

Source Water Assessment REPORT – S2TAG MODULES 1, 2 7 &8 Town of Oliver Groundwater Supply

Prepared for:

Town of Oliver, B.C.
c/o TRUE Consulting
#201-2079 Falcon Road
Kamloops, B.C.
V2C 4J2



July 2015

Project: 14-009-01

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July 6, 2015

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c/o TRUE Consulting
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Attention: Mr. Shawn Goodsell, Operations Manager, Town of Oliver

Re: FINAL DRAFT report, Town of Oliver Source Water Assessment, Modules 1, 2, 7 & 8

Western Water Associates Ltd. (WWAL) is pleased to provide this Final Draft Report for BC Source to Tap Assessment Guidelines **Modules 1, 2, 7 & 8** Source Water Assessment (SWA) and proposed Protection Plan for the Town of Oliver groundwater supplies. This version addresses comments received on the second overall draft report.

Should you or any TAC members have any questions, please contact the undersigned. We look forward to your comments and finalizing the report.

WESTERN WATER ASSOCIATES LTD.



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

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I. INTRODUCTION

Western Water Associates Ltd. (WWAL) is tasked with assisting the Town of Oliver with the development of a Source Water Assessment (SWA) pertaining to groundwater wells providing drinking water for the Town of Oliver community water system. The purpose of this study is to complete an assessment of the Town's water supply wells, and the aquifer sources in order to define proposed groundwater protection areas, to identify potential threats to the delivery of safe drinking water, and to establish a framework and strategies for source water protection. The scope of work and methodology for this project is outlined below. A portion of this work was funded by an Okanagan Basin Water Board (OBWB) Water Conservation and Quality Improvement (WCQI) grant, awarded to the town in the spring of 2014 in response to an application made by the Town in February 2014.

This Source Water Assessment is one component of the hydrogeological work that WWAL has conducted on behalf of the Town in recent years. Previous work has included an assessment of Groundwater at Risk of Containing Pathogens (GARP/GWUDI) study in 2011-2012, and overseeing the installation and testing of two new wells at the Buchanan Road well site in 2013-2014.

I.1 SWA Structure, Context, and Scope

This SWA incorporates the principles and procedures of the Comprehensive Drinking Water Source to Tap Assessment Guideline (S2TAG) as published by the BC Ministry of Healthy Living and Sport (Version 1.0, 2010). The S2TAG provides a structured and consistent approach to evaluating risks to drinking water. It serves as a tool to develop a more comprehensive understanding of the risks to drinking water safety and availability, how to operate effectively, and how to produce the best possible water quality. The S2TAG consists of eight modules:

Module 1 - Delineate and characterize drinking water sources

Module 2 - Conduct contaminant source inventory

Module 3 - Assess water supply elements

Module 4 - Evaluate water system management, operation and maintenance practices

Module 5 - Audit water quality and availability

Module 6 - Review financial capacity and governance of water system

Module 7 - Characterize risks from source to tap

Module 8 - Recommend actions to improve drinking water protection

Modules 1 through 6 are hazard identification modules, and Modules 7 and 8 focus on risk characterization and risk management. Depending on the size and complexity of the water system, the regulating health authority (in this case the Interior Health Authority - IHA) requires completion of some or all of the

modules. In this report, we have focused on Modules 1, 2, 7 & 8 but touch upon aspects of Module 5 as there are fairly detailed discussions of well capacity and groundwater quality; but this should not be considered to be a detailed audit of water quantity and quality.

The Province of B.C. (2012) in its “List of British Columbia’s 20 Priority Areas for Aquifer Characterization” identified the aquifers in the Oliver area as being high priority for Aquifer Characterization. Aquifer Characterization is distinguished from Aquifer Classification by the implementation of more detailed and quantitative groundwater studies, such as aquifer testing, detailed stratigraphic and geological modeling, detailed water quality monitoring and modeling, and groundwater flow modeling, as has been done in the Grand Forks area (Wei et al 2010). However, based on discussions with our TAC member from MFLRNO (Thomson pers. Comm. 2014) the Province has not yet funded such studies for the Oliver area. This provides the SWA project, and the TAC, with the opportunity to help form the objectives for further Aquifer Characterization, because the scope of such studies is necessarily issue-dependent.

As stated in the OBWB grant proposal work plan this assessment focuses on Modules 1, 2, 7 & 8 for the domestic drinking water wells only, and also includes a limited review of recent data only to assess groundwater quality (part of Module 5). In this report, we also attempt to provide a reasonably clear picture of how Oliver has used groundwater wells in the recent past as well as the proposed well operations in the future as a result of changes made in the water system including system twinning. The hydrogeological setting is described, based on existing information.

It should be noted, however, that this SWA document is not an exhaustive review of all available hydrogeological information for the Oliver area, nor does it provide a comprehensive update to the understanding of groundwater quality (including detailed well-by-well trend analysis) or aquifer properties and behaviour in the Oliver area. Moreover, we are not intending to supplement or support the previous GWUDI assessment completed on Oliver wells that were in use during 2010-2011. All such studies are beyond the scope of this assessment, but could become part of the scope of a future Aquifer Characterization project, as noted above.

1.2 SWA Process and Technical Advisory Committee

The general process for completing the SWA involves the following steps (those in italics are future tasks):

1. We initiated the project by meeting with Shawn Goodsell of the Town of Oliver in June 2014. This meeting confirmed the schedule, budget and probable timing for reports and meetings.
2. A preliminary meeting was held on *October 21, 2014*, and a Technical Advisory Committee (TAC) was established (members indicated below) to guide to the SWA process. TAC Meeting Minutes are attached as Appendix B.
3. WWAL reviewed existing background information on the wells and land use including previous reports provided by True and the Town, other relevant reports and information, contaminated sites databases, and available water quality data.

4. WWAL staff had previously visited all the well sites in connection with the GWUDI/GARP study. However, a further site reconnaissance of the wells and surrounding areas was completed on August 19, 2014.
5. WWAL reviewed two previous studies that delineated well capture zones for well protection consideration (Golder 2005; Toews and Allen 2007), and updated the capture zones and identified a proposed groundwater protection area.
6. A detailed site reconnaissance and contaminated sites registry search was compiled for the proposed protection area and immediately adjacent areas.
7. Information was compiled into a Draft report consisting of Modules 1 and 2 of the S2TAG, and the Draft report was distributed to the TAC members for review and comment in October 2014. The TAC then met in Oliver on 21 October
8. Following receipt of comments on the Modules 1 and 2 report, a Draft report including Modules 1, 2, 7, and 8 of the S2TAG was prepared and distributed to the TAC for review and comment.
9. *A second TAC meeting was held on February 19, 2015. A final draft Modules 1,2, 7, 8 report was submitted in July 2015.*
10. *A final SWA report was prepared and submitted in August 2015*

Interviews with knowledgeable persons were not conducted due to the amount of historical information that was already available to the project from aerial photos and existing background reports. TAC meeting minutes (more accurately termed summary notes), when completed will be attached as Appendix B to the final report.

The TAC is comprised of the following people:

- Shawn Goodsell, Town of Oliver
- Andre Miller, Rural Town Water Councilor
- Judith Ekkert, Health Protection, Interior Health Authority
- Skye Thomson, Regional Hydrogeologist (Penticton), Ministry of Forests Lands and Natural Resources
- Evelyn Riechert Planner, Regional District of Okanagan Similkameen*
- Stephen Juch, Subdivision Supervisor, Regional District of Okanagan Similkameen*
- Steve Underwood, True Consulting Ltd.,
- Chris Scott, Development Manager, Osoyoos Indian Band
- Doug Geller, P.Geo., Project Manager/Senior Hydrogeologist, WWAL
- Trina Koch, B.Sc., Environmental Scientist, WWAL

* Mr. Juch and Ms. Riechert shared the TAC duties on behalf of RDOS.

1.3 Information Sources

There has been significant work and associated reporting pertaining to the Town water system as a whole, which utilizes both groundwater and surface water sources, with subsequent treatment and distribution. In conducting this assessment WWAL reviewed background reports already in our files from prior Town work relating to the water system and the groundwater well by True and completed concurrent hydrogeological studies that included pumping tests, the GWUDI/GARP assessment, and conceptual hydrogeological model development. The following lists those reports that provided relevant information for this Source Water Assessment (references are also cited at the end of this report).

- Town of Oliver, Annual Water Reports (most recent is for 2013)
- Western Water Associates Ltd. 2012. Assessment of Groundwater Under the Direct Influence of Surface Water (GWUDI), Town of Oliver.
- Western Water Associates Ltd. 2014. Buchanan Road Well Completion Report.
- Golder (2004). Initial Steps of a Wellhead Protection Plan.
- Toews and Allen (2007) report on well capture zone modeling.
- Well and water system design drawings provided by TRUE
- Water system operational records provided by the Town including historical water quality sampling of wells
- A 2011 report on ambient groundwater monitoring networks prepared for MFLNRO
- Various well completion reports and other information as compiled by TRUE (2002) and available on Ecocat.

Additionally, the following sources of information were researched for the SWA:

- MOE contaminated sites registry
- Ecocat (BC Ecological Reports Catalogue)
- Well drillers reports (BC Wells Database)
- BC Water Resources Atlas
- Historical Air Photographs
- Interviews with TAC members and identified knowledgeable persons
- Town information indicating water service areas, sanitary sewer service areas, storm water collection system, and land use / zoning information.

2. BACKGROUND

This section of the report provides an overview of the water system, area well records, site setting and geology/hydrogeological review.

2.1 Town of Oliver Groundwater System Overview

This section gives an overview of the Town of Oliver, and the context of the proposed source protection plan within the larger context of water management and source protection in the Okanagan Basin. Oliver is situated in the southern end of the B.C. portion of the Okanagan valley, between Vaseux Lake to the north and Osoyoos Lake to the south (Figure 1). The elevation of the valley bottom in this area is approximately 250 m above sea level (asl). The highest portions of the surrounding uplands reach approximately 2,300 m asl at Mt. Baldy east of Oliver.

The Town's "Annual Water Report" provides a detailed overview of the municipal and water system including its history, how the system is operated, monitoring details, water use, and a summary of planned or ongoing capital projects. This report and other information are provided on the Town of Oliver website (www.oliver.ca). Oliver operates a municipal domestic water supply that shares a similar history with most of the other major water suppliers in the Okanagan Valley. In the 1920s, a canal diverting water from the Okanagan River north of Oliver was built near McIntyre Bluff by the Province of B.C. to bring irrigation to the southern part of the Okanagan Valley including Oliver and Osoyoos. This irrigation system was turned over to the South Okanagan Land Improvement District (SOLID) in the 1960s; and in 1989, the SOLID system was integrated into the Towns of Osoyoos and Oliver. Today, the Oliver water system serves a population approaching 6,200 including domestic services in Town and surrounding rural areas. There are approximately 2,400 rural and in-town connections (commercial and residential), and the non-domestic system provides irrigation water for approximately 3,000 acres of farmland. Planned twinning of the irrigation and domestic water supply distribution system is now complete. Water wells provide 100% of the domestic supply at all times of the year. Parts of the rural Blacksage area are not twinned and there are no plans to do so at this time.

Historically, the Oliver water system was quite complex and comprised of seven "systems" (similar to zones) that supply domestic and/or irrigation water to various parts of community along a 10 km stretch of the valley. Some water systems, such as the municipal (domestic) system serving the Town core, have been supplied by wells for many years. System twinning has been ongoing for many years and the separation of agricultural and domestic water supplies as noted above is now complete with System 1 at the north end of the area commissioned in 2014. As system twinning progressed, Oliver made connections between supply wells and the new separated domestic connections in the rural areas. The various systems are interconnected and during times when demand is high, a well(s) from a neighbouring system may activate to contribute to adjacent systems. At present, all domestic supplies are provided by wells and agricultural supplies, depending on the location, are provided by a combination of wells and surface water.

Table 1 provides a generalized summary of the Town's water system and shows which wells contribute water to each system. The town water system can now be viewed as a domestic/municipal system and an agricultural system throughout almost all of the areas served (for further details, refer to the Annual Water Report). Table 2 provides a well construction summary of each Town well. A map of the Town well areas is attached as Figure 2. The wells listed in Table 2 in the light blue shaded cells are those wells which Oliver intends to use to supply drinking water to municipal/rural customers and are the focus of

this SWA. Appendix C provides the well drillers logs for the Town wells along with well completion diagrams where available.

Table 1 Wells Contributing to Oliver Water Systems

	Municipal System	System 2	System 4, 5, 6, 7	System 1
Domestic Well Sources	Tuc-El-Nuit #2 Tuc-El-Nuit #3 CPR Lions Park Rockcliffe Fairview (irrigation only) Buchanan Rd.	Primarily Blacksage #1, #2 and #3 in Summer, and occasionally Miller Road when needed. In winter when demand is lower, the municipal system wells supply water to this area.	Miller Road and Municipal System	Surface water source in irrigation season. Buchanan Road, supplemented by municipal when needed during non-irrigation season.

Table 1 Notes:

- 1) In 2014, Oliver replaced the Buchanan Rd domestic well with a new well and also drilled an irrigation supply well at the Buchanan Rd well site. In future Buchanan would supply domestic for System 1.
- 2) Fairview well is no longer used for domestic / drinking water
- 3) Oliver plans to discontinue using the Lion's and CPR wells and replace that capacity with the new Buchanan Rd domestic well. All wells and their status will be addressed in the proposed project.
- 4) In this report, "Tuc-El-Nuit" and "Tuc-El-Nuit" refer to the lake and the wells respectively

Table 2 Well Construction Summary Data for Town Domestic Wells

Well Name	Total depth (m / ft)	Diameter (mm / inches)	Depth to top of screen (m/ft)	Static water level (m/ft)	Rated or Nominal Capacity (L/sec /US gpm)	Notes / Land status
Buchanan Road	22.0 / 72	200 / 8	17.4 / 57	2.1 / 4.5	22.1 / 350	System 1 supplementary supply. Constructed 1968. Closed in 2014. There is also a 600 US gpm irrigation well at the site.
Buchanan Road (new)	22.2 / 73	400 / 16	16 / 53	3.9 / 12.8	63 / 1000	Proposed to be operational in 2015. Town has licence of occupation, on Crown land.
Tuc-El-Nuit #1	14.0 / 46	200 / 8	11.0 / 36.1	3.4 / 11.0	15.8 / 250	Municipal System well (inactive). Constructed 1971.

Well Name	Total depth (m / ft)	Diameter (mm / inches)	Depth to top of screen (m/ft)	Static water level (m/ft)	Rated or Nominal Capacity (L/sec /US gpm)	Notes / Land status
Tuc-El-Nuit #2	14.3 / 47	300 / 12	10.4 / 34.1	3.4 / 11.0	75.6 / 1200	Municipal System well (active). Constructed 1971. Located on Fortis ROW.
Tuc-El-Nuit #3	13.7 / 45	250 / 10	10.3 / 34.0	4.0 / 13.1	41.0 / 650	Municipal System well (active). Constructed 1982. Fortis ROW.
Lions Park Well	23.2 / 76.1	400 / 16	18.3 / 60.0	1.8 / 5.9	77.5 / 1230	Municipal System well, used in peak demand period only (active). Constructed 1980. To be deactivated and then closed.
CPR Well	13.6 / 44.6	400 / 16	9.1 / 29.8	1.2 / 4.0	72.4 / 1150	Municipal System well, used in peak demand period only (active). Constructed 1980. To be deactivated and then closed.
Rockcliffe Well	24.4 / 80.0	400 / 16	15.0 / 49.2	6.3 / 20.6	94.5 / 1500	Municipal System well (active). Constructed 1990. On Town owned land.
Blacksage #1	25.7 / 84.3	400 / 16	11.6 / 38.0 Upper Screen	2.8 / 9.2	126 / 2000	System 2 well (active). Constructed 1981. Well has "double screen". WTN49481; WPN22910. On Town land.
Blacksage #2	15.2 / 50	400 / 16	unknown	2.4 / 8.0	25.2 / 400	System 2 well (active). Constructed 1971. Shallowest of the three Blacksage wells. WTN24513; WPN22911 On Town land.
Blacksage #3	31.1 / 102	200 / 8	unknown	1.8 / 6.0	12.6 / 200	System 2 well (active). Constructed 1970. Likely deepest screened interval of the three Blacksage wells. WTN23793; WPN22912 On Town land.

Well Name	Total depth (m / ft)	Diameter (mm / inches)	Depth to top of screen (m/ft)	Static water level (m/ft)	Rated or Nominal Capacity (L/sec /US gpm)	Notes / Land status
Miller Road Well	18.4 / 59.0	300 / 12	14.3 / 46.9	2.8 / 9.2	69 / 1092	System 6 and 7 well. Constructed 2004. MOTI ROW approval to Town.

Notes for Table 2:

- Tuc-El-Nuit #1: SWL as reported on completion diagram in 1971. Rated capacity from completion report (1971).
- Tuc-El-Nuit #2: SWL as reported on completion diagram in 1971. Rated capacity from a 2000 Kala Groundwater report evaluating the combined yield possible from the Tuc-El-Nuit well field.
- Tuc-El-Nuit #3: SWL and rated capacity as reported in the Kala Groundwater well completion report (1982).
- Lions Park Well: SWL and rated capacity as reported on Well drillers log (1980).
- CPR Well: SWL and rated capacity as reported on Well drillers log (1980).
- Rockcliffe Well: SWL and rated capacity as reported in Kala well completion report (1990)
- Blacksage #1: SWL and rated capacity as reported in Kala well renovation report dated 1985.
- Blacksage #2: A well log for Blacksage #2 was obtained from the B.C. Water Resources Atlas and is the source of the data in Table I.1. No information on screen design is available. The total depth is assumed to be 50 ft based on the total drilling depth on the well log. Specific capacity data on the well log indicates that the well is capable of higher yields than the driller's estimate.
- Blacksage #3: A well log for Blacksage #3 was obtained from the B.C. Water Resources Atlas and is the source of the data in Table I.1. No information on screen design is available. The total depth is assumed to 102 ft based on lithology reported on the driller's log.
- Miller Road well: SWL and rated capacity as reported in the Golder 2004 GWPP report.
- Buchanan Rd (new) SWL and rated capacity as per VVWAL 2014.

2.2 Recent Groundwater Use and Nominal Capacity

As noted in Section I of this report, the scope of this SWA does not include a detailed audit or review of groundwater or water system capacity (Module 4). This report subsection provides an overview of recent groundwater usage and a discussion of how the wells are expected to operate in the future.

The OBWB Water Management and Use Study (Dobson 2008) completed for the Phase 2 OKWSD Project assembled and reviewed several years worth of water use data for the large water purveyors in the Okanagan Valley. According to that study, in 2006 Oliver pumped 3977 ML of groundwater, making it the second largest groundwater user amongst the valley's major water suppliers. The Town's status as a major groundwater user in the valley has probably not changed significantly since 2006 but the Town's groundwater use has decreased, a result of water conservation efforts and system twinning. For example, 2013 groundwater use was under 3,000 ML, but will likely remain steady now that system twinning is complete. As noted above, the Town's water system serves a year-round population of approximately 6,200 residents within the municipal boundary and those in rural areas north and south of the Town core are also included. The table below summarizes recent groundwater well usage for the years 2012 and

2013 and report Appendix H provides monthly and annual well usage data for those two years. Overall use was consistent at approximately 515 million gallons (US) or approximately 2,000 ML for the five domestic/municipal wells. The Town continues to monitor, record and report well usage in its Annual Water Reports, which are available on the Town website.

Table 3 Well Usage Summary for 2012 and 2013

	CPR and Lions Park	Rockcliffe	Tuc-El-Nuit #2	Tuc-El-Nuit #3	Miller Rd	TOTAL
2012 use (US gal)	34,334,059	219,358,557	191,252,601	69,712,403	584,612	515,242,232
% of GW supply	6.7	42.6	37.1	13.5	0.1	
Peak use month	August	May	August	October	June	
2013 use (US gal)	Not used	110,017,715	187,379,931	97,938,077	119,283,266	514,618,989
% of GW supply	0	21.4	36.4	19.0	23.2	
Peak use month	--	May	August	July	February	

Note: the above summary pertains to wells that pump only to domestic supply. For data on the wells pumped in 2012 and 2013 for both agricultural and domestic supply (Buchanan Rd, Fairview and Black Sage, see Appendix H). The major differences between 2012 and 2013 are that the CPR and Lions Park wells were not used in 2013 and the Miller Rd. well was used much more in 2013, partially feeding the system formerly supplied by Rockcliffe and CPR/Lions Park. Some of the Miller Rd well use was for a water treatment pilot test for manganese reduction. The only wells that are typically used year-round are Rockcliffe and Tuc-El-Nuit.

As system operation continues to evolve, the supply wells that Oliver will use are expected to change from the patterns seen in recent years. The major changes over the past several years have been driven by system twinning as well as preference for higher quality groundwater for domestic supplies. These changes are summarized below:

- Replaced old Buchanan Road well (which supplied both domestic and agricultural connections) with two wells, one dedicated to agricultural and one for domestic. The domestic well is a 16 in / 400 mm diameter well with 1000 US gpm design capacity; (net increase of 650 US gpm domestic);
- Eliminate Lions Park and CPR wells from the water supply (decrease of 2,380 US gpm domestic)
- Discontinue use of Fairview well for domestic supply (decrease of 425 US gpm domestic; converted to agricultural).
- Add Buchanan agricultural well (600 US gpm); total increase in Ag supply from wells is 1,025 US gpm

- **Summary:**

- Net overall decrease in groundwater supply = 1,130 US gpm
- Domestic groundwater capacity (nominal) = 4,600 US gpm
- Agricultural groundwater capacity (nominal) = 775 US gpm
- Black Sage system combined capacity (nominal) = 3,692 US gpm

The net change in overall domestic groundwater supply capacity as a result of system modifications will be a reduction in capacity of approximately 70 L/sec / 1000 US gpm, and starting in 2015, seeing the bulk of the domestic supply coming from Buchanan Road, Tuc-El-Nuit, and Rockcliffe well sources, plus the existing Black Sage and Miller Road system operating as it has in the past as a combined domestic/irrigation supply. The individual well usage will be tracked as the Town has done previously, and if necessary, reported out separately to fulfill Source to Tap Module 5. As of 2014, the CPR and Lions Parks wells have been deactivated as the old Buchanan Rd well has been closed. The report recommendations (Section 7) address the requirements for well closure under the Groundwater Protection Regulation for inactive wells.

2.3 Area Well Records

This section identifies known or recorded well locations and information for wells located in the vicinity of the Town of Oliver wells based on information provided in the BC Wells Database. Well records do not typically indicate whether a well is operational, closed, or abandoned, nor do they provide information regarding actual groundwater use in an area, however, they can provide information regarding aquifer characteristics (e.g., aquifer materials, potential yield, and approximate depth to groundwater).

2.3.1 BC Wells Database

The BC Water Resources Atlas was used to identify wells on record in the BC Wells Database within approximately 2.5 km of each well area. The search was separated into areas north and south of Town centre. Well areas north of Town centre include Buchanan, Tuc-El-Nuit, Lion's Park and CPR. Well areas south of Town centre include Rockcliffe, Fairview, Miller Road and Black Sage. The northern well search extended from Similkameen Avenue to Gallagher Lake and the southern well search extended from Similkameen Avenue to 2.5 km south of the Black Sage well area. Both well searches included wells located in the valley bottom and sides.

WELLS database searches indicated that well types and uses were comparable north and south of Town centre. A total of 403 wells are located north of Town centre and 323 wells are located south of Town centre (726 in total). Of these wells, 12 drinking water system wells (private and municipal) were identified north of Town centre and 6 were identified south of Town centre. Most wells north and south of Town centre were identified as being either irrigation or private domestic wells. There were 2 provincial observation wells located north of Town centre (407 and 348) and 3 located south of Town centre (87, 332 and 405) (See Section 2.2.2). North of Town centre, there were 174 drilled wells (61% of total

reported) and 109 dug wells (39% of total reported). South of the Town centre, there were 96 drilled wells (45% of total reported) and 119 dug wells (55% of total reported).

The WELLS Database searches indicate differences between aquifer characteristics north and south of Oliver’s Town centre. Averages of reported well depths, static water depths, bedrock depths and well yields were higher south of Town centre compared to north. South wells were, on average, 30% deeper with static water levels 42% deeper than north wells. Similarly, average bedrock depth was 50% deeper and average well yield was 20% higher in south wells than north wells. It was also noted that more than twice as many wells were drilled into bedrock south of Town centre than north of Town centre. Table 3 summarizes the WELLS Database information. The table includes a summary of averages for depth to bedrock, well yield (driller estimated), static water depth and well depth. It also indicates the documented number of total wells, drinking water system wells, observation wells, drilled wells and dug wells in each search area. Information provided in each well log is variable and missing data is common. Tables providing detailed WELLS data for both search areas are attached as Appendix D. The WELLS data base shows that private well owners utilize existing wells for irrigation and domestic use. However, information regarding the full extent of the groundwater use is not well documented. Areas outside the Town water service area are inferred to primarily utilize private wells for water supply.

Table 4 Summary of Search Areas Well Record Information

Summary of Well Record Information											
Search Area	Total Wells	Sand and Gravel Aquifer	Bedrock Aquifer	Averages				Well Types			
				Well Depth (ft)	Static Water Depth (ft)	Bedrock Depth (ft)	Well Yield (gpm)	Drinking Water System	Obs.	Drilled	Dug
Oliver North	403	311	12	71	20	29	116	12	2	174	109
Oliver South	323	235	28	101	34	58	144	6	3	96	119
Both	726	546	40	86	27	43	130	18	5	270	228

2.3.2 Provincial Observation Wells

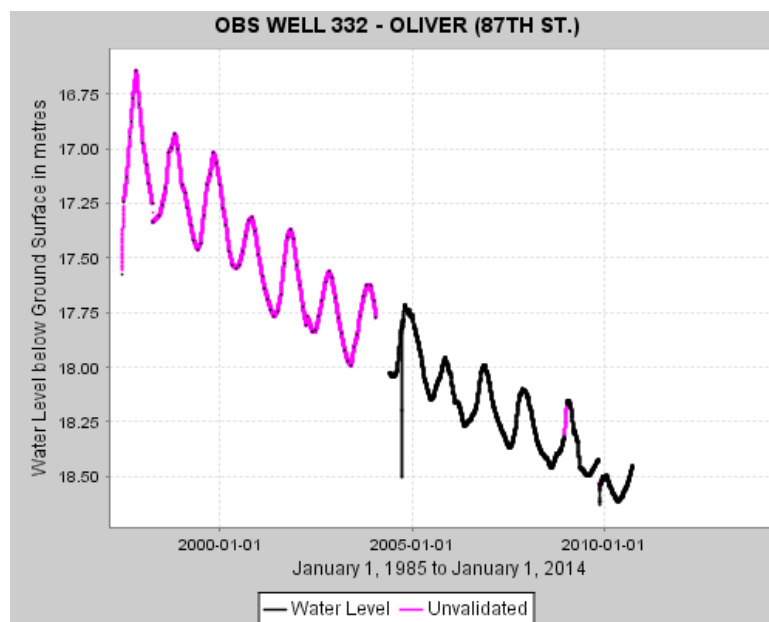
There are five provincial observation wells located within the study area; 2 north of Town centre (407 and 348) and 3 south of Town centre (87, 332 and 405). Of these, three wells are actively monitored: Observation Well 407 is an active observation well drilled in 2011, and located approximately 349 m northeast of the Buchanan Well and 2.6 km north of the Tuc-El-Nuit well area. Observation Well 405 is an active observation well drilled in 2011. It is located approximately 773 m southwest of the Rockcliffe well area and 2.4 km southwest of the Lions Park and CPR well areas. Observation Well 332 is an active observation well drilled in 1983. It is located approximately 1.3 km north of the Miller Road and Blacksage

well areas. The locations are shown on Figure 7 along with the provincial Ambient Water Quality Network monitoring wells (see Section 3.4).

Observation wells 87 and 348 were removed from the network and are no longer available. However, the province considers the Oliver a priority area for monitoring due to heavy reliance upon groundwater and potential groundwater level declines and is actively seeking additional suitable well locations for dedicated long-term monitoring.

Three observation wells are viewable on the interactive mapping application on the Ministry of Environment website http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html

Water levels in Observation wells 405 and 407 (not shown in this report) appear relatively stable or slightly rising in the past couple of years. In contrast, the hydrograph for Observation well 332 (which has a longer period of record) is shown below. Approximately 1.5 m of water level decline is evident from the period of record shown. This well is completed in Aquifer 254, about 1 km north of the Town's Black Sage and Miller Road wells. The data do not appear to have been updated since 2011. See Recommendations for use of this well to inform the Town's groundwater management efforts.



2.4 Setting, Topography and Surface Water Hydrology

Oliver's supply wells are in the Okanagan Valley located in the southern interior of BC about 20 km north of the Canada/US border and adjacent to Osoyoos Indian Reserve No., which borders Oliver's eastern city limits. The wells are located within the Bluebunch Wheatgrass and Ponderosa Pine Biogeoclimatic Zones. The hot, dry climate in these zones result in fragile ecosystems with limited plant productivity and

soil development that support a diverse array of wildlife and plant species. Oliver's economy relies principally on agriculture and tourism, with the many wineries in the area creating a close link between these two sectors. Other land uses include residential, industrial, cultural, recreational and urban. Increased development over the years has elevated the demand for water in the Town of Oliver.

Topography surrounding the supply wells is dramatic. The valley bottom is relatively flat with elevations ranging between 300 and 330 masl. Its width fluctuates between about 1-6 km with the narrowest section north of the Buchanan Road between Gallagher Lake and McIntyre Bluff and the widest section surrounding the Town's centre. The highest point to the southwest is Mt. Kobau at a height of 1,870 masl. The eastern valley sides rise more gradually through the Inkaneep Provincial Forest with the highest point being Mt. Baldy at 2,300 masl located about 40 km from the Oliver's Town centre. The western valley sides rise abruptly and are incised with drainage channels that flow into the valley bottom. These include Testalinden Creek, Hester Creek, Tinhorn Creek, Togo Creek and Reed Creek to the south, Park Rill to the north and unnamed ephemeral channels. About 10 drainage channels flow into the valley bottom from the eastern valley sides including Inkaneep Creek to the south, Atsiklak and Wolfcub Creeks to the north and numerous unnamed ephemeral channels.

The Okanagan River watershed generates runoff from rainfall and snow melt that contribute to recharge water in the aquifers. The Okanagan River flows freely passed the Buchanan Road well but is continuously channelized for 17.1 km, from 1 km north of Tuc-El-Nuit Lake to Osoyoos Lake. Many oxbow lakes (oxbows) exist along either side of the Okanagan River as a result of its channelized state. Oxbows are located within 200 m of the Lions Park, CPR, Miller Road and Blacksage well areas. Tuc-El-Nuit Lake has a surface area of about 1 km² and is located about 1.3 km south of the Buchanan well area and 189 m from the Tuc-El-Nuit well area. It receives surface flow from the eastern highlands in its southeast section and flows into the Okanagan River from its northwest section. Other lakes within the watershed include Gallagher Lake and small kettle lakes. Gallagher Lake is a kettle lake with no surface inflow or outlet, and has an area of 5.1 HA. It is located about 3.2 km northeast of the Buchanan Road well area. A small unnamed lake (about 2.5 HA) with surface flow from a channel along the eastern valley side is located south of Gallagher Lake and about 1.6 northeast of the Buchanan Road well area. Another small kettle lake (2.7 HA) is located 818 m southeast of the Rockcliffe well. Small kettle lakes also dot the highlands west of the valley.

2.5 Surface Water Quality

A review of water quality assessment results for Tuc El Nuit Lake, Okanagan River and some of its oxbows was completed.

A report on long term trends in Okanagan River's water quality (1979 – 2002) from samples collected at ENVIRODAT station 08NM0001 located near No. 18 Road between Oliver and Osoyoos was reviewed (BWP 2013). Analyzed parameters included general chemistry, nutrients, metals and bacteria. Results included the following:

- Fecal coliform was detected in 25% of the samples. Concentrations ranged from below detectable limits (<1 CFU/100 mL) to < 20,000 CFU/100 mL. Input from irrigation flumes are a possible source of these coliforms since the Town of Oliver ceased the discharge of secondary sewage in 1984¹;
- Chloride concentrations showed an increasing trend;
- Forty-eight percent of turbidity values exceeded the drinking water guideline of 1 NTU, while 9% also exceeded the aesthetic drinking water guideline of 5 NTU;
- Seven percent of the total iron concentrations exceeded the aquatic life and aesthetic drinking water guideline of 0.3 mg/L with exceedances occurring primarily during spring freshet;
- The strong correlation between total iron and turbidity indicates that higher levels of iron are associated with particulate matter;
- Aluminum, chromium, iron and zinc all exceeded drinking water guidelines on a regular occasion. All of these metals appeared to be closely correlated with turbidity, suggesting that the metals were bound to particulate matter and would not be toxic to biota;
- Dissolved organic carbon, true colour, fluoride and sulphate all occasionally exceeded drinking water guidelines, and
- Water temperatures in the Okanagan River regularly exceeded both the aesthetic drinking water guideline of 15°C and the general fisheries guideline of 19°C during summer months (July and August).

Water quality data were also available from WWAL's GWUDI study completed in 2011 for samples collected from Tuc-El-Nuit Lake, Okanagan River and some of its oxbows. Electrical conductivity, pH and temperature measurements were collected on five occasions between July 17 and August 25, 2011. Water quality data showed that Okanagan River and the oxbow samples had a similar chemical signature, regardless of the sampling location and that Tuc-El-Nuit Lake water was distinct from river water, showing greater mineralization (suggesting local groundwater influence).

2.6 Climate

Town wells are located in the Bluebunch Wheatgrass (BB) and Ponderosa Pine (PP) Biogeoclimatic Zones. The hot, dry climate in these zones has resulted in fragile ecosystems with limited plant productivity and soil development that support a diverse array of wildlife and plant species.

Based on data for a climate station located in Oliver (Climate ID 1125760) as reported in 'Canadian Climate Normals, 1971 – 2000 for BC' (Environment Canada), the average annual daily temperature is 9.4°C with daily mean temperatures ranging from -2.6°C in January to 21.1°C in July. Total annual precipitation reported at the Oliver weather station between 1971 and 2000 was 327.5 mm.

2.7 Geology and Hydrogeology Overview

The early work mapping the surficial deposits of the Okanagan Valley by Nasmith (1962) remains a primary reference used by most geological investigations today. Using the Nasmith maps as a basis, the surficial and bedrock geology of the Oliver area is summarized in the Golder (2004) and the Toews and Allen

¹ Pers. Comm. Mabelle Tiernan, Ministry of Forest Lands and Natural Resources. July 7, 2015

(2007) reports, and is very briefly described below. Section 2.7 of the Toews and Allen (2007), which is publicly available, provides the most detailed discussion of the geology and hydrostratigraphy and will not be repeated here. WWAL (2011) also summarized hydrogeology in the GWUDI assessment for the Town's wells. Surficial geology governs the occurrence and behaviour of water in the water supply aquifers of the Okanagan River valley around Oliver. For the purposes of this source water assessment, these deposits can be classified informally as belonging to the following four types of surficial material:

- Modern day Okanagan River floodplain deposits composed chiefly of silt, silty sand, and gravel;
- Alluvial fans and fan-delta complexes associated with the tributary streams entering the valley from the surrounding uplands;
- River terrace and stratified glacial drift sand and gravels associated with the most recent glacialiation;
- Outwash, moraine and ice-contact deposits occupying portions of the valley generally above the level of the Town's supply wells.

The Town wells, with the exception of Rockcliffe, are completed in two provincially-mapped aquifers (Nos. 254 and 255) that both occupy the main valley bottom south of the confluence of Vaseux Creek and the Okanagan River a few km north of downtown Oliver, with 255 present north of Town and 254 present to the east and south of Town (Figure 2).

Provincial aquifers 254 and 255 have a relatively shallow water table, are classified as moderately to highly productive, and have a high vulnerability to potential contamination. These are both "IA" aquifers and as such would fall into a high priority for groundwater protection measures. Wells in and around Oliver as well as other areas in the South Okanagan with a long agricultural land use history exhibit elevated nitrate levels. Observed nitrate concentrations in the valley range from about 0.5 mg/L to more than 10 mg/L. See also Section 3.4.

Provincial aquifer 256 is described as a confined to semi-confined system, and underlies portions of the Town and areas to the west of the Okanagan River. This aquifer, believed to be the source of water for the Rockcliffe well, is in part associated with alluvial fans emanating from several creeks draining the west side of the valley, such as Testalinden and Hester creeks and may also be associated with buried glacial outwash deposits. The aquifer is less vulnerable to potential contamination sources and likely see less overall groundwater demand than the two shallow aquifers 254 and 255.

Based on well log information (Appendix C and D), as well as the information reported by Golder (2004, Section 5.1.1) the Town wells are all completed in unconfined aquifer settings, including the Rockcliffe well, the log for which noted sand and gravel from surface to a depth of 24 m (the well is completed above a basal silt layer).

The Oliver area aquifers, as mapped by MoE were further assessed during the Phase 2 Okanagan Basin Water Supply and Demand (OKWSD) Project by Golder Associates and Summit Environmental (Golder-Summit 2009). In general, the aquifer system is moderately to highly productive, is unconfined or semi-confined and is moderately to highly vulnerable to contamination originating at the land surface. Its average

annual groundwater flow (discharge) of well over 6×10^7 m³/year makes the aquifer one of the largest aquifer systems in the valley (see Table 10 of the Golder-Summit study).

The aquifer system in Oliver is considered a potentially important contributor to groundwater discharging as baseflow along the mainstem Okanagan valley groundwater system. Because the aquifer is relatively shallow and unconfined in most places, there is a likely a high degree of inter-connectedness between groundwater and surface water. The local and regional significance of the Oliver area aquifer system makes it a high priority for protection. The Province of B.C. identified the Oliver area aquifer system as a high priority for further aquifer characterization (B.C. Ministry of Environment 2012). While such characterization is beyond the scope of the SWA, additional detailed hydrogeological knowledge could help inform future source protection efforts, particularly in the areas to the north of Oliver where existing groundwater quality is thought to be better (as evidenced by lower TDS values and lower nitrate – see also, Section 3.4 below), and where groundwater extraction by the Town as well as Osoyoos Indian Band, are expected to increase. The list of priority aquifers is also subject to change based on emerging local issues and concerns, and although there are no currently ongoing projects for the Oliver aquifers, we understand that the province is open to exploring opportunities to fund additional aquifer characterization with interested municipalities.

3. MODULE I: DELINEATION AND ASSESSMENT OF WATER SOURCES

Module I provides the framework for completing the SWA and involves aquifer assessment, and a summary review of water quality, followed by delineation of well capture zones and source protection areas. Note that we are not using the term “aquifer characterization”, which in B.C. has a specific meaning as described by MoE (2012). Instead, our review of existing information is considered an assessment, consistent with this project being a source water assessment.

3.1 Aquifer Assessment

3.1.1 Regional Aquifer System

The Oliver SWA study area overlies the main valley bottom aquifer system of the South Okanagan. This aquifer system is principally recharged by seepage from Vaseux Lake, Vaseux Creek and other tributary streams along with reaches of the Okanagan River that may lose water to the ground seasonally. Toews and Allen (2007) provide a detailed discussion of the aquifer system. The Golder – Summit (2009) report also provides an overview of basin hydrogeology.

3.1.2 Local Aquifer Conditions and Hydrogeological Properties

The main aquifer in the study area is the upper unconfined sand and gravel aquifer adjacent to Okanagan River. Upper unconfined sand and gravel aquifers are also present at higher elevations, along the valley margins. Regions with sufficient geological data show that the saturated thickness of the upper aquifer

adjacent to Okanagan River varies from a few m to 20 m or more (up to 60 m), which is influenced most by the silt top elevation. Some zones of high saturated thicknesses can be associated with kettle holes in the silt top, such as near Rockcliffe, Fairview, Miller Rd., and other production wells. The upper glaciofluvial units in the northern valley bottom contain layers of fine sand, which make some of the wells partially confined. These finer grained confining deposits appear to be discontinuous. Deeper confined sand and gravel aquifers are found along the valley margins, which are in alluvial deposits. Many of these alluvial fan deposits interfinger the glaciolacustrine deposits at depth, and likely extend less than several hundred metres toward the valley centre. These aquifers are likely to be most influenced by ephemeral streams (Toews and Allen 2007).

The B.C. Ministry of Environment maps and classifies known aquifers in the province using the system first described by Kreye et al (1998). There are three mapped and classified aquifers in the Oliver area:

- **Aquifer 254 IA.** This aquifer extends from the south end of Tuc-El-Nuit Lake in the north to the north end of Osoyoos Lake and occupies the valley bottom on both sides of the Okanagan River. Primarily unconfined, the aquifer is classified as having a moderate demand, high productivity and high vulnerability to contamination. Golder's review of well logs in this aquifer (Golder 2004) indicates that the aquifer is comprised predominantly of sand and gravel and is typically underlain by a silt and-or clay layer. Private residential wells completed in the aquifer range from shallow dug wells to drilled wells up to 30 m deep, with static water levels near the river of less than 1 m below ground increasing to 7.3 m in wells further from the river (and presumably at higher elevation). Most of the Town of Oliver wells are completed in Aquifer 254, including the Tuc-El-Nuit wells, the CPR and Lions wells, the Black Sage Wells and the Miller Road Well.
- **Aquifer 256 IIIC.** This aquifer underlies the town core of Oliver on the west side of the Okanagan River. Aquifer 256 is semi-confined or confined, and classified as having a moderate demand, low productivity and low vulnerability to contamination. Wells completed in this aquifer are characterized with thick deposits of silt or clay (sometimes inter-bedded with sands) overlying the aquifer. The Rockcliffe well is located within the mapped extent of Aquifer 256, but is not completed in a confined aquifer. The mapped extent of aquifer 256 overlaps with aquifer 254 south of the Rockcliffe well, and it is likely the area in which an unconfined aquifer overlies a deeper confined aquifer is more pervasive than the mapping indicates.
- **Aquifer 255 IA.** This aquifer is located north of Tuc-El-Nuit Lake and extends to Vaseux Lake. The aquifer is classified by MOE as having a high demand, moderate productivity and high vulnerability to contamination. The high vulnerability to contamination classification suggests that the aquifer is unconfined, but a review of well logs indicates that there may in fact be an unconfined aquifer overlying a deeper confined aquifer in much of its mapped extent. The Buchanan Road well is located with aquifer 255.

In reality, the above mapped aquifers are interconnected and are not distinct. In many places, more than one stacked aquifers are present, and the overall system is more complex than the simplified Provincial mapping might suggest. However, those aquifers classified as IA by the Province are likely the most

sensitive to potential impacts from land uses, and as such, it is apparent that source water protection is an important part of managing the Town's water sources.

As noted previously, Phase 2 of the Okanagan Basin Supply and Demand Study Groundwater component (Golder-Summit 2009) also evaluated the aquifer system occupying the Okanagan River Valley in the Oliver area. Three valley bottom aquifers were delineated in the Oliver area, numbered 213, 214 and 215. The predominant direction of groundwater flow in the aquifer is from north to south, driven by the elevation difference between Vaseux Lake and Osoyoos Lake. Discharge through the most southerly of these three aquifers was estimated to be $1.84 \times 10^7 \text{ m}^3/\text{year}$.

Aquifer vulnerability and direct recharge from precipitation were modelled in the Okanagan Basin (Liggett 2008). The vulnerability study evaluated mapping approaches for regional and local scales using the DRASTIC method. The monthly distribution of recharge from two models in the Oliver area showed a difference in the timing of recharge throughout the year despite using the same code and very similar climate data (Figure 6.15). In the regional model, monthly recharge increased in March to 3.9 mm/month, remained high into May, and then gradually declined to minimum values of 2.7 mm/month in September and October. The local model suggests that recharge increased from a minimum value in March (2.8 mm/month) to a maximum of 4.1 mm/month in July. Recharge remained high until the fall, where it decreased to 3.5 mm/month. Despite the differences between the timing of recharge, the greatest difference in recharge was in July with only a 1.2 mm difference between the local and regional models.

For further discussion on groundwater occurrence in and around Oliver, a good summary is provided in the 2011 report on the Provincial Ambient Water Quality Monitoring wells (WWAL 2011). Water quality information from this report is mentioned below in Section 3.4.

3.2 Previous Well Capture Zone Assessments

Capture zones can be defined as the portion of the well's recharge area that contributes water to the well under an assumed pumping rate and duration. A variety of methods are available to calculate and delineate capture zones (e.g., arbitrary fixed radius, analytical solution, calculated fixed radius, numerical modeling, or hydrogeological mapping; MOE 2006), and these methods vary in terms of their complexity and information requirements. In cases where more data exist, more complicated delineation methods may be employed. Capture zones areas are delineated based on a specified time of travel (TOT). For example, contaminants entering the aquifer within a defined 1 year TOT capture zone have the potential to reach the well within 1 year.

In reality, there is always some error or uncertainty associated with calculated capture zones. To address the inherent uncertainty, **source protection areas** are often defined based on the capture zones. The source protection areas then become the focus for subsequent hazard identification and risk management efforts. As briefly discussed in the report introduction, Golder (2004) and Toews and Allen (2007) previously assessed well capture zones for the Town of Oliver wells. These assessments form a viable

starting point to the process of identifying a groundwater protection area for the currently used Town wells and the aquifers that the wells are completed in.

In addition, we understand that Summit Environmental Consultants recently completed a groundwater protection assessment for the Osoyoos Indian Band Main water system wells located in the vicinity of Tuc-El-Nuit Lake to the north of Oliver. This assessment delineated well capture zones using the Calculated Fixed Radius (CFR) method for the Band's Main wells. If further information on this study becomes available, it will be incorporated into the final SWA report.

Golder also used the CFR method to calculate 60-day capture zones. This method depicts capture zones as being circular and tends to overestimate areas with relatively flat hydraulic gradients, Golder did not determine the hydraulic gradients for the wells but assumed they were flatter near surface water bodies and steeper in upland areas. The 60-day capture zones ranged from a radius of 90 m at the Buchanan Road well to about 200 m at the CPR, Miller Road and Blacksage (1-3) wells. Data gaps that limited the development of more refined capture zones included groundwater flow direction and hydraulic conductivity in areas surrounding the wells. To address these gaps, Golder recommended completing a detailed well analysis of data from Town of Oliver wells and new wells drilled between the Lions Park and CPR wells, upgradient of the Fairview well and upgradient of the Miller Road well. Other recommendations included documenting all septic tanks, ALR lands, disposal fields, abandoned wells and storm water outflows within 60 day travel zones.

Well capture zones were determined by Toews and Allen using MODPATH software for 60 days, 1 year and 10 years. MODPATH is an add-on tool for numerical groundwater flow models developed with the MODFLOW (McDonald and Harbaugh 1988) code. Its application for Oliver's wells is described fully in the referenced report. Capture zones were found to be highly influenced by Okanagan River and surrounding lakes. Compared to the fixed radius capture zones developed by Golder, the MODPATH predicted capture zones were oblong in shape, rather than circular, and had less uniform boundaries. In general, the 10 year capture zones were larger in shape and elongated in the upgradient direction than the 1 year capture zones. Differences in size and shape between the 1 and 10 year capture zones of the Miller Road and Tuc-El-Nuit #2 wells were minimal whereas the 10 year capture zones for the Lions Park and Rockcliffe wells were distinctly larger with longer upgradient extensions. The Toews and Allen well capture zones appear on Province of B.C. mapping applications and have been imported into this SWA project database and reproduced on the attached maps (Figures 3 and 4).

3.3 Proposed Well Capture Zones and Proposed Protection Areas

We propose to adopt the Toews and Allen (2007) well capture zones for this project because they were delineated using a numerical modeling tool. Although some details on individual well pumping rates have changed since those capture zones were determined, such changes do not warrant going through the effort of additional groundwater modeling to update the capture zones. GIS generated data on the capture zones are summarized below in Table 4.

Table 4. Capture Zones Areas (based on Toews and Allen)

Name	Capture Zone	Hectares
Blacksage Wells	1 year	19.7
Blacksage Wells	10 year	24.8
Buchanan Rd. Well	1 year	8.1
Buchanan Rd. Well	10 year	10.5
Miller Rd. Well	1 year	12.6
Miller Rd. Well	10 year	16.2
Rockcliffe Well	1 year	49.8
Rockcliffe Well	10 year	106.0
Tuc-El-Nuit Wells	1 year	17.8
Tuc-El-Nuit Wells	10 year	18.9

Based on Toews and Allen’s capture zone calculations as well as inferred potential groundwater recharge areas identified in the conceptual hydrogeological model, a groundwater source protection area is proposed (Figure 4), which has been modified from the version presented to the TAC in October 2014. The protection area can be thought of as an overall aquifer protection area considering the relatively shallow and sensitive nature of the aquifer, and has been extended further to the north of the Buchanan Rd well as discussed in the TAC meeting. The capture zones are the parts of this protection area that warrant special consideration in managing current and future land use in the protection area.

In terms of a proposed protection area, given that the two main Oliver area water supply aquifers are classified by the Province of B.C. IA, we recommend a preliminary protection area that includes a larger area than just the 1 year or 10 year well capture zones. This proposed area as depicted shown on Figure 4 includes approximately 1,168 ha of land. Note that Town/RDOS, Town/OIB and RDOS/OIB boundaries are shown on this map.

3.4 Source Groundwater Quality

The Town regularly samples its source wells per the terms of its operating permit with IH. The most recent water quality summary is provided below in Table 5, followed by a general discussion of raw groundwater quality compared to surface water quality.

Table 5: Town Well Water Quality Data

			In-Town (1)				Rural (2)						
			CPR Well	Rockcliffe Well	Tucelnuit #2	Tucelnuit #3	Black Sage #1	Black Sage #2	Black Sage #3	Buchanan Road	Fairview Irr. Well	Miller Road	Canal Intake
Parameter	Guide-line	Unit	Domestic	Domestic	Domestic	Domestic	Domestic & Irrigation	Domestic & Irrigation	Domestic & Irrigation	Domestic & Irrigation	Irrigation	Domestic	Irrigation
			August 8, 2011	July 29, 2013	August 8, 2011	July 29, 2013	August 1, 2012	August 1, 2012	April 19, 2010	April 20, 2010	Sept. 23, 2009	July 29, 2013	August 8, 2011
Alkalinity, Total as CaCO3	-	mg/L	194	243	187	197	149	180	300	130	280	234	108
Chloride	≤250	mg/L	10.9	14.7	5.79	14.3	5.37	6.9	11.4	3.96	16	8.34	3.81
Fluoride	1.5	mg/L	0.43	0.34	0.45	0.36	0.12	0.11	0.26	0.32	0.27	0.3	0.15
Nitrogen, Nitrate as N	10	mg/L	0.23	3.75	0.52	1.78	0.379	0.824	3.18	0.01	9.06	1.42	<0.01
Nitrogen, Nitrite as N	7	mg/L	<0.01	<0.010	<0.01	<0.010	<0.01	<0.01	nt	nt	<0.002	<0.010	<0.01
Sulfate	≤500	mg/L	64.6	54.7	35.6	50.8	nt	nt	94	25.3	90	66.4	25.7
Colour, True	≤15	TCU	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	8
Solids, Total Dissolved	≤500	mg/L	317	376	253	310	211	274	449	166	470	346	156
Turbidity	Varies	NTU	0.3	<0.1	<0.1	<0.1	nt	nt	0.2	<0.1	0.14	<0.1	0.7
pH	6.5 to 8.5	pH	8.18	7.92	8.12	8.03	7.86	7.92	7.98	8	8.1	7.95	8.12
Conductivity (EC)	-	uS/cm	501	633	412	530	378	456	703	293	776	595	263
Hardness, Total (as CaCO3)	-	mg/L	206	303	176	241	159	204	373	145	395	295	109
Nitrogen, Nitrate+Nitrite as N	-	mg/L	nt	3.75	nt	1.78	nt	nt	nt	nt	nt	1.42	nt
Aluminum	≤0.1	mg/L	0.008	<0.005	0.008	<0.005	<0.005	0.005	0.005	0.008	0.0007	<0.005	0.028
Antimony	0.006	mg/L	0.0001	0.0002	0.0001	<0.0001	nt	nt	nt	nt	nt	0.0001	<0.0001
Arsenic	0.01	mg/L	0.0043	0.0018	0.0031	0.0033	0.0008	0.0008	nt	<0.0005	0.00072	0.0033	<0.0005
Barium	7	mg/L	0.093	0.058	0.055	0.076	0.039	0.046	0.061	0.0488	0.0905	0.081	0.022
Beryllium	-	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	nt	nt	nt	nt	nt	<0.0001	<0.0001
Bismuth	-	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	nt	nt	nt	nt	nt	<0.0001	<0.0001
Boron	5	mg/L	0.036	0.077	0.021	0.04	0.032	0.049	0.104	0.007	0.141	0.077	0.011
Cadmium	0.005	mg/L	0.00005	0.00002	0.00001	<0.00001	0.00006	0.00003	<0.00001	<0.00001	0.000019	0.00002	0.00001
Calcium	-	mg/L	56.5	82.4	48	67.3	37.9	48	90.7	39.7	114	68.9	29.6
Chromium	0.05	mg/L	<0.0005	0.0006	0.0008	0.0006	<0.0005	<0.0005	0.0019	0.0016	0.0006	<0.0005	<0.0005
Cobalt	-	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0001	0.00005	0.000176	<0.00005	0.00007
Copper	≤1	mg/L	0.0195	0.002	0.0126	0.0035	0.0258	0.011	0.0035	0.0018	0.0703	0.0051	0.0031
Iron	≤0.3	mg/L	0.03	<0.01	<0.01	<0.01	<0.01	0.01	0.1	0.05	0.016	<0.01	0.03
Lead	0.01	mg/L	0.0011	<0.0001	0.0002	<0.0001	0.0018	0.0016	0.0003	0.0001	0.0117	0.0006	<0.0001
Lithium	-	mg/L	0.0053	0.0086	0.0062	0.0081	nt	nt	nt	nt	nt	0.0065	0.0031
Magnesium	-	mg/L	15.8	23.6	13.6	17.7	15.7	20.4	35.5	11	27.1	29.8	8.46
Manganese	≤0.05	mg/L	0.174	<0.0002	0.0012	<0.0002	0.0196	0.0053	0.0003	0.0597	0.00403	0.0866	0.0056
Mercury	0.001	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	nt	nt	<0.00005	<0.00005	nt	<0.00002	<0.00002
Molybdenum	-	mg/L	0.0127	0.005	0.0055	0.0036	0.0068	0.0049	0.0077	0.0035	0.00506	0.0052	0.0034
Nickel	-	mg/L	0.0005	0.0005	0.0003	0.0003	0.0009	0.0006	0.0028	0.0011	0.00188	0.0007	0.0005
Phosphorus	-	mg/L	0.02	<0.020	0.03	0.042	nt	nt	nt	nt	nt	<0.020	<0.02
Potassium	-	mg/L	5.19	5.27	3.56	4.55	3.55	4.14	6.34	2.79	5.79	5.35	2.08
Selenium	0.01	mg/L	0.0018	0.0022	0.0015	0.0046	<0.0005	0.001	0.0031	<0.0003	0.00631	0.0036	<0.0005
Silicon	-	mg/L	9.3	9.8	8.9	11.4	nt	nt	nt	nt	nt	10.6	2.6
Silver	-	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.000021	<0.00005	<0.00005
Sodium	≤200	mg/L	23.2	17.4	15.1	21.5	13.8	16	21	11.2	18.8	15.4	10.2
Strontium	-	mg/L	0.709	0.872	0.557	0.772	nt	nt	nt	nt	nt	0.838	0.247
Sulfur	-	mg/L	nt	17	nt	16	nt	nt	nt	nt	nt	21	nt
Tellurium	-	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	nt	nt	nt	nt	nt	<0.0002	<0.0002
Thallium	-	mg/L	<0.00002	0.00002	<0.00002	<0.00002	nt	nt	nt	nt	nt	<0.00002	<0.00002
Thorium	-	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	nt	nt	nt	nt	nt	<0.0001	<0.0001
Tin	-	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	nt	nt	nt	nt	nt	<0.0002	<0.0002
Titanium	-	mg/L	<0.005	<0.005	<0.005	<0.005	nt	nt	nt	nt	nt	<0.005	<0.005
Uranium	0.02	mg/L	0.0236	0.0106	0.00454	0.00754	0.00311	0.00546	0.0093	0.00186	0.014	0.00619	0.00211
Vanadium	-	mg/L	0.003	<0.001	0.002	0.001	0.002	0.002	<0.001	<0.001	0.0005	<0.001	0.001
Zinc	≤5	mg/L	0.026	<0.004	<0.004	<0.004	0.036	0.013	0.004	0.01	0.0069	0.014	0.009
Zirconium	-	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	nt	nt	nt	nt	nt	<0.0001	<0.0001

Notes:
 1 In-Town wells operate all year, in sequence to supply all in-town customers. They also supplement flows to some rural customers.
 2 Canal intake operates during irrigation season only.
 Standards taken from Summary of Guidelines for Canadian Drinking Water Quality, and are a combination of maximum allowable concentrations and 3 aesthetic objectives (those marked ≤).
 nt Not tested

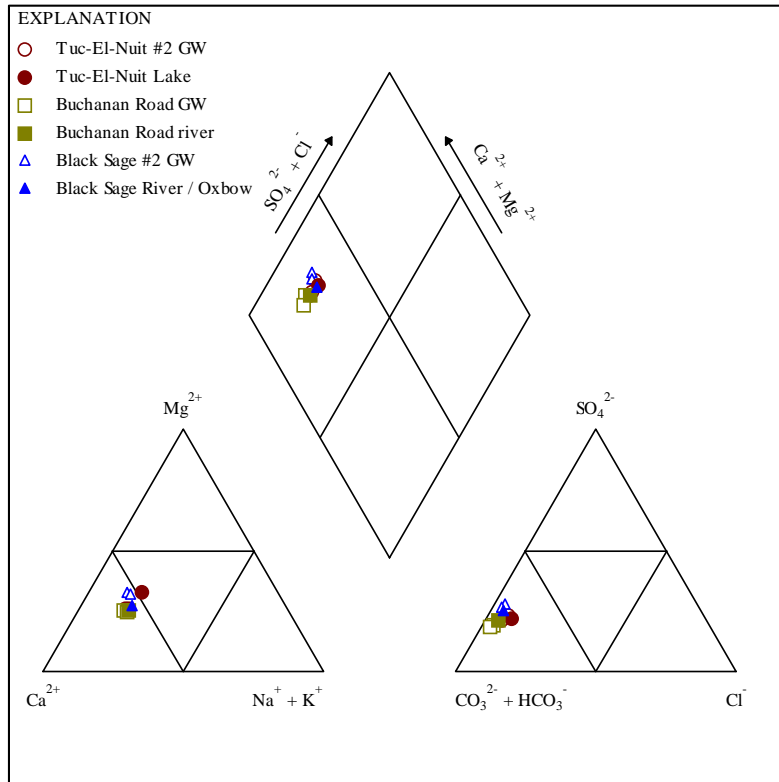
Additional years Town well water quality data are provided in Appendix H. Although we did not prepare time-series graphs of the data, it is apparent that in some wells, water quality has improved over time. Examples of wells showing water quality improvement over time include Tuc-El-Nuit #2 and Rockcliffe; both wells have exhibited declining TDS and nitrate concentrations over a period of several years. The reduction in nitrate at Tuc-El-Nuit has been relatively dramatic, from a high of 7.5 mg/L to present values below 0.05 mg/L. Better water quality is indicated in Tuc-El-Nuit and Buchanan Road wells, as evidenced by lower TDS, nitrate, chloride, and other parameters suggestive of anthropogenic inputs.

Comparison of groundwater geochemistry to that of surface water indicates the following:

- When plotted on a piper diagram, water quality from all of the Oliver wells appears to be similar (Figure 2.1).
- Okanagan River and oxbow samples have a similar chemical signature, regardless of the sampling location. The geochemistry of Tuc-El-Nuit lake water is somewhat distinct from river water, overall showing greater mineralization.
- The geochemical signature (in terms of major cations and anions) of groundwater from the sampled wells that were sampled concurrently with surface water is very similar, and piper plots are not effective at distinguishing these sources.
- Although the ratios of major cations and anions is similar between wells and surface water which results in visual similarity on the Piper plots, groundwater wells are always more mineralized in comparison to their concurrent surface water samples.
- The Rockcliffe well is characterized by elevated electrical conductivity, hardness and TDS in comparison to the other wells. In addition, Nitrate values from the well are consistently the highest of the active Oliver wells, but as noted above, exhibiting a declining trend.
- The CPR and Lions wells are both located in close proximity to each other and the Okanagan River, however the completion of these wells is quite different, with the Lions wells being screened considerably deeper. Despite this construction difference, the geochemistry of these wells is very similar (with the exception of consistently higher manganese at Lions Park). Both of these wells are also characterized by the presence of uranium in concentrations that have exceeded the drinking water guideline of 0.02 mg/L, suggestive of a component of deeper groundwater recharge to both wells.
- The Black Sage wells, although completed within 30 m of each other, have varying geochemistry which appears to be linked to depth of the well screen. Black Sage #2, which is the shallowest, is the least mineralized, softest and has the lowest nitrate concentrations. Black Sage #1, which has a separated screen interval which sources a shallow and deeper portion of the aquifer at the site has intermediately mineralized water and higher nitrate values than the shallower well. Black Sage #3 has the deepest reported drilled depth, but no information on the screened interval. We would speculate that Black Sage #3 is screened exclusively in a deeper part of the aquifer, as it has the highest mineralization and nitrate concentration of any of the Black Sage wells.
- The Buchanan Road well has water quality which is arguably the most similar to surface water of any of the Town of Oliver wells.

- The Tuc-El-Nuit wells have water quality which is indicative in many respects of a groundwater source, with intermediate mineralization and nitrate concentrations below drinking water guidelines (lower nitrate in #2 than in #3).
- The occurrence of total coliform bacteria and E.Coli is common in surface water and rare in groundwater.

Piper plot of Oliver Groundwater and Surface Water



The Province of B.C.'s ambient groundwater quality monitoring network in the Oliver area includes 13 wells completed in Aquifers 254 and 255. Of these, 12 are water supply wells (including some of the Town's wells) and one is a dedicated groundwater monitoring well (VWAL 2011). Locations of all but the northern-most of these wells are shown on Figure 7. A number of water quality parameters were mapped spatially using GIS software during the 2011 review of the network. Appendix H contains a map depicting the locations of all the ambient monitoring wells, and a map depicting the spatial distribution of nitrate in groundwater. In general, as noted above, groundwater becomes more mineralized from north to south, and indicators of anthropogenic effects (such as nitrate) increase from north to south. A few examples of this are as follows:

Chloride is typically <5 mg/L to the north, approximately 10 mg/L around Tuc-El-Nuit and greater than 10 mg/L in areas to the south. Similarly, hardness is less than 100 in the north, 225 around Tu-El-Nuit,

and 300 or more in areas to the south. TDS and nitrate show a similar pattern of lower to the north and higher to the south. This information is consistent with a conceptual model suggesting that most of the freshwater aquifer recharge comes from the north (e.g. Park Rill and Vaseux Creek losses to groundwater). The generally higher quality of groundwater to the north coupled with the Town's plans to utilize the Buchanan source strongly support a protection effort in Aquifer 255 especially those areas near and to the north of Buchanan Road well (see Section 7 for recommendations).

4. MODULE 2: CONTAMINANT SOURCE INVENTORY

Module 2 comprises a contaminant source inventory, which identifies inherent risks to water quality as well as describing land uses, human activities and other potential contaminant sources that could affect source water quality. The term "contaminant source" is defined within the S2TAG to mean both actual/existing and potential sources of contamination.

4.1 Objectives and Methods

The Objective of Module 2 is to inventory existing and known potential contamination sources in and around the proposed source protection area and then to summarize what is known about these sites so that the potential risk to drinking water may be assessed further in Module 7.

We used the following methods in completing the contamination source survey:

- 1) A search of the B.C. Site Registry Database and Federal contaminated sites databases which contain information on reported contaminated sites and spills;
- 2) A review of relevant previous consultant reports;
- 3) A review of historical air photographs;
- 4) A visual survey of areas in and around the source protection area; and
- 5) Discussions with TAC members or knowledgeable people on historic, current and future land uses.

The results of the contaminant source inventory are summarized in Table 6.

4.2 Site Registry Search

A search of the B.C. Site Registry Database provided information on properties that have been investigated and/or remediated with respect to potential for contamination. A one kilometre radius search was conducted, centred on each well area.

The search identified 9 properties on record, located primarily along Hwy 97. Of these properties, five were within 1 km of the CPR well area, two were within 1 km of the Rockcliffe well area and one each was within 1 km of the Lions Park and Tuc-El-Nuit Well areas. Detailed reports were generated for all of the sites. The reports indicated that the properties included two service stations, one sawmill and a

lane/roadway. Three of the properties did not include a site description or site profile. Summaries of the information for each site are provided in Table 6. All search results are included in Appendix E.

Table 6: Summary of BC Site Registry 500 m Radius Search Results

Well or Well Group Name	Site Registry ID Address Site Description Distance from well area	Summary of Search Results
Buchanan Blacksage Wells Miller Road Fairview		No records
Tuc-El-Nuit Wells	ID 12959 36895 - 71st St Unknown Source 590 m from Tuc-El-Nuit wells	Investigation initiated in 2011. No Site Profile. Site Status: Inactive - No Further Action
CPR	ID 5159 36216 - 97th St Former Petro Canada Service Station 73 m from CPR well	Site profile indicates AST and UST. Investigation initiated in 1998. Site Status: Inactive - No Further Action
	ID 7729 35470 - 89th St Sawmill 995 m from CPR well	Site Profile indicates that further investigation is not required. Investigation initiated in 2002. Site Status: Inactive - No Further Action
	ID 7913 35470 - 89th St Sawmill 995 m from CPR well	Site Profile indicates that further investigation is not required. Investigation initiated in 2002. Site Status: Inactive- No Further Action

	ID 10519 34899 - 97th St Station from CPR well	Service 770 m	Site profile indicates AST and UST. Investigation initiated in 2007. Status: Active - Under Assessment	Site
	ID 14670 roadway and laneway adjacent to 34899 97th Street 780 m from CPR well		No Site Profile. Investigation initiated in 2012. Site Status: Active - Under Assessment	
Lions Park	ID 5159 36216 - 97th St Former Petro Canada Service Station 792 m from Lions Park well		Site profile indicates AST and UST. Investigation initiated in 1998. Status: Inactive - No Further Action	Site
Rockcliff	ID 2282 34484 97th St Unknown Source 680 m from Rockcliff well		No Site Profile. Investigation initiated in 1998. Site Status: Inactive- No Further Action	
	ID 7499 34274 95th St Source Rockcliff well	Unknown 424 m from	No Site Profile. Investigation initiated in 1998. Status: Inactive- No Further Action	Site

4.3 Air Photograph Review

WWAL obtained air photographs from 1963, 1974, 1985 and 1996 from the University of British Columbia Geographic Information Centre. Google Earth Imagery was used for 2004 and 2012. The photographs provide an indication of the progression of development in the Oliver area from Gallagher Lake to a few km south of the weir on the Okanagan River near the Blacksage well area. The scale and resolution of the photographs are such that details in the immediate vicinity of the well areas cannot be discerned but general land use can be inferred. From north to south, five aerial coverages were observed. Aerial coverages included 1-3 well areas. Well areas were found within more than one coverage due to overlap. Generally, the majority of the agricultural development in the valley occurred between 1963 and 1974 and the majority of residential development occurred between 1974 and 1985. After 1985, both agricultural and residential development trended up the valley sides. Additionally, residential development intensified around Tuc-El-Nuit Lake and Gallagher Lake. The air photo review did not indicate any

potential environmental concerns or contaminant sources in addition to those identified through other research methods as documented in this report. Summaries of observations related to land development and geologic changes around each well area are provided in Table 7. Selected air photos of each coverage are included in Appendix F.

Table 7: Summary of Air Photo Review

Coverage / Well Area of Focus	1963 Development	Summary of Development Between 1974 and 2012.
<p>Valley bottom and sides between the Buchanan Road well area and Gallagher Lake /</p>	<p>1963: BC4174 – 36, 37, 38, 39 The Buchanan well area does not appear to be developed. Undeveloped sand bluffs located northwest of the well area. There is little development on the east side of Okanagan River. An irrigation canal carrying water from Gallagher Lake is visible along the eastern valley side. Orchards and farms extend from the west side of the Okanagan River to the western valley limit. There are few roads and little development on the western highlands.</p>	<p>1974: BC7581 - 207 The Buchanan well area appears developed. The sand bluffs have been developed into a gravel pit. A large agricultural development is visible west of the west of the Buchanan well area bordered to the west by the valley sides. Irrigated fields are located immediately west of highway 97 across from Gallagher Lake. There appears to be some residential development at the north end of Gallagher Lake. New agricultural development is visible in the highlands immediately west of McIntyre Bluff.</p> <p>1985: BCC 348 - 174, 175, 176 Covered fields or green houses are south of the Buchanan well area. A new subdivision is located about 1 km north of the Buchanan well area across from the gravel pit. The Gallagher Lake Resort appears fully established.</p> <p>1996: 30BCC96023 – 178, 179 Gallagher Lake Resort appears densely populated north and west of Gallagher Lake. A row of commercial buildings are visible across the highway from Gallagher Lake. The gravel pit northeast of the Buchanan well has expanded to the south.</p> <p>2002 Google Earth Imagery A new commercial development is visible along the east side Highway 97 southwest of Gallagher Lake. A new agricultural development is visible north of the gravel pit located west of the Buchanan well area.</p> <p>2012 Google Earth Imagery A new road and land clearing is visible southwest of Gallagher Lake.</p>

Coverage / Well Area of Focus	1963 Development	Summary of Development Between 1974 and 2012.
<p>The valley bottom and sides between the Buchanan and Tuc-El-Nuit well areas.</p>	<p>1963: BC4142 - 133, 134, 135 The valley bottom is dominated by orchards. Land on the east side of Tuc-El-Nuit Lake and along the south east corner of the lake is largely undeveloped. Merlot Avenue and the camp ground north of the Tuc-El-Nuit wells are visible. Area surrounding Tuc-El-Nuit wells is rural, no subdivisions or school, all orchards. A 9-hole golf course appears to be under construction (cleared but not irrigated) in the southeast corner of Tuc-El-Nuit Lake. The highlands west of Tuc-El-Nuit Lake are free of development and pocked with several kettle lakes.</p>	<p>1974 - BC7582 - 80, 81 The Tuc-El-Nuit well area appears to be developed. A fully-developed nine-hole golf course is visible southeast of Tuc-El-Nuit Lake. An R.V. Park is located south of the golf course. A large agricultural development east of Tuc-El-Nuit Lake that extends northeast of the Buchanan well area. New residential development and agricultural development along the north, south and east sides of Tuc-El-Nuit Lake. New industrial development south of the gravel pit east of Tuc-El-Nuit Road.</p> <p>1985 - BCC348 - 132, 133 New residential development northeast and northwest of Tuc-El-Nuit Lake. Expanded R.V. park along the south shores of Tuc-El-Nuit Lake. A new school south of the Tuc-El-Nuit well area and a new subdivision southwest of the Tuc-El-Nuit well area.</p> <p>1996 - 1996 30BCC96023 - 21, 22, 23 Expansion of the RV park south of Tuc-El-Nuit Lake and residential development southwest of Tuc-El-Nuit Lake. Agricultural development east of Tuc-El-Nuit Lake.</p> <p>2002 Google Earth Imagery Agricultural expansion north of Tuc-El-Nuit Lake. The golf course has expanded to 18 holes along the eastern valley side. Agricultural expansion east and southeast of the golf course up to the valley's eastern sides. The gravel pit across on the western valley side across from the Tuc-el-Nuit well area has expanded to the south and north.</p> <p>2012 - Google Earth Imagery Residential development has expanded north of the Tuc-El-Nuit well area along the west side of Tuc-El-Nuit Lake.</p>
<p>The valley bottom and sides from north of the Tuc-El-Nuit well area to north of the Rockcliffe well area.</p>	<p>1963: BC4142 - 95, 96, 97, 98 City centre consists of about three blocks with the majority of buildings located on the west side of Highway 97. Lions Park is not established. A parking area is visible east of the highway and northwest of the Lions Park and CPR well areas. The CPR and Lions Park well areas do not appear to be developed. Residential subdivisions are located east of Okanagan River across from Lions Park and north and west of the Town centre. Cleared and uniformly grassy areas north of the Lions Park well area suggest a golf course. An R.V. park is located south of town on the west side of Okanagan River.</p>	<p>1974:- BC7638 - 67, 68 A campground is visible north of the CPR well area. The R.V. Park south of the Town centre is no longer visible. The area appears undeveloped.</p> <p>1985 - 1996 No visible development changes near the CPR and Lions Park well areas</p> <p>2002 Google Earth Imagery - A skate board park is visible at Lions Park. The Lions park and CPR pumphouses are not visible.</p> <p>2012 Google Earth Imagery - The Lions Park and CPR pumphouses are visible.</p>

Coverage / Well Area of Focus	1963 Development	Summary of Development Between 1974 and 2012.
<p>The valley and sides from the Rockcliffe well area to the Fairview well area.</p>	<p>1963: BC4142 - 71, 72, 73, 74 The highway, railway and Okanagan River are visible. Oxbows border the river's channelized banks. An airstrip is visible east of the Rockcliffe well area on the east side of Highway 97. A nine-hole golf course is visible on the alluvial fan east of the Fairview well area. A small kettle lake is visible east of the airstrip. Orchards are visible on a triangular section of valley bottom east of the Okanagan River. A seasonal drainage channel flows from east to west into the Okanagan River through this agricultural section. A nine-hole golf course is visible on the alluvial fan east of the Fairview well area. A large undeveloped alluvial fan is visible south of the golf course. A small unnamed kettle lake is visible east of the south eastern valley slopes but orchards are visible on a triangular section of valley bottom east side of the Okanagan River. A seasonal drainage channel flows from east to west into the Okanagan River through this agricultural section. A large RV park located south of the Town centre and east of the Rockcliffe well area is developed between an oxbow on the west side of Okanagan River. A series of seasonal drainage channels without established riparian corridors flow eastward from the western valley side into the valley bottom. Alluvial deposits from two of the drainage channels are visible along the valley sides east of the Rockcliffe well area. A subdivision, located further east of the Rockcliffe well area, is limited to the one block surrounding Highway 97. Two small kettle lakes are visible at higher elevations.</p>	<p>1974: BC7582 - 270, 272 A residence is visible immediately west of the Rockcliffe well area. The subdivision located east of the Rockcliffe well area on the east side of Highway 97 has expanded to the south. Agricultural development has expanded south of the 9-hole golf course southwest of the Fairview well area. There is agricultural development on the alluvial fans south of the golf course. There is new agricultural development east of the Fairview well area on the east side of Okanagan River.</p> <p>1985: 30 BCC348 - 007, 008, 009 Agricultural development has expanded south of the nine-hole golf course. Large irrigated areas have been established south of the new subdivision along the east side of the valley. The subdivision north of the Rockcliffe well has expanded to the west and southwest. There is a new agricultural development and subdivision across from the Rockcliffe well area in the highlands east of the Okanagan River.</p> <p>1996: 30BCC96022 – 45, 46, 47, 48 An airstrip and kettle lake are visible east of the Rockcliffe well area. A new agricultural development is visible in the highlands west of the Rockcliffe well area. An industry with many rectangular buildings is located on the east side of Highway 97 between the Rockcliffe well area and the Fairview well area. There is continuous commercial development along Highway 97 south of Fairview Road for four blocks. Agriculture east of the Okanagan River has expanded along the valley bottom east of Blacksage Road and includes two large irrigated sections.</p> <p>2002 2002 Google Earth Imagery Fewer irrigated fields on the eastern valley side. There is new land clearing along the western valley side.</p> <p>2012 Google Earth Imagery Agricultural development as expanded up the eastern valley sides.</p>

Coverage / Well Area of Focus	1963 Development	Summary of Development Between 1974 and 2012.
<p>The valley bottom and sides between the Fairview well area and the Blacksage well area.</p>	<p>1963: BC4142 - 35, 36, 37 Seven drainage channels, including two with established riparian corridors that flow through undeveloped alluvial fans, flow eastward down the western valley sides through orchards covering the valley bottom. The two larger drainage channels flow into the west side of the Okanagan River. One channel flows into the river about half way between the Fairview and the Blacksage well areas and the other flows into the river immediately south of the Blacksage well area. Orchards cover the majority of developable land along the valley bottom except for the valley bottom east of Blacksage Road on the east side of the valley. There are sparsely concentrated pockets of riparian and wetland areas surrounding oxbows along either side of the river.</p>	<p>1974: BC7602 - 007, 008, 009 There is more agricultural development west of the Miller Road and Blacksage well areas in the valley bottom along the western valley sides. There are more defined crops located north of the Miller Road well area on the east side of Okanagan River.</p> <p>1985: BCC343 - 133, 134 Large spray irrigation fields are evident on the eastern valley floor, east of the Blacksage well area. There is expanded agricultural development west of the Okanagan River and the Blacksage well area.</p> <p>1996: 30BCC96022 – 10, 11, 12 Two large circular irrigated areas are located along the valley bottom near the Miller Road and Blacksage Road intersection. The Blacksage pumphouse and the pond located south of the pumphouse are visible. The Miller Road well area appears undeveloped. Extensive agricultural development is located along plateaus on the western valley sides southwest of the Fairview well area.</p> <p>2002 Google Earth Imagery Rectangular agricultural plots have replaced the area where the large circular green spray irrigation footprints had been located. The oxbow south of the Blacksage well area appears to be drier in its southern half.</p> <p>2012 Google Earth Imagery Agricultural development has expanded along the eastern extent of the valley. Agricultural development has expanded along the eastern valley sides to the north east of the Miller Road well area.</p>

Coverage / Well Area of Focus	1963 Development	Summary of Development Between 1974 and 2012.
<p>The valley bottom and sides north of Miller Road and south of Blacksage well areas</p>	<p>1963: BC4142 - 15, 16, 17 Hwy 97, the railway and Okanagan River are visible. Oxbows border the river's channelized banks. Miller Road, the weir that crosses the Okanagan River, and the pond located near the Blacksage well area are also visible. A clearing is visible at the Blacksage well area but no buildings are visible at the site. Riparian vegetation is visible north and south of the Blacksage well area. An oxbow surrounds the Blacksage well area. Riparian vegetation is abundant between the oxbows and the river. A large wetland is located about 5 kms south of the Blacksage well area on either side of the river. The Miller Road well area is surrounded by orchards. There is no discernable clearing where the Miller Road well now exists. Land south of the Blacksage well area is undeveloped on the east side of Okanagan River but is covered by agricultural crops on the west side of the river. Agricultural land use is limited to the valley bottom with little development east of the railway line. Land is undeveloped on the western valley slopes. A drainage channel identified by an established riparian corridor flows west to east along the western valley slope and forms an undeveloped alluvial fan west of highway 97. There is no development on the alluvial fan. There is agricultural land use north and east of the fan and no development west or south of it. Drainage flows through the fan across highway 97 and the railway line before entering the Okanagan River near the weir west of the Blacksage well area.</p>	<p>1974: BC7592 - 192, 193, 194 The area around the Blacksage wells appeared to be more developed. Extensive agricultural development is visible directly east and southeast of the Blacksage well area on the plateau east of Blacksage Road. The alluvial fan west of the Blacksage well area has been developed with agricultural crops. The Miller Road well area appears developed.</p> <p>1985: 30 BCC343 - 16, 17 Oliver's sewage treatment facility and spray irrigation fields are located west of the Blacksage well area. Agricultural development has expanded north of the alluvial fan on the west side of the valley.</p> <p>1994: 30BCC96021 – 99, 100, 101 There is new agricultural development visible on either side of the river immediately north of the large wetland located about 5 km south of the Blacksage well area.</p> <p>2002 Google Earth Imagery East of the Miller Road and Blacksage well areas, rectangular agricultural plots have replaced the area where the large circular green spray irrigation footprints had been located. The oxbow lake south of the Buchanan well appears to be dry in its southern half.</p> <p>2012 Google Earth Imagery Agricultural development has expanded along the eastern valley sides to northeast of the Miller Road well area. A large mud slide has deposited debris across the valley bottom from the western highlands along the Testalinden Creek channel. Debris from the slide reached the western bank of the Okanagan River located directed west of the Buchanan well.</p>

4.4 Visual Surveys of Source Protection Area

In addition to providing a thorough discussion of the general concerns around agricultural land uses, and other potential threats to groundwater such as abandoned or poorly constructed wells, Golder (2004) completed a visual survey of potential contamination sources but this information requires updating. Doug Geller, P.Geo. and Ryan Rhodes, P.Geo. of WWAL each have visited the Oliver supply wells several times over the past few years, but a focused assessment of potential contamination sources was not undertaken until this project was initiated. For this task, environmental scientist Trina Koch, B.Sc., R.P.Bio of WWAL, completed the visual survey of the source protection area on August 19, 2014. Photographs with observational captions of the visual survey are included in Appendix G. Observations pertaining to the contaminant source inventory are noted below and are summarized in Table 8.

The visual survey targeted two primary areas: The immediate well area (300 m radius) and the surrounding source protection area. Specific potential environmental concerns or potential contaminant sources identified during the inspection at each well area are indicated below. Comparing the results of our survey with that of Golder (2004; Table 2) indicates most of the potential land uses or contamination threats identified in 2004 still exist today.

- **Buchanan Road:**

- Potential sources of agricultural contaminants such as fertilizers, pesticides, herbicides and hydrocarbons (i.e. fuel storage) associated with the nearby nursery, orchards and a winery;
- Potential contamination of the aquifer during flooding of the Okanagan River via an abandoned and uncapped dug well located nearby;
- Potential contamination of the aquifer during extraction of material at the gravel pit located immediately east of the 1 year capture zone (Figure 3);
- Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products, and
- Potential hazard may result if the Okanagan River flooded and caused restricted access to the well and/or reduced the well pump's effectiveness.

- **Tuc-El-Nuit:**

- Potential sources of contaminants such as fertilizers, pesticides and herbicides associated with school fields;
- Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products, and
- Potential sources of contaminants such as septic release (bacteria and nutrients), hydrocarbons, household cleaning products, fertilizers, pesticides, herbicides associated with the campground (Lakeside Resort) and the R.V. park
- There are no mapped Town dry wells in the Tuc-El-Nuit well area.

- **Lions Park and CPR (deactivated; information provided for completeness):**

- The OK Tire gas station west of the well areas may use/store large volumes of potential contaminants. Underground storage tanks are inferred to be present at these businesses;
- Potential sources of contaminants such as chemical cleaners are associated with numerous businesses west of the well areas including: retail stores, restaurants, meeting halls and a movie theatre;
- Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products.
- Potential contaminant sources that may be associated with other businesses in the downtown area could include automotive products, batteries or dry cleaning solvents.
- Potential sources of contaminants such as hydrocarbons, glycol, solvents, pesticides, herbicides and fertilizer are associated with residential areas, and
- The eutrophic oxbow north of the well area may represent a contaminant source if flooding allowed its water to travel into the aquifer via abandoned wells.

- **Rockcliffe:**
 - Potential sources of contaminants such as hydrocarbons, glycol, solvents, pesticides, herbicides and fertilizer are associated with residential areas;
 - Potential sources of contaminants such as fertilizers, pesticides, herbicides and hydrocarbons associated with the orchards and other agricultural lands. Town of Oliver personnel who were onsite at the time of the field investigation indicated that manure placed on the grape orchard east of the well (upslope) was thought to create the potential for elevated bacteria counts in the well;
 - Potential contamination from reclaimed water sprayed at the airport located adjacent to the 10 year capture zone (Figure 3), and
 - Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products.
 - There are no mapped Town dry wells in the Rockcliffe well area

- **Miller Road:**
 - An above ground oil tank north of the well area store hydrocarbons like gasoline or old oil, or it may store pesticides or herbicides.
 - Minor garbage/debris was observed in various locations (oven and toilet).
 - Potential sources of contaminants such as hydrocarbons (tar and fuel) and glycols associated with home construction.
 - Potential sources of contaminants such as septic release (bacteria and nutrients), hydrocarbons and glycols associated with on-site camping and outhouse use.
 - Potential sources of contaminants such as fertilizers, pesticides, herbicides and hydrocarbons associated with the orchards.
 - Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products.

- **Blacksage:**
 - A sensitive wildlife management area is located close to the well area.
 - Potential sources of contaminants such as fertilizers, pesticides, herbicides and hydrocarbons associated with the orchards.
 - Vehicle traffic and parking – potential for small releases of fuel/oil/or automotive products. It was at this site that Town of Oliver staff were observed using gas-powered weed removal equipment.
 - Potential hazard may result if the Okanagan River or oxbow flooded and restricted access to the pumphouse or reduced the pump's effectiveness.

4.5 Zoning in the Ten Year Capture Zones and Utilities in the Source Protection Area

Figure 5 indicates the RDOS zoning for the Buchanan Road, Miller Road and Blacksage within their ten year capture zones. The Buchanan Road, Miller Road and Blacksage well's 10-year capture zones are currently zoned for agricultural use (AGI).

Figure 6 indicates the Town of Oliver zoning for the Tuc-El-Nuit, and Rockcliffe sources within their ten year capture zones. The Tuc-El-Nuit 10-year capture zone includes residential medium density (RM1) zoning northeast and southeast of the wells, resort commercial (RC) zoning in the RV park northeast of the wells, tourist commercial (CT2) zoning in the campground N of the wells and institutional and assembly (PI) zoning in the in the school properties northeast and southeast of the wells. The Rockcliffe well's 10-year capture zone is zoned mainly as agricultural to the south (AG) and west and combination of residential and commercial to the north and northeast. The next draft of the SWA report will provide a map depicting the Town's infrastructure in relation to each well, specifically, water and sewer mains.

4.6 Threats from Surface Water Pathogens

WWAL completed an assessment of the Town of Oliver's municipal water supply, including the 10 drinking water wells featured in this report, to determine the well's status with respect to the potential to be considered Groundwater at Risk (GWAR) and/or or Groundwater Under the Direct Influence of surface water (GWUDI). The assessment made the following conclusions:

- Total coliform bacteria are rare or absent in the groundwater samples from Oliver's drinking water wells;
- Sufficient filtration is occurring in the aquifer and large diameter pathogens associated with surface water are not making it to the wells. *Giardia* and *Cryptosporidium* were not detected in any samples collected on what we judged to be the wells with the highest risk of being GWUDI;
- The majority of Oliver drinking water wells do not meet the definition of GWUDI;
- Insufficient data were collected for the CPR well (and by association the Lions well) to make a definitive statement regarding these well's GWUDI status. Additional data should be collected if the wells are planned for future use;
- The Rockcliffe, Tuc-El-Nuit and Miller Road wells have provision for primary disinfection;
- The Buchanan Road well has a large diameter contact pipe installed, and when the planned Buchanan replacement well is installed it will allow for primary disinfection of the Buchanan source;
- The CPR and Lions wells are chlorinated at the source and have mainlines to a reservoir resulting in some disinfection of these sources;
- The Rockcliffe well is at some risk of being effected by reclaimed water spray irrigation occurring at the airport (Figure 3);
- Blacksage wells are the only Oliver wells that have no provision for chlorination, increased monitoring of these sources is warranted, and
- The Blacksage #1 is at some risk of being GWUDI.

4.7 Town Well Construction

(See also information presented on Tables 1 and 2). With the exception of the Miller Road and new Buchanan Road domestic wells, construction of the Town's wells pre-dated the B.C. Groundwater Protection Regulation. This Regulation requires certain minimum well construction standards, including a surface seal, a secure well cap, floodproofing, and a Well ID plate affixed to the casing. A preliminary review of Town well compliance with the Regulation indicates no non-conforming issues. The older wells likely do not have surface seals, but at this time the seal requirement is not retroactive for existing wells unless there is an immediate threat in which case retrofitting is required. The older wells are also located inside pump house buildings, which means direct short-circuiting of surface drainage down the unsealed well bore is unlikely. The wells are located either on Town land or in established easements and/or rights of way. The potential for wellhead upgrades is considered further under Modules 7 and 8 of the SWA.

4.8 Potential Contaminant Source and Hazard Inventory

Based on the information presented above, the results of the potential contaminant source and hazard inventory are presented in Table 8. A total of 40 hazards are identified, but only 28 of these apply to future well sources as 12 pertain to Lions Park and CPR which are planned to be deactivated and eventually closed.

Table 8: Potential Contaminant and Hazard Inventory

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
Buchanan Road Well Area					
1	Nursery	100 m SE	Pesticides, herbicides, fertilizer (bacteria and nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
2	Abandoned dug well next to Okanagan River	50 m N of well area	Contaminants in Okanagan River floodwaters	Migration down to the aquifer via the uncapped well opening	Low permeability materials above the aquifer may impede downward migration of contaminants.
3	Apple orchard	50 m N	Pesticides, herbicides, fertilizer (bacteria and nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
4	Winery and grape orchard	200 m W	Pesticides, herbicides, fertilizer (bacteria and nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
5	Gravel pit	310 m NE	Hydrocarbons (fuel), potential for residual subsurface contamination	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
6	Transportation corridor and parking area	Buchanan Road (40 m SE), well-access parking (10 m S)	Hydrocarbons (fuel), potential for residual subsurface contamination	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
<i>Tuc-El-Nuit Road Well Area</i>					
7	Public school parking area and field	50 m SE	Hydrocarbons (fuel, oil), fertilizers, pesticides, herbicides fertilizers (possible bacteria and nutrients)	Infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
8	Seventh Day Adventist School parking area and field	50 m NE	Hydrocarbons (fuel, oil), fertilizers, pesticides, herbicides fertilizers (possible bacteria and nutrients)	Infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
9	Transportation corridor and well access parking area	Merlot Drive and parking area (5 m N), Lakeside Drive (20 m W)	Hydrocarbons (fuel). Potential for residual subsurface contamination.	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
10	Residential / Commercial Development	200 m SW	Hydrocarbons (fuel, oil,), glycol, solvents, pesticides, herbicides, fertilizer	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
11	Camp ground parking and septic	40 m N	Hydrocarbons (fuel, oil), glycol, solvents, pesticides, herbicides, septic leakage - possible bacterial (eg. <i>E.coli</i>) and nutrient (Nitrate- N)	infiltration through soil and sediment to aquifer	small volumes likely
12	Trailer Park	300 m NE	Hydrocarbons (fuel, oil), glycol, solvents, pesticides, herbicides, septic leakage - possible bacterial (eg. <i>E.coli</i>) and nutrient (Nitrate- N)	infiltration through soil and sediment to aquifer	small volumes likely
Lions Park Well Area					
13	Above and Below Ground Storage Tanks at Gas Station	Along Hwy 97, 100 m W	Hydrocarbons (fuel) Potential for leaks/spills.	infiltration through soil and sediment to aquifer if a spill occurs	On record with the Ministry of Environment
14	Transportation corridor and parking area	Hwy 97 and Lions Park parking lot, 100 m NW, Welcome Centre parking lot 180 m SW	Hydrocarbons (fuel). Potential for residual subsurface contamination.	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
15	Bathroom Building Septic Field	90 m NW	Fecal coliforms (<i>E.coli.</i> , viruses, nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
16	Residential / Commercial Development	200 m W and E	Hydrocarbons (fuel, oil,), glycol, solvents, pesticides, herbicides, fertilizer for residential use	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
17	Lions Park Lawn Areas	2 m N, W, E and S	Pesticides, herbicides, fertilizer (bacteria and nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
18	Camp ground parking and septic	200 m S	Hydrocarbons (fuel, oil), glycol, solvents, pesticides, herbicides, possible bacterial (eg. <i>E.coli</i>) and nutrient (Nitrate- N)	infiltration through soil and sediment to aquifer	small volumes likely
CPR Well Area					
19	Above Ground Storage Tanks and Below Ground Storage Tank at Gas Station	Along Hwy 97, 150 m NW	Hydrocarbons (fuel) Potential for leaks/spills.	infiltration through soil and sediment to aquifer if a spill occurs	On record with the Ministry of Environment
20	Transportation corridor and parking area	Hwy 97 and Lions Park parking lot, 150 m NW, Welcome Centre parking lot 80 m SW	Hydrocarbons (fuel). Potential for residual subsurface contamination.	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
21	Bathroom Building Septic Field	140 m NW	Fecal coliforms (<i>E.coli.</i> , viruses, nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
22	Residential / Commercial Development	200 m W and E	Hydrocarbons (fuel, oil,), glycol, solvents, pesticides, herbicides, fertilizer for residential use	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
23	Lions Park Lawn Areas	2 m N, W and S	Pesticides, herbicides, fertilizer (bacteria and nutrients)	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
24	Camp ground parking and septic	150 m S	Hydrocarbons (fuel, oil), glycol, solvents, pesticides, herbicides, possible bacterial (eg. <i>E.coli.</i>) and nutrient (Nitrate- N)	infiltration through soil and sediment to aquifer	small volumes likely
Rockcliffe Well Area					
25	Residential Homes	10 m N	Hydrocarbons (fuel, oil,), glycol, solvents, pesticides, herbicides, fertilizer for residential use	potentially mobilized in storm run-off water which enters the storm water system	small volumes likely
26	Reclaimed Water Spray Irrigation	500 m W	Fecal coliforms, viruses and nutrients	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
27	Storage Shed in Orchard	50 m S	Hydrocarbons (fuel, oil,), glycol, solvents, pesticides, herbicides, fertilizers	infiltration through soil and sediment to aquifer if a spill occurs	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
28	Grape Orchard	50 m SW	Pesticides, herbicides, fertilizer - specifically the addition of manure to surface soils (bacteria and nutrients)	infiltration through soil and sediment to aquifer if a spill occurs	Low permeability materials above the aquifer may impede downward migration of contaminants.
29	apple orchard southeast of well	20 - 40 m SE	Pesticides, herbicides, fertilizer including fecal coliforms, viruses, nutrients	infiltration through soil and sediment to aquifer if a spill occurs	Low permeability materials above the aquifer may impede downward migration of contaminants.
30	Transportation corridor and well access parking area	Fairview Road 2-5 m N	Hydrocarbons (fuel). Potential for residual subsurface contamination. (ex. adding fuel to weed removal equipment in the parking area)	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
31	Treated spray effluent	Airport grounds, 250 m east of the Rockcliffe well (overlaps the 10 year capture zone)	Fecal coliforms, viruses and nutrients	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
Miller Road Well Area					
32	Above Ground Storage Tank (AST)	100 m N	Hydrocarbons (fuel, waste oil).	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
33	Residence Under Construction	40 m S	Potential for future leaks/spills of building materials (eg. tar coating for foundation, paint, varnish).	infiltration through soil and sediment to aquifer	small volumes likely
34	Mobile Trailer and Possible Outhouse	50 m S	Hydrocarbons (fuel, oil), glycol, solvents, pesticides, herbicides, possible bacterial (eg. <i>E. coli.</i>) and nutrient (Nitrate- N)	infiltration through soil and sediment to aquifer	small volumes likely
35	Orchard	5 - 10 m E, S and N	Pesticides, herbicides, fertilizer including fecal coliforms, viruses, nutrients	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
36	Transportation corridor and well access parking area	2-5 m N	Hydrocarbons (fuel). Potential for residual subsurface contamination. (ex. adding fuel to weed removal equipment)	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.
Blacksage Well Area					
37	Transportation corridor and parking area	Access route along Okanagan River (10 m W), well access parking area (5 m W)	Hydrocarbons (fuel). Potential for residual subsurface contamination. (ex. adding fuel to weed removal equipment in the parking area)	potentially mobilized in storm run-off water which enters the storm water system	Low permeability materials above the aquifer may impede downward migration of contaminants.

Potential Contaminant/Hazard Inventory					
Hazard Reference No.	Contaminant Source or Hazard type and Description	Location Description and Approx. Distance from Well Area	Possible Contaminants of Concern	Contaminant Transport Method	Associated Barriers
38	Orchards	Grapes (10-20 m NE), Apples (5 m S)	Pesticides, herbicides, fertilizer including fecal coliforms, viruses, nutrients	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
39	Unknown contents of sealed buckets	Caged area outside of the pond's pumphouse (30 m S)	Miscellaneous contaminants	infiltration through soil and sediment to aquifer	Low permeability materials above the aquifer may impede downward migration of contaminants.
General					
40	abandoned wells	Unknown locations	Miscellaneous contaminants	Migration down to the aquifer via the uncapped well opening	Low permeability materials above the aquifer may impede downward migration of contaminants.

5. MODULE #7 CHARACTERIZE RISKS FROM SOURCE TO TAP

Module #7 of the S2TAG probably forms the most important step in the source-to-tap assessment process. The general purpose of the module is to synthesize all of the water system information (strengths and vulnerabilities) into a comprehensive assessment of the major water supply elements and the system as a whole. As noted previously in this report, a detailed assessment of the distribution and treatment system, including risks and recommended mitigative measures, has been completed by Agua (2012), and therefore, Module #7 in this report focuses on the groundwater wells and associated aquifer system.

The risk evaluation procedures completed for this report, outlined in subsequent sections, follow the structured approach for the assessment of risk in the S2TAG. The approach considers risk of both low probability / high consequence and high probability / low consequence events with the use of a qualitative risk analysis matrix.

5.1 Methodology

The qualitative evaluation of risk involves an analysis of both the “level of likelihood” (probability) and the “level of consequence.” These aspects are assessed based on available site and hydrogeological information compiled in Modules 1 and 2 and application of professional judgment.

Likelihood depends on both the probability of the potentially harmful event or condition happening, and the probability that negative impacts on water quality could result. Therefore, consideration is given to both the likelihood of a release of contaminants and the likelihood that such a release could reach the aquifer within the proposed source protection area. As suggested in the S2TAG, a time period guideline of 10 years has been assumed and incorporated into the assessment of likelihood. The likelihood of a given risk event has been assigned a value of ‘A’ to ‘E’ according to the S2TAG approach presented in Table 9.

The relative consequences associated with the occurrence of a given risk event have been assigned a value of 1 to 5 according to the S2TAG approach presented in Table 10. The qualitative evaluation of consequence includes consideration of: nature of the event/condition; severity of impact; duration; proportions of population affected.

The assigned levels of likelihood and consequence are then used to qualitatively evaluate risk using the Qualitative Risk Analysis Matrix, Table 11.

Table 9: Levels of Likelihood Description

Level	Descriptor	Description	Probability of Occurrence in Next 10 Years
A	Almost certain	Is expected to occur in most circumstances	>90%
B	Likely	Will probably occur in most circumstances	71-90%
C	Possible	Will probably occur at some time	31-70%
D	Unlikely	Could occur at some time	10-30%
E	Rare	May only occur in exceptional circumstances	<10%

Table 10: Relative Levels of Consequences Descriptions

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in normal operating costs.
2	Minor	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs.
3	Moderate	Minor impact for large population, mild to moderate illness probable, significant modification to normal operation but manageable, operating costs increase, increased monitoring.
4	Major	Major impact for small population, severe illness probable, systems significantly compromised and abnormal operation if at all, high level monitoring required.
5	Catastrophic	Major impact for large population, severe illness probable, complete failure of systems.

Table 11: Qualitative Risk Analysis Matrix

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A (almost certain)	Moderate	High	Very High	Very High	Very High
B (likely)	Moderate	High	High	Very High	Very High
C (possible)	Low	Moderate	High	Very High	Very High
D (unlikely)	Low	Low	Moderate	High	Very High
E (rare)	Low	Low	Moderate	High	High

5.2 Risk Characterization Table

Table 12 presents the Risk Evaluation Summary for the 40 potential drinking water hazards identified for the proposed source protection area. The information for the CPR and Lions Park wells is presented, but recommended actions to mitigate identified risks are not provided as the wells are deactivated with no plans to use them again for domestic supply.

The potential contaminant sources and hazards were assigned levels of likelihood that were “unlikely” to “rare”. The level of consequence for the identified hazards ranged from 2 to 4. Included in our assessment of the level of consequence is the recognition that the water system involves treatment with chlorine.

As a result of the likelihood and consequence evaluation, the level of risk associated with the hazards ranges from low to high. High risks are associated with Hazard 11 (the system reliance on 2 wells in close proximity). Low to moderate risks were identified for Hazards 7 and 8 associated with the implications of potential for bacteriological impacts. Low risk is indicated for all other Hazards.

Table 12: Risk Characterization

Risk Characterization Summary					
Hazard Reference No.	Potential Drinking Water Hazard	Likelihood Level (from Table)	Consequence Level (from Table)	Risk Level (from Table)	Comments
<i>Buchanan Road Well Area</i>					
1	Nursery	C	2	Moderate	Possible likelihood with minor consequence
2	Abandoned dug well next to Okanagan River	D	3	Moderate	Unlikely with moderate consequence, but proximity to Town well makes this a moderate to high risk. Refer to Recommendations to mitigate
3	Apple orchard	C	2	Moderate	Possible likelihood with minor consequence
4	Winery and grape orchard	C	2	Moderate	Possible likelihood with minor consequence
5	Gravel pit	C	3	High	Possible likelihood with moderate consequence
6	Transportation corridor and parking area	C	2	Moderate	Possible likelihood with minor consequence
<i>Tuc-El-Nuit Road Well Area</i>					
7	Public school parking area and field	C	2	Moderate	Possible likelihood with minor consequence
8	Seventh Day Adventist School parking area and field	D	2	Low	Unlikely with low consequence
9	Transportation corridor and well access parking area	D	2	Low	Unlikely with low consequence
10	Residential / Commercial Development	D	2	Low	Unlikely with low consequence
11	Camp ground parking and septic	C	2	Moderate	Possible likelihood with minor consequence
12	Trailer Park	C	2	Moderate	Possible likelihood with minor consequence

<i>Lions Park Well Area (presented for completeness only; well is deactivated)</i>					
13	Above and Below Ground Storage Tanks at Gas Station	B	3	High	Likely with moderate consequence
14	Transportation corridor and parking area	D	1	Low	Unlikely with insignificant consequence
15	Bathroom Building Septic Field	C	2	Moderate	Possible likelihood with minor consequence
16	Residential / Commercial Development	D	1	Low	Unlikely with insignificant consequence
17	Lions Park Lawn Areas	D	1	Low	Unlikely with insignificant consequence
18	Camp ground parking and septic	C	2	Moderate	Possible likelihood with minor consequence
<i>CPR Well Area (deactivated well)</i>					
19	Above and Below Ground Storage Tanks at Gas Station	B	3	High	Likely with moderate consequence
20	Transportation corridor and parking area	D	1	Low	Unlikely with insignificant consequence
21	Bathroom Building Septic Field	C	2	Moderate	Possible likelihood with minor consequence
22	Residential / Commercial Development	D	1	Low	Unlikely with insignificant consequence
23	Lions Park Lawn Areas	D	1	Low	Unlikely with insignificant consequence
24	Camp ground parking and septic	B	2	High	Likely with minor consequence
<i>Rockcliffe Well Area</i>					
25	Residential Homes	D	1	Low	Unlikely with insignificant consequence
26	Reclaimed Water Spray Irrigation	C	2	Moderate	Possible likelihood with minor consequence
27	Storage Shed in Orchard	D	1	Low	Unlikely with low consequence
28	Grape Orchard	C	2	Moderate	Possible likelihood with minor consequence
29	apple orchard southeast of well	C	2	Moderate	Possible likelihood with minor consequence
30	Transportation corridor and well access parking area	D	1	Low	Unlikely with insignificant consequence

31	Treated spray effluent	C	2	Moderate	Possible likelihood with minor consequence
<i>Miller Road Well Area</i>					
32	Above Ground Storage Tank (AST)	C	2	Moderate	Possible likelihood with minor consequence
33	Residence Under Construction	C	2	Moderate	Possible likelihood with minor consequence
34	Mobile Trailer and Possible Outhouse	B	3	High	Likely with moderate consequence
35	Orchard	C	2	Moderate	Possible likelihood with minor consequence
36	Transportation corridor and well access parking area	D	1	Low	Unlikely with insignificant consequence
<i>Black Sage Road Well Area</i>					
37	Transportation corridor and parking area	D	1	Low	Unlikely with insignificant consequence
38	Orchards	C	2	Moderate	Possible likelihood with minor consequence
39	Unknown contents of sealed buckets	C	2	Moderate	Possible likelihood with minor consequence
<i>General</i>					
40	Abandoned wells	B	3	High	Likely with moderate consequence

6. STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

The significant factors with potential to influence drinking water quality and availability now and into the future are discussed below in a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis.

System Strengths:

- The systems are inter-connected and not reliant upon a single well source, the loss of which would mean an interruption in supply.
- The municipal stormwater system (Appendix H) draws stormwater away from the Tuc-El-Nuit and Rockcliffe wells and into dry wells; (there are no dry wells near either of these Town wells)
- Water usage and well usage are tracked and reported on. Water quality sampling is done regularly. The Town has gained long term experience in operating a groundwater based water supply.
- Raw groundwater is disinfected with chlorine prior to distribution.
- System twinning is complete. Most agricultural areas are supplied by surface water and all domestic water for drinking is supplied by wells. This is a significant strength relative to the situation 10 or more years ago when canal water was still being consumed in rural areas.

System Weaknesses:

The S2TAG describes a system weakness as a “fundamental deficiency in the protective and preventative measures in the water supply system.”

- The Tuc-El-Nuit and Rockcliffe wells are located adjacent to transportation corridors where a spill could immediately affect water quality;
- Dry wells may act as a connection to deeper sediments allowing hydrocarbons to enter the aquifer; as such stormwater management has the potential to be both a strength and a weakness; however, we found no indications of dry wells adjacent or nearby to Town domestic wells.
- The Miller Road, Blacksage and Buchanan wells are located adjacent to the Okanagan River which could cause pump failure or well contamination during a flood event (however, the river flow is regulated);
- Aquifer protection area and capture zones extend onto private property;
- The Rockcliffe well’s 10 year capture zone is located in the heart of the city and includes industrially zoned areas;
- Reclaimed water sprayed at the airport is adjacent to the Rockcliffe well’s 10 year capture zone and if not properly managed has the potential to impact groundwater quality;

-
- The Tuc-El-Nuit well's 10 year capture zone is located in a busy suburban area adjacent to a busy resort that is thought have an onsite septic field
 - The gravel pit near the Buchanan wells may act as a direct pathway to the subsurface if any contaminants were released there.
 - Abandoned wells or poorly constructed wells could be located near or within capture zones. Abandoned wells have the potential to allow unknown contaminants to enter the aquifer.

System Opportunities:

- Recommendations related to the water supply and distribution system are provided in a separate reports completed by the Town and its engineering consultant TRUE Consulting.
- The Town has the ability, through creation of bylaws and/or through the regional growth strategy, to control activities within the source water protection area and near the wells; such measures give the Town the opportunity to coordinate land uses with adjacent RDOS and to a lesser extent, Osoyoos Indian Band lands.
- The Town has the ability to communicate to residents within the proposed source protection area to raise awareness surrounding aquifer protection (e.g., through signage or other means of communication).
- Completion of a study to compile the locations and conditions of abandoned wells within the Town of Oliver;
- Development of adequate emergency response plans and specification of appropriate emergency water supply options in the unlikely event that the well source becomes compromised due to an unforeseen event.

System Threats:

- Contaminated sites (potential contaminant sources) are known to exist or historically exist within the proposed source protection area.
- The wells are mostly located in topographically low areas in and near the valley bottom, which indicates the potential for contaminant releases in surrounding higher elevation areas to migrate in the direction of the wells.
- Cumulative effects of existing groundwater extraction and potential future increases in groundwater extraction from the Oliver area aquifers could influence the overall availability of water within the aquifer system.

7. MODULE #8: RECOMMENDED ACTIONS FOR GROUNDWATER PROTECTION

The source aquifers used by the Town of Oliver are relatively vulnerable to contamination because they occupy the valley bottom, are relatively shallow, unconfined in some areas, and within developed areas. However, owing to the mostly residential and agricultural nature of the land use in the Oliver area, historical impacts to groundwater quality have been relatively limited, with elevated nitrate being notable south of town, but with no evidence of other widespread anthropogenic impacts to groundwater quality. Overall, existing information indicates that the quality of groundwater is higher north of town than south and so a strategy to keep groundwater quality from being degraded in the north is recommended.

Although natural hydrogeological barriers have been identified, a review of existing land uses as well as field reconnaissance has identified potential contaminant sources that exist (or could exist given land uses) within the proposed source protection area. Releases of hydrocarbons (fuels, oils, etc.), or other chemicals (e.g., in maintenance products, fertilizer, pesticides), and impacts due to low density agricultural activities such as cattle grazing, either occur or have potential to occur within the proposed source protection area. Higher volume potential contaminant sources are associated with the above ground or underground fuel/waste oil storage tanks, and the potential for residual subsurface contamination at former service station or bulk fuel storage facilities. Given the hazards and risks identified, the following recommendations are provided to promote source protection and to address the levels of risk identified. We have attempted to identify the key partners that the Town should anticipate working with to address recommendations. This is not a prioritized list. We anticipate that some recommendations will take more effort and require a longer time period than others. #6 having to do with effecting appropriate land use controls tends to be one of the more challenging when there are multiple jurisdictions.

RECOMMENDED ACTION	KEY PARTNERS
1. Adopt the proposed protection area and consider a number of proactive measures to protect groundwater and promote awareness of the role groundwater plays in providing drinking water to area residents and businesses. Work with RDOS and OIB to place a high priority on protecting the northern part of the aquifer system, i.e., Aquifer 255 north of Buchanan wells and in the vicinity of OIB’s Senkulmen Park wells	RDOS, OIB
2. Add signage to alert residents and visitors that they are entering a groundwater protection zone. Prepare additional public outreach information and provide detailed project information to OBWB	Ministry of Highways, OBWB
3. Notify the Oliver residents regarding the source protection area and encourage safe handling storage practices and best management practices for potential contaminants.	
4. Develop an emergency response plan to implement if a nearby spill of a potential	

contaminant occurs. The emergency response plan should include immediate implementation of a sampling program for the Town wells to monitor for the presence of contaminants of concern.	
5. Recommend that Town discuss with MFLNRO possible steps to be taken toward protecting surface waters that recharge groundwater, particularly, Aquifer 255 in the northern part of the protection area. This would include Okanagan River and Vaseux Creek.	MFLNRO
6. Develop a water supply contingency plan for an alternative water source if impacts to a well are indicated. This is recommended for any water system. Alternative supplies should be identified and evaluated, and roles and responsibilities in the case of a water emergency should be clearly identified and reviewed regularly with IHA staff assigned to the water system.	
7. The presence of the source water protection area should be identified in Town of Oliver and RDOS community planning documents. Proposed changes to land use within the source protection area should trigger a focused review of land use in light of the recommendations in this report. Consider requiring advanced treatment of effluent disposal fields in newly developing areas to reduce nutrient loading to the ground. Further restrict future land uses within the 10 year capture zones (e.g., no fuel or chemical storage, no community waste disposal facilities, and so on)	RDOS, IH, MFLNRO, Area businesses and developers
8. The presence of a surface seal for all Town of Oliver Wells should be confirmed and if not present, a surface seal should be installed where practical (e.g. if and when a pump house is replaced, as most wells are in pump houses). If upgrades are completed, these should comply with requirements of the BC Groundwater Protection Regulation. A hydrogeologist or a qualified well driller or well pump installer can be consulted with in this regard.	MFLNRO, IH
9. Locate and inspect all abandoned / unused wells to confirm decommissioning status. Report information regarding any on site abandoned / decommissioned wells to BC Ministry of Forest Lands and Natural Resource Operations, regional hydrogeologist. This information would	MFLNRO

include the well log, if available, name of contractor(s) involved in decommissioning the well, the date of abandonment/decommissioning, and any other pertinent information. Close Town wells not in use in accordance with regulations. Close the abandoned dug well noted near the Buchanan Rd. well site.	
10. Review the analytical program to ensure the program monitors for potential contaminants of concern, and that analytical results are promptly reviewed. Invite Ministry to update Town on Ambient GW Quality Network findings, focusing on the northern area wells. Consider annual or bi-annual water quality review meetings with Ministry and IH.	IH, MFLNRO
11. Review the existing emergency response plan for adequacy and ease of implementation if sampling indicates the presence of any contaminants above acceptable levels.	
12. Regular review of this SWA/SWPP and incorporation of new information or changes in conditions that could impact the findings of this assessment.	IH
13. Make the final SWA report available on the Provincial Ecocat database	MoE
14. Through discussions with the IH Drinking Water Specialist, set achievable timelines for each of the recommendations provided herein. Regularly check with IH on progress being made and the need for any mid-course adjustments. Most of the recommendations provided herein are considered achievable within one to three years.	IH, RDOS, OIB

8. LIMITATIONS

The specific tasks undertaken in completing this SWA were conducted in keeping with current industry standards and followed existing guidance documents and the Town of Oliver approved scope of work. Available data were reviewed and incorporated into this SWA report as required and where deemed relevant. In preparing this report, WWAL relied on information and comments provided by others and we have taken this information at face value without the ability to verify the accuracy of this third-party information. This is a normal part of the process of conducting an environmental science study that relies in part on the gathering of anecdotal or historical information.

The reconnaissance of the site and surrounding area completed by WWAL involved a non-intrusive visual inspection only and no sampling, testing, or subsurface investigation was conducted. Conditions of the site and area could change from those observed at the time of the reconnaissance.

The level of detail of the site reconnaissance was limited to visual inspection of specific target areas of interest that were identified either by others or through our review of available background information and reports. There are areas within the Proposed Source Protection Area and beyond that were not specifically inspected.

The visual inspection of areas surrounding the site involved a windshield survey from public roads to indicate general land usage in the area. Specific activities on or conditions of individual properties were not recorded unless major potential environmental concerns were apparent.

The analysis conducted in preparation of this report and the findings and recommendations could be influenced by new information and or future changes to existing conditions.

Our standard limitations are included at the end of this report.

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¹ Note. This report was actually prepared under a contract between Sustainable Subsurface Solutions (SSS), and MFLNRO, but was issued in final form after the date when SSS dissolved into what became WWAL. WWAL had no contract with MFLNRO.