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Greater Vernon Water - Water Capacity Study

Final Report – Revision No. 2
September 2, 2026
KWL Project No. 0773.226

Prepared for:

REGIONAL DISTRICT NORTH OKANAGAN

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Executive Summary

Kerr Wood Leidal Associates Ltd. (KWL) was retained by the Regional District of North Okanagan (RDNO) to prepare a Water Capacity Study (the Study) to evaluate the ability of the Greater Vernon Water (GVW) water utility to meet current and future demands. The Study reviews existing water storage capacity, water supply and demand conditions and applies projections for development and climate change to assess long-term system capacity and reliability.

The primary objective of the Study is to determine whether sufficient water is available—both now and in the future—to accommodate anticipated growth while maintaining the current level of service. In addition, the Study evaluates how climate change may affect water availability and GVW's ability to sustainably meet demand over time. The analysis considered water supply and demand under single year drought conditions as detailed analysis of multiple year drought conditions was beyond the scope of the study. However, based on review of recent records it is likely that multi-year drought conditions could increase the frequency and severity of water supply shortfalls. The analysis also considered projected demands based largely on current water uses and reasonably anticipated rates of change. Notably this includes the assumption that agricultural water use will continue at a fraction of the total allocated supply quantity. Should agricultural demands increase to the full allocated supply quantity, the frequency and severity of supply shortages would increase significantly.

The Study identified the following key findings:

1. Annual supply in average years is more than double demand. However, total annual demand exceeds annual supply approximately once in every twenty years under current conditions. By 2050s and the 2080s, total annual demand is expected to exceed annual supply once in every 10-years and once in every 5-years, respectively.
2. The best estimate of total required demand is expected to reach 19,947 ML in the 2050s with the total ranging between 16,900 ML for the low estimate and 22,689 for the high estimate.
3. The best estimate of total required demand is expected to reach 21,912 ML in the 2080s with the total ranging between 17,600 ML for the low estimate and 26,164 for the high estimate.
4. The foregoing projections are based on the assumption that the area of agricultural land irrigated using GVW water does not significantly increase. If all the areas that currently have unused allocation were irrigated in the future, projected demands would be at least 10,000 ML higher when the impact of climate change on agricultural water demands is taken into account.
5. Implementation of Stage 3 watering restrictions is targets a reduction in 50% of seasonal water use. This equates to a best estimate water consumption savings of 5,944 ML in 2050s and 6,073 ML by 2080s.
6. For the existing horizon: the available supply and storage in the Duteau Creek watershed (above Headgates) is sufficient to support community withdrawals and minimum required EFNs for an average year followed by the 1:10, and 1:20drought scenarios with a relatively small (140 ML) deficit modelled for the 1:50-year drought. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the recommended EFN targets are significantly more whenever possible.
7. For the 2050s: the available supply and storage in the Duteau Creek watershed (above Headgates) is sufficient to support community withdrawals and minimum required EFNs for an average year followed by the 1:10 year drought scenario. The storage, and likely also the supply, is estimated to be short by between 1,040 ML and 4,240 ML for an average year followed by the 1:20 drought scenario and short by between 2,740 ML and 6,140 ML for an average year followed by the 1:50 year drought scenario. However, further assessment of year over year drought will be required to confirm. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the RDNO targets supplying significantly more flow to support ENFs whenever possible.

8. For the 2080s: the available supply in the Duteau Creek watershed (above Headgates) may be short of supporting community withdrawals and minimum required EFNs for an average year followed by the 1:10 year drought scenario by up to 5,240 ML. The storage, and likely also the supply, is estimated to be short by between 3,240 ML and 9,140 ML for an average year followed by the 1:20 drought scenario and short by between 5,040 ML and 11,440 ML for an average year followed by the 1:50 year drought scenario. However, further assessment of year over year drought will be required to confirm. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the RDNO targets supplying significantly more flow to support ENFs whenever possible.
9. The preliminary water balance results presented in this study suggest that there may sufficient storage in the Duteau Creek Reservoir Complex to support supply under current and future drought conditions. However, the preliminary results are based on the assumption of maintaining the minimum required EFNs in the water balance for drought years. This assumption was discussed and selected with input from RDNO staff given the current uncertainty in magnitudes of EFNs for Duteau Creek. The preliminary water balance results, using the minimum required EFN values, provide a good understanding of the volumes required should the goal during drought conditions be to reduce EFNs to the minimum required amounts. However, if operations continue to aim to release as much flow as possible to support EFNs, the preliminary water balance results may be optimistic and are likely underestimating future storage needs. There may be both operational changes and licencing updates required to realize the preliminary water balance finding. Additional analysis varying the amount of EFN releases as well as modelling of multi-year drought scenarios is required to explore this further.
10. Potential additional surface source water storage options for up to 40,100 ML may be available within the GVW area. However, further analysis of the ability to refill storage from available sources under year over year drought conditions is required.

Based on the Study findings, the following key actions are recommended:

Water Conservation and Demand Management

1. Investigate non-revenue water during summer, including minimum overnight flow analysis and a comparison of supply flows and total metered demands at a pressure zone scale to determine areas of focus for further investigation to determine the causes of seasonal non-revenue water and pursue appropriate remedies.
2. Conduct a review of metering infrastructure age and condition, and a business case analysis of options and timelines for renewing and upgrading metering systems to reduce non-revenue water and introduce new tools for direct customer engagement in water efficiency such as AMI.
3. Conduct a study on potential future agricultural water use scenarios, including effects of crop changes based on market pressures (such as shift to tree fruit crops), full utilization of current water use allocations, changes to water use based on planned billing structure change, etc. The study should be coordinated with the Ministry of Agriculture to potentially leverage tools and resources such as the Agricultural Land Use Inventory, Agricultural Water Demand Model and Environmental Farm Plan Program and other resources available for building climate resiliency in BC's agriculture sector.

   The objectives of this study should be to inform policies for managing the GVW agricultural water allocation, policies for curtailing agricultural water uses during shortages with the lowest impact practicable on agricultural assets and production, and cooperation with producers, the province and other interest holders on sustainably managing all water sources in the GVW service area and watershed areas.
4. Consider minor and gradual amendments to residential water rates over time, including a modest reduction in the fixed quarterly charge and in the tier 2 and 3 thresholds, and the addition of a fourth tier with a much higher consumption charge for single-family (or SSMUH) properties using more than 100 cubic metres per quarter.

5. Consider adding dedicated industrial, commercial and institutional demand management programs, including targeted promotion of free facility free water use assessments and flexible incentives (capacity buy-back) based on clear eligibility thresholds.

Water Supply Planning and Optimization

1. Confirm acceptable target for source water supply for the community and GVW.
2. Review Gold-Paradise Diversion capacity and timing to see if it can meet the outstanding supply for the various scenarios in the 2050s.
3. Carry out multi-year analysis using the Water Balance model (ex., normal year followed by drought year, 2 consecutive drought years, etc.) to evaluate the potential for supporting multi-year storage by raising Aberdeen Reservoir and confirm long-term reliability of water supply. This action may need to be further supported by:
    a. A discussion and/or approval by regulators regarding multi-year storage.
    b. Evaluation of how the option would support and impact existing community users versus agricultural users.
    c. Evaluation of how the option would support future development of community users versus agricultural users.
4. Carry out evaluation of water supply yield for the supplemental sources.
5. Carry out multi-year water system simulation using the Water Balance model to test and optimize potential operational opportunities, such as varying EFN flows, and to evaluate system reliability under multi-year drought conditions.
6. Consider optimizing use of Goose Lake storage to support high demand periods.
7. Consider Aberdeen dam raising combined with assessing the future capacity of the Gold-Paradise Diversion.
8. Secure additional water rights (up to 9,600 ML total) on Okanagan Lake by transferring existing licences where possible to Okanagan Lake. This includes evaluating the potential for new intakes or horizontal well groundwater withdrawals from Okanagan Lake or other.
9. Once the final water potential is fully explored, assess how the results will impact development potential and whether an upper limit for what the water supply can support needs to be determined.

Groundwater and Regulatory Actions

1. Address the issues identified with the 2017 groundwater licence application and re-submit separate applications for the Ranch Wells and Antwerp wells coupled with revised requests for annual volumes based on actual or reasonable estimates of usage prior to February 29, 2016. A meeting with Provincial water licensing staff in advance of resubmission would be valuable, to confirm the approach and path forward.
2. When updating the licence application information, submit the construction information for Ranch Well 3.
3. Address potential compliance with the B.C. *Environmental Assessment Act* regarding the Antwerp wells (e.g. request exemption or proceed with obtaining certificate).
4. Should there be a need to develop more groundwater capacity, use the overview of potential areas to explore for more groundwater provided herein as a first step in planning and conducting a more detailed Well Siting Study to identify specific properties on which to conduct exploratory test well drilling.
5. Continue to monitor ongoing climate change in the region and carefully track water levels in all wells, in particular the shallow wells paying particular attention to non-pumping water levels in the fall and winter after the irrigation season ends. Should any well appear to begin to lose yield, take action to investigate the possible cause(s).
6. Identify and investigate potential areas for future groundwater development if additional capacity is required.

1. Introduction

Kerr Wood Leidal Associates (KWL) was retained by the Regional District of North Okanagan (RDNO) to prepare a Water Capacity Study (the Study). The purpose of the study is to review the Greater Vernon Water (GVW) supply and demand and apply future development and climate change projections to assess if the utility has sufficient water to accommodate planned development while maintaining the long-term viability of the service it provides.

1.1 Background

GVW services over 50,000 people across to the City of Vernon, the District of Coldstream (DoC), and parts of Electoral Areas “B”, “C”, & “D” and a small area in Spallumcheen, providing both irrigation (non-potable) and potable water to the users. The water is used for a mix of residential, commercial, industrial and agricultural uses. The largest usage is irrigation during the growing season each year.

To service this population with clean water year-round, the GVW maintains two main water sources: Kalamalka Lake and the Duteau Creek sourced from the Aberdeen Plateau. These sources are independent and are operated separately. The Kalamalka supply can be used to supply the Duteau service area for short periods of time; however, the sources cannot be used concurrently to meet peak summer demands of each service area.

In 2013, water supply studies were carried out to support the previous GVW Water Master Plan. These studies reviewed several supply options and identified that increasing storage at Aberdeen Dam, in the Duteau Creek Watershed, to be top priority option to support future demands. At the time, risk of climate change was identified but no quantification of projected climate change impacts on water supply within Duteau Creek watershed was carried out.

1.2 Project Scope

The main objective of this study is to answer these questions:

1. Does GVW have sufficient water available now and in the future to accommodate planned development and maintain the current level of service?
2. How will climate change affect the water available to the water utility?

Although the licenced capacities of GVW sources are an important determinant of availability of water supply that will be assessed as part of this study, the physical capacities of source catchments and storage infrastructure, Environmental Flow Needs (EFN), and projected demands are likely the primary determinants of the reliability of the supply sources in the drought cycles that are typically used for planning. Climate change will increase demands while altering the timing of freshet as well as the volume of flow at all times of year, thereby shifting source water availability and potentially reducing the capacities during high demand periods for at least some sources. These considerations drive key aspects of our proposed methodology and prioritization of the budget available for the study.

The purpose of the Study is to assess the ability of the existing Duteau Creek source water supply to support existing and future water demands under current and future projected climate conditions and to outline potential improvements to water supply capacity through increasing storage at Aberdeen Reservoir. The Study reviews licencing and infrastructure to assess the capacity of other sources to support the Duteau Creek supply in meeting future demands. At a high level, it explores viable options for optimization opportunities within the existing GVW supply and operation and identifies other water sources that could be used to supplement demands.

1.3 Planning Horizon

The planning horizons that have been considered in this study are:

- Existing;
- 30 years into the future (2050s); and
- 60 years into the future (2080s).

1.4 Levels of Service

There are no regulations governing specific levels of service for source water supply for community water systems; however, there are provincial guidelines and decisions from other local governments that help define an acceptable level of service for communities.

The Design Guidelines for Drinking Water Systems in British Columbia recommend that water sources for drinking water systems should meet maximum projected water withdrawals up to the 50-year return period drought or the extreme drought of record including considerations for multiple years of drought and changes in drought frequency (Ministry of Health, 2023). A system being reliable during 50-year return period drought is equivalent to a reliability of 49 out of 50 years or 98%.

Some examples of reliability targets for community water supply systems in BC include:

- The reliability target for the CRD Regional Water Supply Service 2022 Master Plan (Stantec, 2022) is based on inflows during 2008 and 2009, which are considered to be a 1:50-year return period drought condition under current climate/demand and future climate/demand conditions to evaluate reliability of the Sooke Lake source water supply.
- As part of the Water Supply Strategy prepared for the City of Nanaimo, the South Fork and Jump Creek reservoirs (KWL, 2022) were found to have a reliability of about 86 out of 90 years or 96% which was considered suitable for supply.
- North Salt Spring Waterworks District (NSSWD) considered reliability of supply across a range of reliability targets: 9 out of 10 years (90%), 19 out of 20 years (95%) and 49 out of 50 years (98%) (KWL, 2024). After review of the results, the NSSWD Board selected the 95% reliability target as a reasonable level for their system.

Based on review of available guidelines and targets established by other jurisdictions, a reliability target of the 1:50 year drought be used for evaluating the capacity of the water supply system and required upgrades. The analysis will also evaluate storage requirements for the 1:10-year drought and 1:20-year drought for comparison.

1.5 Study Area

The water capacity study focuses on assessment of water supplies across RDNOs current water supply watersheds and aquifers and includes review of other water licence users within those watersheds and aquifers. However, due to limitations of the scope, the review focuses only on surface water sources upstream of Okanagan Lake for the Coldstream River, Kalamalka Lake and Vernon Creek watersheds and upstream of the Shuswap River for the Duteau Creek and Basset Creek watersheds. It has been assumed that supply water up to the licenced maximum withdrawal volumes is available for RDNOs intakes on Okanagan Lake.

1.6 Project Team

The following Regional District of North Okanagan, Kerr Wood Leidal and Western Water Team Members were involved in the project.

Regional District of North Okanagan

Dustin Heidt	Project Manager
Zee Marcolin	General Manager, Utilities
Tricia Brett	Manager, Water Quality, Utilities
Amanda Summerfelt	Water Efficiency Coordinator, Utilities
Skyler Ganz	Infrastructure Analyst, Utilities

Kerr Wood Leidal

Mark Forsyth, P.Eng. (BC)	Project Manager
Adrian Chantler, PhD, P.Eng. (BC)	Senior Technical Advisor, Water Supply and Climate Change
Colwyn Sunderland, P.L. Eng. (BC)	Senior Technical Advisor, Water Demand and Conservation
Craig Sutherland, MSc, P.Eng. (BC), IRP	Senior Engineer/Climate Change/Surface Water Supply
Dana Haasz, MSc	Senior Water Sustainability Specialist
Jacqueline Smith, P.Eng. (BC)	Project Engineer – Surface Water Supply
Brandon Johnson, P.Eng. (BC)	Project Engineer – Demand Forecasting

Western Water Associates Ltd. (WWAL)

Ryan Rhodes	Senior Hydrogeologist
Douglas Geller	Principal Hydrogeologist

1.7 Glossary

ADD	Average Day Demand
AMI	Advanced Metering Infrastructure
BD	Base Demand
ENV	Ministry of Environment and Parks
EFN	Environmental Flow Needs
FAR	Floor Area Ratio
GCM	Global Circulation Model
GVW	Greater Vernon Water
GWELLS	Groundwater Wells and Aquifers database
ICI	Industrial Commercial Institutional
IPCC	International Panel on Climate Change
LLO	Low Level Outlet
m^3	Cubic metre (1,000 litres)
m^3/s	Cubic metre per second
MAD	Mean Annual Discharge
MDD	Maximum Day Demand
Mm^3	Million cubic metres (1,000,000 m^3)
ML	Megalitre (1,000 m^3 or 1,000,000 litres)
MWh/year	Megawatt hours per year
ML/D	Megalitres per day (1,000 m^3/d or 1,000,000 L/d)
NRW	Non-Revenue Water
PCIC	Pacific Climate Impacts Consortium
RCP	Representative Concentration Pathway
RCP 4.5	IPCC future climate change scenario with greenhouse gas concentration resulting from projected low-to-moderate emissions
RCP 8.5	IPCC future climate change scenario with greenhouse gas concentration resulting from projected high emissions
RDNO	Regional District of North Okanagan
SCADA	Supervisory Control and Data Acquisition
SD	Seasonal Demand
SSP	Shared Socioeconomic Pathway
WSA	Water Service Area
WSW	Water Source Wells

2. Current Water Supply System

2.1 Existing System Overview

The GVW supply system is supplied from several sources. These are:

- The “Duteau Creek Reservoir Complex” including:
  - Aberdeen Reservoir
  - Grizzly Reservoir
  - Haddo Reservoir
  - Headgates (Harvey Lake) Reservoir and Headgates Intake (or Headgates Diversion)
  - Gold-Paradise Diversion
- King Edward Lake and Deer Creek Intake
- Kalamalka Lake Intake
- Coldstream Ranch Wells 2 and 3
- Antwerp Shallow and Deep Wells
- Okanagan Lake and Canoe Bay Intake
- South Vernon Irrigation District (SVID)

The system also includes Goose Lake which is primarily supplied through the water system from the other sources. It is used primarily to provide storage for non-potable agricultural water during periods of peak demand. In addition, the GVW had an intake on BX Creek; however, the intake has been decommissioned and has not been used since the early 1990s.

Figure 2-1 shows a breakdown of the average annual withdrawal amounts per source from the last five years. Note the following sources are not represented in the chart and are described in more detail in Section 2.3: Goose Lake (volume is supplied from sources within the system); Antwerp Wells (not routinely used); Okanagan Lake via Canoe Bay Intake (yet to be integrated into the system); and SVID (small system, no data available).

Figure 2-2 shows an overview of the GVW distribution system and reservoirs, including watersheds.

Figure 2-3 shows a detailed map of the Duteau Creek Reservoir Complex system.

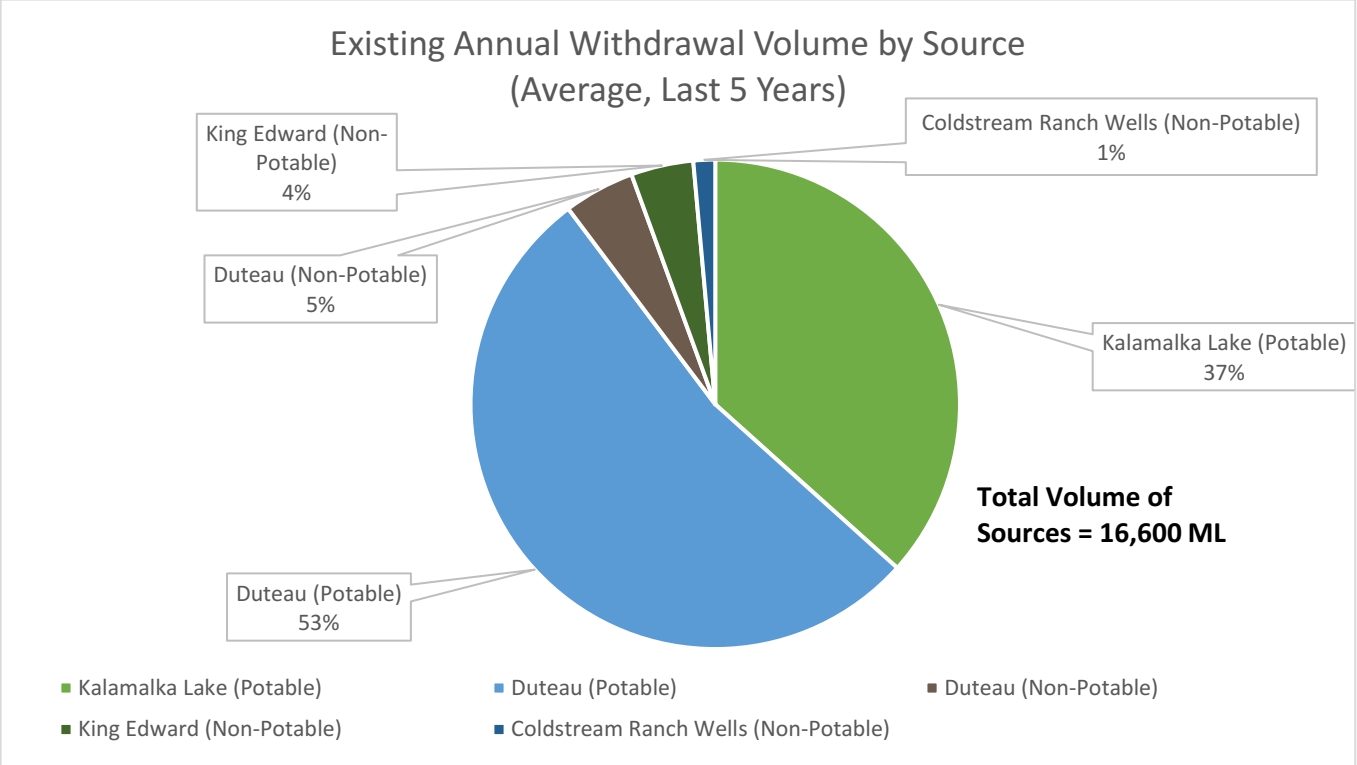


Figure 2-1: Existing Annual Withdrawal Volume by Source

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Regional District of North Okanagan

Water Capacity Study

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N

Deep Creek

B.X. Creek

Coldstream Creek

Vernon Creek

Bessette Creek

Lower Duteau Creek

Upper Duteau Creek

Curtis Creek

Heart Creek

Goose Lake Dam

Goose Lake Intake

Mission Hill Water Treatment Plant

Ranch Well 3

Ranch Well 2

Ranch Well 1 (Inactive)

Kal Lake Intake

King Edward Intake

Antwerp Well 1 (Shallow)

Antwerp Well 2 (Deep)

Duteau Creek Water Treatment Plant

Headgates Intake

Delcliffe Intake

Outback Intake

King Edward Lake Dam

Aberdeen Lake Dam

Haddo Lake Dam

Grizzly Lake Saddle Dam

Grizzly Lake Spillway Dam

Grizzly Lake Specs Dam

Grizzly Lake Main Dam

Gold-Paradise North Head Pond Dam

Gold Paradise Diversion

Gold-Paradise South Head Pond Dam

Legend

- Direction of Flow
- Watersheds

Facilities

- Intake
- Pumping Station
- Reservoir
- Treatment Plant
- Dam
- Hydrometric Stations
- GVW Wells
- Water Pipes
- Lake
- Gold Paradise Diversion

Watersheds

- Haddo Reservoir
- Grizzly Reservoir
- Aberdeen Reservoir
- Goose Lake (Reservoir)
- King Edward Lake Reservoir
- Headgates Reservoir

Service Layer Credits: World Imagery: Earthstar Geographics

Coordinate System: NAD 1983 BC Environment Albers

Scale Disclaimer: The map scale of 1:225,000 is only valid on a 11"x17" print.

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Project No.	773.226
Date	July 2026
Scale	1:225,000

0 2.5 5 10 Kilometers

GVW System Overview and Supply Watersheds

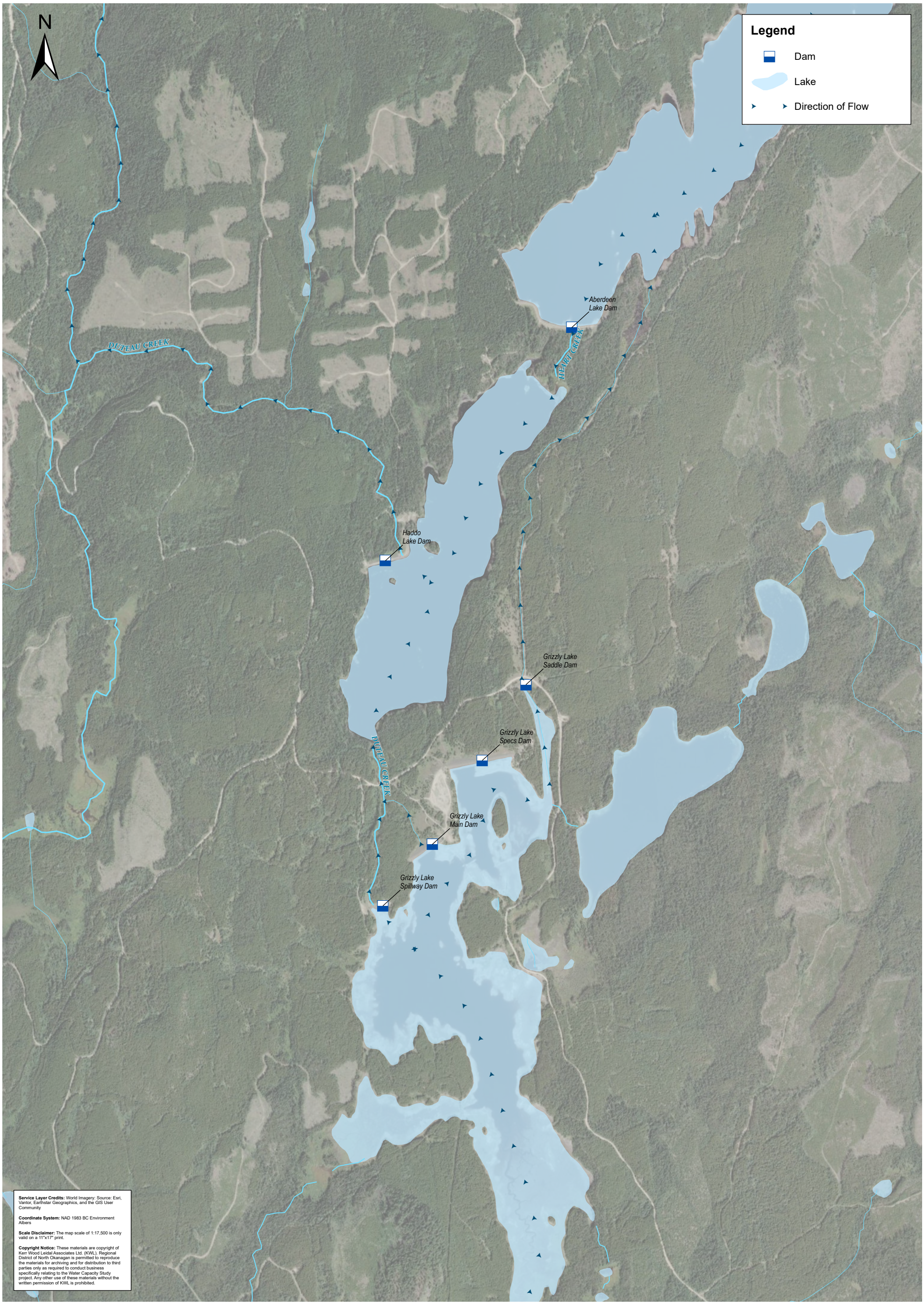
Figure 2-2

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Regional District of North Okanagan

Water Capacity Study

KERR WOOD LEIDAL consulting engineers



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Project No.	773.226
Date	July 2026
Scale	1:17,500

0 25 50 100 Meters

Duteau Creek Reservoir Complex Overview

Figure 2-3

2.2 Existing Water Sources

Surface Water

RDNO holds water licences for storage and diversion of surface water from the surface water sources. These licences, issued by the Province under the *Water Sustainability Act* (WSA), define the maximum allowable volume of storage and maximum allowable withdrawal volume as well as timing of when water can be stored or diverted. RDNO holds approximately 111,437 ML worth of water licences for surface water withdrawal, diversion and storage. Of this amount, approximately 39,166 ML are considered irrigation licences, 18 ML are considered domestic licences, and 28,535 ML are classed as waterworks licences. Further discussion of licences is included in Section 2.5.

The licences do not guarantee a specific volume of water; they only define the maximum allowable withdrawal or storage volume if the water is available. During times of water scarcity, the WSA defines water allocation using the First in Time First in Right (FITFIR) principle based on the date of precedence of the water licence to allocate of water amongst the licence holders. Although, FITFIR is defined in the WSA, in practice the Province works with licence holders to balance potential impacts considering how water is being used such as domestic water use, agricultural, stock watering and other water uses and impacts to environmental flows are considered in allocation during drought periods.

The storage licences define when water can be diverted into storage. Although water diverted into storage during the licenced period can be held and released for use during the non-licenced period, any natural baseflow must be passed through the storage to maintain natural baseflow conditions downstream of the storage location.

The Duteau Creek Reservoir Complex receives inflow from Curtis Creek, Heart Creek, Upper Duteau Creek, and is licenced (WL C017839) to be supplemented by diversions from McAuley Creek via the Gold-Paradise Diversion between April 1 and September 30, which flow into Heart Creek.

Table 2-1 summarizes the physical storage volumes, the maximum licenced storage volumes, the licenced storage periods, and the watershed areas of the reservoirs that store the GVW water supply. Table 2-4 (see notes for summary) may be referenced for GVW's annual licenced withdrawals.

Table 2-1: RDNO Reservoirs Summary

Reservoir (License No.; Purpose)	Watershed Area (km^2)	Physical Storage (ML)	Maximum Licensed Storage (ML)	Available Storage (ML)	Licensed Storage Period
Aberdeen, (C017842; Storage)	45.1	11,147	24,670	9,284[1]	Oct 1 to Jun 15
Haddo (see Aberdeen)	3.7	2,509			
Grizzly, (C034701; Storage)	52.1	5,284	3,700	3,432[1]	Oct 1 to Jun 15
Headgates	-	40	-	-	-
Goose (504777, C015585, C032125, C124618; Storage)	3.86	2,687[2]	8,495	2,386	Oct 1 to Jun 15
King Edward (C110459; Storage)	8.9	1,543	1,357	1,357[3]	Oct 1 to Jun 1
	TOTAL	**22,908**	**38,222**		

Notes
1. Based on the lesser amount of physical or licensed storage, minus operational reserves (2,967 ML for Aberdeen, 1,405 ML for Haddo, 268 ML for Grizzly) identified by RDNO in document provided to KWL on June 18, 2026 pertaining to minimum reservoir levels.
2. Includes 301 ML of dead storage below the LLO.
3. Based on the lesser amount of physical or licensed storage.

Groundwater

GVW operates four groundwater supply wells all located within the District of Coldstream. Two wells (Ranch 2 and Ranch 3) are situated on lands owned by Coldstream Ranch. The other two wells are located on a RDNO owned property at 6282 Highway 6, just south of the highway in Lavington (see Figure 2-2). Table 2-2 summarizes well construction data including Provincial well identifiers, construction date, well diameter, depth, aquifer, known static water levels, and reported yields. For completeness, Table 2-2 also includes information for Ranch Well 1, which was replaced about five years ago by Ranch Well 3.

Table 2-2: Selected Information on GVW Wells

Well Tag Number	Well Description	Aquifer 352 unit	Year Drilled	Nominal Diameter (mm/in)	Depth to Water (m)	Drilled Depth (m)	Reported Well Yield L/s (US gpm)
47818	Ranch 1	Middle	1981	400/16	<1	51	No longer in use
51386	Ranch 2	Shallow	1982	300/12	6.3	25	63.1/1,000
118168	Ranch 3	Middle	2019	400/16	<1	49.7	63/1,000
10062	Antwerp 1	Shallow	1998	300/12	1.2	12.8	41/650
10063	Antwerp 2	Middle	1998	300/12	3.9	62.1	56.8/900
						Total Estimated Yield (L/s) and US gpm	**224/3,550**

Note: Information sourced from GWELLS and Golder (2006), as referenced in the Technical Memorandum: *Greater Vernon Water – Review of Groundwater Sources and Potential Capacity Expansion,* Western Water Associates Ltd., April 17, 2026. (Appendix A).

Ranch Well 3

Ranch 3 replaced Ranch 1 in 2021. Based on the available data, Ranch 3 has been operated for supply the last several years typically between early June and early October. Flow rates have ranged from about 40 to 72 L/s), typically toward the higher end of the range (>60 L/s). Looking at July 2025 data, at a high daily flow 72.5 L/s, well drawdown was approximately 22 m, giving an operating specific capacity of 3.5 L/s/m of drawdown. This compares favourably to the baseline well testing conducted under WWAL's supervision in 2020 (WWAL 2020). The operating level in the well at 72 L/s appears to be about 20 m above the level sensor/ pump intake. Even though the well flow rate is sometimes above the range recommended by WWAL in 2020 (57 to 63 L/s) recent operations do not indicate a problem pumping up to 70 L/s in summer. At lower operating rates, for example approximately 40 L/s the well exhibits excellent performance, with a short-term specific capacity of 5.3 L/s/m of drawdown.

Ranch Well 3 has a pumping capacity of 57 to 63 L/s (4.9 to 5.4 ML/D).

Ranch Well 2

Based on the available data, Ranch Well 2 has also been operated for supply the last several years typically between early June and early October. Typical flow rates range from about 30 to 33 L/s. Well drawdown is typically on the order of 1 to 2 m, giving an operational specific capacity of approximately 20 L/s/m of drawdown. Data indicate approximately 2.2 m of water above the level sensor at a flow of about 33 L/s, which is presumed to represent a level less than 3 m above the pump intake.

Ranch Well 2 has a pumping capacity of 50 L/s (4.3 ML/D).

Antwerp Wells

It is understood the Antwerp wells are maintained as active water sources in the GVW but have not been used for supply in recent years.

Additional detail may be found in WWAL's 2026 Technical Memorandum (Appendix A).

2.3 Water Supply System Operation

The following section provides a general description of how the GVW is typically operated. It provides a description of the key sources and how the sources are operated over the year to supply community demands.

Duteau Creek Reservoir Complex

The Duteau Creek Reservoir Complex comprises the Aberdeen, Grizzly, Haddo, and Headgates reservoirs as well as the Gold-Paradise Diversion. With an average withdrawal of 10,400 ML per year to GVW's system, it is GVW's primary supply of water. Water is withdrawn from Duteau Creek at the Headgates Reservoir and piped to the Duteau Creek Water Treatment Plant (WTP). A portion of the total water withdrawn from Duteau Creek (approximately 2% annually) is diverted into the non-potable water system agricultural irrigation use. Some of the water withdrawn at Headgates Reservoir is piped to Goose Lake to be stored to support periods of higher demand for non-potable water, as described further below.

Upstream of Headgates, the Duteau watershed comprises two sub-watersheds:

1. The Upper Duteau watershed upstream of Haddo Reservoir and including the watersheds flowing into Grizzly Reservoir and Aberdeen Reservoir.

2. The Lower Duteau Creek watershed comprising the watershed flowing from Flyfish Lakes to the south-west of Headgates Reservoir and the intervening watershed area along Duteau Creek between Haddo Reservoir and Headgates Reservoir.

The Lower Duteau Creek watershed is unregulated between Haddo Reservoir and Headgates. The water supply from this portion of the Duteau Creek watershed is “run of river” without any storage and thus provides supports to withdrawals during spring freshet period.

The reservoirs in the Duteau Creek Reservoir Complex are operated seasonally with:

1. The reservoirs filling during the high flow spring freshet period, which typically begins in March and may continue into early July.
2. Water being released from reservoirs during summer to support higher seasonal water community demand and agricultural irrigation demand in summer from July to September.
3. Maintaining over-winter storage to support community withdrawal, environmental flows and to protect infrastructure during colder winter low flow periods from October to February.

Spring Freshet

In anticipation of high stream flows and reduced water quality during freshet, storage may be systematically released from each of the three reservoirs. To maximize storage capacity, Grizzly storage may be diverted to Aberdeen via the Grizzly Canal when Grizzly levels are above 6.7 m. On average over the last 10 years, this opportunity is available approximately 43% of the time, annually. However, Grizzly can be subject to algal blooms, thereby limiting this option in warmer months due to water quality concerns; between November 1 and April 30, Grizzly is high enough to divert water to Aberdeen approximately 23% of the time. Beginning April 1, Water Licence C017839 allows the Gold-Paradise Diversion to be opened to divert flow from the McAuley Creek watershed into Aberdeen Reservoir via Heart Creek.

The water stored in Aberdeen Reservoir and Grizzly Reservoir is then used to support the higher summer water demand period (early May to mid-September) and Environmental Flow Needs (EFN) in Duteau Creek downstream of the community intake at Headgates. Water released into Duteau Creek from the Duteau Creek Reservoir Complex flows to Headgates Reservoir and combines with runoff generated above the Headgates Intake, which has limited storage and serves to supply system pressure and allow for some sediment settling for the Duteau Creek Water Treatment Plant (DCWTP) . Releases from Headgates either flow to Lower Duteau Creek or are diverted to the GVW water system via the DCWTP where water is used for domestic or agricultural purposes, or to the non-potable bypass pipe where water is used for agriculture only.

Duteau Creek is a tributary of Bessette Creek. Environmental flows and any additional spill flow in excess of the Environmental Flows from Headgates Dam supplements flow in Bessette Creek. However, the licenced storage volumes within the Duteau Reservoir Complex are allocated to RDNO waterworks purposes and are not directly available for use for downstream water licences.

Total storage in Aberdeen Reservoir, Grizzly Reservoir and Haddo Reservoir is 18,900 ML.

Summer Reservoir Draw Down

During the summer period (July to September), flow into Aberdeen Reservoir can continue to be supplemented either through Heart Creek via the Gold-Paradise Diversion from the McAuley Creek watershed or via Grizzly Reservoir. Although the Gold-Paradise Diversion is licenced for use starting April 1, historically it is typically not opened until mid-to-late May, due to freeze up. As noted above,

even though reservoir levels are high enough to allow movement from Grizzly Reservoir through the Grizzly Canal, this typically does not occur in summer months due to water quality concerns. Water can be supplied to the Haddo Reservoir directly from Aberdeen Reservoir or from Grizzly Reservoir, with Haddo Reservoir being used as a balancing reservoir to manage flow released into lower Duteau Creek.

The normal operating objective in the summer is to minimize spill at Headgates and maintain storage to avoid water scarcity later in the year, while meeting community water withdrawal requirements and environmental flows. From June 16 to September 30; while water stored earlier in the year may be held back in the reservoirs to supply, the water licence requires , as outflow must equal inflow during this time, thereby meeting licence conditions. Operations consider the watercourse sensitivity to minimum and maximum releases, which may result in fish stranding due to downstream low flows, or erosion and sedimentation, each potentially negatively impacting the Duteau Creek fish habitat downstream of Headgates.

Winter Carry-Over Storage

Winter carry-over storage is critical to protecting infrastructure and supplying community withdrawals and environmental flows. In the fall and winter, the reservoirs continue to supplement flow in Lower Duteau Creek for community withdrawals and to meet EFNs. Depending on conditions in the Lower Duteau Creek watershed, there may be sufficient flow allowing the reservoirs to begin to refill if inflows exceed the water demands and downstream EFN. Historically, due to precipitation in the early fall, inflows will exceed outflows and the reservoirs begin to refill; however, if there is sometimes insufficient inflow from rain and outflow to support community withdrawals and Environmental Flow needs and storage will drop. Aberdeen, Grizzly, and Haddo Reservoir levels should be maintained above 2.1 m, 3.7 m, and 4.3 m, respectively, to protect the works from damage caused by freezing conditions. Between the three reservoirs, RDNO maintains a volume of 4,640 ML to manage these operational constraints, therefore the volume available for supply is approximately 14,260 ML for community withdrawals and environmental flows.

A graph of the typical annual cycle of total reservoir storage for Aberdeen Reservoir, Grizzly Reservoir and Haddo Reservoirs over the past 10 years (2015-2025) is shown in Figure 2-4.

with minimum, maximum values show in Table 2-3. Over these 10 years, the Duteau Creek Reservoir Complex has failed to completely refill 95% or more of the available volume (i.e., per the noted operational constraints) in two out of ten years. One of these years (2024) was short by a notable amount of 20% while the other year (2019) was short by 6-7%.

The reservoir level has been drawn down to less than 10% of available storage volume 7 out of the past 10 years. The minimum storage volume over the last 10 years was approximately 223 ML (2% of the available volume) and occurred in 2024. The 2023, 2024 and 2025 years were the three driest over the past ten years having annual inflow volumes 54%, 43% and 53% of the average annual volume over the last ten years, respectively.

The review of historical data indicates that inflow to the Upper Duteau Complex may not be sufficient to refill reservoir volumes, especially during multi-year drought conditions similar to 2023 to 2025. In addition, the records show that most of the reservoir volume is depleted (less than 10% of available volume) in most years. The draw down of the reservoirs are due to both seasonal demands as well as operational decisions to release as much flow as possible to support Environmental Flows. This review indicates that storage and supply during multi-year drought conditions may be limiting factors for water supply from Duteau Creek complex.

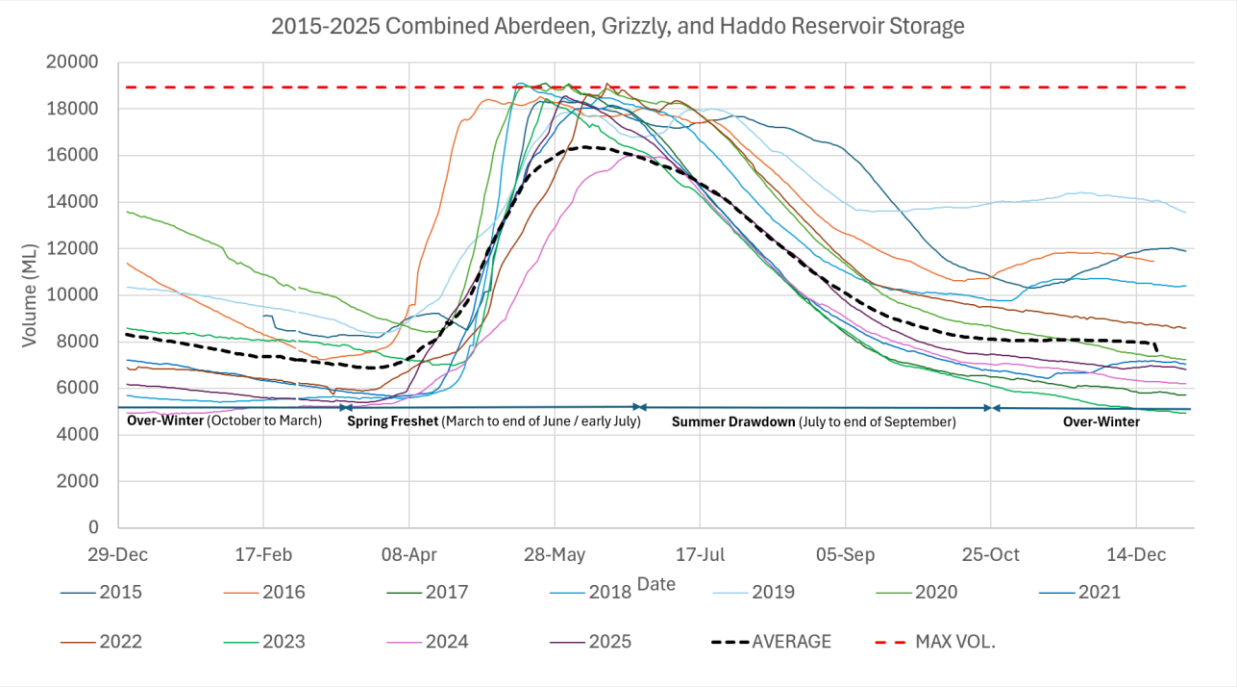


Figure 2-4: Annual Storage Cycles of Aberdeen, Grizzly and Haddo Reservoirs (Last 10 Years) and Modelled Drought Cycles

Table 2-3: Summary of Minimum and Maximum Record Storage Volumes for Duteau Creek Reservoir Complex (2016 - 2025)

Year	Annual Inflow[1] (ML) Water Year of Jan 1 to Dec 31	Minimum Storage		Maximum Storage	
		Useable Volume[2] (ML)	% Remaining of Available Volume	Useable Volume (ML)	% Remaining of Available Volume
2016	48,704	2,587	18%	13,888	98%
2017	66,988	1,064	7%	14,300 (fills)	100%
2018	54,487	771	5%	14,300 (fills)	100%
2019	34,563	3,735	26%	13,375	94%
2020	82,729	2,588	18%	14,300 (fills)	100%
2021	37,139	1,025	7%	13,522	95%
2022	62,586	1,094	8%	14,300 (fills)	100%
2023	24,363	300	2%	13,815	97%
2024	19,452	223	2%	11,379	80%
2025	24,121	756	5%	13,910	98%

Notes
1. Includes Gold Paradise Diversion.
2. Adding the operational reserve (4,640 ML) to the useable volume gives the total storage volume.
3. % of available storage volume does not include the operational reserve.

Kalamalka Lake Intake/Mission Hill Water Treatment Plant

Kalamalka Lake Intake is the second primary source of water for the GVW with an average annual withdrawal volume of 6,041 ML. Water is pumped from the lake to the Mission Hill WTP and is used for potable water use. In the winter, the Kalamalka Lake Intake withdrawals are typically higher than the withdrawals at Duteau with about 67% of total water demand from mid-October to mid-April coming from Kalamalka Lake. The higher withdrawal rate at the Kalamalka Lake intake in winter is due to the turn down of agricultural demand for the winter, which is normally supplied by the Duteau system. As a result, there is reduced demand on the water stored in the Duteau Creek Reservoir Complex over the winter months. This helps to maintain carry-over winter storage in the Duteau Creek Reservoir Complex as discussed in the previous section.

Storage in Kalamalka Lake is controlled by an outlet structure at the outlet to lower Vernon Creek, which stores up to 35,200 ML of water. The outlet structure is operated by the Province to supply water supply storage, maintain environmental flow needs in Lower Vernon Creek, and manage flood risk in Kalamalka Lake, Vernon Creek and Okanagan Lake during spring freshet as part of the Okanagan Lake Regulatory System. The operating water levels for the weir are as follows:

- Full Supply Level = 391.67 m
- Pre-freshet Maximum Level = 391.40 m
- Target Elevation Sept 30 to Jan 31 = 391.20 m
- Minimum Operating Level = 390.67 m
- Outlet structure sill level = 390.60 m

The available storage at the pre-freshet maximum level (winter level) is 25,700 ML. The Province has deemed Kalamalka Lake to be at capacity for withdrawals therefore will not grant new licences for this purpose. RDNO's water licence for withdrawal is for 9,031 ML.

Okanagan Lake and Canoe Bay Pump Station

The Canoe Bay Pump Station is a raw water pump station on Okanagan Lake. Its construction began in April 2025 with substantial completion anticipated for June 2026. Raw water from Okanagan Lake will be able to be pumped to a 300 m^3 balancing tank (closed concrete reservoir) to supply non-potable water for agricultural uses, particularly on the west side of Vernon[1]. In constructing the pump system as well as completing the transfer of existing water licences (i.e., from BX Creek), up to 6,000 ML of water will become accessible to GVW from Okanagan Lake.[2]

Goose Lake (Reservoir)

Goose Lake acts as a balancing storage reservoir with a storage capacity of 2,386 ML. On average 819 ML of water is diverted from the potable water system during the lower water demand season and is stored in Goose Lake for non-potable irrigation use during the higher water demand season. A portion of this water comes from the Duteau WTP and a portion comes from the Mission Hill WTP. On average about 735 ML is returned to the non-potable system from Goose Lake during the higher irrigation demand period, with an average evaporation/seepage loss at Goose Lake of about 84 ML on average.

[1] RDNO. *Canoe Bay Pump Station*. 2026. https://www.rdno.ca/canoebaypumpstation. Accessed July 2026.

[2] RDNO. Technical Memorandum: Greater Vernon Water – Review of Water Licenses and Long-Term Water Capacity Concerns, Table 4. May 7, 2025 – Revised.

King Edward Lake/Deer Creek Intake

The smaller King Edward Lake, located on Deer Creek, a tributary of Coldstream Creek, is used only for non-potable irrigation supply to the King Edward Lake Service area; this separated service area is also supplied by Ranch Wells 2 and 3. In a typical year, runoff water is collected and stored in the reservoir through the late fall, winter, and spring months for use during the peak irrigation water demand period of June through September. Water released from King Edward Lake flows into Deer Creek and then to GVW Deer Creek Intake near the valley level.

A plot of typical storage volume cycles at King Edward Lake are shown in Figure 2-5.

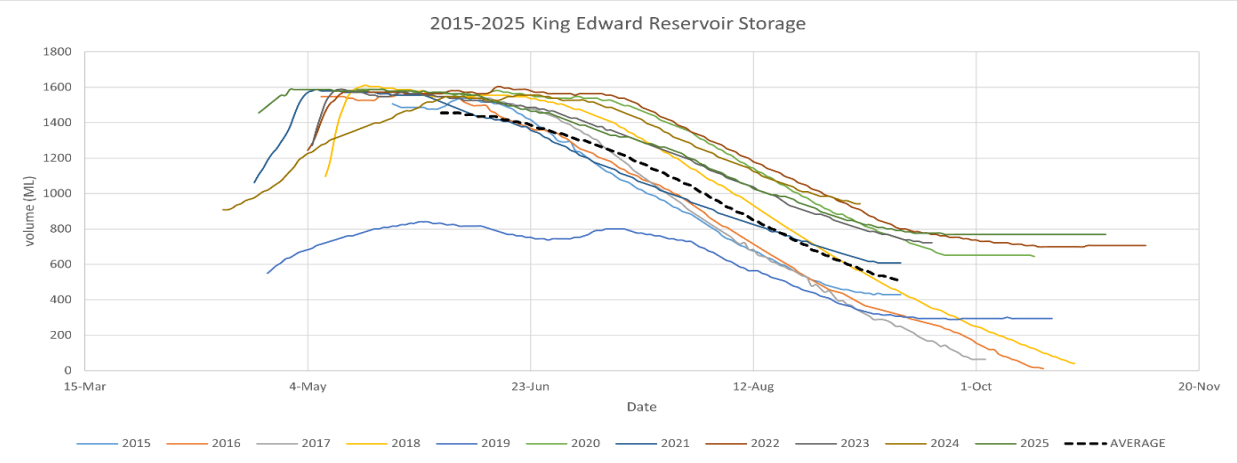


Figure 2-5: Typical Annual Storage Cycle, King Edward Lake

BX Creek

BX Creek does not currently contribute to the system. The system was decommissioned in the 1990s due to poor water quality and lack of storage to supplement later summer water demand.

Groundwater Wells

Well usage and the use purposes have changed over the years. While formerly used for potable and/or irrigation supply, all the wells are now considered to be supplemental irrigation sources that are used seasonally. The Antwerp wells are currently not used routinely. The shallow well, which was contaminated in the past, has no pump and will not be used until the non-potable water supply system is extended so that it is close enough to connect. The deep well is connected to the potable water supply and is an emergency backup well. The Ranch Well 1 casing overflow is valved closed; the pump and hydro service are removed, and seal plate is installed on the well head.

The South Vernon Irrigation District is a small, non-potable utility owned and managed by the RDNO which is used to service irrigation for 26 properties between approximately May 1 and September 19, annually, from well water.[3]

For additional detail. Including well water licensing information see WWAL's full technical memorandum (Appendix A).

[3] RDNO. *South Vernon Irrigation District*. 2026. https://www.rdno.ca/svid. Accessed July 2026.

2.4 Regulations

BC Water Sustainability Act

The *BC Water Sustainability Act, SBC 2014, C. 15* (WSA) and associated regulations came into effect on February 29, 2016. The WSA is intended to protect surface water and groundwater resources in BC and requires licensing of non-domestic groundwater use (e.g., water systems, irrigation, commercial or industrial use) in the province.

Regulations that are enacted under the WSA to aid the province in management of water include:

- Water Sustainability Regulation, B.C. Reg. 184/2024
- Groundwater Protection Regulation, B.C. Reg. 253/2022
- Dam Safety Regulation, B.C. Reg. 32/2023
- Water Sustainability Fees, Rentals and Charges Tariff Regulation, B.C. Reg. 187/2023
- Water Districts Regulation, *B.C. Reg. 38/2016*

Through water licenses issued to GVW under the WSA, the Ministry of Water Land and Resource Stewardship (WLRS) regulates the maximum volume of water that can be stored in reservoirs and the maximum withdrawal rate from the source watersheds along with the required Environmental Flow Needs (EFN) to be maintained in the river downstream of the intakes to support river habitat health. The WSA also regulates the total volume of water that can be withdrawn from groundwater. Furthermore, the WSA authorizes construction and operation of the works associated with the source water supply system including reservoirs, intakes and groundwater wells.

Drinking Water Protection Act and Regulation

The BC *Drinking Water Protection Act, SBC 2001* (DWPA) governs the construction and operation of drinking water supply systems in BC to protect public health and safety. Supplying water to two or more residences is considered a water supply system. The DWPA requires that a Construction Permit and a Permit to Operate be issued by the local health authority, in accordance with the DWPA *Drinking Water Protection Regulation (B.C. Reg. 168/2025)* (DWPR) prior to operating any new water source that will be connected to an existing water system.

The DWPA and DWPR are outcome-based and rely on broad powers delegated to Medical Health Officers and Drinking Water Officers of the five independent Health Authorities to interpret the legislation and supporting policy issued by the province. The GVW is within the jurisdiction of the Interior Health Authority. Decisions regarding drinking water safety are prioritized based on risks to human health. Three key policy references for drinking water regulation in BC are the Drinking Water Officers' Guide, the Design Guidelines for Drinking Water Systems in British Columbia, and the Health Canada Guidelines for Canadian Drinking Water Quality.

Drinking Water Officer's Guide

The Drinking Water Officer's Guide (DWOG) contains all provincial health policy related to drinking water (Ministry of Health, 2025). The DWOG is intended to assemble practical public health knowledge and experience for the benefit of public health officials and the public, and to refine policy and practice to reflect the legislative regime established under the DWPA. This regime is based upon a multi-barrier approach, which seeks to address threats to drinking water at various stages, including its source, treatment systems, distribution, and at the tap.

Design Guidelines for Drinking Water Systems in British Columbia

The Design Guidelines for Drinking Water System in British Columbia recommend that water sources for drinking water systems should have a sufficient reliability to provide the maximum projected water withdrawals up to the 50-year return period drought, or the extreme drought of record including considerations for multiple years of drought and changes in drought frequency. This is equivalent to a reliability of 49 out of 50 years or 98%, (Ministry of Health, 2023).

Guidelines for Canadian Drinking Water Quality

Guidelines for Canadian Drinking Water Quality are developed by the Federal-Provincial-Territorial Committee on Drinking Water and published by Health Canada. Although non-binding under BC legislation, the Guidelines are an important standard which guide construction and operation of drinking water systems in BC and regulatory decisions by the regional Drinking Water Officer under the DWPA and DWPR (Health Canada, 2025).

Provincial Fisheries Act

The BC *Fisheries Act, RSBC, 1979, Chapter 137* regulates the licensing of fisheries, the licensing of fish and aquatic plant processors and fish buying stations as well as fish protective devices including maintaining fish passage at dams and other hydraulic facilities through installation of fish passage works, fish screens and proper operation to maintain adequate river flows.

Federal Fisheries Act

The under the federal *Fisheries Act, RSC, 1985, F-14* the Department of Fisheries and Oceans (DFO) regulates the proper management and control of fisheries as well as the conservation and protection of fish and fish habitat. Under Sections 34.4 (1) and 35(1) of the Fisheries Act, no person shall carry out any work, undertaking or activity that results in killing fish or in the harmful alteration, disruption or destruction of fish habitat.

Environmental Flow Needs (EFN) is regulated under the provincial WSA; however, the WSA, the provincial Fisheries Act, and the federal Fisheries Act work in unison to protect aquatic habitat from potential harm resulting from water withdrawals. Although both the provincial and federal fisheries acts do not directly regulate the water supply system, the GVW could be liable for contravention of these acts if operation of the water system is found to result in death of fish, harmful alteration, disruption or destruction of fish habitat and/or adversely impact fish passage.

Local Government Act and Community Charter

The *Community Charter, SBC, 2005* provides the statutory framework for all municipalities in BC except the City of Vancouver. The Community Charter sets out municipalities' core areas of authority, including the provision of services, public health regulation, entering into agreements, property taxation, financial management, and procedures such as adopting and enforcing bylaws.

The BC *Local Government Act, RSBC 2015* (LGA) is the primary legislation for regional districts and improvement districts, setting out the framework for structure and operations, as well as the main powers and responsibilities. Certain municipal provisions of the LGA also apply to municipalities for matters not covered by the Community Charter. The LGA covers planning and land use powers.

All of the source water for GVW is in other jurisdictional areas so the RDNO does not have direct powers over land use which has been problematic when issues arise.

2.5 Water Licences

As discussed previously in Section 2.2, water licences are issued by the Province to permit use of water including defining the maximum quantity that can be diverted or stored, where the water can be diverted and for what purpose. The licences do not guarantee a specific volume of water; they only define the maximum allowable withdrawal or storage volume if the water is available.

During times of water scarcity, the WSA defines water allocation using the First in Time First in Right (FITFIR) principle based on the date of precedence of the water licence to allocate of water amongst the licence holders. Although, FITFIR is defined in the WSA, in practice the Province works with licence holders to balance potential impacts considering how water is being used such as domestic water use, agricultural, stock watering and other water uses and impacts to environmental flows are considered in allocation during drought periods.

The storage licences define when water can be diverted into storage. Although water diverted into storage during the licenced period can be held and released for use during the non-licenced period, any natural baseflow must be passed through the storage to maintain natural baseflow conditions downstream of the storage location.

Water licences pertaining to GVW were provided to KWL in January 2026 to aid in the assessment of RDNO's water needs. GIS was used to generate a list of water licences for each relevant creek system, including both GVW and non-GVW licences. The licences were reviewed for duplication and categorized into flow and storage allowances.

A summary of the licences is included in Table 2-4.

GVW holds approximately 111,437 ML worth of water licences, including both flow and storage licences. Of this amount, approximately 39,166 ML are considered irrigation licences, 18 ML are considered domestic licences, and 28,535 ML are classed as waterworks licences.

Duteau Creek

The largest contribution of water to GVW is from Duteau Creek. There are currently 33,051 ML of storage licences allocated to the Duteau Creek system. However, only 28,370 ML are allocated within the Aberdeen, Haddo, and Grizzly reservoirs. Duteau Creek is the only source flow to Grizzly, while Aberdeen and Haddo are supplemented by Heart Creek and Curtis Creek. Flow in Heart Creek can be supplemented by the Gold-Paradise Diversion.

The remaining 4,681 ML of Duteau storage are split between Goose Lake and Kalamalka Lake.

Kalamalka Lake

For the purpose of waterworks, GVW is licenced to store 5,347 ML/year in Kalamalka Lake between October 1 and July 1 (Water Licences F017529 and F072834) and is licenced to withdraw 8,842 ML/year.

Table 2-4: Summary of Water Licenses within Greater Vernon Water Sources

Licence	Sum of Max Day (ML)	Sum of Max Annual (ML)	No. of Licences	Other Licences		GVW Licences	
				Consumption (ML/yr)	Storage (ML)	Consumption (ML/yr)	Storage (ML)
B.X. Creek	29.51	5,917.7					
Other Private Licences			2	0.83	59.21		
Private Irrigation			8	559.38			
Other Government Entities			6		958.68		
GVW Waterworks			4			7,715.85	
GVW Irrigation			2			1,515.95	
GVW Storage			1				1,911.89
Conservation – Ducks Unlimited			1	1.75			
Conservation Storage – BC Wildlife Branch			1		2,658.00		
Conservation Storage – City of Vernon			1		325.64		
		Sub-total	**26**	**561.96**	**4,001.52**	**9,231.80**	**1,911.89**
Aquifer 347	0.015	2.73					
GVW Irrigation			1			2.73	
		Sub-total	**1**	**0.00**	**0.00**	**2.73**	**0.00**
Dixon Creek	2.73	995.59					
Other Private Licences			15	111.00	61.67		
Private Irrigation			11	1,015.09			
GVW Waterworks			1			995.59	
GVW Storage			1				148.02
		Sub-total	**28**	**1,126.10**	**61.67**	**995.59**	**148.02**
Schon Creek	0.034	12.44					
Private Irrigation			2	10.36			
GVW Waterworks			1			12.44	
		Sub-total	**3**	**10.36**	**0.00**	**12.44**	**0.00**
Vernon Creek	5.91	1,089.26					
Other Private Licences			7	71.60			
Private Irrigation			30	1,559.89			
Other Government Entities			34	32,951.88	625.37		
First Nations Licences			3	388.55			
GVW Incidental Domestic			2			16.59	
GVW Irrigation			5			1,072.67	
		Sub-total	**81**	**34,971.91**	**625.37**	**1,089.26**	**0.00**
Antwerp Creek	0.98	358.41					
GVW Waterworks			1			358.41	
		Sub-total	**1**	**0.00**	**0.00**	**358.41**	**0.00**
Coldstream Creek	1.14	414.83					
Other Private Licences			5	28.21	91.28		
Private Irrigation			5	149.25			
Other Government Entities			3	5,357.97			
First Nations Licences			1	175.40			
GVW Waterworks			1			414.83	
		Sub-total	**15**	**5,710.83**	**91.28**	**414.83**	**0.00**
Craster Creek	0.67	81.41					
Other Private Licences			2	3.32			
Private Irrigation			2	272.99			
GVW Irrigation			1			81.41	
		Sub-total	**5**	**276.31**	**0.00**	**81.41**	**0.00**
Deer Creek	11.05	4,032.3					
Other Private Licences			76	1,411.66			
Private Irrigation			15	369.03			
Other Government Entities			5	8,950.75	442.82		
GVW Waterworks			1			331.86	
GVW Irrigation			1			3,700.44	
		Sub-total	**98**	**10,731.44**	**442.82**	**4,032.30**	**0.00**

Licence	Sum of Max Day (ML)	Sum of Max Annual (ML)	No. of Licences	Other Licences		GVW Licences	
				Consumption (ML/yr)	Storage (ML)	Consumption (ML/yr)	Storage (ML)
King Edward Lake							
GVW Storage			1				1,356.83
		Sub-total	**1**	**0.00**	**0.00**	**0.00**	**1,356.83**
Swayne Brook	0.023	8.3					
GVW Waterworks			1			8.30	
		Sub-total	**1**	**0.00**	**0.00**	**8.30**	**0.00**
Deep Creek	0.28	34.04					
Other Private Licences			14	31,566.68	55.51		
Private Irrigation			26	1,165.10			
Other Government Entities			7	12,833.73	135.68		
First Nations Licences			1	682.85			
GVW Irrigation			1			34.04	
		Sub-total	**49**	**46,248.36**	**191.19**	**34.04**	**0.00**
Okanagan Lake	54.59	7,391.9					
Other Private Licences			947	14,666.91			
Private Irrigation			208	5,730.00			
Other Government Entities			77	98,605.25			
First Nations Licences			12	26,787.65			
GVW Irrigation			2			896.18	
GVW Waterworks			13			6,476.36	
GVW Domestic			1			0.83	
GVW Storage			1				2,069
		Sub-total	**1261**	**145,789.80**	**0.00**	**7,373.37**	**2,069.00**
Kalamalka Lake	26.82	8,617.36					
Other Private Licences			100	224.17			
Private Irrigation			19	327.35			
Other Government Entities			11	2,214.62	1,233.48		
GVW Domestic			1			0.83	
GVW Waterworks			12			8,841.58	
GVW Storage[1]			2				5,347.14
		Sub-total	**145**	**2,766.14**	**1,233.48**	**8,842.41**	**5,347.14**
Paradise, McAuley (Gold), Gal, Crib, and Stoplog Creeks	54.22	9,867.84					
GVW Irrigation			1			9,867.84	
		Sub-total	**1**	**0.00**	**0.00**	**9,867.84**	**0.00**
Duteau Creek	136.44	24,959.51					
Other Private Licences			2	2.49			
Private Irrigation			3	366.42			
Other Government Entities			3	950.35			
GVW Waterworks			5			3,379.87	
GVW Irrigation			2			21,994.80	
GVW Storage			4				32,884.58
Conservation – Fisheries and Oceans Canada			2	1,233.37			
Conservation Storage – Fisheries and Oceans Canada			1		1,233.48		
Conservation – Private			1	2,232.43			
		Sub-total	**23**	**4,785.06**	**1,233.48**	**25,375.67**	**32,884.58**

Notes:
1. Licence F017529 included under Kalamalka Lake Storage with the sources being Duteau Creek and Vernon Creek.
2. Total 70 licences for GVW:
   - Storage: 10 licences with total of 43,718ML/yr
   - Waterworks: 40 licences with total of 28,535 ML/yr
   - Irrigation: 16 licences with total of 39,166 ML/yr
   - Domestic / incidental domestic: 4 licences with total of 18 ML/yr

2.6 Environmental Flow

Duteau Creek

Headgates Reservoir is located on Duteau Creek, which flows into Bessette Creek, and eventually into the Shuswap River, all of which are considered high-value fish habitat watercourses. The DFO holds licences on Duteau Creek for conservation (fish protection) purposes. In addition, there are downstream licences using water for domestic, stock watering, and irrigation needs. Together, these licences establish four seasonal minimum release requirements to Lower Duteau Creek throughout the year. These release rates were established following a 1994 agreement between DFO and Vernon Irrigation District that is based on private water licences held below Headgates (F05279 and F03599) and Fisheries and Oceans Canada licences (C050424 and 117040) and define the current EFN. The corresponding values are presented in Table 2-5.

In 2015, DFO, WLRS, and GVW developed revised EFN values for Duteau Creek through a study they completed for Bassette Creek. The EFNs were adjusted so that GVW provides more water than the flows listed in Table 2-5 based on amount of water availability. However, these EFNs are an informal agreement and the flows in Table 2-5 are the minimum required and hence, for the purposes of the assessment, the required EFN flows listed in Table 2-5 have been used in the Water Balance.

Table 2-5: Environmental Flow Needs for Duteau Creek (ML/D)

Start Date	End Date	Required EFN (ML/D)
1-Jan	31-Mar	4.9
1-Apr	31-Aug	14.7
1-Sep	1-Oct	17.1
2-Oct	31-Dec	12.3
Total Annual EFN Volume: 4,300 ML		

Lower Vernon Creek

A license adjudication process by the Province in 2001 determined that Kalamalka Lake was over allocated and as such, no new water licenses would be issued and that any additional water (licenses) that became available (i.e., through transfers or changes in hydrology) would be designated to fisheries (EFNs). The resulting 2001 Kalamalka / Wood Lake Basin Water Licencing Plan established a minimum EFN target of 0.085 m^3/s (7.4 ML/day or 2,700 ML/year) for Lower Vernon Creek below Kalamalka Lake[4]. If additional water is made available from Kalamalka Lake in the future, the water licences would be held to meet an increased EFN of 0.235 m^3/s (20.3 ML/day or 7,400 ML/year) for Lower Vernon Creek.

[4] Ministry of Sustainable Resource Management, Water Management, South Interior Region. *Kalamalka / Wood Lake Basin – Water Licencing Plan*. August 2001.

3. Water Demand Forecast

This section describes the available demand data, development of the water demand forecast model, and summary of the model results.

3.1 Source Flow

Potable water supply for the GVW includes the Duteau Creek Reservoir Complex, which is piped to the Duteau Creek WTP, and Kalamalka Lake, which is pumped from the lake to the Mission Hill WTP. In addition, there are non-potable water systems which provide water for use in irrigation of agricultural properties including:

- The Duteau Creek Non-Potable systems (including Von Keyserlingk and Springfield Areas) supplied directly from the Duteau Creek Reservoir Complex.
- The Goose Lake Service Area supplied from Goose Lake via the potable water system from Duteau Creek Reservoir Complex.
- The King Edward Lake Service Area supplied via the Deer Creek Intake or Coldstream Ranch Wells.

A historical record of Daily Source flows from GVW was provided from January 1, 2019 through December 31, 2025 (Source Water Daily Flow.xlsx). The daily source flow has been discretized into each of the potable and non-potable water systems.

A stacked area chart summarizing the daily totals from each supply source is shown in the following figures. The stacked column totals represent the total daily water supplied from each of the systems to the GVW. The first figure shows all potable and non-potable systems. The second figure just shows daily flows supplied from each of the non-potable system.

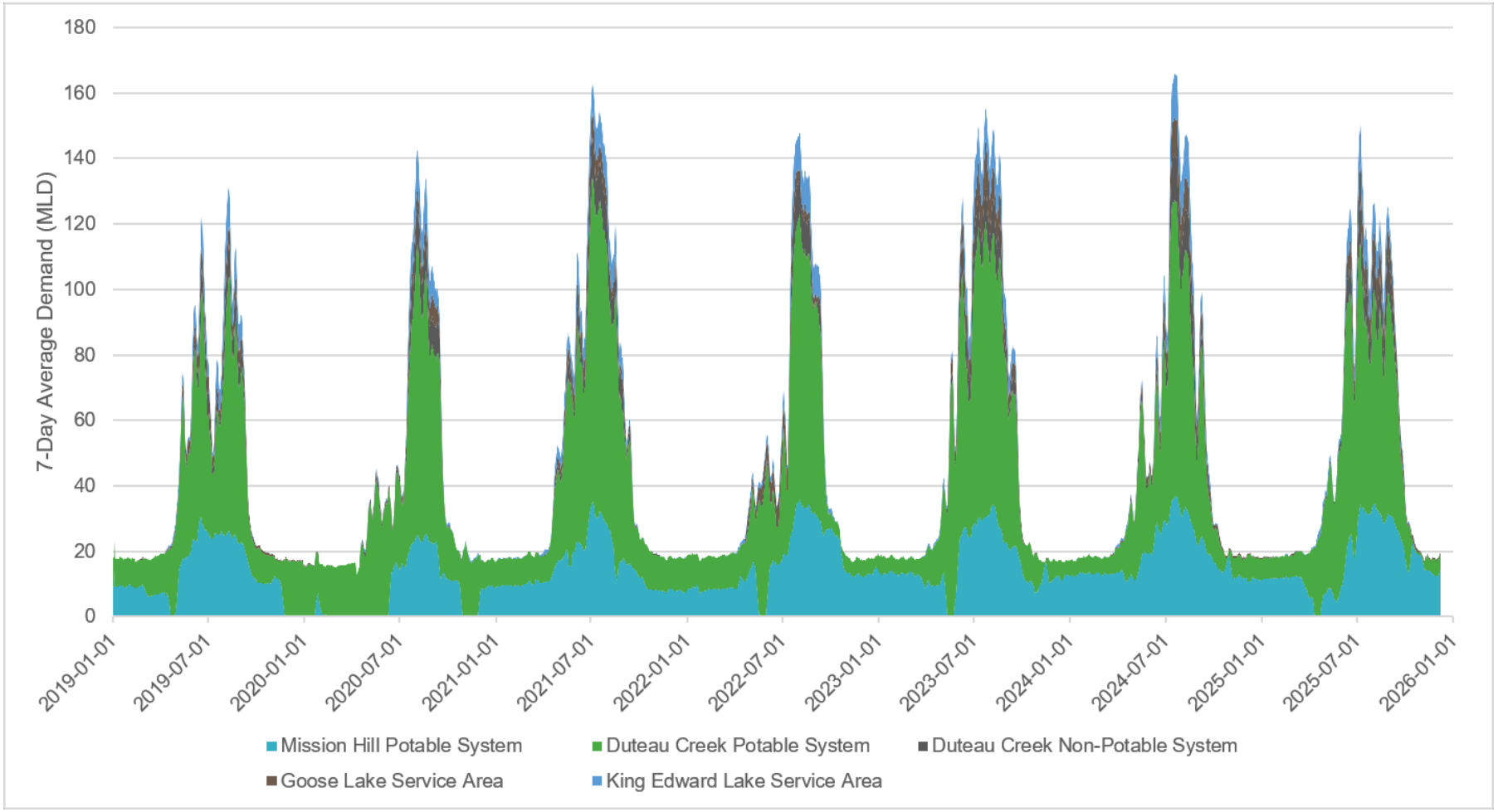


Figure 3-1: 7-Day Average Water Demand by Water Supply System

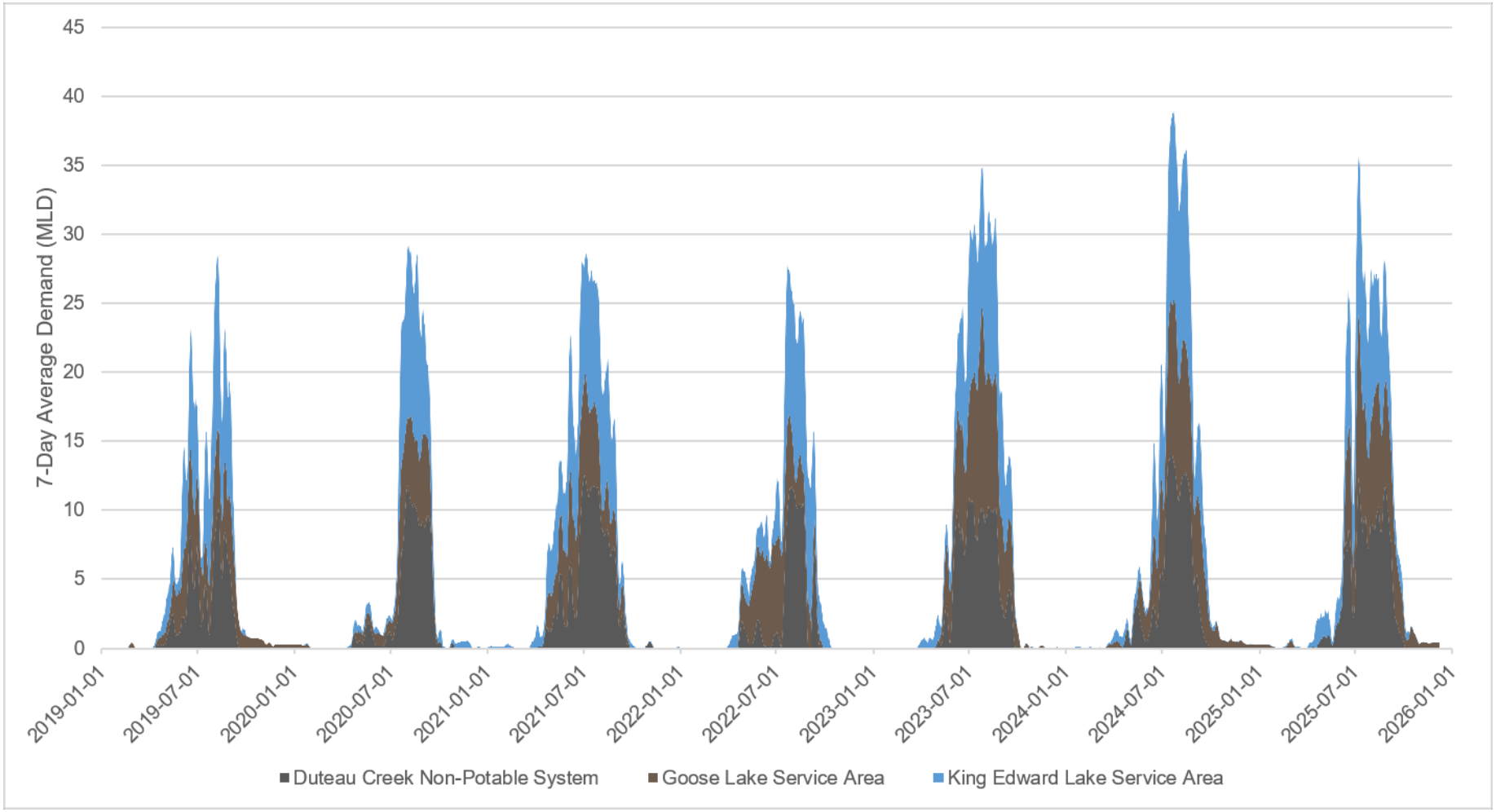


Figure 3-2: 7-Day Average Water Demand by Non-Potable-Water System

3.2 Historic Water Use

Metered water demands in the GVW have decreased since the 2012 Water Master Plan was completed, based on the quarterly billing record data provided between 2021 and 2025 (spreadsheet named GVW_Annual_Consumption+Counts.xlsx). All existing and forecast water demand are based on the provided billing and daily consumption data.

Average day demand (ADD) represents the average daily water use and is calculated by dividing the total annual water use by the number of days in the year. ADD has decreased from 62 ML/d as estimated in the 2012 Water Master Plan to an average of 47.1 ML/d metered between 2021 and 2025. The decrease in ADD can be attributed to combination water efficient irrigation practices, changes to billing structure (introduction of tiered rates), and water conservation initiatives spearheaded by RDNO including escalation of watering restrictions; however, some of the reduction may also be a result in over-estimation of agricultural water use which was not fully metered at the time of 2012 Water Master Plan.

Base demand (BD) represents the component of water demand that occurs year-round and typically includes primarily indoor water use and water losses. BD has decreased slightly from 21 ML/d in 2011 to an average of 19.9 ML/d between 2021 and 2025. The decrease in BD can be attributed to a combination of improved efficiency of indoor water use fixtures, and water conservation initiatives spearheaded by RDNO.

The annual seasonal component of demand is the component of water demand that occurs seasonally typically includes outdoor water use and agricultural use. Total annual seasonal demand is measured as the difference between ADD and BD and has substantially decreased from 41 ML/d in 2011 to 27.3 ML/d (58% of annual total demand) since 2011.

Removing the agricultural water use from the total water use shows that the community demands (treated drinking water) have increased slightly from an estimated ADD of 26.5 ML/d in 2011 (included in the 2012 Water Master Plan) to an average of 26.7 ML/d between 2021 and 2025 (from quarterly water use data). BD has stayed relatively constant from 19.7 to 19.9 ML/d while SD has stayed constant at 6.8 ML/d.

The agricultural component of irrigation (untreated) water demands have decreased from 34.5 ML/d in 2011 (estimated but not metered as part of the 2012 water master plan) to an average of 20.5 ML/d between 2021 and 2025. Irrigation demand is almost entirely seasonal (BD to agricultural users averaged 0.5 ML/d between 2021 and 2025).

Residential Water Demand

The residential component of water demand includes water used indoors by residents (included as part of BD). For the GVW, all residential water use is measured via residential water meters and has been summarized by quarter in billing information spreadsheet provided. The residential demand was broken out into single-family housing type and multi-family housing type demand for each of Vernon, Coldstream and RDNO.

It is best practice to measure indoor base water consumption during the winter months when there is minimal outdoor water consumption. The average indoor residential water consumption was estimated by averaging the first quarter demand over the past 5 years.

The existing population was provided for each of the Vernon, Coldstream, and the RDNO which was used in conjunction with the metered water usage to calculate the per capita indoor water usage (measured in L/cap/day).

The results of the existing residential base demand analysis are included in Table 3-1.

Table 3-1: Existing Residential Base Demand Analysis

Community	Base Residential Water Use (ML/D)	2026 Population	Per Capita Water Usage (L/cap/day)
Vernon	6.9	42,498	154
Coldstream	1.7	9,849	175
RDNO	0.8	4,661	179
Total	**9.4**	**57,008**	**160**

ICI Water Demand

Industrial, commercial, and institutional (ICI) water use includes all non-residential users (included as part of BD). For the GVW all ICI connections are classified under Commercial or Mixed-Use in the water meter summary data provided and is measured at the connection.

It is best practice to measure ICI base water consumption during the winter months when there is minimal outdoor water consumption and seasonal use. The average ICI base water consumption was estimated by averaging the first quarter demand over the past 5 years of 2.7 ML/D in the Vernon, 0.2 ML/D in Coldstream, and 0.1 ML/D in RDNO.

Community Seasonal Water Use

Seasonal water consumption includes the outdoor water use component of both the residential and ICI sectors as well as usage in parks. All water usage at parks is metered as of 2025, prior to 2025, water usage at some parks was estimated.

For the GVW the seasonal component of residential and ICI sectors was estimated by subtracting the expected base demands (described above) from the total annual water use for each sector. All metered usage at parks was assumed to be seasonal water use. This resulted in average annual seasonal water use for each community as shown in Table 3-2.

Table 3-2: Average Annual Seasonal Water Use per Community

Community	Residential Seasonal Water Use (ML)	ICI Seasonal Water Use (ML)	Parks Seasonal Water Use (ML)
Vernon	1,067	431	90
Coldstream	483	77	87
RDNO	185	56	19
Total	**1,737**	**565**	**196**

Agricultural Water Use

The total agricultural water demand is metered for the entire GVW. The existing average total agricultural water demand was divided into community based on the total land area zoned for agricultural water use in the water service area. The agricultural water allocation is determined for agricultural properties by allowing for 5500 m3 of water per hectare of farmland.

The average agricultural water consumption was estimated to be 526 ML/yr in Vernon, 4,100 ML/yr in Coldstream, and 2,847 ML/yr in RDNO.

It is estimated that 40% of the total agricultural allocation (an average of 7,473 ML/year of the allocated 18,900 ML/year) was used on average in the past 5 years with the maximum and minimum used over the past 5 years varying by +/- 5%.

Non-Revenue Water

Non-Revenue Water (NRW) is the difference between the measured or estimated quantities of water supplied into the distribution system and billed to customers. Typically, NRW includes leakage, unauthorized uses, and discrepancies due to metering inaccuracies. The average NRW for the GVW in the past 5 years was estimated to be 20.8% of total annual supply flow use based on the summary of meter data provided.

Based on the daily source water data, the NRW of winter demand is estimated by subtracting the base demands (sum of base residential and ICI demands) resulting in a winter NRW demand of 5.7 ML/D.

To match the total annual NRW of 15.6% of the annual water usage, it appears that NRW use is higher in the summer period when irrigation systems are in use. This indicates that there may be unauthorized use on the irrigation system that does not pass through point-of-sale meters, or the irrigation meters are under-registering.

3.3 Forecast Water Demand

Best Practices for Water Demand Forecasting

Water demand forecasting methodologies broadly fall into two general categories:

1. End-use methods based on population and land use projections and adjustments to estimates of unit water demands.
2. Statistical methods that involve data collection and regression analysis to extrapolate historical trends.

End-use methods are generally more reliable for long-term forecasts (e.g., ten years or more) than statistical methods, and do not rely on complex software models or large quantities of historical data. For these reasons, an end-use approach that incorporates population and land use forecasting is used as the basis for the water use forecasting completed as part of the Study.

The Pacific Institute (Heberger, Donnelly, & Cooley, 2016) identifies eight best practices for developing urban water demand forecasts that avoid the potential pitfall of consistently overestimating future water demand. The eight best practices from the Pacific Institute guide, and features of a forecast that incorporate them, are as follows:

1. **Account for Water Conservation and Efficiency.** The primary cause of over-estimation of water demand in forecasts is failure to account for reductions in unit water demands that result from new construction that use fixtures and appliances that meet current codes and standards, as well as

retrofits of existing housing stock over time. The analysis includes separate parameters for the following:

a. Separate unit water demands in existing and new building stock.
b. Replacement rates for fixtures and appliances that gradually reduce unit water demands associated with existing building stock.
c. Demand reductions resulting from water conservation programs and metering.

2. **Account for Changes in Economic Activity.** Changes in population and land use that drive water demand are influenced by economic conditions for the community and its primary industries. Without specific information about the community and its economic context, foreseeable opportunities and risks, and economic plans, the potential for large errors in long-range water demand forecasts is high. The forecast mitigates this major source of potential error by tailoring growth rates to the community based on the planning department's forecasts and allowing for commercial and institutional growth to keep up in line with residential growth.

3. **Account for Changes in Water Price.** Customers typically respond to rising prices by decreasing consumption; however, no adjustments were made to account for water pricing for this forecast. In general, if a large increase in consumption charges for water or sewer service (relative to inflation) is expected to occur during the forecast timeframe, a reduction in the forecast should be considered.

4. **Check for Consistency with Other Relevant Planning Documents.** Water demand forecasts used for this plan incorporate growth forecasts that are consistent with other community plans, policies, and forecasts.

5. **Account for Expected Land Use Changes.** Gradual changes in land use patterns significantly impact water demands. A gradual shift in the mix of housing types from predominantly single-family homes toward smaller homes with less landscape area tends to occur in urban communities as they grow, resulting in a reduction in per capita demands. Additionally, the ICI area in the community is already developed and future ICI growth is accounted for by increasing the Floor Area Ratio (FAR) at existing ICI zoned properties. The forecast reflects realistic rates of change in the quantity and character of land use and building stock over the forecast period based on the best available information.

6. **Account for Climate Change and Drought.** Climate change may reduce the availability of water in some communities over time, necessitating increased efforts to conserve water and imposing constraints on water-intensive forms of development. Cycles of drought can have long-lasting impacts on water demands. In some regions, the longer, hotter summers predicted in climate models may increase water demands for irrigation and cooling systems. The forecast estimates current and future irrigation demands using an evapotranspiration (ET) calculation that includes adjustments for climate change for the RDNO region that was developed as part of the hydrological modelling (See Section 5.1)

7. **Account for Uncertainty.** Even with the best available data and tools specific to the subject community, forecasts of water demand beyond a decade into the future rely on many assumptions about what will happen, most of which are beyond the control of the local government. Future legal, economic, and technological changes cannot reliably be predicted, but can profoundly impact growth rates and efficiency of water use. The forecast incorporates margins of uncertainty on several inputs and assumptions used in developing demand forecasts, including rates of community growth, future climate parameters influencing irrigation demands, and unit water demands for all indoor uses of water. The combined margin of uncertainty resulting from these factors is reported and illustrated as part of the demand forecast.

8. **Ensure Transparency, Stakeholder Engagement, and Review.** The purpose of a water demand forecast must be clearly stated, and the methodology should be transparent and subject to independent expert and stakeholder review. This water forecast has been prepared and reviewed by a multidisciplinary team that includes expertise in water system engineering, community planning, water demand management, and irrigation.

Demand forecasts have been completed incorporating the best practices noted above with a general approach to develop an estimate of current water demand that is segmented based on base and seasonal water use in residential, industrial, commercial and institutional (ICI) sectors. The estimates are based on population for residential indoor demands, land areas and floor area ratios for ICI indoor demands, and land areas for irrigation, which is the majority of seasonal demand. In addition, non-revenue water is estimated separately using information about the water system such as lengths of watermains and services.

Unit rates for each segment of water demand are estimated and calibrated using recent historical demands for the corresponding sector. To obtain an estimate of future base (winter) demands, the resulting model of current water use is modified based on forecast changes in population and ICI sector total floor areas based on anticipated modes of growth, as well as changes in unit demands resulting from anticipated efficiency improvements. Future seasonal (primarily irrigation) demands are estimated based on estimated changes in both climate and the total areas of land irrigated, including changes in residential density and housing forms and changes to agricultural land area irrigated using GVW sources. The specifics for each segment of water use are described in the following sub-sections.

Residential Base Demand

The existing residential base demand is calibrated using the calculated existing per capita base water demand.

The primary drivers of changes to residential water demand are plumbing fixture and appliance efficiency and population growth. The population growth forecast provided by RDNO (from BC Stats) includes a separate projection for each of Vernon, Coldstream, and RDNO Unincorporated Areas for 2026 and 2046. These were used to calculate an annual average population growth rate for each community, which was extrapolated to 2056 and 2086:

- Vernon: 0.52%
- Coldstream: 0.86%
- RDNO Unincorporated Areas: 0.57%

These growth rates were varied by +/- 0.25% to yield low and high estimates of 2056 and 2086 population.

Based on the Residential End Uses of Water study by the Water Research Foundation,[5] newly constructed or renovated properties, with fixtures and appliances that reflect current averages and plumbing code requirements, are expected to use water at a rate of 140 L/cap/day on average. For this demand forecast it is assumed that all new construction will use water at this rate. In addition, it is expected that older water fixtures will be replaced at a regular interval, resulting in a gradual reduction of per capita demand in existing housing stock to 140 L/cap/day. A fixture replacement rate of 2.5% of fixtures being replaced each year, which results in all fixtures being replaced over a 40-year period, was used for this analysis.

[5] Water Research Foundation. (2016). *Residential End Uses for Water, Version 2*

Table 3-3: Future Base Residential Water Use Scenarios per Community

Community	Scenario	2056 Base Residential Water Use (ML)	2056 Population	2086 Base Residential Water Use (ML)	2086 Population
Vernon	Low	2,680	48,275	3,461	63,661
	Best Estimate	3,102	56,032	4,016	73,875
	High	3,588	64,986	4,659	85,697
Coldstream	Low	556	10,275	548	10,718
	Best Estimate	597	11,073	636	12,448
	High	641	11,931	739	14,452
RDNO	Low	255	4,664	239	4,667
	Best Estimate	274	5,027	277	5,422
	High	294	5,417	322	6,296
Total	**Low**	**3,491**	**63,215**	**4,247**	**79,047**
	Best Estimate	**3,972**	**72,132**	**4,930**	**91,745**
	High	**4,523**	**82,334**	**5,719**	**106,444**

ICI Base Demand

The existing ICI base demand is calibrated by assuming an existing water use intensity of ICI properties to be 1.57 m3 /m2/year for existing building stock. This comes from the 75% percentile of water use for a large range of ICI facilities included in the Water Research Foundation (WRF) study "Developing Water Use Metrics for the Commercial and Institutional Sectors"6. Using the assumed water use intensity and the total area zone for ICI use in each sector, an existing floor area ratio (FAR) was calibrated to match the total existing ICI base demand.

The primary drivers of changes to ICI water demand are plumbing fixture and appliance efficiency and ICI floor area growth. Although there is much wider variability in ICI water use than residential, on average trends in ICI water use intensity are similar to those of residential stock. This similarity results from the fact that ICI water use is largely driven by building occupancy by employees and customers, students, patients or other visitors, all of whom use washroom facilities. The water efficiencies of commercial kitchen, medical, laboratory and industrial process equipment have also improved over time similarly to plumbing fixtures and appliances.

ICI floor area was assumed to grow at 80% of the population growth rate. The majority of growth was assumed to occur in the form of densification of existing ICI land, which is modelled as an increase to the existing FAR. In the City of Vernon, an additional 17 ha of ICI land was added by the 2056 time-horizon to account for known developments including Anderson Way, 20 Street, Predator Ridge, and Lakeshore Road. The best estimate of ICI floor area growth was varied by +/- 0.25% growth to get a low and high estimates of future ICI floor area.

Based on Developing Water Use Metrics for the Commercial and Institutional Sectors study by the WRF, new water efficient fixtures in ICI applications are expected to use water at a rate of 1.21 m^3/m^2/year (the median of the 50th and 75th percentiles from the WRF study). It is assumed that all new ICI construction will use water at this new water efficient rate. In addition, it is expected that older

[6] Water Research Foundation. (2019). *Developing Water Use Metrics for the Commercial and Institutional Sectors*

water fixtures will be replaced at a regular interval. A fixture replacement rate of 2.0% of fixtures being replaced each year which results in all fixtures being replaced over a 50-year period. The forecast ICI demands for 2056 and 2086 for each community are included in Table 3-4.

Table 3-4: Forecast ICI Demands

Community	Scenario	2056 Base ICI Water Use (ML)	2086 Base ICI Water Use (ML)
Vernon	Low	979	996
	Best Estimate	1,029	1,084
	High	1,077	1,176
Coldstream	Low	72	67
	Best Estimate	76	74
	High	81	82
RDNO	Low	36	32
	Best Estimate	38	36
	High	40	40
Total	**Low**	**1,087**	**1,094**
	Best Estimate	**1,142**	**1,194**
	High	**1,198**	**1,298**

Community Seasonal Demand

The existing measured total seasonal water use in each sector was used to calibrate the total expected land area of each type in each community that is irrigated using typical lot sizes and the average evapotranspiration rate for the Vernon area.

The weekly pattern of seasonal use over the year was developed by averaging the total weekly water supplied over the past 5 years. This created an “average year” irrigation season which was applied to the existing water demand forecast to create a weekly water use pattern.

To estimate peak year demands the average seasonal water use was multiplied by a factor of 1.09 based on the ratio of the highest observed difference of metered seasonal use versus the average seasonal use in the last 5 years.

Seasonal water use is expected to increase with climate change and population growth; however, these changes are expected to be offset to a degree with densification expected with new developments.

The climate change scenarios developed as part of the total supply estimate work described in Section 5 were also used to also estimate the change to the length of the irrigation season. The forecast shift in timing for the start of the freshet was also used to shift the start of the irrigation season earlier in the year. The earlier start to irrigation results in more irrigation use over the entire irrigation season.

Table 3-5 describes the changes to the seasonal water demand due to climate change.

Table 3-5: Seasonal Water Demand Changes Resulting from Climate Change

Climate Change Scenario	Water Demand Forecast Scenario(s)	Timing Shift from Current (Weeks)
Current	Existing 2056 Low 2086 Low	NA
RCP 4.5 - 2050s	2056 Best Estimate	2
RCP 4.5 - 2080s	2086 Best Estimate	3
RCP 8.5 - 2050s	2056 High Estimate	3
RCP 8.5 - 2080s	2086 High Estimate	5

The other driver for seasonal water use increase is population growth and irrigation of new residential properties. Due to the limited space for growth, a lot of residential growth will be denser than existing residential areas leaving less space available for irrigation. To model the densification, new population has been added on new lots estimated to be half the size of the average exiting lots. In other words, it is assumed that the total land area of residential zones will grow at half the rate that population grows. The result of this assumption is that both residential land area and irrigated area per capita will decrease as population grows, contributing to a reduction in per capita seasonal demand and annual average demand. However, total irrigated area for residential lawns and gardens would continue to increase over time.

A summary of the modelled seasonal water demand change for each community in the 2056 and 2086 scenario is included in Table 3-6.

Table 3-6: Modelled Seasonal Water Demand Change per Community

Community	Scenario	2056 Seasonal Water Use (ML)	2086 Seasonal Water Use (ML)
Vernon	Low	1,647	1,723
	Best Estimate	1,969	2,274
	High	2,201	2,740
Coldstream	Low	649	658
	Best Estimate	763	828
	High	856	996
RDNO	Low	258	258
	Best Estimate	302	322
	High	337	384
Total	**Low**	**2,555**	**2,639**
	Best Estimate	**3,033**	**3,380**
	High	**3,394**	**4,021**

Agricultural Water Use

The forecast agricultural water use scenario forecast assumes a status quo agricultural scenario similar to existing conditions. No additional allowances were included for future agricultural crop changes or maximization of current water use allocations. The existing measured agricultural water use in each community is used to calibrate the total expected agricultural land area in each community that is irrigated using the total land area, typical crop type, and the average evapotranspiration rate for the Vernon area.

The weekly pattern of seasonal use developed for the community seasonal water use was used to estimate the weekly agricultural water use pattern.

To estimate peak year demands the average seasonal water use was multiplied by a factor of 1.09 based on the ratio of the highest observed difference of metered seasonal use versus the average seasonal use in the last 5 years.

The change in agricultural water demand is expected to be influenced by climate change. The same scenarios used to estimate other seasonal water use were applied to the agricultural water use which includes extending the growing season which is assumed to trigger a longer growing season allowed under the regulated turn-ons/shut-offs by GVW.

The total agricultural allocation used each year has varied approximately by +/- 5% in the past five years. For the future forecast horizons a 5.0% decrease in the allocated use (calculated prior to climate change factor was applied) was used for the low estimate scenario and 5% increase in the allocated usage for the high estimate scenario. The effect of this approach is that variation in the quantity of water used for agriculture in the past five years is used as a basis for estimating a range of variation in irrigated area in the forecast between the low and high scenarios. Water use per hectare irrigated will also increase over time as a result of climate change, primarily due to a longer season with warm, dry weather that results in greater annual total evapotranspiration and natural precipitation deficit during the growing season. A summary of the modelled agricultural water demand change for each community in the 2056 and 2086 scenario is included in Table 3-7. As noted above, all of these projections are based on the assumption that the land area irrigated does not significantly change from the range irrigated over the past five years. None of these projections accounts for irrigation of land that currently has unused irrigation allocation.

Table 3-7: Modelled Agricultural Water Demand Change per Community

Community	Scenario	2056 Agricultural Water Use (ML)	2086 Agricultural Water Use (ML)
Vernon	Low	505	505
	Best Estimate	623	648
	High	725	781
Coldstream	Low	3,936	3,936
	Best Estimate	4,857	5,052
	High	5,654	6,089
RDNO	Low	2,734	2,734
	Best Estimate	3,374	3,509
	High	3,927	4,229
Total	**Low**	**7,175**	**7,175**
	Best Estimate	**8,855**	**8,879**
	High	**10,306**	**10,362**

Non-Revenue Water

The existing NRW use is calibrated in two steps. First, the estimated winter NRW is calibrated by varying the infrastructure condition factor (ICF) which factors the unavoidable background leakage (UBL) calculated as a function of water system characteristics including pipe length, number and length of service connections, water system pressure, and meter accuracy. Secondly, the estimated agricultural metering accuracy is varied to account for the noted seasonal variation in NRW to match the annual 20.8% NRW value calculated as a function of overall water use.

Forecast changes in NRW are primarily driven by changes to the water system characteristics. Pipe length and number and length of service connections are expected to grow along with the growth in service area. The existing watermain length and service connections per ha of service area were applied to the new expected service area to account for densification. The total water loss correlates well with the level of maintenance and is not expected to vary considerably from current without significant intervention.

The base winter period NRW in the future is expected to range from 5.1 ML/D (low estimate), 6.0 (best estimate), to 7.0 MLD (high estimated) by 2056 and 5.3 ML/D (low estimate), 6.5 ML/D (best estimate), to 7.7 ML/D (high estimate) by 2086 while the total annual NRW is expected to equate to around 20.8% of total annual water use.

3.4 Forecast Water Demand Change Summary

The water demand for the entire GVW is expected to increase from the current peak year estimate of approximately 18,000 ML to a best estimate of 20,000 ML by 2056 (10% increase from existing) and 22,000 ML by 2086 (21% increase from existing). The low and high forecast scenarios range from -4% and +26% of existing (between 19,000 and 24,000 ML) by 2056, and 0% and +48% from existing (between 19,000 ML and 29,000 ML) by 2086.

Figure 3-3 shows the various demand forecast scenarios graphically and disaggregates the overall water use in the end uses.

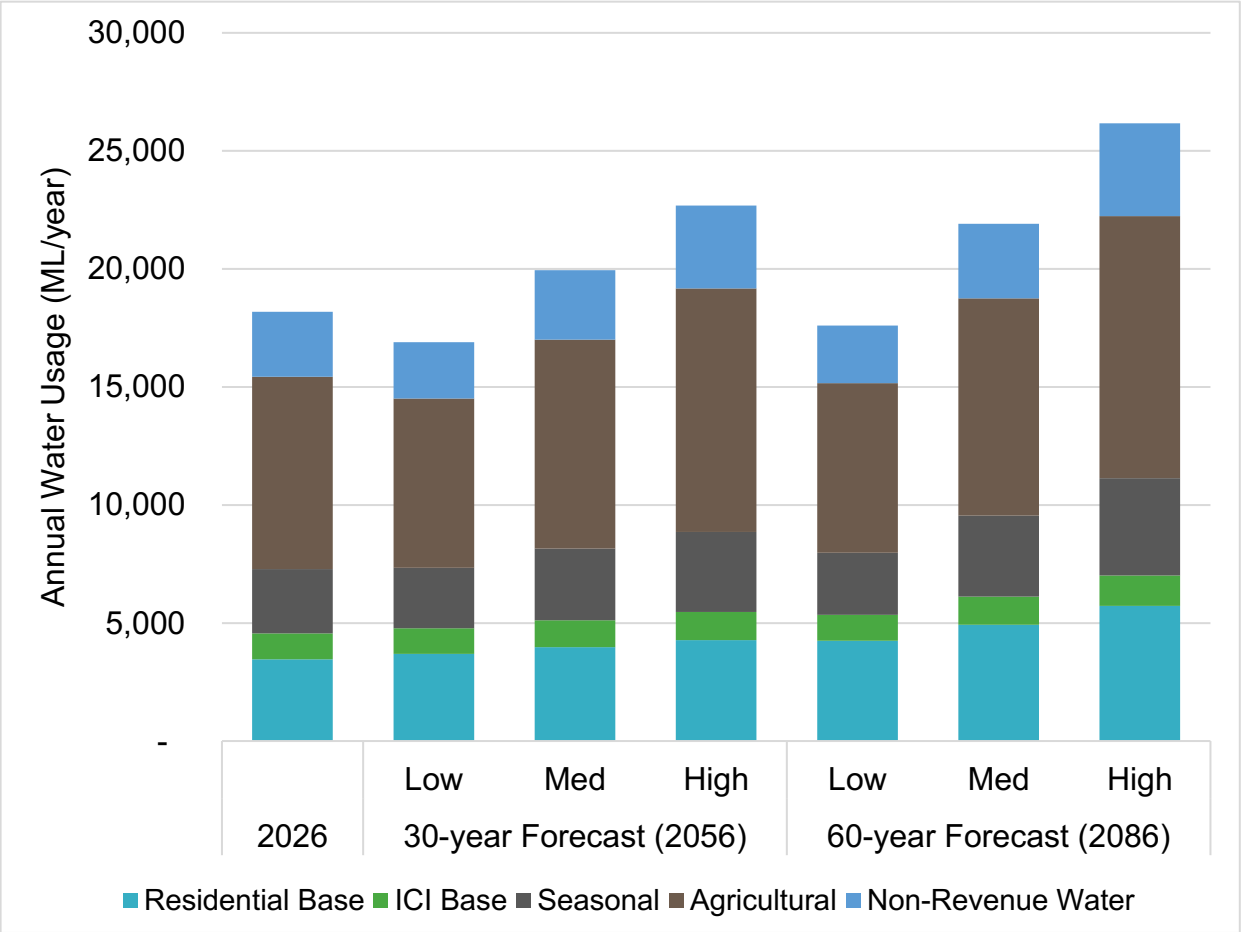


Figure 3-3: Annual Demand Forecast Scenarios

3.5 Target Water Use Reduction under Stage 3 Restrictions

Under drought conditions GVW has a water use restriction program in Bylaw 3089 that targets a 50% reduction to seasonal water use. Achieving the targeted 50% reduction to seasonal water use would result in the following water savings under each scenario.

Table 3-8: Target Water Savings under Stage 3 Watering Restrictions

Scenario	Existing Target Water Savings under Stage 3 Restrictions (ML)	2056 Target Water Savings under Stage 3 Restrictions (ML)	2086 Target Water Savings under Stage 3 Restrictions (ML)
Low	5,433	4,865	4,907
Best Estimate		5,944	6,316
High		6,850	7,609

4. Water Conservation Opportunities

This section provides a high-level review of water conservation opportunities with good potential for the GVW based on the foregoing analysis of historical and forecast demands.

4.1 Non-Revenue Water

Non-revenue water includes distribution system leakage, uses of water for system maintenance such as flushing and hydrant testing, hydrant use for fire protection, unauthorized uses of water including theft, and measurement errors. While some elements of non-revenue water are essential and cannot practically be reduced, the two typically largest components, distribution leakage and measurement errors, can often be significantly reduced over time through prioritized asset renewal in combination with proactive maintenance and repairs.

Real losses (primarily supply and distribution system leakage) are likely higher in the GVS system than in some other water systems of similar size in BC due to the original development of parts of the system as irrigation supplies that were not constructed to municipal standards. Monitoring real losses over time in these parts of the system through regular AWWA M36 audits including district metered area (DMA) night flow analysis can help to prioritize repairs and renewal of areas of the system that have high real losses.

Nearly half of non-revenue water in the GVW (ranging from 1.6-6.5 ML/year) is seasonal, meaning that it only occurs during the irrigation season, which strongly indicates that it is not distribution leakage. The two most likely causes of this NRW are meters used for irrigation that substantially under-register flow (generally old, worn mechanical meters) and unauthorized, unmetered connections used for irrigation (theft). A third possibility is that some parts of the GVW non-potable system are only pressurized during the irrigation season and have high leakage.

It is recommended to investigate non-revenue water during summer, including minimum overnight flow analysis and a comparison of supply.

4.2 Agricultural Water Use

GVW is moving towards consumption rates for agricultural water users which may affect how water is used. The current billing structure for agricultural water use is a flat fee up to the user allocation total with overage charges for any use over their allocation.

This study assumes a status quo agricultural scenario (no change in total area actually irrigated relative to the past five years) with a longer growing season expected with climate change. Future agricultural water use may change significantly in the future. For example, there may be crop changes based on market pressures shift, such as shifting to additional tree fruit crops, or additional agricultural water use because of farmers maximize their current water use allocations.

Water available for agricultural users is also restricted under the Bylaw 3089 which under stage 3 watering restrictions reduce the allocation per hectare by 70%. For years where water use restrictions are escalated to stage 3 the total Agricultural water use would theoretically be restricted to 7000 ML for the season; however, the intent of the requirement to reduce consumption per hectare by 70% is to ensure that the overall 50% reduction target is achieved. This policy places a considerably higher burden on producers that rely on GVW irrigation for their livelihood than on homeowners and businesses that use water outdoors for irrigating aesthetic gardens and topping up swimming pools.

Further study on the effects of various agricultural water use scenarios, water use restrictions, and potential changes to the billing structure to the existing and forecast water use is recommended as a follow up to this study.

4.3 Rate Adjustments

RDNO currently uses an inclining block rate structure that largely aligns with water efficiency best practice; however, the consumption charges across all three residential tiers are relatively low, the fixed charges are relatively high, and the tier thresholds are relatively generous based on current water use patterns. At the GVW current average single-family residential base demand of less than 160 L/c/d, a family of three would pay an average winter water bill based almost entirely in the bottom tier at $\$1.04/m^3$, with total consumption charges less than $50 per quarter.

The stated rationale for fixed charges in the RDNO's online Q&A is that most of the costs of water service do not vary based on consumption, which is accurate. However, consumption charges that are routinely adjusted to reflect current costs of service, in combination with the use of reserve funds to balance year-to-year weather-based variations in demand, effectively manage revenue risks. Reducing fixed charges increases price incentives to conserve water and improves affordability for lower-income households that also tend to use less water than more affluent customers. When the marginal costs of developing new sources of supply are considered, those water service costs are closely aligned with consumption.

We understand that the current GVW rate structure is the result of a long process of analysis and broad community engagement, and that significant changes to the rate structure in the short term are undesirable. For these reasons, a full cost of service analysis and rate review is not recommended at this time. However, minor and gradual adjustments over time to proportionally increase rates and decrease tier thresholds for high consumption while decreasing fixed quarterly charges (e.g. holding them constant as overall consumer prices increase) would fully align GVW rates with best practices for water demand management and provide a stronger foundation for future conservation programs.

It is recommended that RDNO consider minor and gradual amendments to residential water rates over time, including a modest reduction in the fixed quarterly charge and in the tier 2 and 3 thresholds, and the potential addition of a fourth tier with a much higher consumption charge for single-family (or SSMUH) properties using more than 100 cubic metres per quarter.

4.4 Industrial, Commercial and Institutional Efficiency Measures

The RDNO has well-established programs and communications for residential water efficiency, although a review of online program information does not indicate programs are offered for non-residential customers. Well-designed, targeted industrial, commercial and institutional (ICI) programs can very effectively target substantial water savings with relatively low program effort. Effective programs include targeting of accounts with high annual total or seasonal water use, including high normalized use based on information about the size of operation (e.g. floor area, number of employees, hotel beds, restaurant seats, or land area for seasonal demand). Customer contacts, including a standardized walk-through assessment of potential efficiency opportunities (facility water use assessment or water audit), are typically coupled with a flexible incentive program based on cost-effective opportunities to improve water efficiency.

The unusually high seasonal water demand associated with ICI customer accounts in the GVW service area suggests good potential for water efficiency gains among non-residential accounts.

It is recommended that RDNO consider adding dedicated industrial, commercial and institutional demand management programs, including targeted promotion of free facility free water use assessments and flexible incentives (capacity buy-back) based on clear eligibility thresholds.

5. Water Supply System Capacity

5.1 Source Watersheds

The existing capacity of the source watersheds is analysed based on drought condition inflows and is presented in Section 6. The future capacity of the watersheds is estimated based on impacts resulting from climate change, as described in this section.

Climate Change Impacts

In the most recent Assessment Report 6 (AR6), the International Panel on Climate Change (IPCC) has stated that global climate records and modelling indicate warming of the global climate system is unequivocal[7]. Evidence of the warming can be found in increased observed temperatures, widespread melting of snow and ice, and increased sea levels. A review of future climate projections for the region has been performed to better understand impacts to water supply and options for adaptation to these changes in the study area. Climate change impacts on the water system were assessed over three 30-year time periods:

- A 2020s time horizon representing from 2011 to 2040
- A 2050s time horizon representing from 2041 to 2070
- A 2080s time horizon representing from 2071 to 2100

Regional Projected Climate Change

Climate projections completed for the Okanagan Region in 2020[8] indicate that for the RDNO:

- Warmer temperatures can be expected year-round with considerably hotter summers with the number of days above 30 ˚C increasing from an average of 6 days in the past (1971 to 2000) to an average of 16 days above 30 ˚C by the 2050s and an average of 31 days over 30 ˚C by the 2080s.
- The increased summer temperatures will increase the growing season length. Under past climate conditions, the growing season in the valley bottom was approximately 7.5 months and is projected to increase to 9 months by the 2050s and to 10 months by the 2080s.
- Decreased summer precipitation is expected to increase dry periods. Summer precipitation is expected to be 23% less by the 2080s.
- Winter temperatures are projected to increase, thereby reducing the number of days below freezing with an average of 80 days below freezing under past climate conditions, 50 days below freezing on average by the 2050s and 33 days below freezing on average by the 2080s. These are average values across the entire region, including the higher elevation areas.
- With warmer winter temperatures, the winter season is expected to be shorter with less snowfall with an earlier warming and spring snowmelt period, moving spring runoff earlier in the year.

[7] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change IPCC, Geneva, Switzerland, 184 pp.

[8] Climate Projections for the Okanagan Region, February 2020, Regional District North Okanagan, Regional District of Central Okanagan, Okanagan Similkameen and Pinna Sustainability.

Although the current RDNO agricultural season is 6 months (April 15 to September 15), controlled by GVW water supply turn-ons/offs, in general the combination of longer growing season and less precipitation is expected to both increase seasonal irrigation demand while at the same time reducing flow in the Duteau Creek watershed during the summer period. Therefore, under future climate conditions, community water demand is expected to increase while summer water availability in the Duteau Creek watershed is expected to decrease, thus increasing reliance on storage to support both EFN and community water withdrawal.

5.2 Reservoirs

Refer to Table 2-1 for a summary of existing physical and licensed capacities of the GVW reservoirs.

5.3 Water Treatment Capacity

The system Water Treatment Capacity is met by the Duteau Creek Water Treatment Plant (DCWTP) with a design capacity of 142 ML/D and the Mission Hill Water Treatment Plant (MHWTP) with an operational capacity of 42 ML/D.

6. Water Supply Assessment

This section describes the modelling approach to assessing the current and future water supply and summarizes the results of the model.

6.1 Water Balance

Previous analysis completed in 2013 used regional low flow regression curves (annual runoff vs median elevation) to estimate annual volumes for the Duteau Creek watershed. However, as these curves were developed using recorded discharges this approach cannot be used to evaluate how future changes in water supply and water demand resulting from climate change impact required storage volumes.

To evaluate change in required water storage, a Water Balance for the Duteau Creek Reservoir Complex was carried out using a mass balance approach where the difference between inflow and outflow volume in the watershed is equal to the change in storage volume over a specific time interval.

For the purposes of the analysis, the watershed was divided into two sub watersheds (see Figure 2-2): the Upper Duteau Creek watershed (or Haddo Reservoir Dam watershed, upstream of Haddo Reservoir) and the Lower Duteau Creek watershed (or Headgates Intake watershed, upstream of the Headgates Dam) and a weekly timestep was used. Although daily data were available, a weekly timestep serves the purpose of smoothing out short term noise in daily supply and demand data (variability, random fluctuations in data, measurement errors, day-of-week effects, etc.), which help make underlying trends easier to pick out and model as well as reduces the sensitivity of the model to timing assumptions.

The inflows used in the analysis include the natural runoff from the upper watershed, the lower watershed and the Gold-Paradise diversion flow. Outflows include the community and agricultural non-potable withdrawals at Headgates Reservoir, the EFN release into Duteau Ck below Headgates Dam and the uncontrolled spillway flow at Headgates Dam.

The first step of the Water Balance is to assess whether the unregulated lower Duteau Creek flow is sufficient to supply community and non-potable withdrawal and the EFN target or if releases from Haddo Reservoir are required to supplement the lower Duteau Creek flows to support the withdrawals and the target EFN flows, such that:

(If lower Duteau Creek flow > Withdrawals + Target EFN then Haddo Release = 0 else Haddo Release = Withdrawals + Target – Lower Duteau Creek Flow)

Then the second step of the Water Balance is carried out for the upper Duteau watershed such that:

(Natural Inflow + Gold Paradise Diversion) – (Haddo Reservoir Release) = Combined change in storage at Grizzly Reservoir, Aberdeen Reservoir and Haddo Reservoir

As per previous analysis, the Gold-Paradise Diversion is approximately 22% of the total recorded flow in Heart Creek. For the purposes of this initial analysis, the total diversion flow under normal conditions is assumed to be the same as what has been diverted previously. For drought conditions, the total available flow for Gold-Paradise diversion is used up to the previously calculated total (22% of Heart Creek flow).

The Water Balance has been carried out over a two-year period with an average year, to establish starting reservoir level, followed by the selected drought year conditions for the second year of the analysis. The study did not explore consecutive drought year scenarios, which are a potential reality for the system. Due to the lack of available data required to quantify how year over year drought conditions

are expected to change into the future and the limitation of the project scope and timeline the detailed analysis required to carry out long term simulation modelling to capture year over year drought analysis under climate change conditions where not carried out in this preliminary study.

The analysis assumes there are no hydraulic constraints such that flow required to be released to meet demands can be achieved across the full range of reservoir levels in Aberdeen Reservoir, Grizzly Reservoir and Haddo Reservoir as well as through the Gold-Paradise Diversion.

During operation of the reservoirs within the Duteau Creek Reservoir Complex, flow releases are not continuously adjusted to meet EFN and community water supply needs. The time lag for the flow to travel from Haddo Reservoir to Headgates Dam raw water intake as well as balancing storage between Aberdeen, Grizzly and Haddo Reservoirs makes it challenging to exactly match releases to meet EFN targets and community withdrawals. The flow releases at the dams are adjusted incrementally based on the operators' judgement, past experience and precautionary approach given to maintain downstream flows near the EFN target and support variations in water withdrawals at Headgates to supply community and non-potable water needs.

These operational limitations result that on average a higher volume of flow is usually released from the Duteau Creek Reservoir Complex dams than what the Water Balance calculates assuming exact operation. Therefore, an operational allowance of 15% of the weekly community withdrawal volume and EFN volume was added to account for the operational limitation. The magnitude of the operational allowance was confirmed by comparing the recorded flow downstream of Headgates Dam (EFN release plus Headgates spillway flow) to the total spill + EFN volume (Lower Duteau Inflow and Haddo Releases minus community and non-potable withdrawals) calculated in the Water Balance for the average year assuming perfect operation. The magnitude of the operational allowance was adjusted until the modelled total flow outflow closely matched the recorded.

6.2 Drought Condition Inflows

Natural inflows to the Duteau Creek watershed have been calculated by back calculating inflow using the Water Balance with recorded outflows including withdrawals and recorded discharge in Duteau Creek downstream of Headgates Dam (which includes both EFN and spillway flow) and total change in storage in Aberdeen Reservoir, Grizzly Reservoir, and Haddo Reservoir. This analysis was used to calculate the total annual inflow volume and was validated using available RDNO hydrometric data. The records available allowed for calculation of the total annual natural flow in Duteau Creek watershed upstream of Headgates Dam for the period from 2016 to 2025. The back calculated annual inflow ranges from 19,500 ML to 82,700 ML with an average of 45,500 ML.

A Log Pearson Type 3 extreme value distribution was fit to the annual total water year (Jan 1 to Dec 31) volumes to estimate annual volumes for various drought return periods. The results are shown in Table 6-1, with a copy of the distribution fitting results attached in Appendix B. The total volumes estimated for Duteau Creek from the 2013 study, which were based on regional drought curves prepared as part of Phase 2 of the (Summit 2009), are included for comparison with the values updated for the current study. Generally, the updated volumes are smaller than the previous estimates by between 15% to 20%. The lower values estimated for the current study reflect results based on records from the watershed rather than regional estimates and include the influence of the low flow winter of 2023/2024. Additionally, the estimates are based on 10-year of recorded data, which is less than typical 30 years of record recommended, as the shorter period of record may not include the effect of longer term climate cycles such as the El-Nino Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO). Despite this, it is our opinion that the estimates based on the recorded values for Duteau Creek provide good indication of the annual volume available under drought conditions for the purposes of initial planning.

As Curtis Creek had the most complete hydrometric record of those stations monitoring inflows into Aberdeen Reservoir, the weekly distribution of the calculated annual inflow volume was developed using recorded flows on Curtis Creek). Figure 6-1 shows a hydrograph of the weekly distribution of flow compared to the recorded weekly distributions.

The total watershed annual volume was then split between the upper and lower watersheds using the same unit runoff ratio, volume divided by watershed area, as those calculated in the 2012 study. This indicates that on average about 62.5% of the total watershed volume flows from the upper watershed while about 37.5% flows from the lower watershed. Using the same approach, the total annual flow volume available for the Gold-Paradise diversion is estimated to be about 10% of the total Duteau Creek volume.

Table 6-1: Total Annual Runoff Volumes for Duteau Watershed

Annual Flow Condition	Total Runoff Volume (ML)					
	Headgates Intervening Watershed		Upper Duteau Watershed		Total Watershed	
	2026 Estimate	2013 Estimate	2026 Estimate	2013 Estimate	2026 Estimate	2013 Estimate
Average	17,100	17,340	28,400	33,618	45,500	50,958
1:10 Year Drought	8,100	9,936	13,600	19,162	21,700	29,097
1:20 Year Drought	6,700	Not available	11,200	Not available	17,900	Not available
1:50 Year Drought	5,400	6,416	8,900	12,439	14,300	18,555

Notes:
Values rounded to nearest 100 ML.
2026 estimate for Duteau Creek Watershed upstream of Headgates Dam (Watershed Area 171 km^2) and 2013 estimate for Duteau Creek Watershed upstream of Haddo Dam (Watershed Area 100.9 km^2).

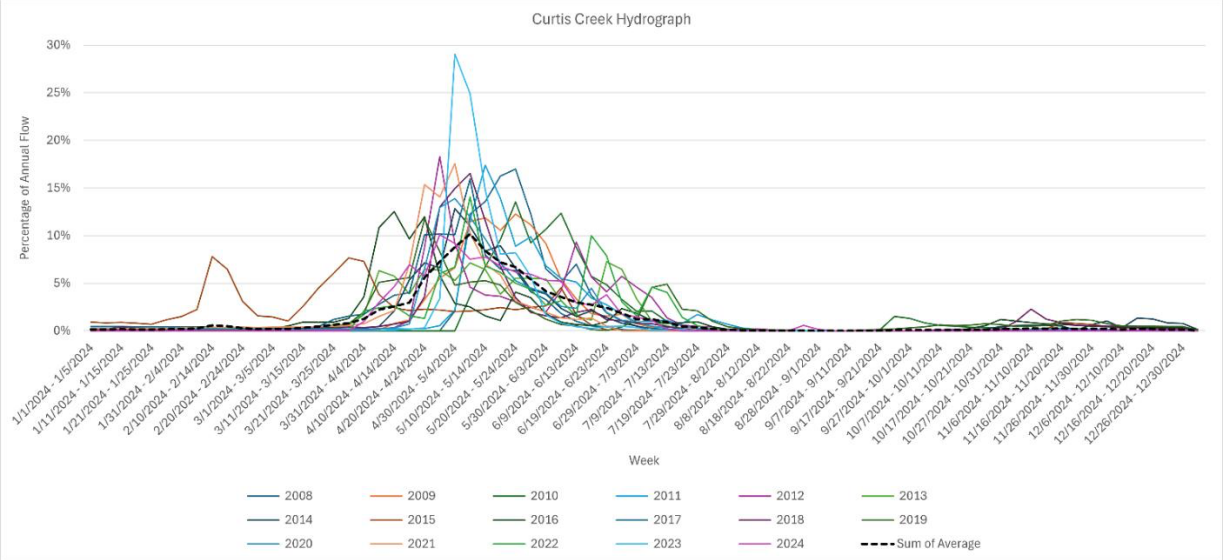


Figure 6-1: Curtis Creek Hydrograph, Recorded Weekly Flows

6.3 Water Balance Scenarios

Water Balance scenarios representing current conditions and future conditions were developed to assess Duteau Creek system. A summary of the key assumptions used in the analysis are included in Table 6-2.

Table 6-2: Summary of Water Balance Scenario Assumptions

Scenario	Inflow Distribution[1]	Community and Non-Potable Withdrawals[2]
Existing	Based on records from past 10 years	Average recorded withdrawals for normal year (first year) + modelled current drought demands (second year)
2050s Medium (Best) Projection	Adjusted to weekly distribution for RCP 4.5 for 2050s	Medium (Best) Projection for 2050s
2050s High Projection	Adjusted to weekly distribution for RCP 8.5 for 2050s	High Projection for 2050s
2080s Medium (Best) Projection	Adjusted to weekly distribution for RCP 4.5 for 2050s	Medium (Best) Projection for 2080s
2080s High Projection	Adjusted to weekly distribution for RCP 8.5 for 2050s	High Projection for 2080s

Notes:
1. Total annual flow under current and future climate conditions assumed to remain constant into the future with only the weekly distribution changing.
2. Community and non-potable withdrawals are based on modelled volumes discussed in more detail in Section 3.3.
3. All scenarios are based on existing available storage and system operation.

As discussed previously, the simulation has been carried out over a two-year period with average conditions followed by the selected drought conditions. For each of the scenarios, the EFN volume has been set to the recommended EFN flows for the average year while the minimum EFN flow rates required by the water licence have been used for the drought year. The purpose of this was to allow the simulation to reproduce the observed average conditions under current climate conditions. Then the simulation could then be used to project how both average and drought conditions changed for future runs based on changes in timing of inflow volume into the reservoirs.

6.4 Existing Scenario

The Water Balance model was run for the 1:10, 1:20, and 1:50 Year drought scenarios using the modeled existing withdrawals for Duteau Creek (combined Duteau WTP and non-potable flows and EFN).

The maximum storage deficit for each model run is presented in Table 6-3. This indicates the amount of additional storage that would be required to support withdrawals and EFN over the summer drawdown and over-winter storage seasons, assuming a drought year follows an average year as discussed previously.

The findings suggest that the Duteau Creek Reservoir Complex is fairly tolerant to drought condition for the existing scenario. For example, for the 1:10 Year and 1:20 Year droughts that follow an average year, the model results indicate that the system does not experience deficit and for the 1:50 Year drought following an average year, the system is minorly stressed with a modelled storage deficit of 140 ML, meaning the modelled supply is short of the modelled demand by approximately 140 ML (approximately 1% of the available storage). The model indicates the reservoir goes into this deficit in late-February following the drought year and begins to recharge from the deficit in late March. For the purposes of this study, the model timing does not extend past the beginning of the recharge (i.e., extending the model run to explore the timing of the supply recovery has not been completed at this time).

Table 6-3: Current Annual Storage Deficit Summary

Annual Flow Condition	Existing Demand Scenario	
	Max Annual Deficit (ML)	Deficit in Excess of Existing Storge (ML)
1:10 Year Drought	10,700	0
1:20 Year Drought	12,800	0
1:50 Year Drought	14,400	140

Notes:
1. Values rounded to nearest 100 ML.
2. Demand includes 15% operational allowance on withdrawals (community, agricultural, EFN).

6.5 Future Scenarios

The demand forecast model estimates the future total annual demand for the GVW for the 2050s and 2080s with a medium ("Best") demand projection scenario and a high demand projection scenario. See Section 3 for the description of the modelled demand forecasts. The Water Balance model was run for the 1:10, 1:20, and 1:50 Year drought scenarios using the "Best" future demand forecast combined with the RCP4.5 Climate Change Scenario and the high build out demand forecast combined with the RCP8.5 Climate Change Scenario.

The maximum reservoir deficit for each model run is presented in Table 6-4 for the 2080. The existing supply system is found to be reliable for the 1:10 Year drought scenarios under RCP 4.5 climate change projections for both the 2050s and the 2080s but is not reliable in any of the other scenarios. For the scenarios that result in a supply deficit, additional water supply must come from alternate sources to meet future demands or demands must be reduced (or both).

Table 6-4: Projected Annual Supply Deficit Summary (ML)

Annual Flow Condition	Future Demand Scenario (ML)			
	Best Demand Forecast		High Demand Forecast	
	RCP 4.5 Climate Projection		RCP 8.5 Climate Projection	
	Max Annual Deficit	Deficit in Excess of Existing, Usable Storge	Max Annual Deficit	Deficit in Excess of Existing, Usable Storge
2050s				
1:10 Year Drought	12,000	0	14,500	240
1:20 Year Drought	15,300	1,040	18,500	4,240
1:50 Year Drought	17,000	2,740	20,400	6,140
2080s				
1:10 Year Drought	13,500	0	19,500	5,240
1:20 Year Drought	17,500	3,240	23,400	9,140
1:50 Year Drought	19,300	5,040	25,700	11,440

Notes:
1. Values rounded to nearest 100 ML.
2. Based on minimum operational reserve volume of 4,640 ML.
3. RCP 4.5 is representative of moderate future GHG emissions; RCP 8.5 is representative of high GHG emissions.

The results of the projected storage deficit analysis indicate for 1:50 year drought conditions that by the 2050s, between 2,700 ML to 6,140 ML of additional supply is estimated to be required to support the best and high projected water demands, respectively. By the 2080s, between 5,040 ML to 11,440 ML is estimated to be required under 1:50-year drought conditions to support the best and high projected water demands, respectively.

Although sufficient supply is available to refill required storage volumes in an average year. A review of recent records, discussed in Section 2, indicates that during periods of year over year drought, there may not be sufficient inflow to refill storage volumes and as such increasing both storage and overall water supply volumes may be necessary to support projected future demands. Therefore, additional analysis beyond the scope of this assessment is needed to determine the impacts of year over year drought on water supplies.

It should be also be noted that the water balance analysis assumes that required minimum EFN rates are released during drought conditions. However, given that recommended EFN volumes for normal years can be up to four times higher than required minimum flows, the reliability of storage to support community and agricultural withdrawals as well as EFN is sensitive to the assumed EFN rate.

Finally, future water demand rates used in the analysis are based on current agricultural irrigation demand and not on full allocation. Under full allocation, approximately an additional 10,000 ML of water would be required to support irrigation demand.

6.6 King Edward Lake/Deer Creek

Previous analysis completed in 2013 identified that King Edward Lake and Deer Creek have a limited supply due to the relatively small size of the watershed at 20.3 km2 and a licenced reservoir volume of 1,357 ML. Estimates of annual runoff volume are shown in Table 6-5. The annual runoff volumes are based on regional analysis results carried out in the 2013 study and are based on runoff vs elevation relationship developed as part of the OWSDP.

Table 6-5: King Edward Lake/Deer Creek Annual Water Supply (ML)

Average Year	1:10-year Drought	1:50-year Drought
5,900	3,300	2,200

King Edward Lake/Dear Creek supplies water for non-potable use and is primarily used during the irrigation season between April to September. Current water withdrawals at the Deer Creek intake are estimated to be 684 ML and 790 ML for average year and drought year, respectively. By the 2050s, demands during drought conditions are forecast to increase to between 880 ML to 980 ML for medium (best) estimate and high estimate, respectively. Demands are forecast to continue increasing with forecast demands for drought conditions of between 1,000 ML and 1,180 ML by the 2080s. This indicates that existing King Edward Lake and Deer Creek are likely to continue to supply future water demands but with very limited margin for any additional supply.

7. Supply Supplementation Opportunities

The water balance analysis discussed in Section 6 identified a shortage of available storage to support future demands. The following section outlines supplemental storage opportunities that could be implemented to support demands.

Although the water balance indicates that additional storage is necessary to support demands, a review of recent records shows that there may also not be sufficient inflow during year over year drought conditions to refill storage. Year over year drought analysis is beyond the scope of this assessment and will be required to identify supplemental water sources Therefore, only surface water storage opportunities within the existing source watersheds are discussed below.

7.1 Previous Analysis

Previous analysis completed as part of the 2012 MWP efforts included a comprehensive analysis of potential storage options and identified several potential supplemental storage locations [9] including:

- Upgrades to Aberdeen Dam
- Extension of Gold-Paradise Diversion
- Kalamalka Lake Intake
- Incorporation of MacKay Reservoir
- Expansion of Goose Lake
- Lower Duteau Creek Dam
- Flyfish Diversion
- Grey Line – BX Creek
- Swan Lake
- Greenhow Diversion – BX Creek
- Okanagan Lake

Of these options, Aberdeen Reservoir Upgrades, Gold-Paradise Diversion, MacKay Reservoir, Goose Lake Expansion, Lower Duteau Creek Dam and Okanagan Lake were considered to have good to fair water storage opportunities and construction potential.

Therefore, these options were selected for re-evaluation in the following section considering the updated Water Balance results and discussed below.

[9] GVW 2023 Master Water Plan – Technical Memorandum No. 3: Source Storage and Supply. February 2013. AECOM, Associated Engineering, and Kerr Wood Leidal Associates Ltd.

7.2 Raising Aberdeen Dam

Additional storage gained by raising Aberdeen Dam was considered to supplement supply. The Water Balance analysis indicates that approximately 14,500 ML of additional water is available for storage during average year conditions with no additional water available during drought years. This is approximately equivalent to raising Aberdeen Dam by 4 metres. However, this assumes that Aberdeen Reservoir could be supplied from both the Gold-Paradise Diversion as well as from Grizzly Reservoir with higher reservoir levels.

Therefore, this may be a promising option to supply a portion of the projected water supply demand. However, given that the Water Balance indicates that refill would not be possible during drought conditions a more detailed multi-year drought analysis under current and future climate conditions will need to be carried out to confirm if raising Aberdeen Reservoir could result in multi-year storage compared to the current seasonal storage in the current system. In addition, water licencing currently allows storage on an annual basis and opportunities for multi-year storage would need to be discussed with the Ministry of Water, Land and Resource Stewardship.

7.3 Kalamalka Lake Intake

A water licencing plan carried out by the Province in 2001 has concluded that Kalamalka Lake is fully allocated and no additional water licencing can be supported. As previously discussed, the province has established an EFN target of 0.085 m^3/s (7.4 ML/day or 2,700 ML/year) for Lower Vernon Creek below Kalamalka Lake. If additional water is made available from Kalamalka Lake in future, the water licences, including any that GVW might be privy to receiving through a transfer or gain if hydrology changed favourably for creek flows, would first be held to meet an EFN of 0.235 m^3/s (20.3 ML/day or 7,400 ML/year) for Lower Vernon Creek. Given these limitations, no additional supply, beyond the current water licence amount of 8,840 ML is assumed to be available from Kalamalka Lake. The water demand analysis has incorporated this limitation into the analysis.

7.4 Gold-Paradise Diversion

The Gold-Paradise Diversion (GPD) has typically been opened mid-May. According to its licence, it could be opened as much as 6 weeks earlier. Presently this is not an opportunity, as for most years the diversion gate is frozen shut until it is opened in May. However, as climate change is expected to shift precipitation events and increasing temperatures to earlier in the season, leading to the potential for the gate to be opened early and also for snow melt to occur earlier in the year, this could present an opportunity for the RDNO to divert water earlier and increase the refill potential of the Duteau Creek Reservoir Complex. Further, more detailed analysis is required to assess the viability of this option.

The RDNO currently holds a licence to divert 9,864 ML from the Gold-Paradise Diversion. According to the GPD records (2018 to 2024) 326 ML to 2,466 ML has been diverted annually, though some of the annual records appear to be missing data. For comparison, the RDNO estimates that the average seasonal volume of water diverted makes up 22% of the total volume recorded at the Heart Creek hydrometric station. In applying this assumption to the Heart Creek data, the existing annual volume diverted appears to range from 663 ML to 2,855 ML.

Previous estimates from 2013 indicate that available annual supply for the Gold-Paradise diversion is estimated to be about 4,600 ML, 2,600 ML and 1,700 ML for average, 1:10-year drought and 1:50 year drought conditions, respectively. This indicates that there may be potential to divert additional flow into Aberdeen Reservoir, which could supply expanded storage capacity as discussed above.

However, due to the inter-basin transfer of water in the Duteau System, and because the BC Water Sustainability Act has a ban on inter-basin transfers, securing additional flow from Gold-Paradise Diversion will require further discussions with MWLRS.

7.5 MacKay Reservoir

MacKay Reservoir is owned and operated by the City of Vernon as a storage facility for treated wastewater effluent, a source that is likely to continually increase as population increases. The reservoir has a storage capacity of 9,374 ML.

Although an option, there are several barriers that would need to be overcome. Currently there is insufficient civil infrastructure in place to move the reclaimed water from the reservoir to where the most agriculture is located. In addition, wastewater effluent is small relative to consumptive demands for irrigation. Therefore, this source is likely to have limited benefit except to potentially provide alternative seasonal low-flow season source. Further, there is a market barrier with farmers who do not want to use reclaimed water on their cash crops as they report it would impact their potential marketability.

7.6 Okanagan Lake

Okanagan Lake could provide additional supply to the RDNO water system. As it is understood that new water licences are not available on Okanagan Lake, this could be achieved through the transfer of licences from within the Okanagan Watershed such as the licences for BX Creek, Coldstream Creek and others. As indicated in the water licence summary, up to 9,600 ML is currently licenced for GVW to withdrawal from BX Creek and Coldstream Creek. Transferring these licences to Okanagan Lake is certainly feasible. However, the licences would require amendment, which may result in a change in the precedence date of the licences, as well as further analysis (e.g., via a Water Balance) to confirm if the system could support the proposed changes.

The water licences held by RDNO on BX Creek are important to the overall water supply strategy as the RDNO has plans to amend the existing BX Creek licences and move the points of diversion to be instead withdrawn directly from Okanagan Lake (Canoe Bay Pump Station). This strategy has previously been employed and is intended to be employed for the RDNO water licences that yet remain. It is understood about half the licences on BX Creek have already been transferred.

Any new intake on Okanagan Lake would have the following considerations:

1. Additional distribution infrastructure to transfer water from Okanagan Lake to the GVW.
2. Operational Costs associated with pumping.
3. Potential impacts of zebra mussels on intake infrastructure.

The option for near surface groundwater extraction (such as horizontal wells) may also be possible but further analysis of this option will be required.

7.7 Goose Lake Storage

Additional storage could be developed at Goose Lake to support seasonal irrigation demand. Raising Goose Lake dam and increasing capacity could improve flexibility for operations of the irrigation supply. However, the additional storage would have to be supplied from other sources due to its limited watershed. Some options were previously identified including:

1. Diverting water from existing sources (Duteau Creek and Kalamalka Lake Intake) during periods of lower demand to refill Goose Lake reservoir.
2. Diverting water from BX Creek, thus reducing demand to some degree on the Duteau Creek system. This would require a dedicated non-potable pipeline and pump station from BX Creek to Goose Lake Reservoir.
3. Filling from Okanagan Lake may also be possible.

Further assessment of the ability of these sources to fill Goose Lake storage will be required.

In the future, the RDNO has plans to fill Goose Lake with water from Okanagan Lake via the Canoe Bay Pump Station (Option 3). Option 3 could be further supported by transferring the remaining BX Creek licenses to Okanagan Lake, as discussed in Section 7.6; it is understood that the Canoe Bay Pump Station would be able to add storage water to Goose Lake in the future, following the completion of system improvements.

Goose Lake is in part filled by water generated in the watershed below Haddo (i.e., Lower Duteau Creek watershed or Headgates watershed), separate from the watersheds supplying the Duteau Creek Reservoir Complex). As such, switching to use Okanagan Lake to fill Goose may have some benefits overall, but will not yield equivalent storage gains in the Duteau Creek Reservoir Complex.

Goose Lake is located on the boundary between Electoral Area “B” and Okanagan Indian Band lands. Further consultation with Okanagan Indian Band would be required for development of this option.

7.8 Other Groundwater Potential

Opportunities to increase the yield of any of the GVW wells appear limited based on existing well construction information, aquifer properties, and available well operational data. In the opinion of WWAL, a combined maximum yield on the order of 230 to 250 L/s (7,900 to 8,600 ML/y) for all four wells appears realistic.

Based on previous studies along with the current study, WWAL evaluated the potential to develop additional large capacity groundwater sources in the Vernon-Coldstream area. In the opinion of WWAL, unexplored aquifers could exist in the central and west areas of Vernon as well as in the Coldstream Valley. While technically feasible, there are several constraints to such large-scale groundwater development, notably the timelines associated with required environmental assessments as well as groundwater licensing for new supply, both of which would take years. Water quality would need to be explored to determine potential treatment requirements if the water were to be used for the potable supply. Further, if the potential groundwater supply is linked to Kalamalka Lake it is unlikely to be licensed due to the same constraints as surface source (discussion in Section 7.3).

Additional information, including a figure highlighting the referenced areas and more detailed discussion, can be found in WWAL’s full technical memorandum (Appendix A).

7.9 Summary

A summary of the potential future storage options is included in Table 7-1 and Table 7-2.

Table 7-1: Summary of Current and Potential Future Source Water Storage Options

Source	Current Storage (ML)	Potential Additional Storage (ML)	Total Storage (ML)
Duteau Creek Reservoir Complex (Aberdeen, Grizzly, and Haddo Reservoirs)	14,260[1]	14,500	28,760
Goose Lake	2,400	2,000	4,400
MacKay Reservoir	0	4,000	4,000
Lower Duteau Creek	0	10,000	10,000
Okanagan Lake	0	9,600	9,600
Groundwater	7,900	See Table 7-2 (qualitative potential only)	7,900
Total	**24,560**	**40,100**	**64,660**

Notes
1. Total storage minus operational reserve (4,640 ML).

Table 7-2: Summary of Areas to Explore for Additional Large Capacity Groundwater Supplies

Reference[1]	Description	Correlated Aquifer Numbers	Aquifer Productivity	Overall Potential
Area 1	City Centre	1152, 1227	Moderate - High	Moderate
Area 2	West: Okanagan Landing	346, 347, 1227	Moderate - High	Good
Area 3	South	1227,346	Moderate - High	Moderate - Good
Area 4	BX Road/Dog Park	1152, 1154	Low - Moderate	Low
Area 5	Coldstream Valley	352	Moderate - High	Very Good

Notes
1. See WWAL's technical memorandum in Appendix A for map of referenced areas.

For comparison, the total additional storage required to support future demands is presented in Section 6.5.

8. Key Findings and Recommended Actions

8.1 Key Findings

1. Annual supply in average years is more than double demand. However, total annual demand exceeds annual supply approximately once in every twenty years under current conditions. By 2050s and the 2080s, total annual demand is expected to exceed annual supply once in every 10-years and once in every 5-years, respectively.
2. The best estimate of total required demand is expected to reach 19,947 ML in the 2050s with the total ranging between 16,900 ML for the low estimate and 22,689 for the high estimate.
3. The best estimate of total required demand is expected to reach 21,912 ML in the 2080s with the total ranging between 17,600 ML for the low estimate and 26,164 for the high estimate.
4. The foregoing projections are based on the assumption that the area of agricultural land irrigated using GVW water does not significantly increase. If all the areas that currently have unused allocation were irrigated in the future, projected demands would be at least 10,000 ML higher when the impact of climate change on agricultural water demands is taken into account.
5. Implementation of Stage 3 watering restrictions is targets a reduction in 50% of seasonal water use. This equates to a best estimate water consumption savings of 5,944 ML in 2050s and 6,073 ML by 2080s.
6. For the existing horizon: the available supply and storage in Duteau Creek watershed (above Headgates) is sufficient to support community withdrawals and minimum required EFNs for an average year followed by the 1:10, and 1:20drought scenarios with a relatively small (140 ML) deficit modelled for the 1:50-year drought. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the recommended EFN targets are significantly more whenever possible.
7. For the 2050s: the available supply and storage in the Duteau Creek watershed (above Headgates) is sufficient to support community withdrawals and minimum required EFNs for an average year followed by the 1:10 year drought scenario. The storage, and likely also the supply, is estimated to be short by between 1,040 ML and 4,240 ML for an average year followed by the 1:20 drought scenario and short by between 2,740 ML and 6,140 ML for an average year followed by the 1:50 year drought scenario. However, further assessment of year over year drought will be required to confirm. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the RDNO targets supplying significantly more flow to support ENFs whenever possible.
8. For the 2080s: the available supply in the Duteau Creek watershed (above Headgates) may be short of supporting community withdrawals and minimum required EFNs for an average year followed by the 1:10 year drought scenario by up to 5,240 ML. The storage, and likely also the supply, is estimated to be short by between 3,240 ML and 9,140 ML for an average year followed by the 1:20 drought scenario and short by between 5,040 ML and 11,440 ML for an average year followed by the 1:50 year drought scenario. However, further assessment of year over year drought will be required to confirm. It is important to note that these results are based on modelling the minimum required EFNs, where in reality the RDNO targets supplying significantly more flow to support ENFs whenever possible.
9. The preliminary water balance results presented in this study suggest that there may sufficient storage in the Duteau Creek Reservoir Complex to support supply under current and future drought

conditions. However, the preliminary results are based on the assumption of maintaining the minimum required EFNs in the water balance for drought years. This assumption was discussed and selected with input from RDNO staff given the current uncertainty in magnitudes of EFNs for Duteau Creek. The preliminary water balance results, using the minimum required EFN values, provide a good understanding of the volumes required should the goal during drought conditions be to reduce EFNs to the minimum required amounts. However, if operations continue to aim to release as much flow as possible to support EFNs, the preliminary water balance results may be optimistic and are likely underestimating future storage needs. There may be both operational changes and licencing updates required to realize the preliminary water balance finding. Additional analysis varying the amount of EFN releases as well as modelling of multi-year drought scenarios is required to explore this further.

10. Potential additional surface source water storage options for up to 40,100 ML may be available within the GVW area. However, further analysis of the ability to refill storage from available sources under year over year drought conditions is required.

8.2 Recommended Actions

Based on the initial findings, it is recommended to:

Water Conservation Actions

1. Investigate non-revenue water during summer, including minimum overnight flow analysis and a comparison of supply flows and total metered demands at a pressure zone scale to determine areas of focus for further investigation to determine the causes of seasonal non-revenue water and pursue appropriate remedies.
2. Conduct a review of metering infrastructure age and condition, and a business case analysis of options and timelines for renewing and upgrading metering systems to reduce non-revenue water and introduce new tools for direct customer engagement in water efficiency such as AMI.
3. Conduct a study on potential future agricultural water use scenarios, including effects of crop changes based on market pressures (such as shift to tree fruit crops), full utilization of current water use allocations, changes to water use based on planned billing structure change, etc. The study should be coordinated with the Ministry of Agriculture to potentially leverage tools and resources such as the Agricultural Land Use Inventory, Agricultural Water Demand Model and Environmental Farm Plan Program and other resources available for building climate resiliency in BC's agriculture sector.

   The objectives of this study should be to inform policies for managing the GVW agricultural water allocation, policies for curtailing agricultural water uses during shortages with the lowest impact practicable on agricultural assets and production, and cooperation with producers, the province and other interest holders on sustainably managing all water sources in the GVW service area and watershed areas.
4. Consider minor and gradual amendments to residential water rates over time, including a modest reduction in the fixed quarterly charge and in the tier 2 and 3 thresholds, and the addition of a fourth tier with a much higher consumption charge for single-family (or SSMUH) properties using more than 100 cubic metres per quarter.
5. Consider adding dedicated industrial, commercial and institutional demand management programs, including targeted promotion of free facility free water use assessments and flexible incentives (capacity buy-back) based on clear eligibility thresholds.

Water Supply Actions

1. Confirm acceptable target for source water supply for the community and GVW.
2. Review Gold-Paradise Diversion capacity and timing to see if it can meet the outstanding supply for the various scenarios in the 2050s.
3. Carry out multi-year analysis using the Water Balance model (ex., normal year followed by drought year, 2 consecutive drought years, etc.) to evaluate the potential for supporting multi-year storage by raising Aberdeen Reservoir. This action may need to be further supported by:
    a. A discussion and/or approval by regulators regarding multi-year storage.
    b. Evaluation of how the option would support and impact existing community users versus agricultural users.
    c. Evaluation of how the option would support future development of community users versus agricultural users.
4. Carry out evaluation of water supply yield for the supplemental sources.
5. Carry out multi-year water system simulation using the Water Balance model to test and optimize potential operational opportunities, such as varying EFN flows, and to evaluate system reliability under multi-year drought conditions.
6. Consider optimizing use of Goose Lake storage to support high demand periods.
7. Consider Aberdeen dam raising combined with assessing the future capacity of the Gold-Paradise Diversion.
8. Secure additional water rights (up to 9,600 ML total) on Okanagan Lake by transferring existing licences where possible to Okanagan Lake. This includes evaluating the potential for new intakes or horizontal well groundwater withdrawals from Okanagan Lake or other.
9. Once the final water potential is fully explored, assess how the results will impact development potential and whether an upper limit for what the water supply can support needs to be determined.

Groundwater Supply Actions

1. Address the issues identified with the 2017 groundwater licence application and re-submit separate applications for the Ranch Wells and Antwerp wells coupled with revised requests for annual volumes based on actual or reasonable estimates of usage prior to February 29, 2016. A meeting with Provincial water licensing staff in advance of resubmission would be valuable, to confirm the approach and path forward.
2. When updating the licence application information, submit the construction information for Ranch Well 3.
3. Address potential compliance with the B.C. *Environmental Assessment Act* regarding the Antwerp wells (e.g. request exemption or proceed with obtaining certificate).
4. Should there be a need to develop more groundwater capacity, use the overview of potential areas to explore for more groundwater provided herein as a first step in planning and conducting a more detailed Well Siting Study to identify specific properties on which to conduct exploratory test well drilling.
5. Continue to monitor ongoing climate change in the region and carefully track water levels in all wells, in particular the shallow wells paying particular attention to non-pumping water levels in the fall and winter after the irrigation season ends. Should any well appear to begin to lose yield, take action to investigate the possible cause(s).
6. Identify and investigate potential areas for future groundwater development if additional capacity is required.

9. Report Submission

Prepared by:

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0	July 31, 2026	FINAL		BLJ/CS/JLS
1	August 14, 2026	Revision 1		BLJ/CS/JLS
2	September 2, 2026	Revision 2		BLJ/CS/JLS

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Appendix A

Technical Memorandum
Greater Vernon Water – Review of Groundwater Sources and Potential Capacity Expansion
Western Water Associates Ltd.
April 17, 2026

TECHNICAL MEMORANDUM

western water ASSOCIATES LTD

TO: Kerr Wood Leidal Ltd.
Attn: Jacqueline Smith, P.Eng.

DATE: April 17, 2026

FR: Doug Geller, M.Sc., P.Geo. and Ryan Rhodes, P.Geo.

REFERENCE: 26-046-01VR

RE: GREATER VERNON WATER – REVIEW OF GROUNDWATER SOURCES AND POTENTIAL CAPACITY EXPANSION

This technical memo provides Western Water Associates Ltd. input into the Greater Vernon Water (GVW) review of water capacity being carried out by Kerr Wood Leidal Ltd. (KWL). Our assignment for this project is summarized as follows:

1. Provide a brief summary overview of the four GVW wells in the Coldstream / Lavington area (construction information, reported yields, recent usage, and licensing status).
2. Comment on the feasibility/probability of increasing the yield of any or all of the existing four groundwater supply wells operated by GVW in the Coldstream/Lavington area.
3. Discuss other potential areas where municipal scale groundwater supplies could be developed.
4. Review and comment on potential climate change impacts to existing and potential future groundwater supplies in the GVW service area.

Our desktop review and the recommendations to follow are premised on the understanding that the existing four wells are valued water system assets that GVW will maintain into the future as part of its water supply plans. Sources of information used in our assessment included publicly available reports, Provincial aquifer mapping, climate data, Provincial observation well data, SCADA water level and pumping data provided by GVW and background information on groundwater licence applications and water use provided to us by KWL.

1. OVERVIEW OF GREATER VERNON WATER WELLS

The Regional District North Okanagan (RDNO) water utility GVW operates four groundwater supply wells all located within the District of Coldstream. Two wells (Ranch 2 and Ranch 3) are situated on lands owned by Coldstream Ranch. The other two wells are located on a District of Coldstream owned property at 6282 Highway 6, just south of the highway in Lavington (see Figure 1 from KWL, attached). Selected photos of the well sites are provided herein. Table 1 summarizes well construction data including Provincial well identifiers, construction date, well diameter, depth, aquifer, known static water levels, and reported yields. For completeness, Table 1 also includes information for Ranch Well 1, which was replaced about five years ago by Ranch Well 3.

All of the wells are correlated to Coldstream Aquifer 352, which is actually better described as an aquifer system with a series of stacked unconsolidated units separated by confining layers. The three main aquifers or hydrostratigraphic units within Aquifer 352 comprise a shallow unconfined unit, a middle confined unit and a deep confined unit. The two deeper aquifers develop flowing artesian pressures in lower elevation locations such as near Ranch Well 3. Although the Antwerp wells were drilled at a location where there was formerly a natural groundwater spring (discharge zone) neither of these wells typically flow under artesian pressure. Antwerp 2 is inferred to be completed in the middle unit whereas Antwerp 1 is screened in the shallow unconfined unit as is Ranch 2.

More thorough descriptions of the Coldstream aquifers are found in the 2006 report by Golder and the more recent aquifer mapping project report by Piteau Associates Ltd. 2018 (Stewart and Allard). Whereas the latter report considered Aquifer 352 to be the confined portions only with the unconfined units being localized aquifers, WWAL considers the entire valley bottom sedimentary package to comprise a complex layered aquifer system.

Table 1: Selected Information on GVW Wells

Well Tag Number	Well Description	Aquifer 352 unit	Year Drilled	Nominal Diameter (mm/in)	Depth to Water (m)	Drilled Depth (m)	Reported Well Yield L/s (US gpm)
47818	Ranch 1	Middle	1981	400/16	<1	51	No longer in use
51386	Ranch 2	Shallow	1982	300/12	6.3	25	63.1 / 1000
118168	Ranch 3	Middle	2019	400/16	<1	49.7	63 / 1000
10062	Antwerp 1	Shallow	1998	300/12	1.2	12.8	41 / 650
10063	Antwerp 2	Middle	1998	300/12	3.9	62.1	56.8 / 900
	Total estimated yield (L/s) and US gpm						224 / 3,550

Note: Sources of information - GWELLS and Golder (2006).

Well usage and the use purposes have changed over the years. While formerly used for potable and/or irrigation supply, all of the wells are now considered to be supplemental irrigation sources that are used seasonally. However, Ranch 3 and Antwerp 2 are maintained for emergency potable water sources in the event of a major disruption in GVW's primary surface water sources (Duteau Creek and/or Kalamalka Lake). Although not in use Ranch 1 has not been decommissioned and we understand when pressures are high enough in the aquifer, it spills via a buried overflow pipeline to Coldstream Creek, as does its replacement well Ranch 3. For well water licensing information see our discussion below.



Photo 1. Ranch Well 3 Pump House, April 2026



Photo 2. Ranch Well 2 Pump House, Jan. 2024



Photo 3. Antwerp Well Site. April 2026

Water Licensing Information

As at this writing, water licences have not been issued for any of the four active GVW wells. However, RDNO holds a water licence for Antwerp Spring (Licence F007834) with a priority date of 1928 and an annual volume of approximately 358,414 m^3 for Waterworks use purposes. This equates to an average flow of 11.4 L/s and is not currently used, as the original water source (the "large diameter well") was decommissioned in 2010.

RDNO applied for an existing use groundwater licence in February 2017 as summarized in the staff memo by sustainability coordinator Jennifer Miles (RDNO 2017). The table below summarizes the requested water licence that would be granted to all four of the wells under a single licence.

Table 2: Summary of Pending GVW/RDNO Water Licence Application (# 100177979)

Requested Use Purpose	Requested Volume	Requested Period of Use
Irrigation – Water Conveyed by local provider	7,843,318.56 m^3/year	Year round
Waterworks local provider	412,806.24 m^3/year	Year round

The licence application and the RDNO staff report provided the rationale for the requested licence volume. These were (in summary):

- The total annual volume was based on the estimated combined capacity of the four wells (approximately 250 L/s) and assumed year-round continuous use to arrive at the requested annual amount of water.
- The application stated the request for irrigation use was based on potential well pumping capacity but the actual amount used would be substantially less unless there was a loss of the primary surface supplies due to drought or emergency.
- The waterworks requested volume was based on potential use of groundwater for emergency purposes, mainly for non-potable agricultural customers but also potential emergency use for drinking water purposes [Ranch 1 (now 3) and Antwerp 2 only].

This water licence application was made more than nine years ago in the early days of the *B.C. Water Sustainability Act* and Regulation and much has been learned since then. In WWAL's experience, GVW's application is not the only large municipal licence application that has not yet been processed. Currently, Ministry of Water Lands and Resource Stewardship (MWLRS) administers water licensing across multiple regional offices. Applications first go through a completeness review at FrontCounterBC before going to regional offices for technical review, referrals, consultation and decisions. Licensing decisions include: refusal, approval, and (typically) approval with changes and conditions. It is not unusual for the water manager to reduce the volume requested in the application, even for existing uses.

For our review we were not made aware of any communication that may have taken place between the MWLRS and GVW in connection with the licence application and it is not known whether the application has been forwarded to a regional office for technical review. However, based on WWAL's experience with how the Province of B.C. has handled existing use water licence requests and decisions, we see a few potential concerns with the GVW application, which we summarize below:

- We note that the Antwerp Wells have a combined nominal/operating capacity of approximately 98 L/s (1,550 US gpm). These wells were developed in 1998, after the enactment of the original *B.C. Environmental Assessment Act (June 30 1995)* which was updated in 2019. The *Act* and its regulations stipulate that groundwater extraction projects exceeding 75 L/s are potentially reviewable and subject to a process as described in the *Reviewable Projects Regulation*. In WWAL's opinion, these wells formed a definable "project" (as determined in the Regulations) and as such would likely be reviewable. A 2019 Policy Bulletin (Province of B.C. 2019) describes how projects that are potentially reviewable are handled from a licensing standpoint. In summary, for a project (wells) that are potentially reviewable, the MWLRS will not issue a water licence until either an Environmental Assessment Certificate (EAC) or an Exemption Order (EO) is obtained from the EAO. Note that the policy bulletin states *"if a project can be operated at a rate of 75 L/s or more regardless of the intended use, it still requires an EAC or EO"*. While the licence and EA processes can occur in parallel, the BCEAA requirements must be met first before a licence can be issued. Then, one condition of an issued licence would be fulfillment of requirements contained in the EAO order.

- Regarding the large volume of water requested in the 2017 licence application (over 8 million m^3), in our experience with other large groundwater users, it is unlikely that the MWLRS will grant a groundwater licence as large as that requested by RDNO in its application, particularly for the irrigation portion. The irrigation request was based on year-round irrigation and continuous well operation at rated pumping capacities. Virtually all irrigation licences in B.C. stipulate that such use is seasonal, and typically authorized between May 1 and September 30. We note a good case could be made for a modest extension of this time period due to climate change and RDNO's knowledge of early irrigation water requests, as well as years when irrigation demand extends into early October. Additionally, most irrigation sources operate intermittently during the irrigation season based on crop demands and local weather. Most likely, the irrigation licence once authorized would be a fraction of that requested.

- There is a good chance that MWLRS will decide to issue separate groundwater licences for the Ranch wells and Antwerp wells owing to their locations being separated by several kilometres and the dates of first use are quite different (Ranch wells pre-date the BCEAA and Antwerp wells post-date the BCEAA). Presumably, the old surface licence at Antwerp springs would be abandoned at the time of the water licence decision for the wells at that location, or accounted for in the licence decision making process.

In light of the above, consideration should be given to amending the licence application and taking a proactive stance with MWLRS aimed at getting a licence decision for the Ranch wells sooner rather than later with annual volumes that are realistic based on documented use prior to 2016, and in line with the existing supply plans, and then addressing the Antwerp wells so that GVW has certainty with respect to its groundwater rights moving forward as it develops a future water supply plan.

We also note that it appears that Ranch Well 3 is not yet cross-referenced with the licence application, so the construction information (well report, drawings) can be submitted at such time RDNO updates the water licence application.

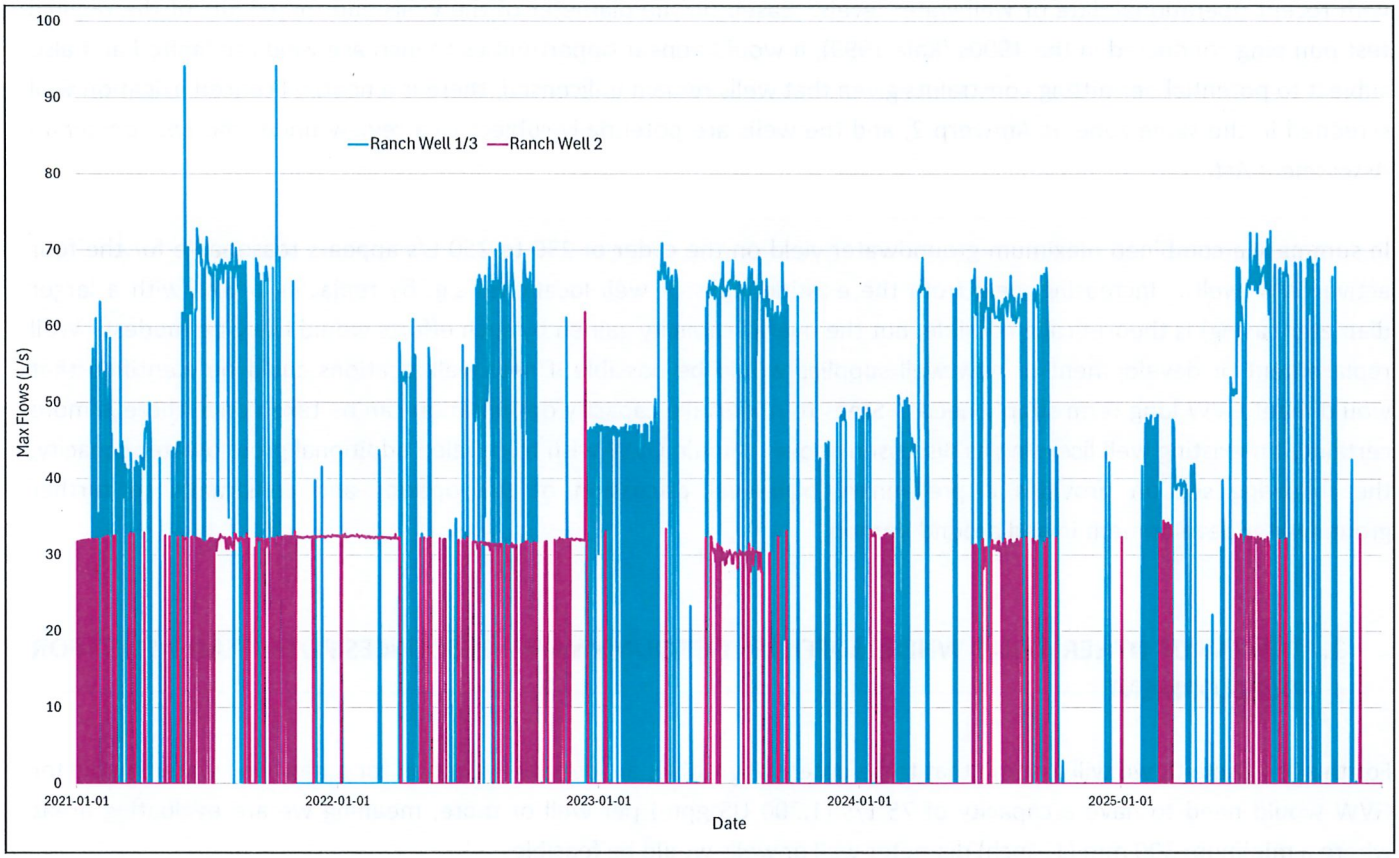
Recent GVW Well Usage and Well Capacity Discussion

For this assignment WWAL was provided with GVW's record of well operations for the two Ranch wells, based on SCADA system monitoring of well flows and well water levels. The flow data provided were maximum daily flows with no cumulative volumes provided. We also maintain records of Ranch 3 water level and pumping in connection with another project that GVW is involved with (use of the licenced Veg Pro well). We understand the Antwerp wells are maintained as active water sources in the GVW system, but have not been used for supply in recent years. Figure 2 below depicts data from the last few years of well operations.

Ranch Well 3. Ranch 3 replaced Ranch 1 in 2021. Based on the available data, Ranch 3 has been operated for supply the last several years typically between early June and early October. Flow rates have ranged from about 40 to 72 L/), typically toward the higher end of the range (>60 L/s). Looking at July 2025 data, at a high daily flow 72.5 L/s, well drawdown was approximately 22 m, giving an operating specific capacity of 3.5 L/s/m of drawdown. This compares favourably to the baseline well testing conducted under WWAL's supervision in 2020 (WWAL 2020). The operating level in the well at 72 L/s appears to be about 20 m above the level sensor/ pump intake. Even though the well flow rate is sometimes above the range recommended by WWAL in 2020 (57 to 63 L/s) recent operations do not indicate a problem pumping up to 70 L/s in summer. At lower operating rates, for example approximately 40 L/s the well exhibits excellent performance, with a short-term specific capacity of 5.3 L/s/m of drawdown.

Ranch Well 2. Based on the available data, Ranch 2 has also been operated for supply the last several years typically between early June and early October. Typical flow rates range from about 30 to 33 L/s. Well drawdown is typically on the order of 1 to 2 m, giving an operational specific capacity of approximately 20 L/s/m of drawdown. Data indicate approximately 2.2 m of water above the level sensor at a flow of about 33 L/s, which we presume represents a level less than 3 m above the pump intake.

Figure 2. Chart of Ranch Wells 2 and 3 Usage/Flow rates 2021 to 2025



2. FEASIBILITIY OF INCREASING YIELD FROM EXISTING WELLS

Based on the available information reviewed for this study, it appears that there is minimal opportunity to increase the yield of the existing four wells. Ranch 3 has operated at average daily flow ranging from about 40 to 72 L/s, but mostly operates in the range of about 65 L/s, which is slightly higher than the flow rates WWAL recommended in 2020 without any noted operational concerns. However, we do not advise a further increase to the pumping rate without further detailed review. The well's specific capacity (performance) appears to be maintaining and possibly improved since the original testing in 2020.

With regard to Ranch 2, that well's capacity is governed by the diameter of the well casing (300 mm or 12 inches) which would typically limit the practical flow rate to about 750 US gpm (48 L/s) depending on total pumping lift required. Therefore, we believe the well's current operational flow rate of 30 to 33 L/s could be increased by perhaps 200 US gpm (12.5 L/s) if needed, with this concept subject to further detailed review and testing. This well is relatively shallow and recent operational data suggest only 2.2 m of water above the level sensor when the well is pumping (i.e. limited additional available drawdown). If the level sensor is close to the pump intake, increasing the pumping rate might not be feasible.

Our confidence in assessing the potential to increase yields from the Antwerp wells is low as we were not provided with recent operational data or well water levels. Based on the diameter of the wells and the results of the original test pumping conducted in the 1990s (Kala 1999), it would appear opportunities to increase yield are limited and also subject to potential permitting constraints given that wells remain unlicensed, there is a nearby licenced irrigation well screened in the same zone as Antwerp 2, and the wells are potentially subject to a review under the *Environmental Assessment Act*.

In summary a combined maximum groundwater yield on the order of 230 to 250 L/s appears reasonable for the four active GVW wells. Increasing yield from the existing wells or well locations (e.g. by replacing a well with a larger diameter casing) is theoretically possible, but the overall capacity gained by such efforts would likely be modest. Well replacement or development of new well supplies would be possible if new well locations could be identified that would meet GVW long term supply needs. Steps to undertake capacity optimization can be taken once there is more certainty on existing well licensing as discussed above. Should GVW wish to develop additional groundwater capacity, the following section provides a preliminary high-level discussion of the options and constraints to further groundwater development in and around Vernon.

3. REVIEW OF OTHER AREAS WHERE SUFFICIENT GROUNDWATER RESOURCES POTENTIALLY EXIST FOR DEVELOPMENT

For this assessment, we will assume that to be potentially viable, an identified location for a new well water supply for GVW would need to have a capacity of 75 L/s (1,200 US gpm) per well or more, meaning we are evaluating areas where a minimum 300 mm (12 inch) diameter well or wells would be feasible.

Background and Previous Studies

Historically, most of the large capacity groundwater well development in the Greater Vernon area has been in the Coldstream Valley. Within current Vernon City limits, well records for higher capacity wells (>20 L/s) are sparse, limited to a few areas in the Okanagan Landing area, near downtown Vernon and in the BX Creek area south of Swan Lake. WWAL is not aware of any wells in Vernon having reported yields greater than 35 L/s (550 US gpm) but large areas of the city remain unexplored in terms of potentially productive deeper confined aquifers occupying buried valleys where sediment thicknesses could surpass 200 metres.

Golder Associates (1988) undertook a study of the Vernon area to examine the potential for developing additional groundwater supplies for the municipality prior to the formation of GVW, which now serves a larger area. At that time, the City relied principally on Kalamalka Lake whereas outlying areas were served by the former Vernon Irrigation District, which conveyed water from Duteau Creek and the Ranch wells along with other sources. The 1988 Golder study area did not consider locations outside the City such as the BX or the Coldstream Valley.

Golder's study defined large supply as equal to or greater than 150 L/s (2,400 US gpm). WWAL reviewed this study and considers its principal conclusions remain valid. The study identified three areas with good groundwater development potential:

- West Area (Okanagan Landing): the area south of Vernon Creek bounded approximately by the creek and Okanagan Avenue in the vicinity of Marshall Field, Ellison Elementary School and Fulton High School.

- Central Area (Downtown Vernon): the central core area of the City between 27th St and 41 Ave south of 39th Avenue and north of 25 Ave. Also includes West Vernon.

- South Area: the area east of Vernon Creek in the vicinity of Kalamalka Lake Rd between the Vernon Golf Course and south of Highway 6.

The above areas are depicted on Figure 3, attached, as Areas 1, 2 and 3 respectively.

Additional Potential Areas to Explore for Groundwater

Based on our experience in the area, WWAL would add two other areas that could be considered:

1) The BX Ranch Dog park adjacent to BX Creek immediately adjacent BX Road and BX Creek could have a shallow aquifer that has the potential to yield a relatively large quantity of water to a well or wells. This location has not been explored but we understand has been considered in the past. One potential complication relates to the water allocation status of BX Creek, which is fully recorded, meaning that additional new licences are not likely to be issued. We do note however that GVW holds multiple significant water licences on BX Creek in this area, that could potentially be transferred to shallow well in hydraulic connection with the creek.

2) It is WWAL's opinion that the Coldstream Valley and specifically the deepest Coldstream aquifer (the one that the RW3 relief well, used to facilitate the closure of the infamous Coldstream Ranch Well [CRW] drilled in the 1960s and now property of Coldstream Ranch) has the highest probability of providing large capacity groundwater supplies. Additional significant supplies could also be obtained from the middle aquifer at locations suitably distant from Ranch 3.

The above areas are depicted on attached Figure 3 as Areas 4 and 5 respectively.

For sake of brevity, we will not review detailed aquifer mapping and aquifer classification information for each of these areas. The table below provides a summary of mapped aquifers in each of the potential areas. Of all the known/mapped aquifers, it is our opinion that the highest capacity would be available from wells completed in Aquifers 1227 and 352.

The 2013 GVW Master Water Plan supply options review (RDNO 2013) evaluated source options and the groundwater component of that study identified similar areas to the above (see MWP Technical Memorandum #2 from the 2012-13 study).

Table 3. Summary of Areas to Explore for Additional Large Capacity Groundwater Supplies

Reference	Description	Correlated Aquifer Numbers	Aquifer productivity	Overall potential
Area 1	City Centre	1152, 1227	Moderate to high	Moderate
Area 2	West: Okanagan Landing	346, 347, 1227	Moderate to high	Good
Area 3	South	1227,346	Moderate to high	Moderate – good
Area 4	BX Road/Dog park	1152, 1154	Low to moderate	Low
Area 5	Coldstream Valley	352	Moderate to high	Very good

Deeper portions of Aquifers 1227 and 352 develop flowing artesian conditions in low-lying areas. The shut-in pressure at RW3 at Coldstream Ranch (60 PSI) is the highest known artesian pressure in the area. Data are lacking on artesian pressure at other locations including Okanagan Landing where flowing conditions also occur. We will review the deep Coldstream aquifer in more detail below.

Deep Coldstream Aquifer 352 Discussion

The extent of the Coldstream strongly artesian deep aquifer zone in Aquifer 352 is unknown as it appears to have only been penetrated by boreholes at the Coldstream Ranch well site (e.g. WTN 118026) and lithology information is absent from the public well record. However, other evidence suggests that the aquifer is not only productive but is laterally extensive and receives recharge on a continuous basis from upgradient sources. The decommissioned CRW well flowed for approximately 50 years and yet after it was decommissioned and the relief well was shut-in, artesian pressure built up to 60 PSI. We do not know if at one time artesian pressure was even higher, but 50 years of unrestricted flow clearly did not deplete the aquifer. The relief well reportedly now flows (by design) year-round with discharge to Coldstream Creek and is also seasonally used for irrigation supply by Coldstream Ranch.

Exploration for this deep aquifer could conceivably be undertaken anywhere in the Coldstream Valley between the Antwerp Wells and the Coldstream town centre (e.g. at Coldstream Park, or any other RDNO or District of Coldstream owned lands that have sufficient space for a supply well). Figure 2 outlines a broad area that could be considered in a more detailed well siting study. Owing to the potential for high artesian pressure, the amount of water that would be generated during drilling would likely be considerable, so adequate space for drilling and well operations would be critical to selecting exploratory drilling sites. The cost to construct test and production wells in this aquifer would be high (on the order of $500,000 or more per production well) but the yield would also be potentially quite high (75 L/s per well or more) with pumping costs being relatively low owing to probable wellhead pressure.

Any such large-scale groundwater development undertaken in the Vernon-Coldstream area would need to be conducted in close consultation with MWLRS and the Environmental Assessment Office, as well as First Nations, and would likely involve years of testing, monitoring and reporting before a decision could be made. Because most of the Vernon area has streams that are fully recorded for licensing, an assessment of hydraulic connection and potential impacts to surface water would likely be required for the licensing of any new well source. The timeline for permitting is difficult to predict but conservatively we estimate up to 10 years from initiation to an EA decision and licence.

Summary of Well Capacity Expansion Opportunities and Constraints

In WWAL's opinion, from a hydrogeological perspective it is feasible to develop additional large capacity groundwater wells in the Vernon area. Should GVW wish to evaluate potential groundwater development further at any of the above-discussed areas, a detailed well siting study could be conducted to identify suitable properties where exploratory test well drilling could be completed. The siting study would evaluate potential locations on the basis of a number of criteria developed by the project team, such as size of property, any identified potential contamination sources, proximity to existing GVW water transmission and storage infrastructure, water management factors (to deal with discharge during drilling and test pumping), land ownership, zoning, and nearby land uses. Preliminary costs would be developed to include well drilling, testing, as well as site improvements should full-scale production wells be constructed. The constraints to further large-scale development would likely include a number of factors ranging from the time required to secure adequate lands, permitting timelines for environmental assessment and water licensing, and public support for groundwater development in a region largely accustomed to surface water supplies.

4. POTENTIAL CLIMATE CHANGE IMPACTS

WWAL is aware from our ongoing work in a number of areas in southern B.C. that the climate has already changed and continues to change. As of early 2026 we are in the fifth year of a long-term precipitation deficit in the region. For the last three winters, low elevation snow (i.e. below about 800 m elevation) has been sparse to absent through most of the winter while snow accumulation on the highlands surrounding Vernon and Coldstream has been lower than average most years.

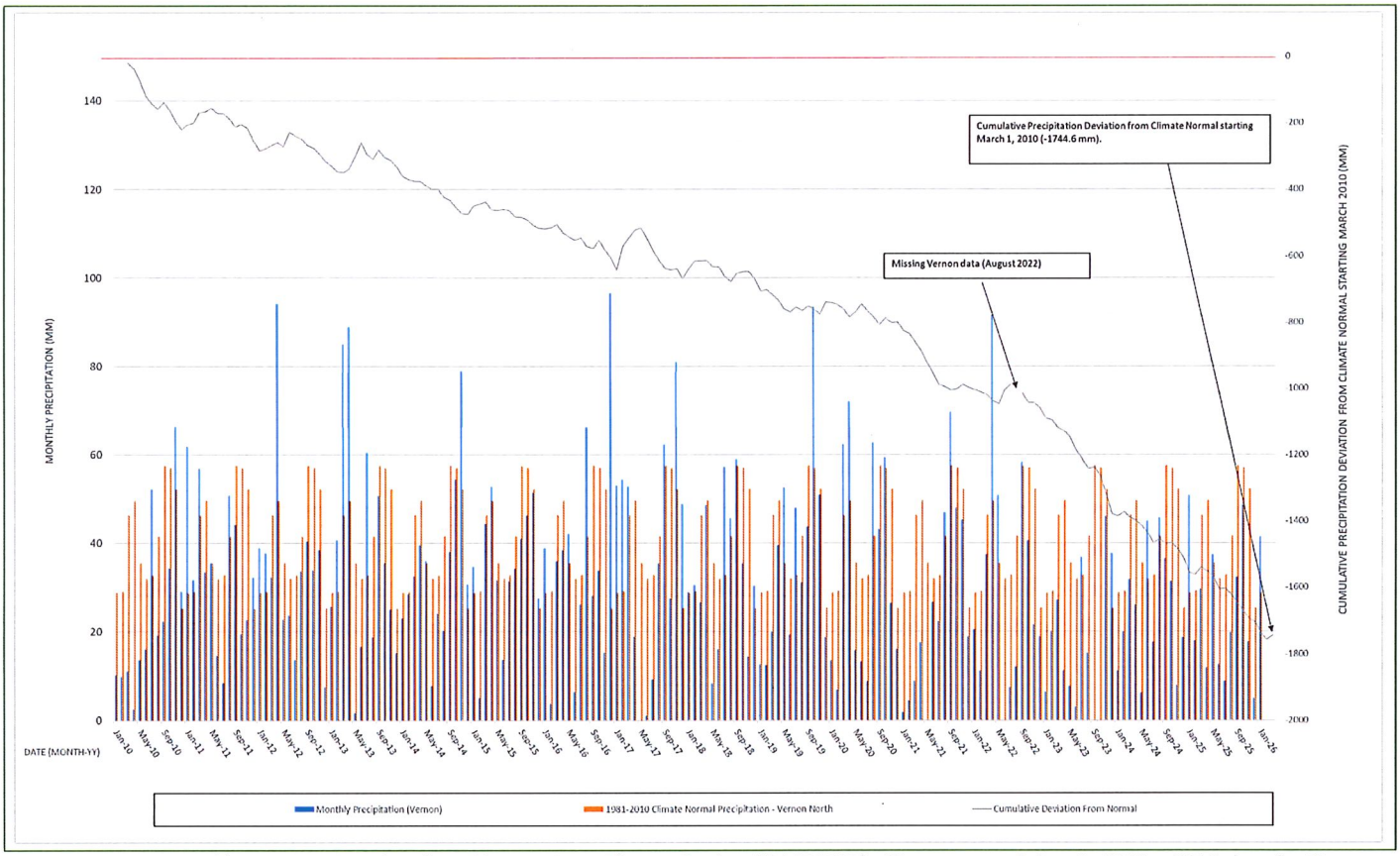
An early review of potential climate change impacts to groundwater resources was provided in a paper by Dr. Diana Allen (2009). To summarize a few concepts from that paper, aquifers and wells respond to long-term climate changes and short-term weather events differently than surface water resources. This is mainly due to how groundwater enters, moves through and exits aquifers and how this process varies considerably both spatially and temporally, whereas with surface water, such resources are quite sensitive to even a single drought year (causing incomplete filling of reservoirs), whereas multiple drought years can sometimes occur without having a major impact on groundwater resources.

In a general sense, a long-term precipitation deficit will eventually impact both surface water and groundwater together and alter the seasonal processes of low-flow, peak flow, baseflow recession, groundwater recharge and groundwater discharge. This alteration in the hydrologic cycle would inevitably result in a reduction in natural groundwater recharge, which in turn would mean a rebalancing of the aquifer system leading to a decline in typical non-pumping (static) water levels over time. Higher temperatures tend to "kick start" a longer growing season which impacts natural processes such as evapotranspiration, timing of snowmelt, and runoff while also increase crop water demands. Climate change is also characterized by the occurrence of shorter-term weather extremes that may range from flooding to drought. The Okanagan saw such events for example floods in 2017 and 2018 followed by extremely hot summers and worsening wildfire seasons.

In general, owing to the fact that we are in a multi-year drought or dry weather cycle, we see some evidence of groundwater level declines in the southern interior of B.C. and will provide a few examples using data from the

Provincial Observation Well Network. At this time, the water levels appear to be within the range seen in the last 20 years of the period of record for most observation wells. However, in many wells including the two examples given below, water levels have not returned to those seen in the 1980s and 1990s. Clear declining trend is evident in both wells, consistent with the drier than normal years the valley has experienced since the "heat dome" summer of 2021. Figure 4 below depicts the cumulative precipitation departure from the climate normal from 2010 to 2026 in the Vernon area. As can be seen, the deficit has built steadily over the last several years where annual precipitation has been well below (sometimes 100 mm) below historical normals. As of 2026 the cumulative deviation is over 1.7 metres of precipitation deficit, with about 800 mm deficit since 2021. For comparison, the 1981-2010 climate normal annual average precipitation was 487 mm.

Figure 4. Monthly precipitation data for Vernon area 2010 to 2026 with cumulative deviation from normal



Data Sources: Monthly precipitation data from Vernon Auto Climate Station (ID1128582). Climate normal data is 1981 – 2010 data for Vernon North Climate Station (ID1128583).

On a provincial scale the most recent "State of the Environment" report on groundwater levels in BC (2023) looked at 10-year trends in 140 wells completed in 113 aquifers across BC and found that only 8 wells showed moderate to large rates of decline with most observation wells classified as stable or without significant increase or decrease in groundwater level. Give the last 3 years of continued dry conditions, it is possible more wells are showing declines now.

Unfortunately, there are no active observation wells recording water levels in the unconsolidated aquifers found in the City of Vernon or in the Coldstream Valley. Below in Figures 5 and 6 we provide historical water level graphs of two long-term Okanagan Valley Provincial wells (Province of B.C. 2026), one located in southeast Kelowna (Observation Well 262 in Greater Kelowna Aquifer 464) and the other in Spallumcheen (Observation Well 180 in the Eagle Rock Aquifer # 353). Focusing on the last several years of data we see a clear declining trend in water levels that mirrors the precipitation deficit since approximately 2021. The magnitude and rate of the declines is relatively small, approximately 2 metres over 5 years (0.4 m/year) but is nevertheless a trend that correlates well with the recent string of drier than normal years.

Figure 5. Hydrograph Observation Well 180 Spallumcheen BC.

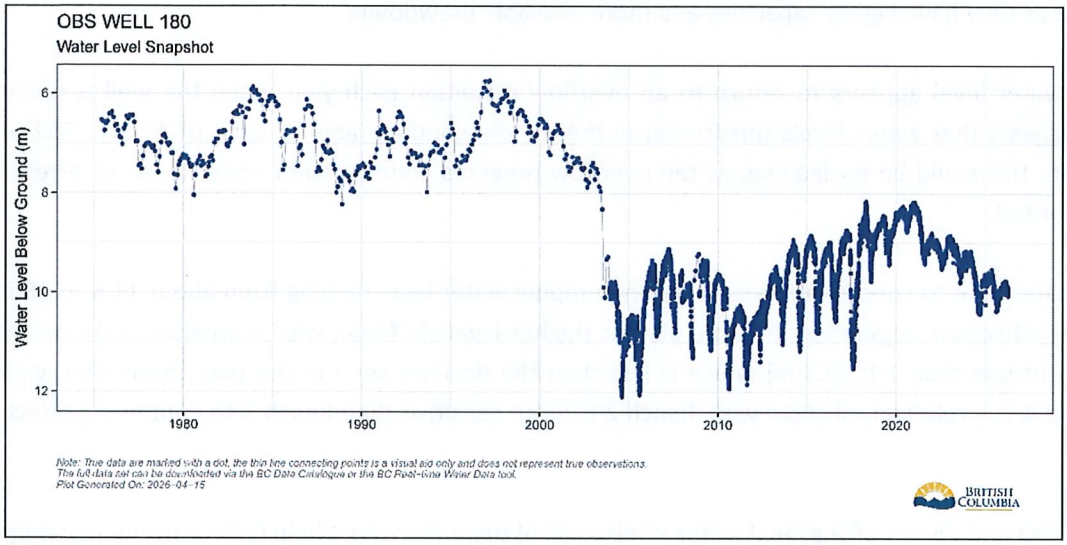
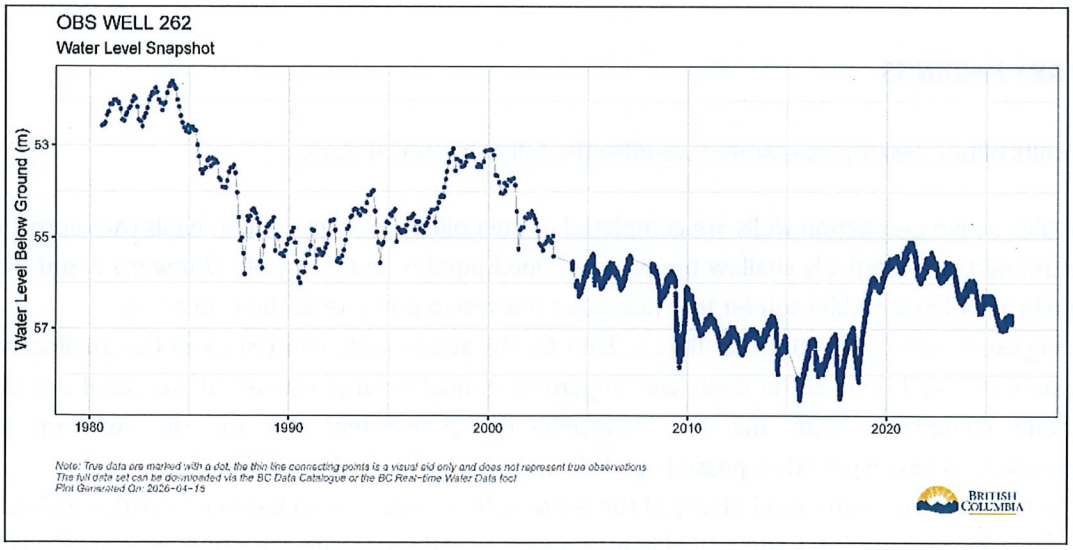


Figure 6. Hydrograph Observation Well 262 Southeast Kelowna BC.



Climate Change and the GVW Wells

As with any water source a deficit of precipitation has the potential to stress the available capacity of wells including the GVW wells. The two main ways this occurs is through increased water demand, which in turn can result in more intensive pumping, and the effects of groundwater level decline on long-term well yields. Groundwater level decline in an unconfined aquifer reduces the effective saturated thickness of the aquifer, which then translates to a reduction on the aquifer transmissivity (T) which is the ability of the aquifer to yield water to wells per unit decline in water level. The two GVW wells completed in shallow unconfined aquifers (Ranch 2 and Antwerp 1) would likely be the most susceptible to effects of longer-term groundwater level declines as well as increased demands because they have less available drawdown and the productivity of the local aquifers could drop as water drains from the unconfined aquifers. The two deeper wells completed in confined aquifers (Ranch 3 and Antwerp 2) are relatively less susceptible to climate change impacts as they have higher capacities and more available drawdown.

Ranch Well 3 water level appears to return to an overflow condition each year when the well is not in use. This observation suggests that water levels (pressures) in the middle confined aquifer zone of Aquifer 352 are relatively stable. We note this could be misleading, as the overflow prevents actual aquifer water levels or artesian pressures from being recorded.

Ranch Well 2 data seem to consistently report a non-pumping water level ranging from about 11.5 to 15 ft (3.5 to 4.6 m) above the level sensor depending the time of year (higher levels in May), with a possible slight overall decline in 2024 and 2025 of less than 1 ft (0.3 m) which is less than the declines seen in the two observation wells discussed above. Because it is a relatively shallow well, Ranch 2 is more sensitive than Ranch 3 to continuing effects of climate change.

Careful monitoring and review of seasonal water levels in all of the wells would help GVW determine if ongoing climate change and dry weather patterns are impacting the well supplies. It would also be beneficial for one or two Provincial observation wells to be established in the Coldstream valley where GVW has significant groundwater supply assets.

5. SUMMARY FINDINGS

Based on the results of our desktop assessment we offer the following conclusions:

1. All of GVW's active production wells are completed in the Coldstream valley. Two wells (Antwerp 1 and Ranch 2) are screened in a relatively shallow upper unconfined aquifer and two wells (Antwerp 2 and Ranch 3) are screened in a confined middle aquifer that flows under artesian pressure at the Ranch site.
2. An existing use licence application was filed in 2017 for the above wells. Our review of this application revealed some issues that will need to be dealt with regarding annual volume requested, seasonal use of irrigation water, and compliance with the B.C. *Environmental Assessment Act for* the Antwerp wells. Our recommendations below provide a possible path forward on licensing the existing sources.
3. Opportunities to increase the yield of any of the GVW wells appear limited based on existing well construction information, aquifer properties and available well operational data. In our opinion, a combined maximum yield on the order of 230 to 250 L/s for all four wells appears realistic.

4. Previous studies along with the current study have evaluated the potential to develop additional large capacity groundwater sources in the Vernon-Coldstream area. In our opinion, unexplored aquifers could exist in the central and west areas of Vernon (Areas 1 and 3 on Figure 2) as well as in the Coldstream Valley (Area 5). While technically feasible, there are a number of constraints to such large-scale groundwater development, notably the timelines associated with required environmental assessments as well as groundwater licensing for new supply, both of which would take years.
5. Mapped aquifers correlated to the areas considered as having the highest potential for large capacity wells include Aquifer 1227 present in parts of West Vernon and Okanagan Landing and the Coldstream Valley Aquifer 352 complex (deep artesian zone).
6. A more detailed Well Siting Study could be undertaken to identify specific sites to explore for groundwater. That study could develop sufficient detail to plan for capital expenditures to cover the costs of things like land acquisition, exploratory well drilling and testing and initiation of permitting with Provincial regulators and consultation with First Nations.
7. It is clear from recent experience that the climate has already changed in the Okanagan Valley and continues to change. A years-long precipitation deficit is widespread in the southern Interior of B.C. and the effects of this can be seen in the hydrographs of many Provincial Observation wells. In the Vernon area, the cumulative precipitation deficit since 2010 approaches 1.4 metres with 800 mm deficit since 2021. Unfortunately, there are currently no Provincial observation wells monitoring water levels in the unconsolidated aquifers in the Vernon-Coldstream area. Recent groundwater level declines in Okanagan Valley wells appear to be noticeable but of relatively low magnitude. GVW's shallow wells (Antwerp 1 and Ranch 2) would be expected to be more susceptible to the effects of groundwater level decline brought on by climate change. So far, such effects on Ranch 2 appear minor but warrant careful monitoring if dry conditions persist in the coming years.

6. RECOMMENDATIONS

Based on our desktop assessment and findings we provide the following recommendations to GVW.

- Address the issues identified with the 2017 groundwater licence application and re-submit separate applications for the Ranch Wells and Antwerp wells coupled with revised requests for annual volumes based on actual or reasonable estimates of usage prior to February 29, 2016. A meeting with Provincial water licensing staff in advance of resubmission would be valuable, to confirm the approach and path forward.
- When updating the licence application information, submit the construction information for Ranch Well 3.
- Address potential compliance with the B.C. *Environmental Assessment Act* regarding the Antwerp wells (e.g. request exemption or proceed with obtaining certificate).
- Should there be a need to develop more groundwater capacity, use the overview of potential areas to explore for more groundwater provided herein as a first step in planning and conducting a more detailed Well Siting Study to identify specific properties on which to conduct exploratory test well drilling.
- Continue to monitor ongoing climate change in the region and carefully track water levels in all wells, in particular the shallow wells paying particular attention to non-pumping water levels in the fall and winter after the irrigation season ends. Should any well appear to begin to lose yield, take action to investigate the possible cause(s).

We trust that the professional opinions in this document are sufficient for your current requirements. Should you have any questions, or if we can be of further assistance in this matter, please contact us.

Western Water Associates Ltd.
EGBC Permit to Practice #1001419

PROFESSIONAL ENGINEERS AND GEOSCIENTISTS PROVINCE OF BRITISH COLUMBIA D. J. GELLER #146907 GEO SCIENTIST

Sept. 2026

Douglas Geller, M.Sc., P.Geo
Principal Hydrogeologist

Reviewed By:

Ryan Rhodes, P.Geo.
Senior Hydrogeologist

Attachments: KWL Figure 1 - Overview
WWAL Figure 3 – Potential Areas to Explore for Large Capacity Wells

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Regional District of North Okanagan

Water Capacity Study

DRAFT

KERR WOOD LEIDAL consulting engineers

N

Deep Creek

B.X. Creek

Coldstream Creek

Vernon Creek

Bessette Creek

Lower Duteau Creek

Curtis Creek

Heart Creek

Upper Duteau Creek

Gold Paradise Diversion

CROSSMAN CREEK
GARDOM CREEK
LAMBERT CREEK
JIDA CREEK
BRASH CREEK
JIROD CREEK
GOOSE CREEK
FALA CREEK
SHUSWAP RIVER
DELORME CREEK
SALMON RIVER
SILVER CREEK
HAINES CREEK
RICARDO CREEK
ASHTON CREEK
BARNES CREEK
SWIDSK CREEK
GLEITZ CREEK
MUDRA CREEK
SPA CREEK
ALLARDICE CREEK
EDUC CREEK
STEPHEN CREEK
FOWLER CREEK
FORTUNE CREEK
HARLAND CREEK
HUSSARD CREEK
SLACK CREEK
SNEESBY CREEK
LINDSAY CREEK
OLEEN CREEK
SAMESH CREEK
STYX CREEK
LYSTER CREEK
GLANZIER CREEK
MCACHANEY CREEK
SUTTON CREEK
DEEP CREEK
ALDERSON CREEK
KENDRY CREEK
SOUTH FORTUNE CREEK
JOYCE CREEK
MEIGHAN CREEK
VLEM CREEK
LOSSIE CREEK
CHRISTIAN CREEK
MIRIAM CREEK
DOUGLAS CREEK
ROUND CREEK
SHERIDAN BROOK
JOHN BROOK
WEST MAID CREEK
EAST MEIGHAN CREEK
MANN CREEK
MOFFAT CREEK
GURNEY CREEK
IRISH CREEK
WILLIAM CREEK
BANKS CREEK
MUSGRAVE CREEK
PATERSON CREEK
HUTTLEY CREEK
MAID CREEK
PUTNAM CREEK
TRUMPY CREEK
BUTTONHEAD CREEK
BEAVERJACK CREEK
VANCE CREEK
PINE CREEK
KEDLESTON CREEK
GREENHOW CREEK
MALLORY BROOK
NEWPORT CREEK
BRADLEY CREEK
ABBOTT CREEK
DIXON CREEK
COLDSTREAM CREEK
DEADIES CREEK
ALBERTS CREEK
BUCHANAN CREEK
WOODWARD CREEK
BROOKSIDE CREEK
GALLON CREEK
SPIDER CREEK
BESSETTE CREEK
SHUSWAP RIVER
BLUE SPRINGS CREEK
NASWHITO CREEK
EQUESIS CREEK
LAWSON CREEK
CREIGHTON CREEK
VERNON CREEK
WHITEMAN CREEK
BOLTRES CREEK
BREW STREAM
STURT CREEK
BREWER CREEK
REITH'S CREEK
HARRIS CREEK
VIDLER CREEK
BONNEAU CREEK
FISHER CREEK
COSENS CREEK
DUTEAU CREEK
BEATTIE CREEK
MCAULEY CREEK
NICKLEN CREEK
HOME CREEK
ANDERSON BROOK
NORTH OKANAGAN CREEK
OKANAGAN CREEK
HAYTON CREEK
RIBBLEWORTH CREEK
CLARK CREEK
WEST HARRIS CREEK
FISH CREEK
FERRY CREEK
GALL CREEK
ECHO CREEK
WINFIELD CREEK
HILDA CREEK
MURRAY CREEK
HISELHAWK CREEK
WEST BRUER CREEK
DIMETRI CREEK
REID CREEK
HORSE CREEK
VERNON CREEK
MILL CREEK
BULMAN CREEK
CONROY CREEK
MUGFORD CREEK
MISSION CREEK
STANLEY CREEK
LOCH KATRINE CREEK
GUNNAR CREEK
MORRISON CREEK
VICTOR CREEK
JAMES CREEK
SCOTTY CREEK
STOVE CREEK
HAGGART CREEK
WHELAN CREEK
ROCKFACE CREEK
GUEST CREEK
SIDLEOF CREEK
EMERY CREEK
DAVEY CREEK
DARLEY CREEK
STEVENSON CREEK
RYDER CREEK
WEST KETTLE RIVER
PEARSON CREEK
BELGO CREEK
SPLIT CREEK

Goose Lake Dam
Goose Lake Intake
Mission Hill Water Treatment Plant
Ranch Well 3
Ranch Well 2
Ranch Well 1 (Inactive)
Kal Lake Intake
King Edward Intake
Antwerp Well 1 (Shallow)
Antwerp Well 2 (Deep)
Duteau Creek Water Treatment Plant
Headgates Intake
Delcliffe Intake
Outback Intake
King Edward Lake Dam
Aberdeen Lake Dam
Haddo Lake Dam
Grizzly Lake Saddle Dam
Grizzly Lake Spillway Dam
Grizzly Lake Specs Dam
Grizzly Lake Main Dam
Gold-Paradise North Head Pond Dam
Gold-Paradise South Head Pond Dam

Legend

- Direction of Flow
- Watersheds

Facilities

- Intake
- Pumping Station
- Reservoir
- Treatment Plant
- Dam
- Hydrometric Stations
- GVW Wells
- Water Pipes
- Lake
- Gold Paradise Diversion

Watersheds

- Haddo Lake Dam
- Grizzly Lake Dam
- Aberdeen Lake Dam
- Goose Lake Dam
- King Edward Lake Dam
- Headgate Intake

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Coordinate System: NAD 1983 BC Environment Albers

Scale Disclaimer: The map scale of 1:225,000 is only valid on a 11"x17" print.

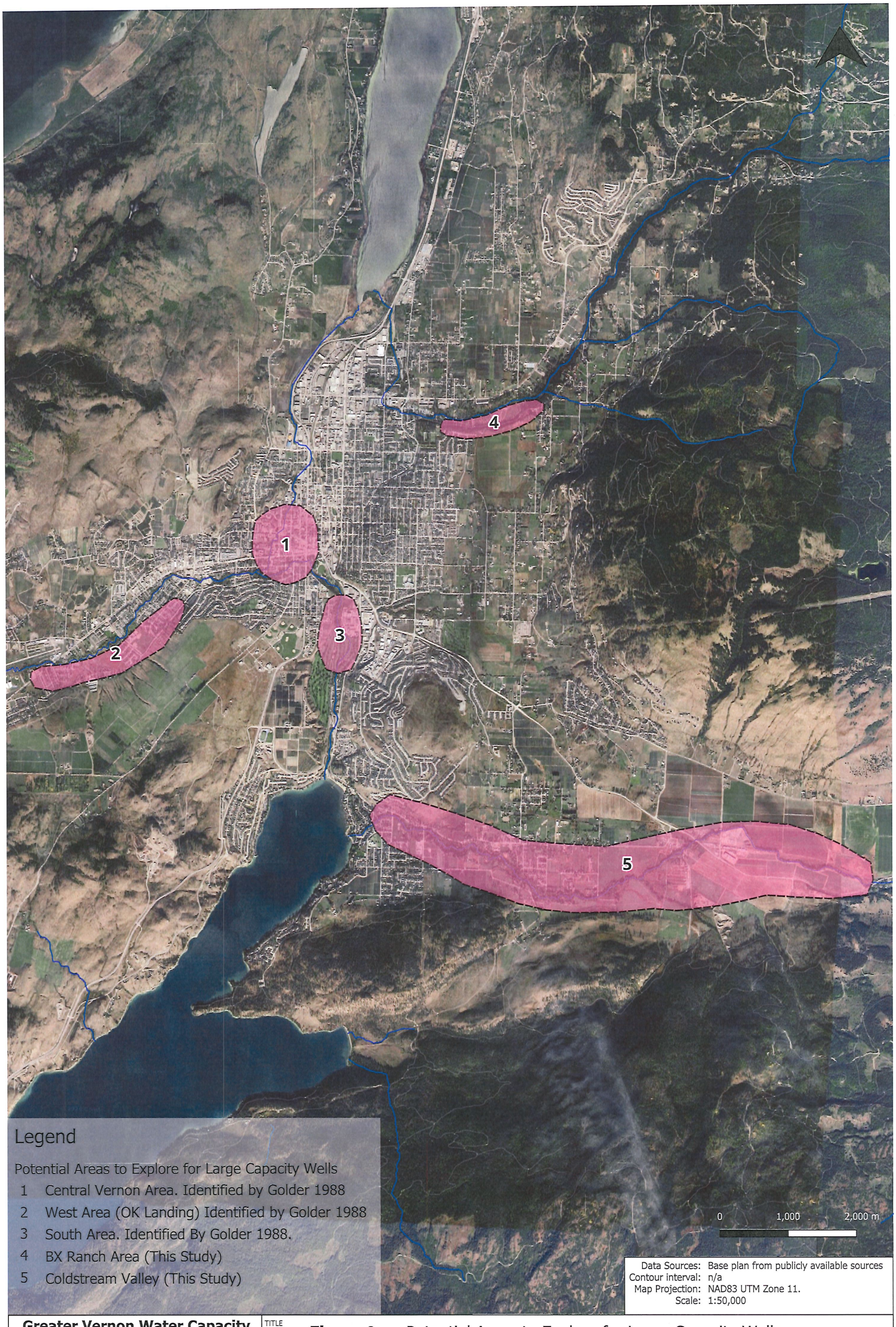
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Project No.	773.226
Date	April 2026
Scale	1:225,000

0 2.5 5 10 Kilometers

Overview

Figure 1



Greater Vernon Water Capacity Study	TITLE **Figure 3 :** Potential Areas to Explore for Large Capacity Wells		
western water ASSOCIATES LTD	DRAWN MA	DATE April 15, 2026	CLIENT KWL
	REVIEWED DG	PROJECT NO. 26-046-01VR	REVISION NO. A

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Appendix B

Duteau Creek Drought Frequency Analysis Results

KWL Drought Frequency Analysis Summary Report

Station ID:	**NA - Client Records Used as Inputs (DCWTP, Duteau non-potable, EFNs, Aberdeen-Grizzly-Haddo Reservoir Volumes)**
Station Name:	**NA - Collective Aberdeen/Grizzly/Haddo Volumes**
Watershed Area (km²)	NA
Software used:	HYFRAN
Date completed:	13-Apr-26
Completed by:	JLS
Date Reviewed:	
Reviewed by:	CS

P:\0700-0799\773-226\400-Work\DroughtFreqAnalysis\[20260413_droughtFreqAnalysis.xlsx]FFA_Inst Peak_CALENDAR YR

FFA Summary

Flood Frequency Analysis Summary Table (HYFRAN):

T	GEV	3 Paremeter Log Normal	Log Pearson Type3	Average
	Weighted Moments	Max. Likelihood	WRC	
1.005	121770		1.34E+05	**128055**
1.0526	87485		89793	**88639**
1.25	63027		62239	**62633**
2	42537		41605	**42071**
5	26315		27263	**26789**
10	19149		21682	**20416**
20	13777		17870	**15824**
50	8237.3		14309	**11273**
100	4803.9		12305	**8554**
200	1824		10697	**6261**
500	-1598.9		9005.4	**3703**
1000	-3887.2		7967.9	**2040**
Decision	Accept	Reject	Accept	Update average to neglect any rejected distributions

Hypothese Tests	Results	Note	Conclusions
Independence (Wald-Wolfwitz) *H0: the observations are independent*	accept H0 at a signifcance level of 5%		Observations are independent
Stationary (Kendall) *H0: no trend is apparent in the observations*	accept H0 at a signifcance level of 5%		No trend is apparent in the data
Homogeneity test at annual scale (Wilcoxon) *H0: the averages of the two samples are equal*	accept H0 at a signifcance level of 5% It can not be concluded that the averages of the 2 samples are different	n/a	N/A
Homogeneity test at seasonal scale (Wilcoxon) *H0: the averages of the two samples are equal*	reject H0 at a signifcance level of 5%, but accept at a signifcance level of 1% the two subsamples might not be homogeneous	n/a	N/A

Copy + "Paste Values" from Annual or WY Min Spreadsheet

Input Data

Missing data in:

n =	10
Min Volume (Annual)	**Year**
ML	**yyyy/mm/dd**
48703.70345	2016
66987.6968	2017
54487.2256	2018
34563.46192	2019
82729.37674	2020
37139.13992	2021
62585.58273	2022
24362.57987	2023
19452.45595	2024
24121.13425	2025

Detailed Output Data

Generalized Extreme Value (GEV)

RDNO Water Capacity Study (0773.226)

Results of the fitting

GEV (Method of weighted moments)

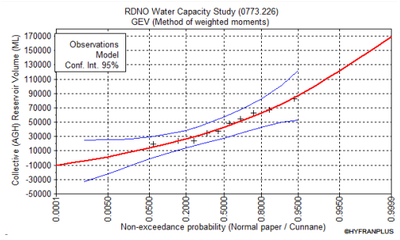
Number of observations 10

Parameters

alpha	19187.13
k	0.064018
u	35586.29

Quantiles
q = F(X) : non-exceedance probability
T = 1/q

T	q	XT	Standard deviation	Confidence interval (95%)	
10000	0.0001	-10192	18332	N/D	N/D
2000	0.0005	-5969.9	15898	N/D	N/D
1000	0.001	-3887.2	14779	-32861	25086
500	0.002	-1598.9	13615	-28290	25092
200	0.005	1824	12008	-21716	25364
100	0.01	4803.9	10748	-16266	25874
50	0.02	8237.3	9471.7	-10331	26805
20	0.05	13777	7852.2	-1616	29171
10	0.1	19149	6854.3	5711.6	32586
5	0.2	26315	6388.3	13791	38839
3.3	0.3	32003	6556.2	19151	44856
2	0.5	42537	7454.7	27923	57151
1.5	0.6667	52416	8538.9	35676	69156
1.25	0.8	63027	10044	43337	82717
1.1111	0.9	75798	13060	50196	1.01E+05
1.0526	0.95	87485	17712	52763	1.22E+05
1.0204	0.98	1.02E+05	26418	N/D	N/D
1.0101	0.99	1.12E+05	34714	N/D	N/D
1.005	0.995	1.22E+05	44284	N/D	N/D
1.001	0.999	1.43E+05	7.06E+04	N/D	N/D
1.0005	0.9995	1.51E+05	8.34E+04	N/D	N/D
1.0001	0.9999	1.69E+05	1.16E+05	N/D	N/D



Three-Parameter Log-Normal (LN3)

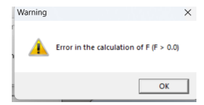
Results of the fitting

3 parameter lognormal (Maximum Likelihood)

Number of observations

Parameters

m
mu
sigma



Quantiles
q = F(X) : non-exceedance probability
T = 1/(1 q)

T	q	XT	Standard deviation	Confidence interval (95%)
10000	0.0001			
2000	0.0005			
1000	0.001			
500	0.002			
200	0.005			
100	0.01			
50	0.02			
20	0.05			
10	0.1			
5	0.2			
3.3	0.3			
2	0.5			
1.5	0.6667			
1.25	0.8			
1.1111	0.9			
1.0526	0.95			
1.0204	0.98			
1.0101	0.99			
1.005	0.995			
1.001	0.999			
1.0005	0.9995			
1.0001	0.9999			

Log-Pearson Type III (LP3)

RDNO Water Capacity Study (0773.226)

Results of the fitting

Log-Pearson type 3 (WRC)

Number of observations 10

Parameters

alpha	-54.492208
lambda	135.06673
m	7.091696

Quantiles
q = F(X) : non-exceedance probability
T = 1/q

T	q	XT	Standard deviation	Confidence interval (95%)	
10000	0.0001	5498.7	5122.8	-4544	15542
2000	0.0005	7089.2	5224.5	-3152.9	17331
1000	0.001	7967.9	5227.3	-2279.7	18215
500	0.002	9005.4	5199.7	-1188	19199
200	0.005	10697	5112.9	674.01	20721
100	0.01	12305	5011.6	2480.3	22130
50	0.02	14309	4893.8	4715.3	23903
20	0.05	17870	4781.2	8497.2	27243
10	0.1	21682	4851.3	12172	31193
5	0.2	27263	5263.7	16944	37582
3.3	0.3	32048	5783	20711	43385
2	0.5	41605	6952.7	27975	55235
1.5	0.6667	51381	8318.8	35073	67689
1.25	0.8	62239	10651	41359	83119
1.1111	0.9	76237	15632	45592	#######
1.0526	0.95	89793	23107	N/D	N/D
1.0204	0.98	1.08E+05	37135	N/D	N/D
1.0101	0.99	1.21E+05	50984	N/D	N/D
1.005	0.995	1.34E+05	67639	N/D	N/D
1.001	0.999	1.66E+05	1.17E+05	N/D	N/D
1.0005	0.9995	1.80E+05	1.43E+05	N/D	N/D
1.0001	0.9999	2.13E+05	2.13E+05	N/D	N/D

