1.0 INTRODUCTION

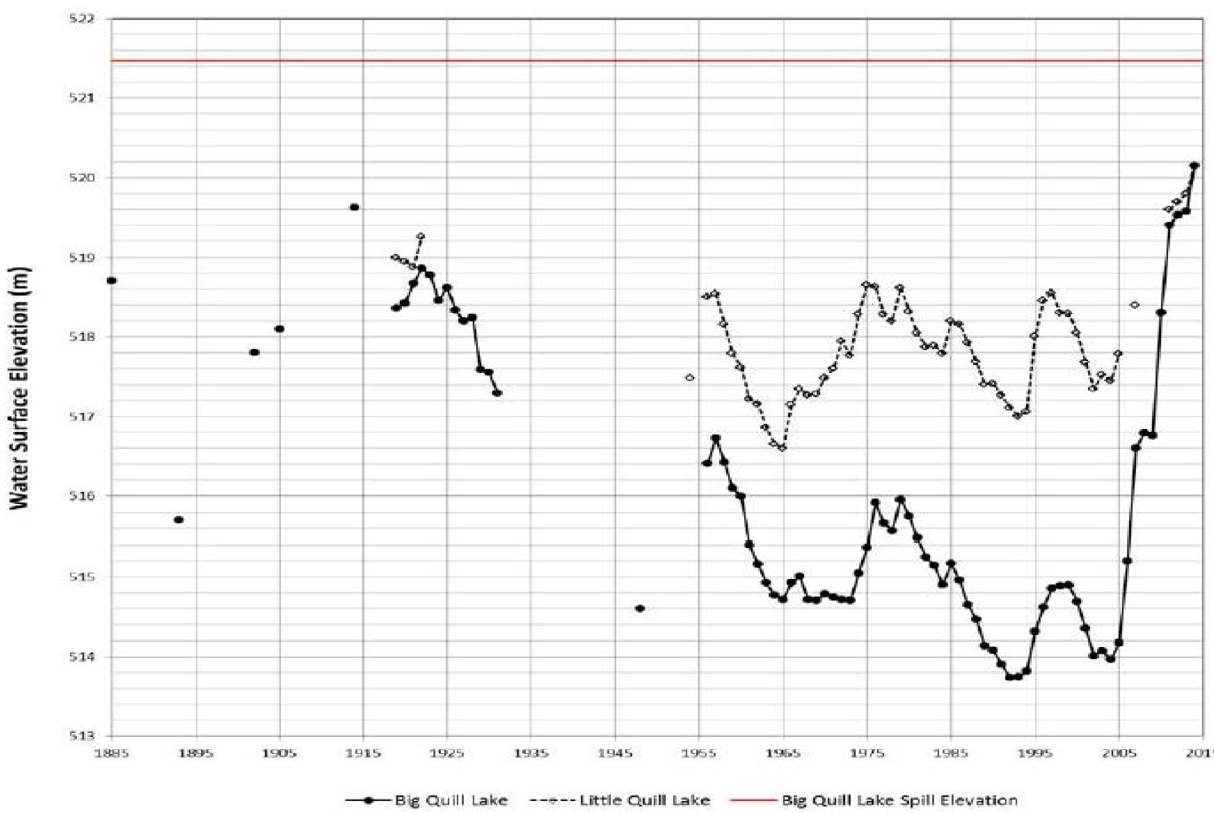
1.1 FLOODING CONCERNS ON THE QUILL LAKES

The Quill Lakes area, shown on Plate 1, is a wetland complex in Saskatchewan that consists of Big Quill Lake (BQL), Mud Lake, and Little Quill Lake (LQL). The lakes are located within a semi-closed drainage basin, approximately 8,760 km^2 (3382 mi^2) in size [1], in which Big Quill Lake is the near-terminal water body. Although the surface area of Big Quill Lake is approximately double that of Little Quill Lake, the inflow magnitude to the two lakes is roughly equal and, typically, water levels are higher in Little Quill Lake due to its smaller size. Little Quill Lake spills into Big Quill Lake once the Little Quill Lake water level exceeds approximately El. 518.2 m (1700.1 ft). Above this elevation, the lakes rise and fall as one water body.

The Quill Lakes water level has been observed intermittently between 1885 and the present and the recorded levels are shown on Figure 1. Currently, the Quill Lakes basin is in a wet cycle and has been particularly wet for the last decade. These conditions have led the water level on Big Quill Lake to rise from El. 513.73 m (1685.47 ft) in 2004 to a peak water level of El. 520.64 m (1708.14 ft) in the spring of 2015. Furthermore, the spring 2016 water levels have already exceeded the historic maximum observed in 2015. The future Quill Lakes water level will depend on hydrologic conditions that are subject to natural cycles and climate variability. Like much of the Western Canadian Interior, the Quill Lakes drainage basin is subject to pronounced wet periods and periods of drought.

The high water levels on the lakes are threatening private and Crown lands, private industry, grid roads including Grid 640, the CP rail line between Lanigan and Wynyard, and Provincial Highways 6, 16 and 35. Although some of these roads and highways have been raised in the past, they are currently overtopped (Grid Road 640) or at risk of being overtopped (Hwy 6). The increase in water level on the Quill Lakes over the past decade has caused significant flooding of adjacent land, including approximately 7,000 ha of private farm land, 9,700 ha of land managed by WSA, and 14,000 ha of Ministry of Agriculture Land [1]. Should the lake level continue to rise, the Quill Lakes will eventually spill at the natural outlet located approximately 38 km (24 mi) southwest of Dafoe, SK (shown on Plate 1). Through survey and LiDAR data, the spill elevation has been estimated to be El. 521.47 m (1710.86 ft) [1]. Once the water level exceeds El. 521.47 m (1710.86 ft), the Quill Lakes have the potential to spill into Peter Lake, Saline Creek, and eventually Last Mountain Lake.

FIGURE 1
RECORDED ANNUAL AVERAGE WATER LEVELS OF THE QUILL LAKES FROM 1885 [1]



Notes: Water levels recorded prior to 1915 are approximate.
1 m = 3.28 ft

The Quill Lakes are generally fairly saline in nature, but the concentration of total dissolved solids (TDS) can vary significantly with lake level. Further, the concentration of TDS can also vary significantly from one end of the Quill Lakes to the other, with Little Quill Lake typically being notable less saline than Big Quill Lake. The measured TDS data indicates that the Quill Lakes TDS concentrations are roughly 70,000 mg/L at low lake levels below El. 515 m (1689.63 ft) and 10,000 mg/L at the current lake level of approximately El. 520 m (1706 ft). The TDS is expected to be further diluted to about 7,500 mg/L if the lake level reaches the spill elevation of El. 521.47 m (1710.86 ft) [1]. In comparison, the measured average TDS in Last Mountain Lake is 1,400 mg/L [1]. Since water from Big Quill Lake has a TDS concentration several times greater than that of Last Mountain Lake, movement of water from Big Quill Lake to Last Mountain Lake will potentially affect downstream water quality and the effects of such movement will need to be evaluated.

To address the concerns associated with the high water levels on the Quill Lakes, the Saskatchewan Water Security Agency (WSA) is studying flood mitigation measures within the Quill Lakes basin. As a result, several studies investigating the feasibility of various flood mitigation measures, as well completing the detailed design for one alternative, have already been completed by KGS Group and other consultants. These studies are described in the following section.

1.2 PREVIOUS STUDIES

1.2.1 Preliminary Assessment of Flood Mitigation Options – Golder

In 2014, Golder Associates Ltd. (Golder) was retained by the Saskatchewan Water Security Agency to provide a preliminary assessment of flood mitigation options for the Quill Lakes. Four flood mitigation options were defined by WSA and were further refined by Golder in the preliminary design study titled “Quill Lakes Flood Mitigation Assessment” [2]. The options that were considered and documented within that report are summarized below.

Option 1: Natural Spills – Golder assessed two options related to allowing natural spills or outflows to Last Mountain Lake. Option 1a, considered allowing the Quill Lakes to fluctuate naturally and outflow to Last Mountain Lake. The other option, Option 1b, considered the construction of a containment dam to hold back outflows that would prevent overflow to Last Mountain Lake.

Option 2: Tributary Diversions – Divert tributary inflows away from the Quill Lakes to reduce the long-term lake level. There were several diversion configurations that were considered by Golder and included the diversion of flow from Wimmer Brook, Ironspring Creek, Romance Creek, and Jansen Lake to Lanigan Creek, the diversion flow from Kutawagan Creek to Saline Creek, and diversion of flow to from the Ponass Lakes to the Red Deer River.

Option 3: Construct a Lake Outlet – The option to construct a lake outlet would reduce the risk of overtopping Highway 6 and would further stabilize the lake level near the current elevation. The outlet channel would convey flow from the Quill Lakes along a 30 km (18.6 mi) excavated channel generally following Kutawagan Creek to Saline Creek and flowing into Last Mountain Lake.

Option 4: Decommission Agricultural Drainage Works – Agricultural drains have been constructed over the years throughout the watershed. Although these drains have likely increased the local runoff to Quill Lakes and resulted in slightly higher water levels, it was Golder's conclusion that the agricultural drains were not a significant cause of the recent high water. The potential decommissioning of the drains was therefore not considered a viable option.

Subsequent to the completion of the preliminary study by Golder, discussions between government officials, consultants, and stakeholders lead to the further alteration and refinement of the options summarized above. The results of this subsequent work was the definition of six options which were detailed in a letter from Golder to WSA titled "Summary of Inter-Ministry Meeting on Quill Lakes Flood Mitigation, Rev 1" [3] and are summarized below.

- ***Option 0 – Natural spills to Last Mountain Lake –*** Allow natural spills to Last Mountain Lake and further raise the highway grade to approximately El. 524 m (1719.16 ft).
- ***Option 1 – Contain the Lake at the Drainage Divide –*** Construct a relatively small dike near the natural spill point to prevent saline lake water from pilling towards Last Mountain Lake, and raise the highway grade to approximately El. 524 m (1719.16 ft).
- ***Option 2 – Contain the Lake at Highway* 6/16 –** Use Highway 6/16 as a containment dike and raise the road grade to approximately El. 524 m (1719.16 ft). This option forces the highway to be designed as a dam. It results in the formation of a larger "Kutawagan Lake" south of Highway 6/16, which eventually diverts most of Kutawagan Creek to Last Mountain Lake.
- ***Option 3 – Contain the Quill Lakes near Highway* 6/16 –** Construct a dike along the old Highway 6 alignment to prevent lake water from spilling towards Last Mountain Lake, and raise the highway grade to El. 524 m (1719.16 ft). The Highway 6 grade raise would use road-building standards. This option similarly results in the formation of a larger "Kutawagan Lake" south of Highway 6, which eventually drains Kutawagan Creek to Last Mountain Lake.
- **Option 4 – Contain the Quill Lakes near Highway 6/16 and divert Kutawagan Creek –** Construct a dike along the old Highway 6 alignment, construct a drainage channel from

Kutawagan Creek to Last Mountain Lake, and maintain the highway grade at the emergency level of 521.7 m (1710.86 ft). A 750 m (2460 ft) section of Highway 16 (east of Dafoe) would still need to be raised to El. 524 m (1719.2 ft).

- **Option 5 – Containment on both sides of Highway 6/16 –** Construct a dike along the old Highway 6 alignment plus a second dike south of the CP Rail Line to provide containment on both sides of the highway; install a pump system to drain water between the two dikes; and main the highway grade at the emergency level of 521.7 m (1710.86 ft). A 750 m (2460 ft) section of Highway 16 (east of Dafoe) would still need to be raised to El. 524 m (1719.16 ft). This option results in the formation of a larger "Kutawagan Lake" south of Highway 6, which eventually drains Kutawagan Creek to Last Mountain Lake.

Ultimately, WSA decided to move forward with Option 4 for the long term mitigation of flooding around the Quill Lakes.

1.2.2 Detailed Design of Kutawagan Creek Diversion Channel – KGS Group

In the summer of 2015 KGS Group was retained by WSA to undertake the detailed design of the dike and channel works to divert Kutawagan Creek and contain Quill Lakes. The report, titled "Kutawagan Creek Diversion Project - Design of Dyke and Channel Works" [4], was submitted to WSA in August 2015. KGS Group's scope of work focused solely on the option selected by WSA officials (Option 4) and no further review nor analysis was completed on any of the other options evaluated during preliminary design. Subsequent to the issue of the draft report, KGS Group was notified that WSA decided not to move forward with this project based on feedback and concerns arising from extensive public consultations for the project. The report was subsequently finalized to document the design in December 2015.

1.2.3 Feasibility of Deep Well Injection – SNC Lavalin

In 2015, SNC-Lavalin Inc. (SNC-Lavalin) was retained by WSA to complete a study titled "Prefeasibility Study for Deep Formation Water Disposal" [5]. The study investigated the feasibility of constructing and operating injection wells capable of injecting excess water from the Quill Lakes in order to lower water levels. The main objectives of the study were to identify potential disposal horizons for the excess water collecting in the Quill Lakes and to identify the potential constraints with respect to well disposal for the excess water. The results of the study indicated that two best options for injection disposal horizons were the Basal Deadwood aquifer and the Mannville aquifer.

Modelling results indicated that both the Basal Deadwood and Mannville aquifer may have sufficient injection capacity to dispose of excess water from the Quill Lakes. However, water quality will likely be a concern at both sites. SNC-Lavalin found that the salinity of the water initially injected into the Mannville aquifer would have to be increased from approximately 10,000 mg/L to 50,000 mg/L to avoid potential issues related to incompatible fluids. As water levels on the Quill Lakes decrease, treatment may no longer be necessary. Similarly, for injection into the Basal Deadwood aquifer, SNC-Lavalin found that the salinity Quill Lakes water would have to be increased from approximately 10,000 mg/L to 135,000 mg/L.

1.3 PROJECT SCOPE

In December 2015, KGS Group was retained by WSA to complete a conceptual level review of numerous flood mitigation options to address the continuing rise of water levels in the Quill Lakes. The mitigation options considered in this study were identified by WSA in conjunction with KGS Group at a scoping meeting and include the following:

- **Do Nothing or "Base Case"**
- **Hold water in Quill Lakes**
  - Block the natural outlet
  - Isolate Little Quill Lake from Big Quill Lake
- **Inflow Diversion**
  - Ponass Lakes diversion
  - Kutawagan Creek diversion
  - Kutawagan Creek and Hwy 16 diversion
  - Jansen Lake diversion
  - Jansen Lake and Romance Creek diversion
  - Jansen Lake, Romance Creek and Ironspring Creek diversion
  - Jansen Lake, Romance Creek, Ironspring Creek and Wimmer Brook diversion
- **Upland Storage**
  - Ponass Lakes
  - Other storage
- **Removal of Water from Quill Lakes**
  - Landowner Plan B
  - Deep well injection
  - Pump and treat water
  - Withdraw water for BHP Jansen Lake Mine
  - Withdraw water for Karnalyte Potash Mine
- **Inflow Reduction**
  - Restoration of partially drained and drained wetlands
  - Closure of drainage works

- **Legislative Policy**
  - Drainage enforcement
  - Invoke drainage moratorium
  - Develop a Watershed Management Policy and Working Group
  - Responsible drainage

Each alternative was evaluated using a water balance model and an autoregressive model to simulate a large array of potential future inflow sequences to the Quill Lakes. The analysis incorporated concepts of risk and uncertainty into the probability assessment of the Quill Lakes reaching specific elevations in the future, and has formed a basis for comparing each of the alternatives. Ultimately, the alternatives were evaluated using a concept comparison matrix and evaluation criteria including the estimated reduction of water to the Quill Lakes, the anticipated change in the Big Quill Lake water level, high level cost estimates, implementation time, and environmental considerations and social acceptance associated with each option.

Section 2.0 of this report provides a description of the water balance and autoregressive models that were developed and used to simulate water levels on the Quill Lakes, including model assumptions, required inputs, and calibrations. Section 3.0 describes the existing conditions of the Quill Lakes, referred to herein as the Do Nothing or “base case” scenario, representative of what could happen should no flood mitigation measures be implemented. Section 4.0 describes each of the various flood mitigation options that were considered and evaluated in this study and Section 5.0 gives a comparison of the model results. A high level cost estimate for each of the options is presented in Section 6.0. Finally, Section 7.0 presents an evaluation matrix to compare and evaluate the options.