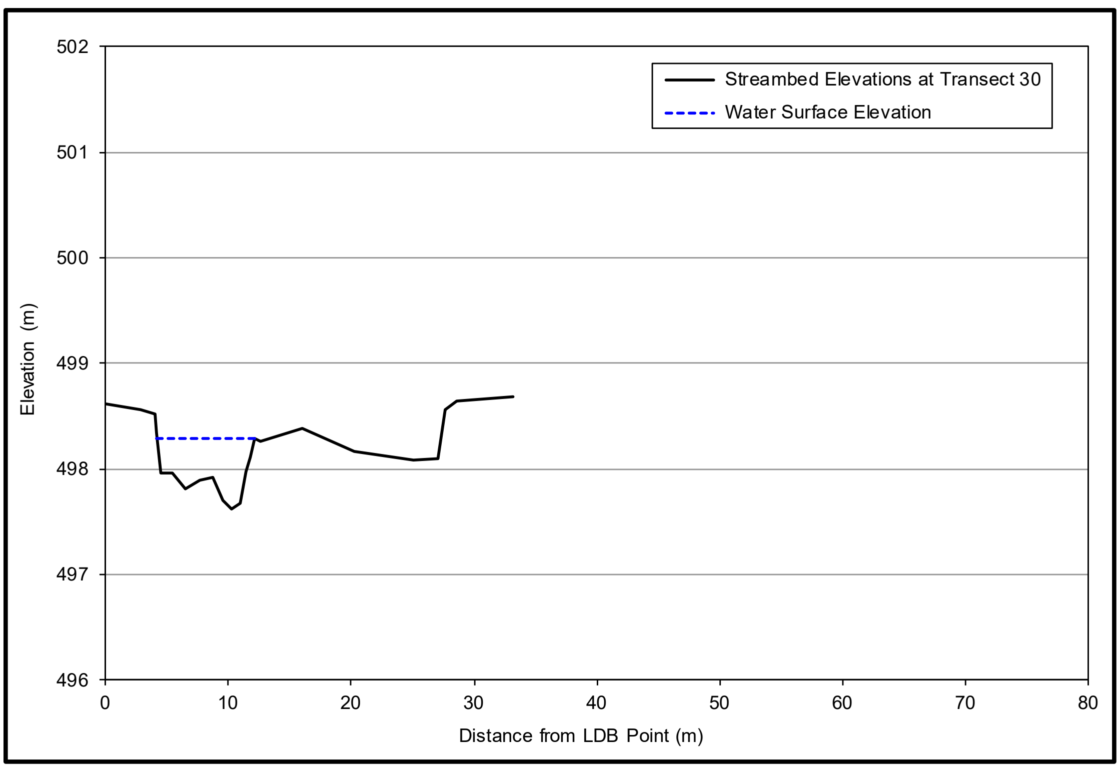

Figure C30: Patterson Lake Outlet Channel, Transect 30 Cross-Section

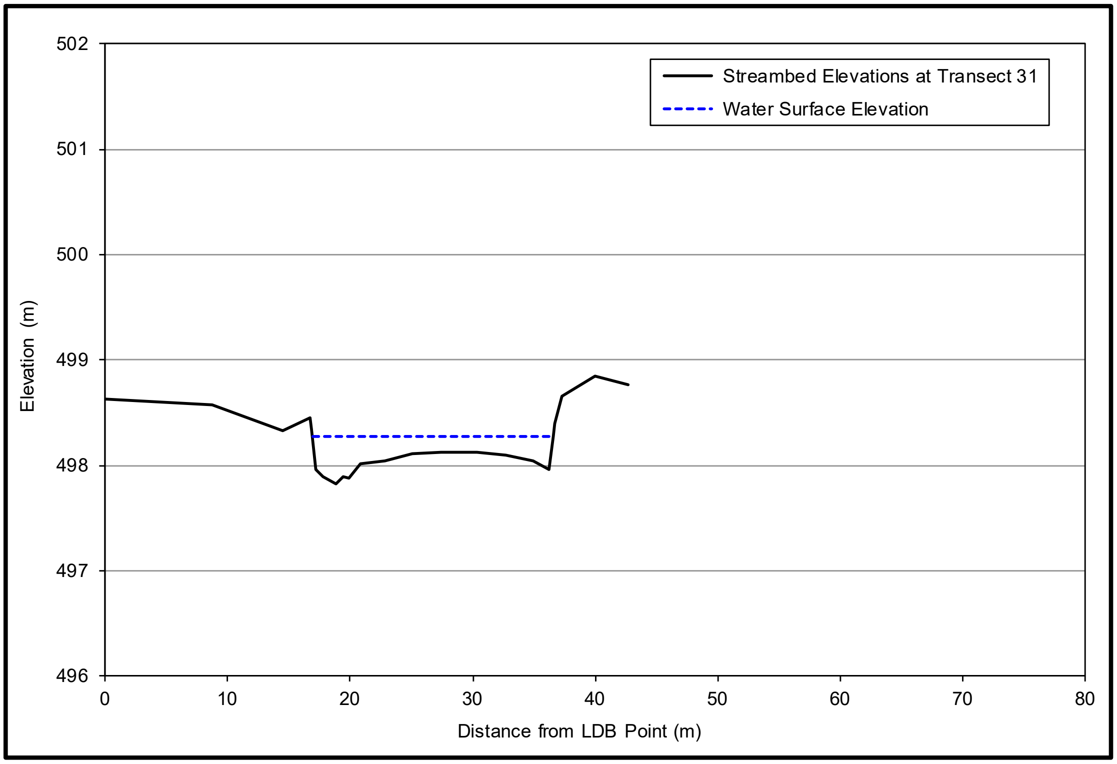

Figure C31: Patterson Lake Outlet Channel, Transect 31 Cross-Section

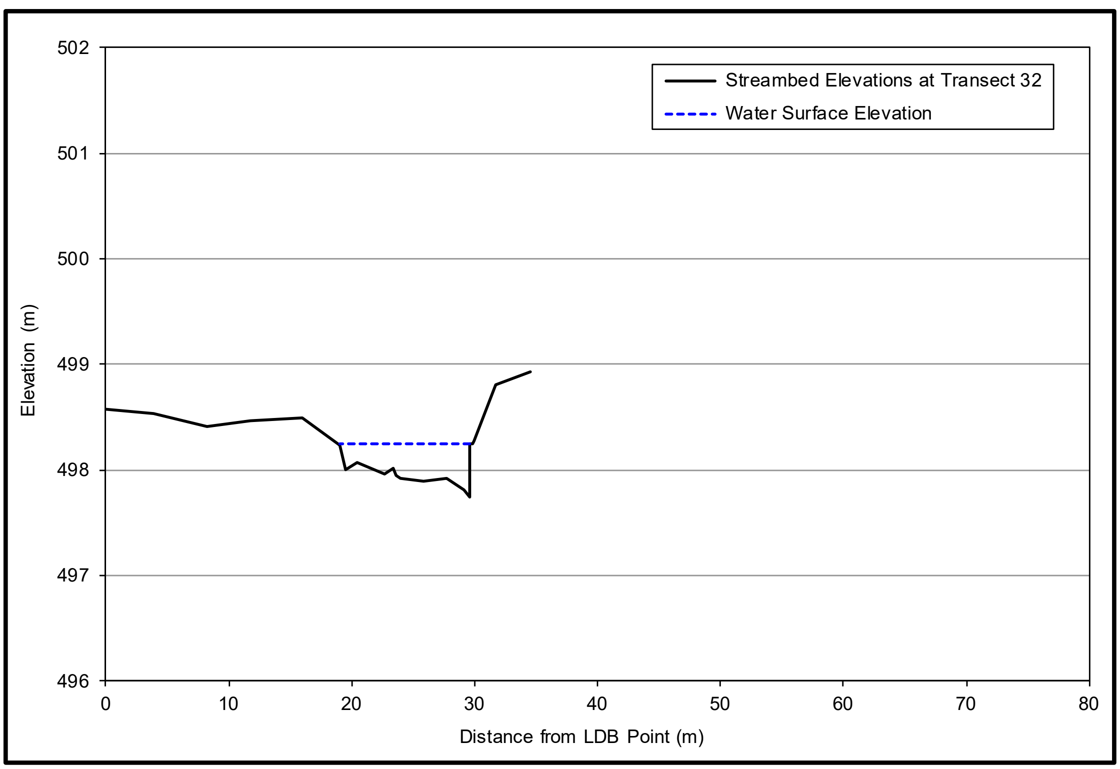

Figure C32: Patterson Lake Outlet Channel, Transect 32 Cross-Section

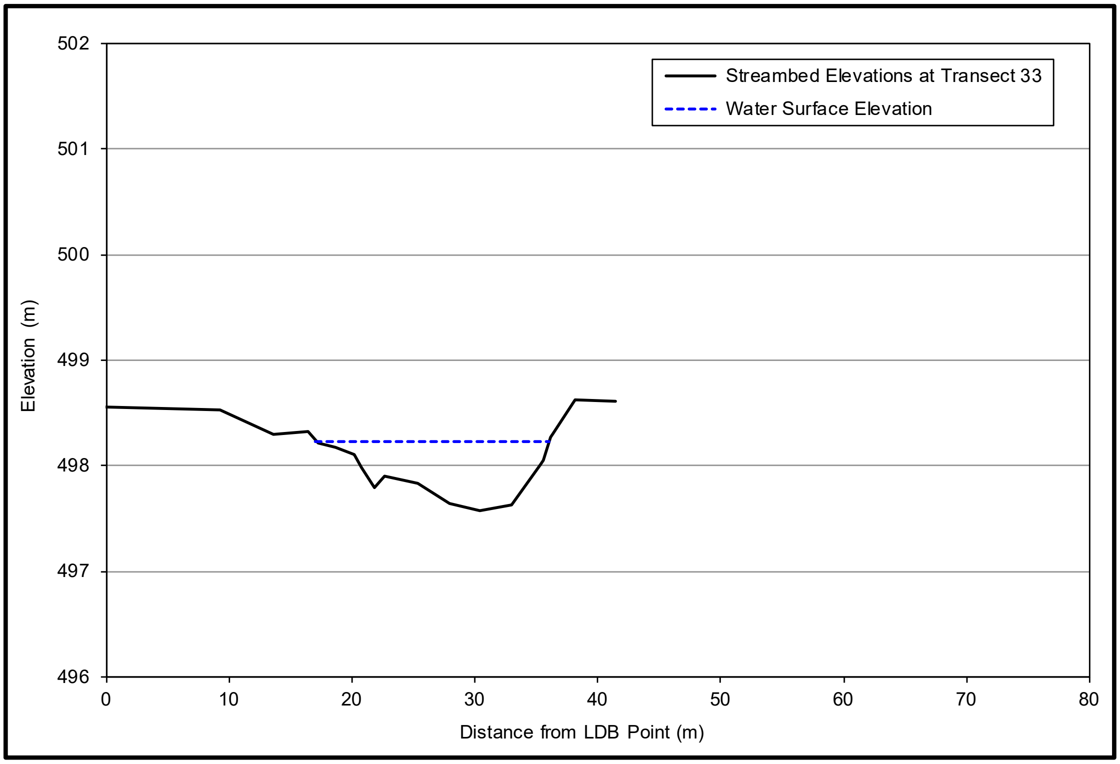

Figure C33: Patterson Lake Outlet Channel, Transect 33 Cross-Section

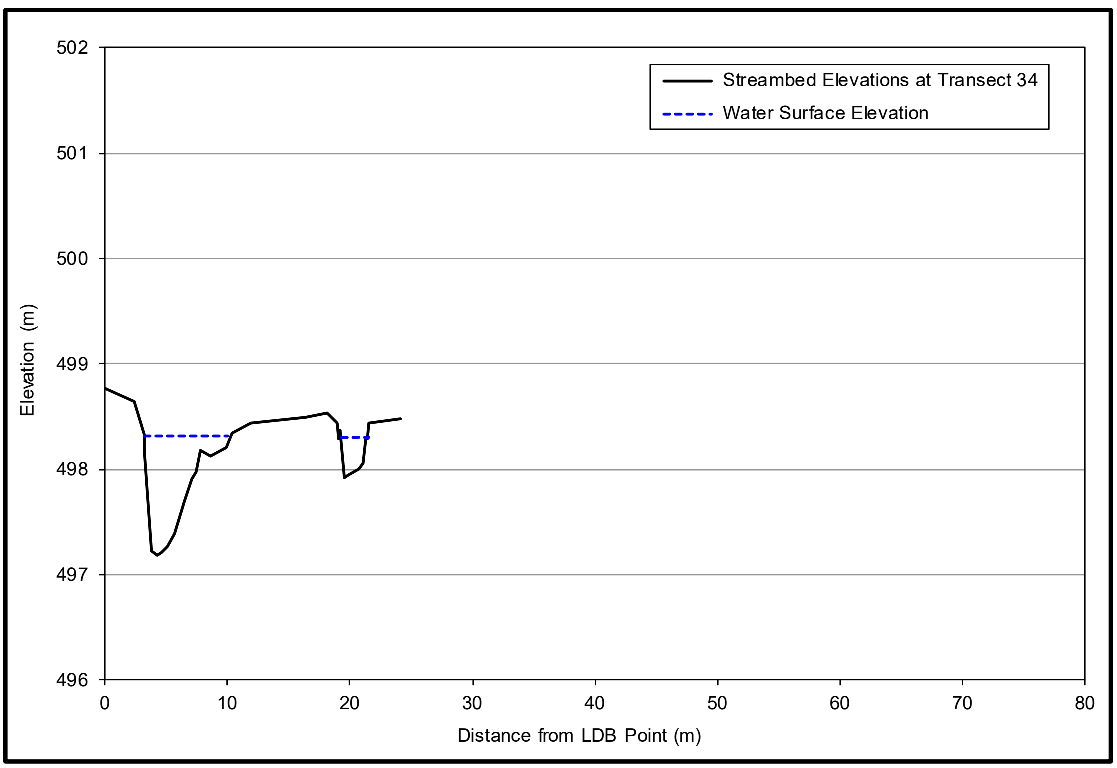

Figure C34: Patterson Lake Outlet Channel, Transect 34 Cross-Section

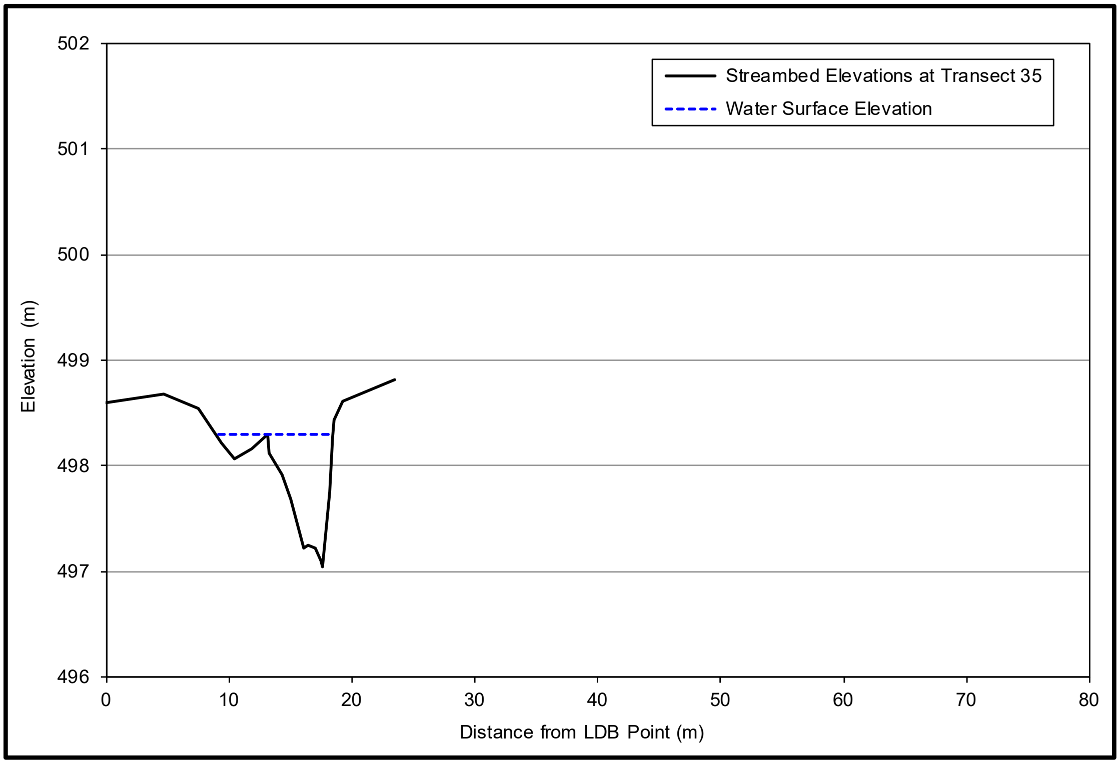

Figure C35: Patterson Lake Outlet Channel, Transect 35 Cross-Section

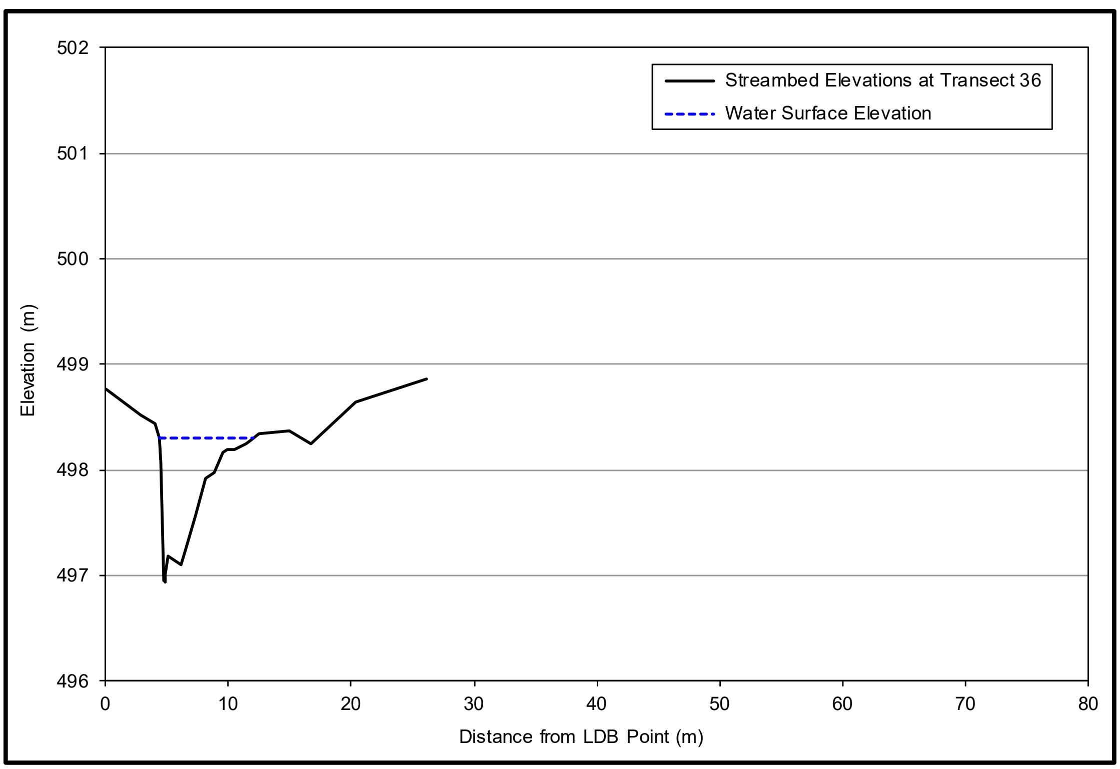

Figure C36: Patterson Lake Outlet Channel, Transect 36 Cross-Section

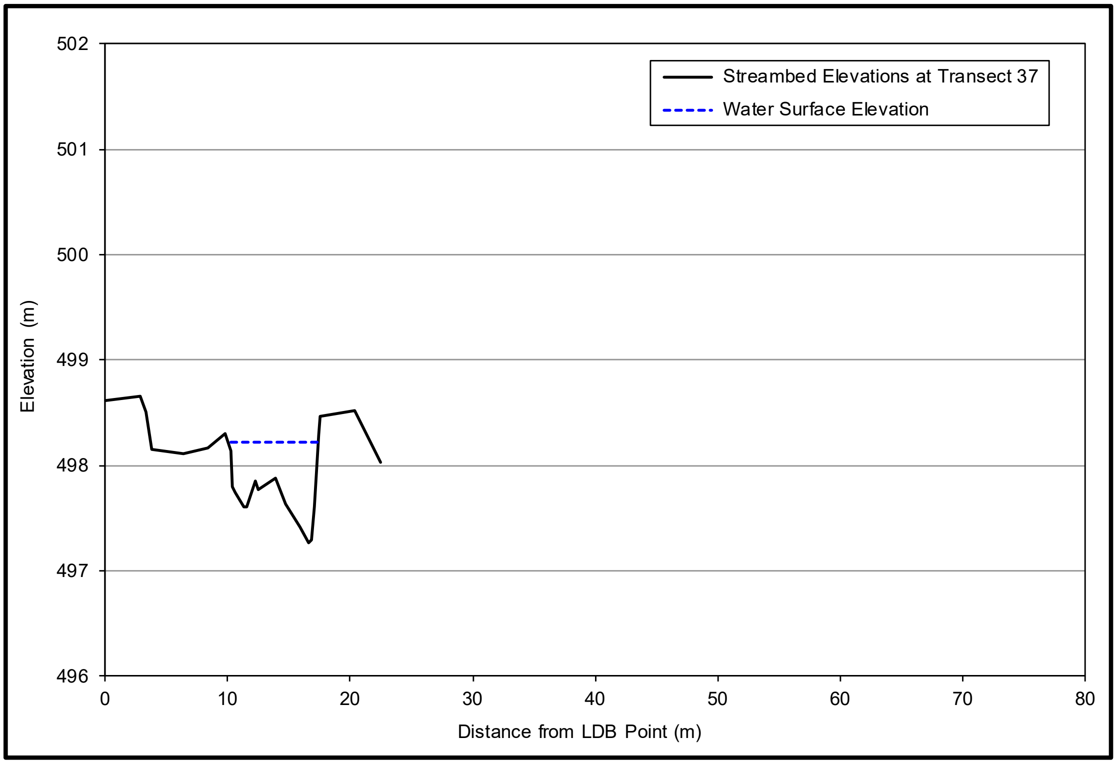

Figure C37: Patterson Lake Outlet Channel, Transect 37 Cross-Section

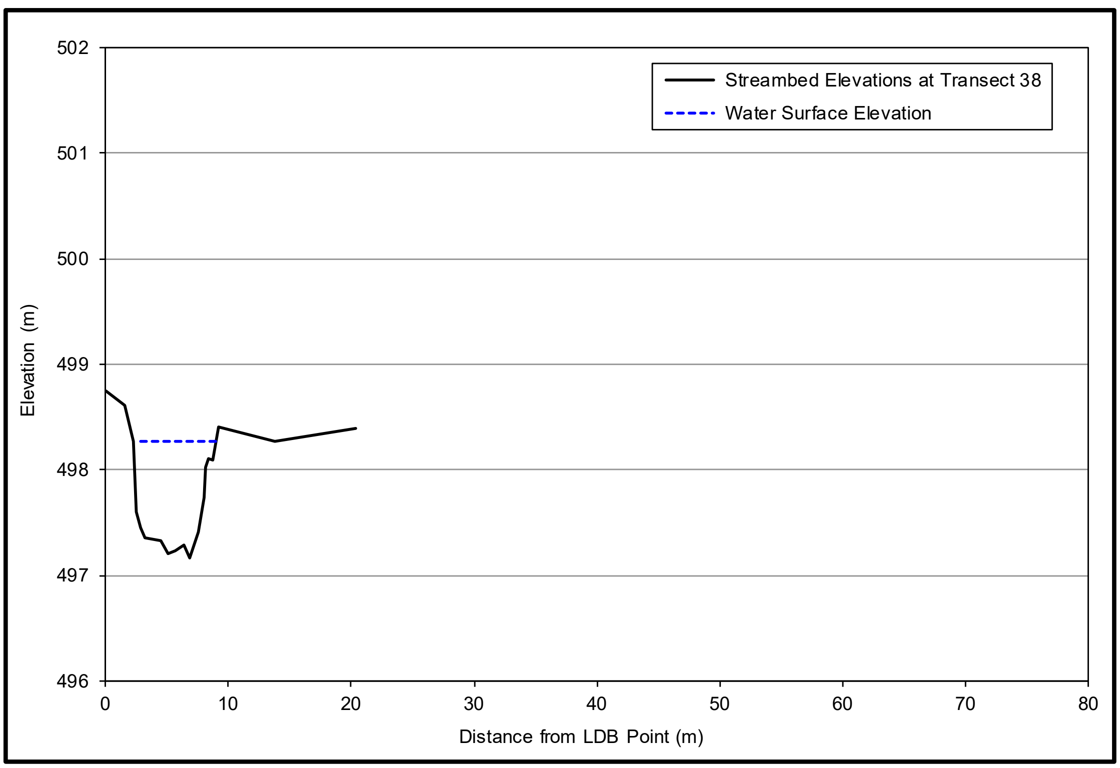

Figure C38: Patterson Lake Outlet Channel, Transect 38 Cross-Section