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REPORT ON

INITIAL PHASES IN THE DEVELOPMENT OF A GROUNDWATER PROTECTION PLAN TOWN OF OLIVER

Submitted to:

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EXECUTIVE SUMMARY

Golder Associates Ltd. ("Golder") is pleased to present the results of our investigation, which was conducted in order to initiate the process of developing a Groundwater Protection Plan ("GWPP") for the Town of Oliver ("the Town"). The GWPP is being developed to allow for the protection of groundwater quality and sources. With the development of the GWPP, the Town of Oliver has complied with the requirements of the Interior Health Authority.

In order to achieve the greatest degree of groundwater protection, this GWPP is being developed by combining the strategies of both *wellhead protection* and *aquifer protection*. Golder has undertaken the first three steps as outlined in the Well Protection Toolkit developed by the Groundwater Management Section of the BC Ministry of Water, Land and Air Protection, namely, Step #1 - forming a community planning team, and Step #2 - defining preliminary well protection areas and Step #3 - identify potential contaminants. Given the dependence of the Town of Oliver on groundwater as a source of water supply, and the risk of groundwater contamination from pressures related to agricultural land use and other sources, the implementation of a Groundwater Protection Plan is important.

This report presents the results of the following activities:

1. Review of existing data and reports.
2. Regional and time of travel zone contaminant inventories.

Study Area

The Study Area considered for the preliminary steps in the development of this GWPP includes the Town of Oliver and areas immediately surrounding the Town. The Town is located in the southern Interior of British Columbia, within the Okanagan Valley, approximately 20 kilometers north of the Canada/U.S. border. Several lakes are located surrounding the Town area, while the Okanagan River traverses Oliver in a north to south direction. The Okanagan River flows in a southerly direction. According to the Ministry of Water, Land and Air Protection ("MWLAP") aquifer classification map, there are three main aquifers within the study area, described as follows:

> Aquifer No. 254 is primarily unconfined and underlies the eastern portion of the Town of Oliver, extending south from Tuc-El-Nuit Lake, along both the west and east side of the Okanagan River, to Osoyoos Lake.
>
> Aquifer No. 255 is semi-confined and extends north from Tuc-El-Nuit Lake, along the valley bottom, to the southern extent of Vaseux Lake.

Aquifer No. 256 is semi confined and underlies the Town of Oliver on the west side of the Okanagan River.

Town Wells

Currently, the Town's main source of municipal water is groundwater supplied from eleven water wells, nine of which are currently in use. The rural area of Oliver (outside of the Town boundaries) is supplied from surface water during the irrigation season, and groundwater at other times. The Town's eleven wells are located within the limits of the Town, and areas to the north and south of the Town. The wells supply water to both the Town of Oliver and outlying areas located within the Regional District of Okanagan Similkameen ("RDOS"). In addition to the existing eleven municipal water wells, Golder has recently monitored the drilling of an additional water well in the Blacksage area (the Miller Road Well). This brings the total number of municipal water supply wells for the Town of Oliver to twelve. A brief summary of the wells is provided as follows:

- *Buchanan Road Well:* Located approximately 1,200 m to the north of Tuc-El-Nuit Lake and north of the Town limits, within the RDOS.
- *Tuc-El-Nuit Well 1, 2 and 3:* Located along the southern shores of Tuc-El-Nuit Lake, within the Town limits. Only Well 2 is currently in use.
- *CPR Well and Lions Park Well:* Located within the Town limits in the Lions Park, near the centre of Town.
- *Rockcliffe Well:* Located in the southern portion of Town, on the west side of the Okanagan River.
- *Fairview Well:* Located along Highway 97 and south of the Town limits, within the RDOS.
- *Blacksage Wells 1 through 3:* Located on the east side of the Okanagan River, to the south of Oliver, outside the Town limits and within the RDOS.
- *Miller Road Well:* Located on the east side of the Okanagan River, to the north of Blacksage Wells 1 through 3, at the western end of Miller Road.

Time of Travel Zones

Preliminary time of travel zones were estimated using the calculated fixed radius ("CFR") method. The CFR method of analyses depicts time of travel zones as being

circular, and tends to overestimate areas with relatively flat hydraulic gradients, and underestimate areas with steeper gradients.

The results of the 60-day time-of-travel zone estimations using the CFR method indicate that the individual time-of-travel zone extents range from a radius of approximately 90 m at the Buchanan Road Well to approximately 200 m at the CPR Well, Blacksage Wells 1 through 3 and the Miller Road Well.

Contaminant Inventory

In summary, the preliminary contaminant inventory for the ten municipal water wells indicated primarily agricultural and residential land uses within the preliminary 60-day time of travel zone for each Town well. Some commercial/light industrial land uses were identified within the 60-day time of travel zone for the Lions Park Well, CPR Well and Fairview Well. Specific issues of concern are noted as follows:

- A fuel service station (OK Tire and Gas Bar) and major transportation route (Highway 97) is located within the 60-day time of travel zone for the Lions Park and CPR Wells.

- A major transportation route is located within the 60-day time of travel zone for the Fairview Well.

Recommendations

Based on the results of this initial phase of the development of a GWPP, the following recommendations are made with regards to continuing the GWPP process for the Town of Oliver. It is important to note that some of these recommendations require the combined collaborative effort of the Town of Oliver, RDOS, MWLAP, IHA and other stakeholders.

Reassessment of Data Gaps and Associated Time of Travel Zones

Based on available information, Golder has provided results regarding the preliminary 60-day time of travel zones only. Due to data gaps regarding groundwater flow directions and hydraulic parameters such as gradient and hydraulic conductivity in areas surrounding the wells, a detailed analyses of one-year, five-year and ten-year time of travel zones was not conducted. It is recommended that a detailed analyses of existing water wells (including a well elevation survey and recording of water level measurements) be conducted to provide an overall depiction of aquifer conditions (flow direction and gradient). In addition, consideration should be given to undertaking a drilling program to supplement available water well information to fill in data gaps in

areas where there are no or limited water well information. It is likely that some of the wells constructed as part of the recommended drilling program could also be used to supplement the ongoing groundwater monitoring program. It is only upon the completion of filling the data gaps that a more detailed reassessment of time of travel zones (one-year, five-year and ten-year) could be conducted.

Conduct a Comprehensive Detailed Contaminant Inventory

Once the time of travel zones of the key wells have been refined, a comprehensive contaminant inventory of the individual time of travel zones should be carried out. This inventory would expand upon the information collected as part of the regional contaminant inventory and preliminary time of travel zone inventory presented in this report.

Water Quality Monitoring Program

It is recommended that the current groundwater monitoring program utilized by the Town be assessed, and that the historical water quality data be reviewed. The purpose of the review would be to identify any outstanding water quality issues and to identify additional monitoring that may be required to address risks identified by the contaminant inventory. Specific attention should be paid to the CPR and Lions Park Well, due to their close proximity to a service station, and the Fairview Road Well, due to its elevated nitrates. It is recommended that a qualified professional be provided all analytical data, for municipal water supply wells and other monitoring wells, such that a detailed review of the water quality can be conducted, and that recommendations can be made regarding sampling parameters, frequencies and methodologies.

Designate Groundwater Protection Areas

Following refinement of the time of travel zones, the Town, in conjunction with other stakeholders (MWLAP, IHA, RDOS) should designate formal groundwater protection areas.

Develop Groundwater Protection Measures

- Once designated groundwater protection areas have been established and additional potential contaminant sources have been identified, the Town and RDOS should embark on the development of groundwater protection measures.

Develop Contingency Plans

Contingency planning consists of developing a plan for the location and provision of alternative drinking water supplies in the event that one or more of the existing wells

cannot be used. Disruptions to wells may be related to either contamination or non-contamination effects. The contingency plan should identify short-term alternatives in the event of a minor disruption, and long-term alternatives in the event of a complete loss of water supply.

Develop Emergency Response Plans

The goal of groundwater protection is to prevent the contamination of underground drinking water supplies. Even under the best prevention plans, a scenario that threatens to contaminate the aquifer may occur. When this happens, an emergency response plan directing a coordinated and timely response is an effective tool for assuring a continued supply of potable water.

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1.0 INTRODUCTION

Golder Associates Ltd. ("Golder") is pleased to present the results of our investigation, which was conducted in order to initiate the process of developing a Groundwater Protection Plan ("GWPP") for the Town of Oliver ("the Town"). This work was conducted for the Town, through TRUE Consulting Group Ltd. ("TRUE").

The project was carried out in accordance with our revised workplan and cost estimate dated May 5, 2004. Golder submitted an initial workplan to develop a preliminary groundwater protection plan for the Town in June 2002; however, after conversations with the Town, Golder revised the workplan to a more reduced scope of work.

The GWPP is being developed in response to the requirements of the Interior Health Authority, as a condition of the Town's water system operating permit. In addition, it is understood this document may be utilized as a supporting document for an application by the Town for an Infrastructure Planning Grant to be submitted to the Ministry of Community, Aboriginal and Women's Services. The purpose of the grant would be to aid in funding the full development and implementation of the GWPP.

Currently, the Town's main source of municipal water is groundwater supplied from eleven water wells, nine of which are currently in use. The rural area of Oliver (outside of the Town boundaries) is supplied from surface water during the irrigation season, and groundwater at other times. The Town's eleven water wells are located within the limits of the Town, and areas to the north and south of the Town. The study area is shown on Figure 1.

Four of these wells supply water to areas within Town municipal boundaries while the other five provide water to areas located within the Regional District of Okanagan Similkameen ("RDOS"). In addition to the existing eleven water wells, Golder has recently monitored the drilling of an additional water well in the Blacksage area (the Miller Road Well). This brings the total number of water supply wells for the Town of Oliver to twelve. A brief summary of the wells is provided as follows, with well locations shown on Figure 2:

- *Buchanan Road Well:* Located approximately 1,200 m to the north of Tuc-El-Nuit Lake and north of the Town limits, within the RDOS. This well is only used during summer months to meet peak irrigation/domestic demands in rural areas.

- *Tuc-El-Nuit Well 1, 2 and 3:* Located along the southern shores of Tuc-El-Nuit Lake, within the Town limits. Only Well 2 is currently in use. This well supplies areas within Town boundaries.

- *CPR Well and Lions Park Well:* Located within the Town limits in the Lions Park, near the centre of Town. This well supplies areas within Town boundaries.

- *Rockcliffe Well:* Located in the southern portion of Town, on the west side of the Okanagan River. This well supplies areas within Town boundaries.

- *Fairview Well:* Located along Highway 97 and south of the Town limits, within the RDOS. This well supplies water to meet domestic demands in rural areas.

- *Blacksage Wells 1 through 3:* Located on the east side of the Okanagan River, to the south of Oliver, outside the Town limits and within the RDOS. These wells supply combined irrigation/domestic demands and are used primarily during summer months.

- *Miller Road Well:* Located on the east side of the Okanagan River, to the north of Blacksage Wells 1 through 3, at the western end of Miller Road.

Historically, aquifers in the area of Oliver have been under threat of contamination from a variety of sources, including agricultural activities, septic systems, leaking underground storage tanks and industrial activities. As the majority of the Town wells are unconfined and completed to depths of less than 30 m, and are located in close proximity to the Okanagan River or Tuc-El-Nuit Lake, they can be described as being vulnerable to surface contamination. Given the dependence of the Town of Oliver on groundwater as a source of water supply, and the vulnerability or elevated risk of groundwater contamination from existing land uses, the implementation of a Groundwater Protection Plan is important. Implementation of groundwater protection measures will not only help to protect public health, but will protect ecosystems associated with streams and lakes that rely on groundwater as a source of recharge.

In order to achieve the greatest degree of groundwater protection, this GWPP is being developed by combining the strategies of both *wellhead protection* and *aquifer protection*. Wellhead protection involves the delineation of time of travel zones (the area of an aquifer from which groundwater will be derived in a predefined amount of time) of community wells and the use of protection measures to manage activities within those zones, while aquifer protection consists of the delineation of entire aquifers and the implementation of protection measures in more vulnerable areas of those aquifers. While wellhead protection is considered essential for protection of existing Town groundwater wells, aquifer-wide protection is important for areas of the aquifer that are currently supplied by private wells and areas where the Town may wish to develop additional groundwater supplies in the future.

The work to conduct the GWPP was authorized by Mr. Bruce Hamilton of the Town of Oliver on April 9, 2003, in response to Golder's initial proposal submitted on June 6, 2002.

2.0 METHODOLOGY

The Ministry of Water, Land and Air Protection's ("MWLAP's") Well Protection Toolkit was used as a guide for work related to groundwater protection planning for the Town of Oliver. The Well Protection Toolkit ("WPT") was developed jointly by MWLAP and the Ministry of Health in 2000, and consists of a six-step process created to assist communities that utilize groundwater to better manage and protect their drinking water sources.

The six steps outlined in the WPT are as follows:

1. Form a Community Planning Team;
2. Define the Well Protection Areas
3. Identify Potential Contaminants;
4. Develop Management Strategies;
5. Develop Contingency Plans; and,
6. Monitor Results and On-going Evaluation of the Plan.

Based on our experience, the process of completing the six steps of the WPT needs to be customized to meet the unique needs of each community and ensure the investment delivers the maximum protection of their water supply. For this study, the first three steps (Steps 1, 2 and 3) of the WPT were followed, with more emphasis placed on wellhead characterization than aquifer characterization. Wellhead characterization was emphasized by assessing subsurface conditions in the area of each Municipal well as opposed to the entire aquifer, and by identifying areas of potential environmental concern within individual time-of-travel zones, as part of the contaminant inventory, rather than conducting a detailed contaminant inventory for the entire aquifer. It is understood that further progress in the development of the Town's GWPP (the completion of Steps 4, 5 and 6) will be a function of funding availability.

The scope of work for this initial phase of the GWPP consisted of the following:

- Assist with the establishment of an aquifer protection planning committee with representation from the stakeholders of the aquifer, community members, government and technical experts;

- Assist the planning committee with the establishment of goals, determining information needs and the development of an action plan;

- Gather and review available information on the aquifer, prepare maps of the aquifer extent and sections through the aquifer to identify physical properties including aquifer thickness and flow direction;

- Identify data gaps and complete a field reconnaissance visit;

- Identify aquifer recharge and discharge areas;

- Estimate the extent of well head time-of-travel zones for the large capacity municipal water wells at current pumping rates using the Calculated Fixed Radius (CFR) method.

- Complete a contaminant inventory within the Town, in particular within wellhead time-of-travel zones, to identify existing and potential threats to groundwater quality; and

- Prepare a report summarizing Steps 1, 2 and 3, with recommendations for work to be included in Steps 4, 5 and 6.

Issues related to the ability of the local aquifers to sustain the current and future water supply requirements of the area were not addressed in this study. Similarly, the potential for well interference between existing or potential production wells and neighbouring wells was not addressed.

3.0 STUDY AREA

3.1 Location and Climate

The Study Area considered for the preliminary steps in the development of this GWPP includes the Town of Oliver and areas immediately surrounding the Town. The Town is located in the southern Interior of British Columbia, within the Okanagan Valley, approximately 20 kilometers north of the Canada/U.S. border (Figure 1). Several lakes are located surrounding the Town area, while the Okanagan River traverses Oliver in a north to south direction (Figure 2). The Okanagan River flows in a southerly direction.

The main economy in Oliver consists of agriculture and tourism, with agricultural activities placing a high demand on water. Other land uses in Oliver include residential, business, and industry.

Oliver has the distinction of being located in one of Canada's deserts, with desert lands providing a habitat for a diverse array of wildlife and plant species. The climate of Oliver consists of warm to hot summers and cool winters. 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 of 9.4° C, with daily mean temperatures ranging from –2.6° C in January to 21.1° C in July. Total annual precipitation for the Oliver weather station is approximately 327.5 mm.

3.2 Topography

The Town of Oliver is relatively flat and is located in the base of a valley at approximately 300 m above sea level. The topography outside of the Town rises steeply to the southwest, eventually reaching Mt. Kobau some 1,870 meters above sea level (masl). Eastern slopes rise more gradually through the Inkameep Provincial Forest. The highest point to the east is Mt. Baldy (2,300 masl), located about 40 km from the center of town. The Okanagan River flows through the Town in a north to south direction, and has an elevation of approximately 300 masl in the Town centre. Tuc-El-Nuit Lake is located within the northern limits of the Town and has a surface area of approximately 1 km^2.

The catchment areas of the Okanagan River, upgradient of the Town, generate runoff from rainfall and snowmelt that contributes recharge water to the aquifer. As the catchment area for the Okanagan River encompasses the entire Okanagan Valley, to areas as far north as Vernon, located approximately 150 km to the north of Oliver, the area representative of the total catchment area was not estimated.

3.3 Surficial Geology

According to "Late Glacial History and Surficial Deposits of the Okanagan Valley, B.C." (Nasmith, 1962), the surficial deposits within the Study Area consist of the following four categories:

1. *Okanagan River floodplain deposits:* These recent floodplain deposits consist of sand, silt, and swamp deposits. The Okanagan River meanders across the floodplain deposits which have been deposited to an unknown depth. These deposits are generally located along the base of the valley, along the Okanagan River.

2. *Alluvial fans and deltas, and associated gully and stream channel deposits:* These are erosional and depositional features of the present day streams. The deposits vary from fine silty sand to coarse bouldery gravel. The most significant of these deposits occurs on the western edge of town at the base of Fairview Creek.

3. *River terrace and channel deposits:* These glacial features are dominantly erosional in character and consist of a thin veneer of river deposits in which the channels and terraces have been cut. These deposits underlie most of the Town of Oliver.

4. *Outwash terrace deposits:* These deposits also originated during period of glacial retreat and are located in the upper benched areas to the west and east of Oliver. Deposits consist of stratified drift ranging in texture from fine sand to coarse gravel, and were likely deposited by melt water streams originating from melting ice. Significant outwash terrace deposits are located northeast of Tuc-El-Nuit Lake and west/southwest of the centre of Town.

3.4 Bedrock Geology

Apart from providing a physical boundary within which the unconsolidated sediments of the valley are situated, the bedrock in the Study Area likely has little effect on the local groundwater flow regime. The bedrock geology is therefore only described briefly in the following paragraph.

The mountainous areas located to the west and south of Oliver consist of the Nelson Plutonic Rock group of middle Jurassic age. This pluton generally consists of massive, moderately foliated, medium to coarse-grained horneblende-biotite granodiorite, quartz diorite and granite. Geology to the east and north of Oliver is described as the Oliver Pluton of Cretaceous or Jurassic age. These Mesozoic deposits consist of massive, unfoliated, medium-grained porphyritic biotite granite with weakly foliated hornblende granodiorite. Included in this pluton are notable sections of biotite-hornblende diorite agmatite and massive garnet-muscovite granite.

4.0 HYDROGEOLOGY

The Town of Oliver has a total of twelve municipal water wells, nine of which are currently in use during various periods throughout the year. The three wells which are not in use are as follows:

- Tuc-El-Nuit Wells 1 and 3 - both of which have not been used for approximately the past five to six years,

- Miller Road Well - newly completed and will likely be brought online in the near future.

According to MWLAP's aquifer classification maps, there are three distinct aquifers within the area of the Town of Oliver. These aquifers are identified as Aquifer No. 254, 255 and 256, the limits of which are shown on Figure 2. One of the Town's water supply wells (Buchanan Road Well) is completed within Aquifer 255, while nine wells (Tuc-El-Nuit Wells 1 through 3, CPR Well, Lions Park Well, Blacksage Wells 1 through 3 and Miller Road Well) have been completed within Aquifer No. 254. The Rockcliffe Well is completed within Aquifer 256, while the Fairview Well is completed in an area where both Aquifers 254 and 256 intersect. Based on a review of the well log for the Fairview well, subsurface conditions appear to be unconfined. As such, it can be inferred that the Fairview well is completed within Aquifer 254.

Detailed aquifer descriptions are provided in the following section.

4.1 Aquifer No. 254 (Osoyoos Lake to southwest of Tuc-El-Nuit Lake)

Aquifer No. 254 is primarily an unconfined aquifer and underlies the eastern portion of the Town of Oliver, extending south from Tuc-El-Nuit Lake, along both the west and east side of the Okanagan River, to Osoyoos Lake, located approximately 12 km to the south of Oliver (Figure 2). Aquifer No. 254 is approximately 25 km^2 in area, and is classified as "heavily developed and highly vulnerable" (MWLAP Classification IA). It is important to note that the MWLAP classification system is subjective and is based on a number of factors such as aquifer demand, productivity, size, soil types, water quality and vulnerability to surface contamination.

Based on a review of selected water well logs available on the MWLAP water well database for wells completed in Aquifer No. 254, surficial deposits generally consist of sand and gravel, with thicknesses ranging from 37 m to 165 m below ground surface ("mbgs"). The sand deposits are generally underlain with silt and/or clay deposits or bedrock. Although some silt and clay deposits are occasionally noted to be at ground surface or interlayered with coarse-grained sands and gravels, the majority of the aquifer appears to be unconfined. Water well logs for private wells within Aquifer No. 254 vary from shallow excavated water wells to drilled wells up to 30 m in depth. Municipal wells located within Aquifer No. 254 consist of the Tuc-El-Nuit Wells, CPR Well, Lions Park Well, the Blacksage Wells and the new Miller Road Well. The Fairview Well is completed in an area where Aquifer No. 256 overlaps with Aquifer No. 254. Based on a review of the well log for the Fairview well, subsurface conditions appear to be unconfined. As such, it can be inferred that the Fairview well is completed within Aquifer 254. These wells were screened within sand and gravel between depths of approximately 10 m and 28 m.

A lack of detailed water level and well elevation information for the numerous water wells located in the area of Aquifer No. 254 precludes Golder from accurately

determining the hydraulic gradient and/or groundwater flow direction within this area. Available information indicates that the water table within Aquifer No. 254 ranges from approximately 0.6 mbgs adjacent to the Okanagan River, to approximately 7.3 mbgs farther away from the River. The aquifer is recharged by precipitation that falls on the valley floor, runoff from the uplands on both the east and west sides of the valley, and leakage from local creeks flowing from the upland areas into the valley bottom. Groundwater flow on the east side of the Okanagan River, in the area of Aquifer 254, is generally inferred to be towards the west in the topographically upgradient areas, with a southwesterly flow direction likely near the valley bottom. Groundwater flow on the west side of the Okanagan River, in the area of Aquifer 254, is generally inferred to be towards the east in the topographically upgradient areas, with a southeasterly flow direction within the valley bottom. The inferred groundwater flow direction in the immediate area of the Okanagan River is inferred to be southerly, as it is likely influenced by flows within the River.

As the aquifer is generally located within the valley bottom, and consists of sand and gravel, based on our experience, it can be inferred that the hydraulic gradient likely ranges in the order of 0.001 to 0.01. In addition, as static water levels within the municipal wells are similar to the elevation of the Okanagan River, they can be inferred to be hydraulically connected.

4.2 Aquifer No. 256 (Testalinden Creek to Reed Creek)

Aquifer No. 256 underlies the Town of Oliver on the west side of the Okanagan River. MWLAP's aquifer database indicates that Aquifer No. 256 is semi-confined or confined, and approximately 25 km^2 in area (Figure 2). MWLAP classifies this aquifer as "lightly developed and low vulnerability" (MWLAP Classification IIIC).

Based on a review of water well logs available for wells completed in Aquifer No. 256, surficial deposits vary significantly. Subsurface deposits consist of silty to clayey sand and gravel, or till, from the ground surface to a 42 m depth. A thick deposit of silt or clay, interbedded with fine sand, occurs beneath these surficial deposits, and varies in thickness from 27 m to 74 m. The static water level for wells completed within Aquifer No. 256 range from approximately 0.9 mbgs in the eastern portions of the aquifer to 7.9 mbgs in the western portion.

The Town's Rockcliffe Well is completed in Aquifer No. 256. Subsurface conditions for the Rockcliffe Well are discussed in detail in following sections.

Similar to other aquifers in the area, Aquifer No. 256 is recharged by precipitation that falls on the valley floor, runoff from the uplands to the west and leakage from several creeks flowing from the upland areas in an easterly direction. Groundwater flow in

Aquifer No. 256 is inferred to be primarily towards the east/southeast, with groundwater flow in the immediate area of the Okanagan River likely flowing in a southerly direction. Similar to Aquifer No. 254, the hydraulic gradient in the area of Aquifer No. 256 cannot be assessed based on the limited static water level and well elevation information. However, based on our experience in the area, and on the sand and gravel in which the Town wells (Rockcliffe Well and Fairview Well) are completed, it is inferred that the hydraulic gradient ranges from 0.01 to 0.001.

4.3 Aquifer No. 255 (North of Tuc-El-Nuit Lake to Vaseux Lake)

Aquifer No. 255 is a semi-confined aquifer which extends north from Tuc-El-Nuit Lake, along the valley bottom, to the southern extent of Vaseux Lake (Figure 2). According to MWLAP's aquifer classification maps, Aquifer No. 255 is approximately 25 km^2 in area, and is classified as "heavily developed and highly vulnerable" (MWLAP Classification IA).

A review of selected well logs for wells completed in Aquifer No. 255 indicate an upper deposit of sand and gravel, interlayered with minor silt deposits. The upper deposits vary in thickness from 7.3 m to 22.9 mbgs. In the central portion of the aquifer, the silt becomes more significant, and range in thickness from 4.8 m to 11.6 m. Several well logs identify a sand and gravel below the semi-confining silt. The lower sand and gravel deposits generally occur from approximately 12 m to 24 mbgs. Groundwater levels range from approximately 2.7 m to 10.4 mbgs, with the overall direction of groundwater flow towards the valley bottom and the Okanagan River. Previous work conducted by Golder in 1994, in the area between Gallagher Lake and Mud Lake (north of the Buchanan Road Well), indicates the groundwater flow direction within this area is towards the south/southwest.

5.0 GROUNDWATER USE

5.1 Town of Oliver

According to the Town of Oliver's website, the total population in 2000 was approximately 4,360 people, with an additional 4,500 within the rural area surrounding Oliver. The majority of the population located within the Town boundaries is serviced by the Town's water supply system. As stated previously, the water supply for the Town and rural areas is derived from twelve water wells (including the recently completed Miller Road Well), the following nine of which are normally in use at various times throughout the year: Buchanan Road Well, Tuc-El-Nuit Well No.2, CPR Well, Lions Park Well, Rockcliffe Well, Fairview Well, and the Blacksage Wells No.1, 2 and 3.

5.1.1 In-Use Water Wells

Available well logs for the Town's municipal water wells are provided in Appendix I. A description of the nine water supply wells currently used by the Town of Oliver is presented below. In addition, the hydraulic parameters of the aquifer at each well location have been evaluated using historical data provided by the Town. Table 1 provides a summary of characteristics for each well, including aquifer thickness, transmissivity (T) and hydraulic conductivity (K). The aquifer thickness was generally estimated by subtracting the depth to the groundwater level from the depth to the bottom of the screen.

Aquifer transmissivities were estimated for four of the Town's wells, as pumping test data was only available for these four wells; Tuc-El-Nuit Well No.2, Rockcliffe Well, Blacksage Well No.1 and the Miller Road Well. Transmissivities were estimated using the results of previous pumping tests conducted by others and/or Golder, and a commercial computer software program for aquifer test analyses entitled AQTESOLV. Transmissivity values were estimated/re-estimated to ensure that the effects of any lakes or rivers were taken into consideration. The solution used consisted of the Theis solution, with image wells constructed to account for the recharge from the lake/river. No well logs are available for Blacksage Road Wells 2 and 3. AQTESOLV plots are provided in Appendix II.

Buchanan Road Well

The Buchanan Road Well was drilled in October 1968 by Osoyoos Tile Works of Osoyoos, B.C., and is located on the east side of the Okanagan River, at the west end of Buchanan Road. Subsurface conditions encountered during drilling consist of compact clayey sand to a depth of 1.5 m, underlain by sand and gravel to a depth of 22.6 m. A 6.4 m thick sandy silt was located beneath the sand and gravel, followed by a 4.6 m thick silt (encountered to a 33.5 m depth), at which point the hole began to cave. Drilling was stopped at a depth of 34.7 mbgs. The well consists of 200 mm (8 inch) diameter casing, with the well screen installed between 17.4 m to 21.9 mbgs. The well casing was pulled back from 34.7 m to a depth of approximately 17.4 m to expose the well screen. At the time of drilling, a static water level of 2.1 mbgs was measured, with a reported well yield of approximately 400 US gallons per minute (USgpm) (1,510 L/min). Based on a review of this well log, the Buchanan Road Well appears to be screened in an unconfined aquifer.

No pumping test data is available for the Buchanan Road Well.

Tuc-El-Nuit Well No. 2

Well No. 2 was drilled in 1971 by the Groundwater Section of the Inventory and Engineering Branch, BC Ministry of the Environment. Well No. 2 is located on the Fortis right-of-way, south of Tuc-El-Nuit Lake. Well No. 2 consists of 300 mm (12 inch) diameter casing. Available information indicates that subsurface conditions consist of sand and gravel to a depth of 15.2 m. This is underlain with silt to a depth of 14.3 mbgs, to which depth the casing was advanced. The casing was pulled back to expose the well screen installed between the depths of 10.4 m and 14.3 mbgs. The static groundwater level was measured at a depth of 3.4 m. Based on a review of this well log, this well appears to be screened in an unconfined aquifer.

A report in 2000 by Kala Groundwater Consulting Ltd.'s (Kala) regarding a 24-hour constant-rate pumping test conducted at Well No. 2, was provided to Golder for review. Kala estimated that the maximum pumping rate for Well No. 2 (based on available drawdown) is 1,200 USgpm (4,500 L/min). Note that the laminar flow screen transmitting capacity for the screens within Well No. 2 is 700 USgpm (2,600 L/min). Kala's reported estimated transmissivity was approximately 12,500 m^2/day. Golder recalculated the transmissivity using the original pumping test data, an image well representing the constant head boundary (Tuc-El-Nuit Lake) and Aqtesolv hydrogeologic software. Golder's re-estimate of the transmissivity value was approximately 9,500 m^2/day. Based on the transmissivity and aquifer thickness, the hydraulic conductivity of the aquifer in the area of Tuc-El-Nuit Well No. 2 is approximately 1×10^{-2} m/sec, which is within the published range of hydraulic conductivities for these soil conditions.

Lions Park Well

The Lions Park Well was completed on March 4, 1980 in Lions Park, on the west side of the Okanagan River, by Quality Water Wells Ltd. of Okanagan Falls, B.C. This well consists of 400 mm (16 inch) diameter casing. The driller's log indicates that subsurface conditions consist of fine to coarse-grained sand and gravel to a depth of 23.2 mbgs. This was underlain with a 0.6 m thick grey clay, followed by a grey sand to 25.9 mbgs, at which depth the drilling was terminated. The well casing was pulled back to a depth of approximately 18 m to expose the well screen, installed between 18.3 m to 23.2 mbgs. Based on a review of the well log, the Lions Park well appears to be unconfined to semi-confined. The static water level within the well at the time of drilling was reported to be approximately 1.8 mbgs.

According to available information, the laminar flow screen transmitting capacity of the well is approximately 1,230 US gpm (4,600 L/min). No historical pumping test data is

available for the Lions Park Well, and as such, aquifer transmissivity and hydraulic conductivity could not be estimated.

CPR Well

The CPR Well was completed on February 22, 1980 by Quality Water Wells Ltd. of Okanagan Falls, B.C. The CPR Well is located approximately 90 m to the south of the Lions Park Well, within Lions Park, on the west side of Okanagan River. The well consists of 400 mm (16 inch) diameter casing. Available information indicates that subsurface conditions consist of sand and pebbly gravel to a depth of 13.6 mbgs. The sand and gravel is underlain by clay and silt to a depth of 15.2 mbgs, at which depth the drilling was terminated. A screen was installed between 9.1 m and 13.6 mbgs, with the casing pulled back to expose the screen. The static water level within the well at the time of drilling was reported to be approximately 1.2 mbgs. Based on information recorded within the well log, this well appears to be screened in an unconfined aquifer.

According to available information, the laminar flow screen transmitting capacity of the well is approximately 1,150 US gpm (4,350 L/min). No historical pumping test data is available for the CPR Well, and as such, aquifer transmissivity and hydraulic conductivity could not be estimated.

Fairview Well

The Fairview Well was drilled in October 1968 by Osoyoos Tile Works of Osoyoos, B.C. The well is located along 32nd Avenue, and consists of a 200 mm (8 inch) diameter casing. Subsurface conditions encountered during drilling consist of compact sand to a depth of 1.5 m, underlain by sand and gravel, with a varying silt and clay content, to a depth of 35.7 m. Beneath the sand and gravel, a silt and clay was encountered to a depth of 42.7 mbgs, at which depth the well was terminated. A screen was installed between 26.8 m to 28.3 mbgs, with the casing pulled back to expose the screen. At the time of drilling, the static water level was measured to be approximately 9.1 mbgs. Based on a review of this well log, the Fairview well is screened within an unconfined aquifer.

As noted on the well log provided for the Fairview Well, the pumping rate for the Fairview Well is approximately 425 USgpm (1,600 L/min). No historical pumping test data is available for the Fairview Well, and as such, aquifer transmissivity and hydraulic conductivity could not be estimated.

Rockcliffe Well

The Rockcliffe Well was drilled in 1990 by Robbins Water Well Drilling of Okanagan Falls, B.C. The well is located on District Lot 129, near the intersection of 342nd Avenue and 105th Street, which is approximately one block west of Highway 97. The Rockcliffe

Well consists of a 500 mm (20 inch) diameter surface casing that is set to a depth of 6.1 mbgs. Below the surface casing, the Rockcliffe Well consists of 400 mm (16 inch) diameter casing to a terminal depth of 15 m below ground level. The well is screened between 15.0 m and 24.4 mbgs. The subsurface materials encountered during drilling consisted of medium to coarse-grained sand and gravel to a depth of 24.4 mbgs. The sand and gravel is underlain by silt to a depth of 27.4 m, at which depth the drilling was terminated. The static water level was recorded during drilling at a depth of 6.3 mbgs, with a recommended pumping rate of 1,500 USgpm (5,700 L/min).

In November 1990, Kala conducted a 24-hour constant-rate pumping test on the Rockcliffe Well. The results are summarized in their December, 1990 report entitled *"Town of Oliver, Groundwater Development Program, Well No. 4."* Based on the results of their investigation, the aquifer in the area of the Rockcliffe Well was identified to have a transmissivity of approximately 14,200 m^2/day.

Using the data from the pumping test conducted by Kala, Golder estimated a transmissivity of approximately 59,000 m^2/day. Although the Golder and Kala transmissivities are within the same order of magnitude, the cause for the variances in the transmissivity is unclear. The hydraulic conductivity of the aquifer was estimated by dividing the (Golder) transmissivity by the aquifer thickness. As the aquifer appears to be unconfined, the aquifer thickness was estimated by subtracting the static water level from the bottom depth of the screen, for an aquifer thickness of 18.1 m. The hydraulic conductivity of the aquifer in the area of the Rockcliffe Well is approximately 0.04 m/s, which, based on a literature review, is within the range of hydraulic conductivities commonly associated with sand and gravel.

Blacksage Well No. 1

Blacksage Well No. 1 was constructed in 1981 by Quality Water Wells Ltd. Drilling of Okanagan Falls, B.C. The well is located within the System No. 2 Well Field, approximately 5 km south of Oliver, along the east side of the Okanagan River. The well field is situated next to an oxbow lake associated with the Okanagan River. At present, there are three wells in the Blacksage Well Field. Information regarding subsurface conditions is only available for Well No. 1.

Well No. 1 is completed with a 400 mm (16 inch) and 300 mm (11 inch) diameter well casing. Subsurface conditions encountered at Well No. 1 consist of varying deposits of sands and gravels, with a variable silt content, to a depth of 27.6 m. A silt and clay was encountered underlying the sand and gravel, to a depth of 33.5 mbgs, at which depth the drilling was terminated. A screen was installed from 11.6 m to 14.2 m and from 20.2 m to 25.7 m. The casing was pulled back to expose the well screen. A blank section of casing separates the two well screens from 14.2 m to 23 m. The static water level was

reported at 2.8 mbgs at the time of drilling. This well is screened within an unconfined aquifer.

In February 1985, Kala conducted a constant-rate pumping test for 6 hours. The purpose of the pumping test was to evaluate modifications made to the screen assembly to prevent the production of sand in this well. Based on the results of the 6-hour pumping test, Kala rated the long-term yield for Well No. 1 at 2,000 USgpm (7,600 L/min). Kala did not estimate the aquifer's transmissivity at the time of the pumping test.

Golder used the data from the short pumping test to obtain an estimate for transmissivity. The model of the pumping test included an image well that represents a constant head boundary, Okanagan River. Golder estimates the transmissivity of the aquifer surrounding Well No. 1 to be approximately 5,200 m^2/day. The hydraulic conductivity of the aquifer has been estimated to be approximately 2.6 x 10^{-3} m/s, which is within the range of published values for these materials.

5.1.2 Existing Water Wells Not In Use

Three wells are currently not in use, including Tuc-El-Nuit Wells No.1 and 3 and the newly constructed Miller Road Well. According to Mr. Bruce Hamilton, both Tuc-El-Nuit Wells have not been in use for approximately five years. In addition, the newly construct Miller Road Well has not yet been commissioned for the Town of Oliver. It is anticipated that this well will be brought online in the near future.

The following provides a brief description of each well, subsurface conditions and pumping test information, if available.

Tuc-El-Nuit Well No. 1

Tuc-El-Nuit Well No. 1 is located on the Fortis right-of-way, south of Tuc-El-Nuit Lake. The well was drilled in 1971 by the Groundwater Section of the Inventory and Engineering Branch, BC Ministry of the Environment, and consists of a 200 mm (8 inch) diameter casing. Available information for this well indicates that subsurface conditions consist of varying deposits of silty sand and gravel to sand and gravel to a depth of 17.6 m. The well is screened between the depths of approximately 11.0 m and 14.0 mbgs. The reported static water level at the time of drilling was reported to be 3.4 mbgs.

The nominal pumping rate for Tuc-El-Nuit Well No. 1 is 250 USgpm (9,450 L/min). No historical pumping test data is available for Well No. 1, and as such, aquifer transmissivity and hydraulic conductivity could not be estimated. According to the Town of Oliver, this well is no longer in use, as sufficient well yields are being collected from Tuc-El-Nuit Well No. 2.

Tuc-El-Nuit Well No. 3

Tuc-El-Nuit Well No. 3 was drilled in 1982, by Quality Water Wells Ltd of Okanagan Falls, BC, and is completed with a 250 mm (10 inch) diameter casing. Well No. 3 is located on the West Kootenay Power right-of-way, south of Tuc-El-Nuit Lake, and southeast of Tuc-El-Nuit Wells No.1. Available information indicates that subsurface conditions consist of fine to medium-grained sand and pebbly gravel to a depth of 17.1 mbgs. A cemented gravel lens was encountered beneath the sand and gravel. Well No. 3 was terminated in the cemented gravel. A screen was installed from 9.9 m to 13.7 mbgs, with the well casing pulled back to expose the well screen. The reported static water level at the time of drilling was approximately 4.0 mbgs. The well yield at the time of completion was estimated to be 650 USgpm (2,500 L/min).

Kala's November 1982 report entitled "S.O.L.I.D., System No.3 Extension, Groundwater Development Program", provided the results of a 22-hour constant-rate pumping test of Well No. 3. Kala reported an estimated transmissivity value of approximately 14,900 m^2/day. Golder re-estimated the transmissivity using the original pumping test data, an image well to represent a constant head boundary (Tuc-El-Nuit Lake) and Aqtesolv hydrogeologic software. Golder estimates the transmissivity to be approximately 9,500 m^2/day.

The hydraulic conductivity of the aquifer in the area of Well No. 3 was estimated by dividing the transmissivity by the aquifer thickness. The aquifer thickness was estimated to be approximately 13.1 m. The hydraulic conductivity of the aquifer in the area of Well No. 3 is approximately 8.4 x 10^{-3} m/s, which is within the published range of hydraulic conductivities commonly associated with these deposits.

This well is considered to be standby well for the Town, and is currently not in use.

Miller Road Well

The Miller Road Well was constructed by Robbins Water Well Drilling & Pump Service (Robbins Drilling and Pumps) of Okanagan Falls, BC, in July of 2004. Golder monitored the construction of the well and a pumping test program. The results of the construction and testing program are summarized in our December 16, 2004 report entitled *"Well Construction and Capacity Testing, New Production Well PW04-1, Oliver, British Columbia"*. The well is located approximately 75 m east of the Okanagan River, in the area of Orchard Grove Lane and Miller Road, approximately 350 m to the north of Blacksage Wells No. 1 through 3. Although this well has not yet been brought online by the Town, the following provides information regarding the well.

Subsurface soil conditions in the area of Miller Road Well consist of sand and gravel to a depth of approximately 18.6 m, underlain with a minimum of 4.6 m of clay. This well was advanced to a depth of 23.2 mbgs. The Miller Road Well is constructed using a 300 mm (12 inch) diameter casing and is screened between 14.3 m and 18 m. The static water level was recorded at approximately 6.7 m at the time of drilling. The sustainable well yield was reported to be 69 L/sec (1,092 US gpm); however, the estimated laminar flow capacity of the screen was reported to be approximately 57 L/s (900 US gpm).

A 52-hour constant-rate pumping test was conducted in September 2004. Based on the results of the pumping test, the transmissivity of the aquifer is estimated to be approximately 1,450 m^2/day. Given a saturated aquifer thickness of approximately 11.9 m, this indicates a hydraulic conductivity of approximately $1.4x10^{-3}$ m/s, which is within the published range of hydraulic conductivities for sand and gravel.

5.1.3 Future Groundwater Development

The Town of Oliver's potential long term plans for additional water supply sources include the following:

1) A second well adjacent to the existing Buchanan Road Well, with a proposed capacity of 400 to 600 US gpm.

2) An additional well between the existing Fairview and Rockcliffe wells, with a projected pumping rate of 500 US gpm.

3) A well located in the area between the north end of Tuc-El-Nuit Lake and the Okanagan River, capable of producing approximately 950 US gpm.

5.2 Other Groundwater Users

A comprehensive inventory of private water wells other than those operated by the Town of Oliver was beyond the scope of this study. However, Golder Associates assembled some information concerning regional groundwater use.

A search of water well records identified over 250 private known water wells in the area of the Town and outlying RDOS areas (see figure in Appendix III). Some of these wells supply water to property owners located outside the area serviced by the Town's system, while other wells are located in areas now supplied by the municipal system and have likely been abandoned. Presumably, some older wells located in rural areas now serviced by municipal supplies may be maintained by property owners for irrigation purposes.

Enquiries were made to Mr. Ron Johnston and Mr. John Beaupre, both of the Interior Health Authority, to obtain information regarding the other smaller public water supply systems sourced by groundwater in the area that service local communities such as trailer parks. Both Mr. Johnston and Mr. Beaupre indicated that they were aware of several water supply wells which provide potable water for small trailer park communities such as the Weeping Willow Mobile Home Park (one well with 25 to 30 connections), various wineries throughout the area and domestic water wells servicing single-family residences not connected to the Town's municipal water supply system.

Although these smaller public water supply systems are known to exist, information regarding subsurface conditions in each of these areas is limited. As such, we cannot assess possible influences between these wells and the Town wells at this time. However, the Town has not identified any noticeable interference concerns to date, on the Town wells.

6.0 WELL PROTECTION TOOLKIT

6.1 Step 1 - Community Planning

6.1.1 Initial Kickoff Meeting

The first step of the Well Protection Toolkit ("WPT") is to form a community planning team. As such, an initial planning meeting was held in April 2003, with Mr. Tom Szalay, Municipal Manger of the Town of Oliver, Mr. Bruce Hamilton, Director of Operations for the Town of Oliver, Mr. Remi Allard, Senior Hydrogeologist for Golder, and Mr. Terry Underwood of the TRUE Consulting Group Ltd. in attendance. The purpose of the meeting was to review the terms of reference for the study and to develop an action plan, as well as provide an overview of the WPT and discuss the roles and objectives of the community planning team.

During the initial planning meeting it was agreed that the development and implementation of the GWPP should include a wide range of community interests. Local government bodies, citizens, business owners and community groups all have an interest in protecting groundwater in the area for domestic and agricultural use. The technical committee would consist of the following persons:

Mr. Bruce Hamilton, Director of Operations - Town of Oliver
Mr. Ron Johnston, Interior Health Authority
Mr. Terry Underwood, TRUE Consulting Group Ltd.
Mr. Des Anderson, Ministry of Water, Land and Air Protection (Kamloops)
Mr. Remi Allard, Golder Associates Ltd.

It was initially decided that the primary focus of groundwater protection planning at this point is technical and does not require the input from the general public. Input from the public would be solicited following the completion of Steps 2 and 3, with additional members added to the community planning team at a later date.

The objective of the initial planning committee is to understand the technical aspects of the aquifers in the Study Area, prior to embarking on public workshops to solicit stakeholder input. Concerns identified during the kickoff meeting regarding the aquifers included:

- Protection of individual wellhead areas;
- A service station in the area of two Town wells (CPR and Lions Park Wells); and
- Groundwater quality within the area of several municipal wells.

Other potential concerns common to communities similar to the Town of Oliver include:

- Old wells not properly abandoned acting as direct conduits for contaminants to migrate from ground surface into the aquifer;
- Agricultural chemicals, including pesticides, herbicides and fertilizers; and
- Stormwater disposal to ground.

6.1.2 Action Plan and Objectives

The action plan outlined at the kickoff meeting was to complete the characterization of the aquifer systems underlying the Town of Oliver. It was deemed important to first characterize the aquifers before approaching the public, to enable officials to be confident in answering the public's questions during the process.

The committee decided that the general objective of the GWPP will be to protect groundwater quality and quantity. More specific objectives and an action plan would be determined once the initial phase of the Study was completed and the aquifers characterized. Tools that would be examined in the future to assist in the protection of the groundwater source would likely focus on public education, control of land use (bylaws, rezoning, etc.), and more detailed analysis of Best Management Practices in the agricultural and industrial community.

6.2 Step 2 - Define Well Protection Area Based on Time of Travel Zone Analyses

6.2.1 General

During the pumping of a water production well, groundwater is removed from a finite volume of the aquifer. In the initial phases of pumping, the drawdown cone created by the well expands and groundwater is removed from storage within the aquifer (due to pore drainage, aquifer matrix compression, and water compressibility). In later stages, once the drawdown cone attains sufficient dimensions and/or intersects a water body, groundwater flows radially towards the production well and the aquifer is replenished by recharge due to precipitation and/or leakage from streams, rivers, and geologic units bounding the aquifer.

To efficiently manage and protect a groundwater supply, an understanding of the well "capture zone" and the "time of travel" zones is required. A "capture zone" is the area of an aquifer from which all groundwater will eventually arrive at the production well, even after a considerable amount of time. A "time of travel" zone is the area of an aquifer from which groundwater will be derived in a predefined amount of time. For example, if the contaminant is released within the 1-year time of travel zone, it can be expected to arrive at the production well in approximately 1 year. Once the time of travel zones are estimated, protective measures can be implemented within the zones to ensure the safety of the water supply.

For the purpose of this study, Golder Associates carried out a *preliminary analysis* of the time of travel zones for the water supply wells operated by the Town of Oliver. The time of travel zones were estimated for the nine existing wells in use, including Buchanan Road Well, Tuc-El-Nuit Well No.2, CPR Well, Lions Park Well, Rockcliffe Well, Fairview Well and Blacksage Wells No.1 through 3, under current pumping rates, and for the newly constructed Miller Road Well, under a projected pumping rate. The following section outlines the methodology used in the time of travel zone analyses, the results of the analysis, and the limitations of the analysis.

6.2.2 Modeling Methodology

Several methods of time-of-travel zone analysis exist including: 1) type curves (calculated fixed radius method) and analytical equations for the time-of-travel zone extent, 2) analytical groundwater flow models, and 3) numerical flow and transport models. The methods vary in their accuracy and applicability, with methods 1 and 2 being restricted to relatively simple groundwater regimes, and method 3 being capable of addressing scenarios with more complicated hydrostratigraphy, hydrogeologic boundaries, and variable pumping scenarios.

Based on the hydrogeological regime in the area of the Town, Golder relied on the calculated fixed radius (CFR) method to estimate the time of travel zones for the Town wells. Attempts were made to assess time of travel zones using a numerical model. However, due to insufficient information available regarding flow gradients, hydraulic conductivities in areas upgradient from the wells and other aquifer parameters, the numerical model could not be calibrated. Based on our experience in comparing the two methods of analyses (CFR versus numerical modeling), it can be inferred that the calculated area of the time of travel zone will be the same. The difference between the two methods is with the shape of the time of travel zone, with the numerical modeling method depicting an elongated area to account for the hydraulic gradient. These elongated areas typically extend hydraulically upgradient and parallel to the direction of groundwater flow.

The CFR method was considered most applicable for the assessment of time of travel zones for the Town of Oliver wells. The CFR method provides for a conservative (likely larger than actual conditions) estimate of the time of travel zones' extent. Detailed (three-dimensional, transient flow) modeling would be required to account for all positive and negative boundary conditions, which was beyond the scope of this study.

The time of travel zones using the CFR method were estimated for early travel times of 60 days for all wells, and are shown on Figures 3 through 6. One-year, five-year and ten-year time of travel zones were not estimated using the CFR method, as the degree of accuracy using this method decreases with increased distance from the well, as a result of uncertain homogeneity in aquifer characteristics.

The following presents a brief methodology for the CFR Method.

Calculated Fixed Radius Method

The CFR method was used to delineate the time of travel zones for each well for 60-days. The CFR method of analyses depicts time of travel zones as being circular, and tends to overestimate areas with relatively flat hydraulic gradients, and underestimate areas with steeper gradients. Hydraulic gradients in the area of the water wells for the Town could not be accurately determined based on available information. However, the gradients are anticipated to be relatively flat in areas adjacent to surface water bodies such as the Okanagan River and Tuc-El-Nuit Lake, with gradients becoming steeper in the upland areas.

Time of travel zones for the majority of the Town's wells are located in close proximity to these surface water features and therefore intersect it. As Tuc-El-Nuit Lake and the Okanagan River are considered natural recharge boundaries, it is unlikely that the time of travel zones will extend beyond these recharge boundaries. As such, time of travel zones

identified on the applicable figures have only been drawn to represent areas up to the surface water features and not into, or beyond, the recharge boundaries (Tuc-El-Nuit Lake and Okanagan River). Furthermore, times of travel zones greater than one year are not considered to be representative of actual conditions. This is a result of the uncertainty regarding hydraulic conductivity and hydraulic gradient estimates at increased distances from the well.

The estimates completed must be considered preliminary only. However, they represent a reasonable first approximation for aquifer protection planning by providing an indication of the reaction time available in the case of threats to the groundwater supply. This information can be used to make contingency plans later in the GWPP process. The CFR method is defined by the following equation:

$$r = \sqrt{\frac{10038 * Q * t}{n * b}}$$

Where:

r = calculated fixed radius around the pumping well (m)

Q = pumping rate (L/s)

t = travel time (usually in years)

n = aquifer porosity (for sand and gravel aquifer n can be assumed to be 0.25)

b = aquifer thickness or screen length (m)

Limitations of Analysis - Calculated Fixed Radius

It should be noted that the calculated fixed radius method used to estimate the time-of-travel zones for the various production wells is a calculation that is based on simple physical assumptions of the aquifer system. The CFR method assumes the aquifer is uniform and that the groundwater velocity prior to pumping is nil. This method is generally applicable when: 1) the hydraulic gradient is relatively small; 2) the aquifer is relatively homogeneous; 3) the pumping well is relatively high; and 4) the pumping well is located at a significant distance form hydrogeologic boundaries. Considering this, the CFR method is considered to be fairly accurate for travel times up to 60 days and somewhat accurate up to one year. Estimates of zones of travel in excess of one year are typically a poor representation of travel time zones. As such, one-year, five-year and ten-year travel time zones have not been estimated.

In addition, the calculated fixed radius method does not take into consideration potential interactions of the time of travel zones with large recharge boundaries. As shown on Figures 3 through 6, the time of travel zones end upon intersecting with the Okanagan River and/or Tuc-El-Nuit Lake, both of which are anticipated to act as a recharge

boundary. It is anticipated that the time of travel zones will not extend beyond the recharge boundaries, provided that the drawdown within the wells does not fall below the base elevation of the recharge boundary (Okanagan River), and based on the following conditions:

i) the general absence of confining river bottom sediments (i.e. silt, clay),
ii) the shallow nature of the Town wells (screen installed at less than 30 m depth),
iii) generally unconfined conditions, and
iv) static water levels similar in elevation to the elevation of the nearby recharge boundaries (Okanagan River and Tuc-El-Nuit Lake).

Should the water level elevation within the pumping wells fall below the base elevation of the Okanagan River, it is possible that the time of travel zones will extend beyond the River.

6.2.3 Time of Travel Zone Results

Estimates of the extent of time of travel zones were completed for the Town of Oliver water wells in Aquifer No. 254, 255 and 256. The pumping rate used for each well was the reported maximum yield indicated in reports for each well as summarized in Table 1. Table 1 also summarizes the results of the CFR analyses for each active well individually, and the combined estimates of the three Blacksage Wells (only one combined pumping rate of 2,000 USgpm (7,570 L/min) was provided to Golder for these wells). As no pumping test data was provided for several Town wells (Buchanan Road Well, Lions Park Well, CPR Well and Fairview Well), aquifer characteristics were assumed based on pumping test results from the other nearby Town wells.

The results of the time of travel zone analyses is shown on Figures 3 through 6, and discussed in the sections below.

60-Day Time of Travel Zones

The results of the 60-day time of travel zone estimations using the CFR method indicate that the individual time of travel zone extents range from a radius of approximately 90 m at the Buchanan Road Well to approximately 200 m at the CPR Well, Blacksage Wells 1 through 3 and the Miller Road Well. None of the individual 60-day time of travel zones intersects each other, with the exception of the following:

- CPR and Lions Park Wells;
- the Blacksage Wells (1 through 3) and the Miller Road Well.

6.3 Step 3 - Contaminant Inventory

6.3.1 Methodology

A contaminant inventory was carried out to identify existing and potential sources of groundwater contamination within the Town. The inventory was comprised of two components:

1. A regional inventory to identify general environmental concerns in the area of the Town; and

2. Preliminary inventories within each time of travel zone identified in Section 6.3.3.

A summary of information sources used to complete the regional and time of travel zone contaminant inventories is presented below.

1. A search of databases maintained by MWLAP to identify sites contained within the Contaminated Sites Registry. Note that MWLAP was requested to review their WASTE database (used to manage information related to permits and approvals) and database for spills reported to the Ministry; however, no information has been received from MWLAP at the time of this report.

2. Enquiries with Mr. Ron Johnston and John Beaupre, Interior Health Authority, Public Health Engineer and Health Inspector, respectively, regarding water quality concerns and groundwater use.

3. Interview with Mr. Dave Jenzen (Town of Oliver Fire Chief), Mr. Richard Simmons (Former Town of Oliver Fire Chief) and Mr. Wade Bliss (Building Inspector), concerning the status of underground storage tanks.

4. Discussions with Mr. Bruce Hamilton (Director of Operations - Town of Oliver) regarding potential environmental concerns.

5. Review of 1:20,000 scale TRIM maps, 1:50,000 scale topographic maps and a 1:20,000 scale community map.

6. General Site reconnaissance of the Town and time of travel zones.

Attempts to contact the regional agricultural impact officer with B.C. Environment, to discuss potential groundwater contamination related to agricultural activities, were unsuccessful.

6.3.2 Results of Regional Contaminant Inventory

The results of the regional contaminant inventory are presented below.

6.3.2.1 Search of Ministry of Water Land and Air Protection Databases

Golder Associates Ltd. conducted a search of the MWLAP Contaminated Sites Registry database to identify registered properties located within the Town of Oliver.

The Contaminated Sites Registry identifies those sites for which the Ministry holds environmental information. These records are limited to information obtained since approximately 1989. The existence of a site within the Contaminated Sites Registry does not necessarily imply that the site is contaminated, as under the existing Contaminated Sites Regulation. The site registration process can be triggered by a number of mechanisms including property transactions and facility upgrades, and not only subsurface contamination. Similarly, there may be a number of contaminated sites within the District that have not been identified by the site registry.

Golder conducted an area search of the Site Registry, which is based on a latitude and longitude location, and provides a list of Site Registry properties located within a 5 km square radius of the search coordinates. Golder conducted an area search on January 23, 2005 for the following two coordinates, which identified Site Registry properties from approximately the southern end of Vaseux Lake to the northern end of Osoyoos Lake. The 5 km area search was conducted for the following two locations:

- Latitude 49°12'53" N and Longitude 119°32'45" W (the approximate location of the Buchanan Road Well); and

- Latitude 49°7'33" N and Longitude 119°34'19" W (the approximately location of the Blacksage Wells No. 1 through 3).

A total of 12 Site Registry Sites were identified as a result of the Buchanan Road latitude/longitude search, while one Site was identified as a result of the Blacksage Wells latitude/longitude and search. The single Site identified as a result of the Blacksage Wells latitude/longitude search was also identified in the Buchanan Road search, indicating a total of 11 Site Registry properties identified. The record status of each property was not provided within the Site Registry area search results. Of the 11 sites identified, the Town of Oliver identified the following six properties within the Town's limits:

34718 - 91st Street	34873 - 97th Street
34484 - 97th Street	36216 - 97th Street
34817 - 97th Street	34274 - 95th Street

In addition, one property (35470 - 89th Street) was identified to be within the Town boundaries, but did not exist. The remaining four properties were identified to be located within the rural areas, outside the Town boundaries. The Town provided a location for the six Site Registry properties located within the Town boundaries, which are illustrated in Figure 7. Attempts were made to locate the remaining Site Registry properties located within the outlying rural areas through the RDOS. However, the RDOS has not yet responded to our request for this information.

Based on the Town's information, the majority of the identified properties are located on the west side of the Okanagan River, within the downtown core. A list of sites contained within the registry is provided in Appendix IV. Site locations are illustrated in Figures 3 through 8.

6.3.2.2 Agricultural Issues

Environmental Concerns Related to the Agriculture Industry

Within the Town and surrounding area, agricultural activity is dominated by orchards and vineyards. Groundwater contamination from agricultural land use can result from the use and storage of animal manure and the application of chemical fertilizers and pesticides. The potential for groundwater contamination from agricultural properties can be low to high, depending on the degree of compliance with the agricultural codes. Environmental issues related to agriculture are regulated according to the *Code of Agricultural Practice* ("the Code") by the *Agricultural Waste Control Regulations* under the *Waste Management Act.* Other regulations applicable to the agricultural industry include the *Pesticide Control Act,* which regulates the use of pesticides, and the *Farm Practices Protection (Right to Farm) Act,* which regulates issues related to noise, odour and dust. The risk of groundwater contamination will also depend on the nature and volume of chemicals used and stored, disposal practices and the presence and maintenance of storage tanks and septic systems. Similar chemical applications that are used on agricultural properties may also be used on playing fields, golf courses and general lawns.

Impact of Agricultural Activities on Groundwater Quality

It is understood that the Town of Oliver is currently collecting and assessing the historical analytical results from their various groundwater sampling programs. In summary, the Town has been historically collecting groundwater from their various wells and

submitting the samples for chemical analyses for metals and other physical parameters. A brief review of available groundwater quality data for selected wells indicates that there are no parameters which repeatedly and consistently exceed the applicable Canadian Drinking Water Guidelines, with the exception of nitrate concentrations noted at the Fairview Well. Based on information provided by the Town, nitrate concentrations are reportedly increasing in the area of the Fairview Road Well. Nitrate concentrations in 2004 range from approximately 8.2 mg/L to 10.2 mg/L, with three sampling events identifying nitrate concentrations greater than the Canadian Drinking Water guideline of 10 mg/L for nitrates.

Contamination of groundwater by human and animal wastes, and agricultural activities can result in elevated levels of nitrates, fecal coliform and biological pathogens. The presence of nitrates in groundwater poses a health risk to infants, particularly those less than six months of age. When infants consume too much nitrate they develop a blood disorder called methaemoglobinaemia, also known as "blue-baby syndrome". For this reason, the Canadian drinking water guideline for nitrates has been established at 10 mg/L nitrate (expressed as nitrogen). In addition to nitrates, bacteria and biological pathogens, in discharges of animal waste to surface water can lead to eutrophication (introduction of excess nutrients resulting in excessive algae growth) and depletion of dissolved oxygen, thereby posing a risk to aquatic organisms.

6.3.2.3 Septic and Sanitary Sewer Systems

According to Town's web site, prior to 1980 the Town treated and disposed of their effluent within the Okanagan River. However, in 1983 the Town constructed a winter storage reservoir and aerated lagoons to store effluent. The storage reservoir and aerated lagoons are located along Fairview Road, to the west of Town. The reclaimed and treated effluent is used to provide irrigation water for the Fairview Mountain Golf Course, located on the upslope/west side of Fairview Road. As there has been a surplus of effluent in the past several years, the Town has constructed a temporary infiltration basin on a parcel of crown land located between the storage reservoir and the golf course, to dispose of the effluent (Figure 5 and 7). According to Mr. Hamilton, the Town has recently completed the construction of an irrigation system at the cemetery, Public Works Yard and Airport, which will allow the Town to use all the reclaimed effluent for irrigation purposes. It is anticipated that the temporary disposal of excess effluent on Crown land will be stopped in 2005.

According to Mr. Hamilton, the majority of the Town is currently connected to the municipal sanitary sewer system. However, septic systems are present outside the Town of Oliver boundaries, within the outlying areas.

Septic systems are common sources of groundwater contamination, contributing bacteria, viruses, nitrates, detergents and chemicals to groundwater. Groundwater contamination from septic systems results in cases where systems are poorly sited, designed or constructed, where systems are poorly maintained, or where septic system densities are too high to allow sufficient renovation.

The Interior Health Authority was contacted to provide documentation on areas within the Town of Oliver where groundwater contamination related to septic systems has been observed, or where septic systems were known to have failed in the past. Mr. Johnston of the Interior Health Authority replied by telephone and indicated that he was not aware of groundwater contamination within the Town of Oliver as a result of septic systems. According to Mr. Hamilton, approximately 95% of the Town's Municipal area is serviced by sewer, with only approximately 5% unsewered. This unsewered area is primarily located within the agricultural areas located within the Town boundaries.

6.3.2.4 Stormwater Disposal

We understand that the Town of Oliver currently disposes of stormwater using the following methods:

- There are approximately six or seven small storm water collection systems that discharge into the Okanagan River, three of which are located along Highway 97, through Town.

- One storm water collection system discharges into an Oxbow located at the north end of Town by Lions Park.

- There are three storm water collection systems that serve the low lying land located north of 350th Avenue and immediately east of the Okanagan River.

- Other storm water disposal throughout Town is provided through the use of catch basins and dry wells. Typically, the connection between the catch basins and drywells is very short with one drywell serving no more than 2 or 3 catch basins.

According to Mr. Hamilton, there are parts of the Town that do not have any storm drainage works, with storm water "trained" to flow and dissipate in areas where it does not cause any problems.

Although the Province of BC's policy document regarding Stormwater Planning advocates the disposal of stormwater through infiltration, there can be adverse impacts to water quality as a result, given the right conditions exist (i.e. coarse grained deposits, large volume of stormwater disposal, infiltration locations). Stormwater runoff

commonly contains contaminants such as oils, antifreeze and biological constituents which could potentially be transmitted directly to the aquifer by the dry wells.

6.3.2.5 Existing and Abandoned Water Supply Wells

As discussed previously, there are potentially many properties with abandoned water wells in the area. Improperly abandoned wells can act as direct conduits for the migration of surface contaminants to the underlying aquifer. Because improperly abandoned wells provide direct pathways to underlying aquifers, their presence represents a threat to groundwater.

In addition to abandoned wells, groundwater contamination can result from active drinking water supply wells that are poorly constructed or poorly sited. Similar to improperly abandoned wells, active wells with corroded casings or improper surface seals can provide conduits for the migration of surface runoff or septic effluent to the aquifer.

6.3.2.6 Surface Water Influences

Potential surface water degradation or contamination of the Okanagan River and Tuc-El-Nuit Lake poses a risk to groundwater quality in the areas where the groundwater flow system is ultimately recharged by the rivers. Ambient surface water quality can be affected by many sources, including upstream effluent discharges from light industrial industries, agricultural runoff and stormwater outfall locations. Specific contaminant events can also occur from transportation accidents or pipeline leaks, presumably with higher risk at designated transportation crossings.

6.3.2.7 Landfilling

The Town of Oliver's landfill is located approximately 7 km to the south of the Town, on Blacksage Road (Figure 6 and 8), servicing the Town and Rural Area C. The landfill is owned and operated by the Regional District of Okanagan Similkameen ("RDOS"). There is no civic address for the landfill, as it is located outside of the Town's boundaries. According to Mr. Hamilton, the Town disposes of its solid waste at the landfill. Facilities at the landfill include the following;

- Waste disposal area
- Wood waste disposal and burning area
- Sludge screening from the Town's treatment facility
- Scrap metal storage area

The landfill is located in the upland area, east of the Aquifer No. 254. The landfill is located along the eastern limits of the valley (at the bedrock interface), and possibly in a

recharge area for the Aquifer. According to Mr. Hamilton, the current landfill has received municipal waste since approximately the late 1970s.

In September 1999, EBA Engineering Ltd. undertook a hydrogeological investigation for the Oliver Landfill, the results of which were discussed in their September 1999 report entitled *"Hydrogeological Study and Operational/Closure Plan for the Oliver Landfill"*. Based on a review of this report, three monitoring wells were installed within the limits of the landfill. Subsurface soil conditions encountered within a borehole located at the hydraulically downgradient end of the landfill consisted of sand and silt to depths of approximately 14 m, underlain with gravel to a depth of approximately 17 m. The gravel was further underlain with sand, clay and silt, to a maximum depth of approximately 85 m, the total depth of the borehole. Groundwater was encountered within this monitoring well at a depth of 66 m, directly below a 5 m thick clay. However, due to a large quantity of sediment within the well, a groundwater sample was not collected for analyses. The remaining two boreholes/monitoring wells were completed to shallow depths of approximately 3 to 15 m, with no groundwater encountered. Bedrock was encountered at a depth of approximately 3.5 m at a borehole located hydraulically upgradient of the landfill.

According to Mr. Hamilton, the municipal landfill was previously located to the west of the Town, along Lonite Lake Road. This area was utilized by the Town for landfilling purposes between approximately 1964 and the 1978, and used to dispose of solid waste and liquid septic waste. In addition, Mr. Hamilton identified another area formerly used to dispose of solid waste prior to 1964. This area is located in the Fairview area, southeast of the Town's wastewater treatment plant.

6.3.2.8 Existing Land Use

A windshield survey identifying general business activities within the Town's municipal boundaries was conducted on June 22, 2004, with specific businesses identified to represent a potential environmental concern shown on Figure 7 and 8. In general, light industrial businesses are located along between 89th Street and 91st Street, on the west side of the Okanagan River. The light industrial area contains businesses such as the Town of Oliver's public works yard, a power substation, fueling station, and car and truck wash, along with other light industrial and commercial businesses.

Service stations noted during the windshield survey, located within the Town's municipal boundaries, consisted of the following:

- Ultra Fuels cardlock located at the intersection of 347th Avenue and 91st Street.
- OK Auto Service and Gas Bar located at 36259 97th Street.

- Sabayan Chevrolet Oldsmobile located at 34899 97th Street.
- Chevron Service Station located at the intersection of 97th Street and 348th Avenue.

These service stations handle and store large volumes of petroleum hydrocarbons and other automotive fluids, which have the potential to adversely impact the subsurface and local groundwater conditions. According to the Town, a major fuel leak occurred at the Chevron Service Station several years ago. During the contamination delineation and property remediation, no water quality issues within the Town's wells were noted.

In addition to the above noted service stations, underground storage tanks and associated fuel pumps were noted at the Town of Oliver's Municipal Airport located on 95th Street. These tanks are currently being removed and replaced with above ground storage tanks.

Service stations observed outside of the municipal boundaries consist of the following:

- Oasis Service Station located at 38686 97th Street.
- Inkameep Food and Fuel located along 71st Street, directly outside of the Town boundary.

Although not specifically noted, fuel tanks are likely present on numerous agricultural properties. Conversations with the Mr. Richard Simmons (former Fire Chief) and Mr. Dave Jenzen (current Fire Chief) indicated that there is no underground storage tank ("UST") registry system for the Town. No additional USTs were identified by Mr. Simmons or Mr. Jenzen. However, both indicated that there are likely fuel storage tanks (both above ground and underground) on the numerous rural properties outside the municipal boundaries.

Other businesses and/or land uses noted during the reconnaissance to handle or store hazardous chemicals consist of the following:

- A car wash located on the east side of 94th Street. Contaminants of concern associated with car washes consist of various stored (on-Site) or leaking (from vehicles) automotive fluids.
- A Fortis substation located on the southwest corner of 347 A Avenue and 89th Street. Substations have the potential to store fuel on Site and/or PCBs within the transformers.
- Terra Link Horticulture Inc. (Fertilizers and Pesticides) located at the corner of 91st Street and 347th Avenue.
- A Fortis Substation located at the eastern end of 370th Avenue. Substations have the potential to store fuel on-Site and/or PCBs within transformers.

- Several automotive repair shops located at various locations throughout Town and outlying areas.

During the reconnaissance within each well time of travel zone, a public water tap discharging to a catch basin and dry well were observed in the area of two water wells, including the Tuc-El-Nuit Well No.2 and Rockcliffe Well. The presence of a publicly accessible dry well located *in the immediate* wellhead area could represent a potential concern to groundwater quality, should contaminants be disposed of within the catch basin and dry well system.

Relevant property uses identified as a result of the windshield survey are shown on Figure 7 and 8.

6.3.3 Results of Contaminant Inventories for Time of Travel Zones

Preliminary contaminant inventories of the 60-day time of travel zones were conducted by means of the field reconnaissance. The inventory did not include interviews with private property owners or site-specific inspections. Other than the information contained within the MWLAP Site Registry, the inventory did not include a review of historical site activities.

A detailed description of land uses throughout the Town and within the time of travel zones is provided in the attached Table 2. In summary, the contaminant inventory for the ten municipal water wells indicated primarily agricultural and residential land uses within the 60-day time of travel zone for each Town well. Some commercial/light industrial uses were identified within the 60-day time of travel zone for the Lions Park Well, CPR Well and Fairview Well. Specific issues of concern are noted as follows:

- A fuel service station (OK Tire and Gas Bar) and major transportation route (Highway 97) is located within the 60-day time of travel zone for the Lions Park and CPR Wells.

- A major transportation route is located within the 60-day time of travel zone for the Fairview Well.

Relevant property uses identified within the 60-day time of travel zones are shown on Figures 3 through 6.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this initial phase of the development of a GWPP, the following conclusions can be made regarding the development of a groundwater protection plan for the Town of Oliver.

- At present, the Town of Oliver collects water for the Municipality and surrounding RDOS area from a total of nine operational water wells, the majority of which are located in close proximity to a large recharge boundary (Tuc-El-Nuit Lake and Okanagan River).

- All Town wells, with the exception of the Fairview Well and Rockcliffe Well are ultimately recharged by precipitation and surface water derived from the Okanagan River or Tuc-El-Nuit Lake. As a result, the water quality in the wells within short travel times of the rivers (less than 60 days) may be influenced by surface water quality.

- Wells are located within primarily residential/agricultural areas, with the exception of the CPR and Lions Park wells, which are located in close proximity to downtown and commercial/light industrial uses.

- The 60-day time of travel zone for the various wells has been estimated using the calculated fixed radius method. As there are data gaps regarding the hydraulic gradient and flow direction in the areas of the wells, numerical modeling as not considered to be applicable.

- The Town currently samples Town wells, as well as various monitoring wells throughout the area on a regular basis.

The following recommendations are made with regards to continuing the GWPP process for the Town of Oliver. It is important to note that some of these recommendations require the combined collaborative effort of the Town of Oliver, RDOS, MWLAP, IHA and other stakeholders.

1. Reassessment of Data Gaps and Associated Time of Travel Zones

Based on available information, Golder has provided results regarding the preliminary 60-day time of travel zones only. Due to data gaps regarding groundwater flow directions and hydraulic parameters such as gradient and hydraulic conductivity in areas surrounding the wells, a detailed analyses of one-year, five-year and ten-year time of travel zones was not conducted. It is recommended that a detailed analyses of existing water wells (including a well elevation survey and recording of water level

measurements) be conducted to provide an overall depiction of aquifer conditions (flow direction and gradient). In addition, consideration should be given to undertaking a drilling program to supplement available water well information to fill in data gaps in areas where there are no or limited water well information. It is likely that some of the wells constructed as part of the recommended drilling program could also be used to supplement the ongoing groundwater monitoring program. Particular areas where additional subsurface information would be beneficial are i) the area between the CPR and Lions Park Wells and nearby service station, ii) areas hydraulically upgradient of the Fairview Well, and iii) areas hydraulically upgradient of the Blacksage Wells and Miller Road Well.

It is only upon the completion of filling the data gaps that a more detailed reassessment of time of travel zones (one-year, five-year and ten-year) could be conducted.

2. Conduct a Comprehensive Detailed Contaminant Inventory

Once the time of travel zones of the key wells have been refined, a comprehensive contaminant inventory of the individual time of travel zones should be carried out. This inventory would expand upon the information collected as part of the regional contaminant inventory and preliminary time of travel zone inventory presented in this report, including the following:

- documentation of all septic tanks and disposal fields within the 60-day time of travel zones for the Town's production wells;
- documentation of the Town's storm water disposal systems, specifically where the points of discharge are located;
- conduct a door-to-door survey to document all wells within the time of travel zone areas and in Town, to determine which wells are abandoned but have not been properly decommissioned. The Town and/or MWLAP, RDOS or IHA could consider providing an incentive program for the public to decommission their abandoned wells;
- a detailed review of the any MWLAP Site Registry property information for the various properties identified during this investigation, with special attention paid to those which fall within the 60-day time of travel zone;
- a review of the current and historical land used for agricultural purposes, including lands located within the agricultural land reserve (ALR), and specifically for those properties which are located within the time of travel zones established for the Town wells. This review would identify historical and current

agricultural lands and practices on those lands, including uses of pesticides and fertilizers, storage of fuels, and identification of abandoned wells and septic tanks.

- interviews with long-time residents of Oliver to identify former landfill areas that may have historically been used by Town residents, or other areas of historical concern.

If required, the detailed inventory may include an analysis of the types and quantities of chemicals used within each time of travel zone (chemical inventory). The major contaminant risks associated with each time of travel zone should be evaluated through a subjective risk evaluation.

3. Water Quality Monitoring Program

It is recommended that the current groundwater monitoring program utilized by the Town be assessed, and that the historical water quality data be reviewed. The purpose of the review would be to identify any outstanding water quality issues and to identify additional monitoring that may be required to address risks identified by the contaminant inventory. Specific attention should be paid to the CPR and Lions Park Well, due to their close proximity to a service station, and the Fairview Road Well, due to its elevated nitrates. It is recommended that a qualified professional be provided all analytical data, for municipal water supply wells and other monitoring wells, such that a detailed review of the water quality can be conducted, and that recommendations can be made regarding sampling parameters, frequencies and methodologies.

4. Designate Groundwater Protection Areas

Following refinement of the time of travel zones, the Town should designate formal groundwater protection areas. This should be conducted with other stakeholders such as MWLAP, RDOS, IHA and other occupying industries (i.e. wine industry). Two different strategies can be employed when designating groundwater protection areas: i) a *wellhead protection approach*, whereby groundwater protection area is defined relative to a time of travel zone or part of a time of travel zone; and, ii) *aquifer protection approach*, whereby part or all of an aquifer is designated for protection.

Groundwater protection areas can be defined based on the entire time of travel zone, or based on a corresponding travel time to a well. The advantage of defining groundwater protection in this manner is that a concerted effort can be made to manage activities near the wellhead, thereby protecting the water supply. In our experience, the greatest degree of groundwater protection is achieved by combining wellhead protection and aquifer protection. The Town of Oliver and other stakeholders may wish to consider designating part of the aquifers that lie outside of the time of travel zones as some form of a

groundwater protection area. The advantage of defining protection areas in this manner is that it allows for the protection of groundwater recharge areas, regions serviced by private water wells and areas where future water supplies may be developed. Additional aquifer characterization and mapping may be required to assist with the designation of areas of the aquifer requiring protection, such as recharge zones.

5. Develop Groundwater Protection Measures

Once designated groundwater protection areas have been established and additional potential contaminant sources have been identified, the Town and RDOS should embark on the development of groundwater protection measures. Groundwater protection measures can be implemented at the municipal/regional level through both regulatory and non-regulatory measures. In our opinion, while non-regulatory measures, such as public education and best management practices, can be highly effective, some degree of regulatory control may be required to ensure the protection of the groundwater resources.

These regulatory strategies often involve the use of municipal land use planning and zoning bylaws to restrict certain high-risk land use activities within protection areas. As an alternative to land use restrictions, some communities, such as Fredericton, New Brunswick, have chosen to restrict the types and quantities of chemicals used within groundwater protection areas.

Public participation and education represents one of the most important forms of non-regulatory groundwater protection. It is essential to the success of a groundwater protection plan and provides a means of securing political and financial support. A public education campaign would identify groundwater protection areas, threats to groundwater supplies in those areas, and measures individuals and businesses can take to protect the resource. Examples of public education tools include the use of the public information meetings, signs erected at strategic locations around groundwater protection areas, the use of media, distribution of information brochures on best management practices and school education programs.

Golder would be pleased to assist with the development of specific groundwater protection measures once some of the preceding work has been carried out. Some examples of groundwater protection measures that may be considered are presented in Appendix V, and consist of establishing a hazardous waste collection system, providing "best management practices" for various businesses, land acquisitions (land donations, exchanges or purchases), establishing agricultural and transportation controls, and applying specific zoning to designated lands. These measures have been adapted from the Environment Canada/Fraser River Action Plan (FRAP) report entitled "*Groundwater Quality Protection Practices*" (Environment Canada, 1995), which was prepared by Golder on behalf of Environment Canada.

In addition, the following recommendations are made regarding groundwater protection measures:

- Guidelines and/or restrictions for pesticide and fertilizer use in public use areas, and possibly residential properties, within time of travel zones should be implemented. These guidelines may include a designated no-spray zone around water supply wells. In addition, contingency plans should be prepared in the event of a pesticide or fertilizer spill or accident. Mixing of chemicals and refilling of containers, spray and applicators should be completed in contained areas away from wells, water sources, and areas characterized by permeable soil conditions.

- Prepare an educational brochure or pamphlet aimed at all Town of Oliver and surrounding area residents on the proper maintenance and use of domestic effluent disposal to septic fields, and the proper application of fertilizers and pesticides and the potential impact of these chemicals on the groundwater quality in the Town of Oliver.
- The public should be made aware of potential impacts to groundwater as a result of stormwater runoff.
- To ensure the security of the water distribution system, we recommend that access to all wellheads and water distribution systems be restricted, to reduce the risk associated with potential vandalism and deliberate contamination of the water supply system.

- The Town should identify transportation routes where dangerous goods are transported, such that in the event of a spill in the area or 60-day time of travel zone of a Town well, appropriate cleanup and protection measures can be implemented.

6. Develop Contingency Plans

Contingency planning consists of developing a plan for the location and provision of alternative drinking water supplies in the event that one or more of the existing wells cannot be used. Disruptions to wells may be related to either contamination or non-contamination effects. The contingency plan should identify short-term alternatives in the event of a minor disruption, and long-term alternatives in the event of a complete loss of water supply. It is recommended that if one is not already in existence, a contingency plan for the various wells be developed.

7. Develop Emergency Response Plans

The goal of groundwater protection is to prevent the contamination of underground drinking water supplies. Even under the best prevention plans, a scenario that threatens to contaminate the aquifer may occur. When this happens, an emergency response plan directing a coordinated and timely response is an effective tool for assuring a continued supply of potable water. Many communities' emergency response plans do not include specific provisions for the protection of groundwater resources in the event of a spill or accident. For example, it may be prudent for emergency response personnel to restrict the use of fire retardant chemicals in sensitive groundwater areas. We recommend that the Town of Oliver's existing emergency response plan be evaluated and revised, if necessary, to allow for the protection of sensitive groundwater resources.

8.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of the Town of Oliver. In evaluating the requirements for groundwater protection, Golder Associates Ltd. has relied in good faith on information provided by sources noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions, misstatements or fraudulent acts of others.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

9.0 CLOSURE

We trust that this report meets your current requirements. Should you have any questions or comments please do not hesitate to call.

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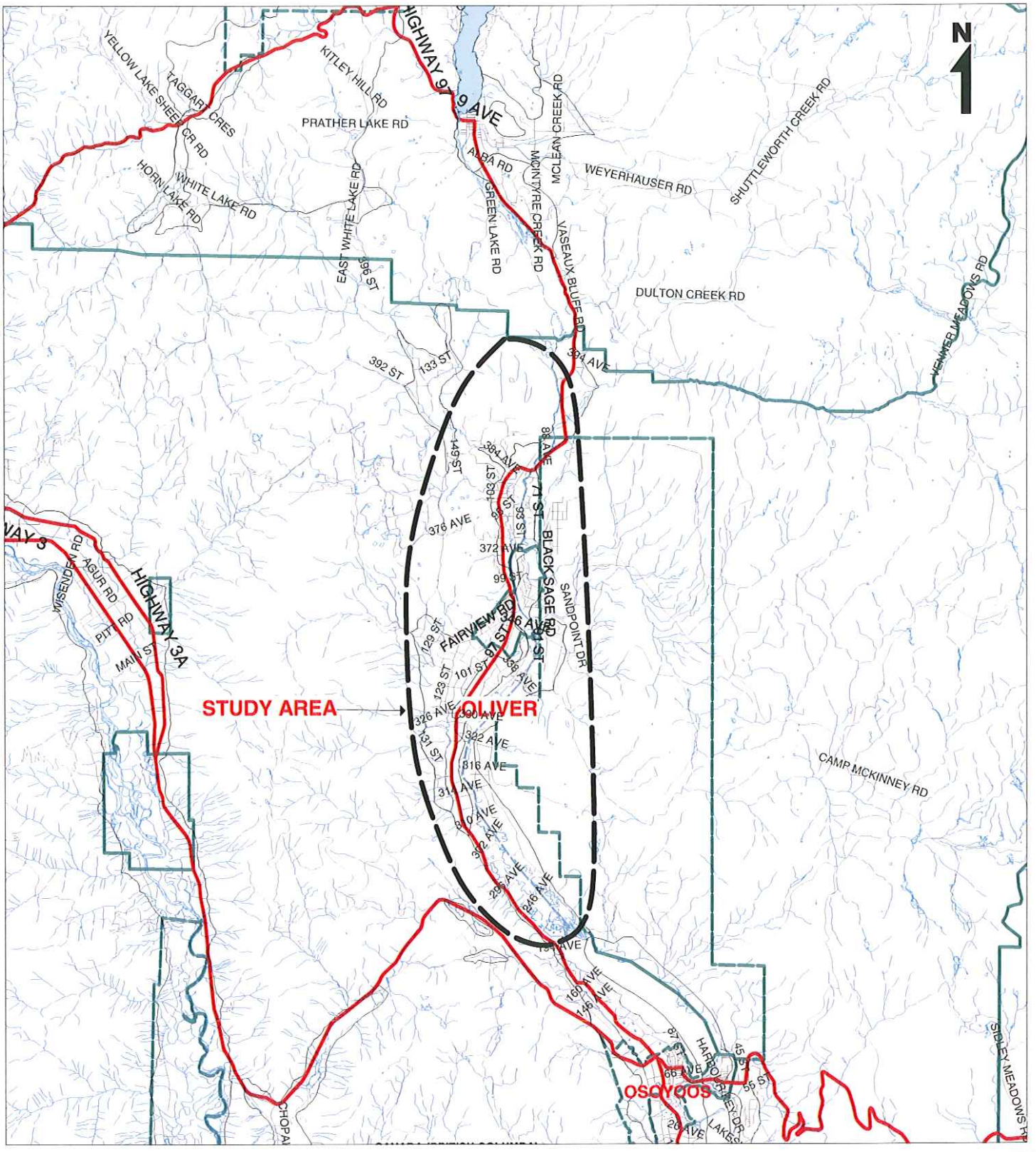
Table 1 - Well Summaries and Time of Travel Zones
Town of Oliver Municipal Wells
Oliver, British Columbia

Oliver Wells	Unconfined/ Semi Confined/ Confined	Construction Date	Screen Top	Screen Bottom	Static Level	Aquifer Thickness (b) Based On Static	Pumping Rate	Pumping Rate	Kala T reported	Kala T reported	Transmissivity (T) Theis with Image Well			Calculated K (K=T/b)	Hydraulic Conductivity (K) (K=T/b)	Calculated K (K=T/b)	Estimated Hydraulic Gradient (I)	Calculated Fixed Radius Time of Travel Zones	
																		60 days	1 year
		year	m	m	m	m	USgpm	L/s	USgpd/ft	m^2/day	m^2/day	m^2/min	m^2/s	m/day	m/sec	m/year	(m/m)	m	m
Buchanan Road Well	Unconfined	1968	17.4	21.9	2.1	19.8	400	25.2	NA	NA	NA	NA	NA	NA	NA	#VALUE!	0.005	92	226
Tuc-el-Nuit Well No. 1	Unconfined	1971	11	14	3.4	10.6	250	15.8	NA	NA	NA	NA	NA	NA	NA	NA	0.005	99	244
Tuc-el-Nuit Well No. 2	Unconfined	1971	10.4	14.3	3.4	10.9	700	44.2	1,008,755	12528	11,500	8.0	0.13	1,055	0.01221	289,383	0.005	164	403
Tuc-el-Nuit Well No.3	Unconfined	1982	10.3	13.7	4.0	9.7	650	41.0	1,199,990	14903	12,100	8.4	0.14	1,247	0.01444	340,506	0.005	167	412
Lions Park Well	Semi Confined	1979	18.3	23.2	1.8	21.4	1230	77.6	NA	NA	NA	NA	NA	NA	NA	NA	0.005	155	382
CPR Well	Unconfined	1980	9.1	13.6	1.2	12.4	1149	72.5	NA	NA	NA	NA	NA	NA	NA	NA	0.005	196	484
Rockcliffe Well	Unconfined	1986	15	24.4	6.3	18.1	1500	94.6	1,140,968	14,170	58,795	40.8	0.680	3,248	0.03760	1,185,645	0.005	186	458
Fairview Well	Unconfined	1968	26.8	28.3	9.1	19.2	425	26.8	NA	NA	NA	NA	NA	NA	NA	NA	0.005	96	237
Blacksage Well No.1	Unconfined	1995	11.6 23	14.2 25.7	2.8	22.9	2000	126.2	NA	NA	5,240	3.6	0.06	228.92	0.00265	83,556	0.005	191	470
Blacksage Well No. 2	Information Not Available																		
Blacksage Well No. 3																			
Miller Road Well	Unconfined	2004	14.3	18.0	6.7	11.3	900	56.8	NA	NA	1,764	1.2	0.02	156	0.00181	56,979	0.005	182	449

Table 2: Preliminary Contaminant Inventory Within 60-day CFR Time of Travel Zone Town of Oliver, British Columbia

Town of Oliver Wells	Capture Zones	Land Uses Within Capture Zones: Potential Contaminants of Concern
		Calculated Fixed Radius
Buchanan Road Well	60 days	***Individual Residential:*** Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
	1 Year	***Commercial Greenhouses (Budget Nursery):*** lawn care chemicals, pesticides and fertilizers, fuel storage tanks.
Tuc-El-Nuit Well No.2	60 days	***Individual and Community Residential:*** lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		Tuc El Nuit Elementary School: lawn care chemicals on the playing fields, chemicals associated with building maintenance (such as waste oils and solvents).
	1 Year	***Fortis Substation:*** PCBs within transformers and equipment and potential fuel storage.
Lions Park Well	60 Days	***Fuel and Automotive Service Station (OK Tire and Gas Bar):*** gasoline, diesel, new and waste oil, glycols, and other liquids associated with vehicle maintenance.
		Highway 97 South (97th Street): Spills or accidents on Highway 97 S., between 99th Street and 360 Avenue, resulting in the release of hazardous materials, could represent a serious threat to groundwater in the area.
		Neighbourhood Commercial Businesses: Various chemicals, including cleaners, solvents and pesticides.
		Lions Park: lawn care chemicals (pesticides and fertilizers).
		MWLAP Site Registry Property: One Site Registry property located at 36216 - 97th Street.
		Individual Residential: Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		Storm water disposal using dry wells: runoff commonly characterized by contaminants such as oils, antifreeze, gasoline, other petroleum products and biological constituents.
	1 Year	***Agricultural land:*** Pesticides, fertilizers, septic tank effluent, animal manure.
CPR Well	60 Days	Same as those noted for Lions Park Well
	1 Year	Same as those noted for Lions Park Well
		Automotive/Repair/Service Station (Imperial Spirit): gasoline, diesel, new and waste oil, glycols, and other liquids associated with vehicle maintenance.
Rockcliffe Well	60 Days	***Individual Residential:*** Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		s
	1 Year	Same as 60 Days
		Highway 97 South (97th Street): Spills or accidents on Highway 97 S., in the area of the Rockcliffe Well, resulting in the release of hazardous materials, could represent a serious threat to groundwater in the area.
Fairview Well	60 Days	***Individual Residential:*** Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		Agricultural land: Pesticides, fertilizers, septic tank effluent, animal manure.
		Highway 97 South (97th Street): Spills or accidents on Highway 97 S., in the area of the Fairview Well, resulting in the release of hazardous materials, could represent a serious threat to groundwater in the area.
	1 Year	Same as 60 Days
Black Sage Wells 1 - 3	60 Days	***Individual Residential:*** Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		Agricultural land: Pesticides, fertilizers, septic tank effluent, animal manure.
	1 Year	Same as 60 Days
Miller Road Well	60 Days	***Individual Residential:*** Lawn care chemicals (pesticides and fertilizers), common household products, and wastes related to property maintenance and automotive repair, potential septic tanks.
		Agricultural land: Pesticides, fertilizers, septic tank effluent, animal manure.
	1 Year	Same as 60 Days



File Location: N:Active\2003\1440\03-1440-057\Figures\Figure 1.wor

Kilometers

0 4 8

NOTE: THIS DRAWING TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT

PROJECT

Groundwater Protection Plan
Oliver, B.C.

TITLE

KEY PLAN

Golder Associates

PROJECT NO.		03-1440-057	FILE	Figure 01.wor
DESIGN	LD	01/12/04	SCALE	1:200,000
CADD	LD	01/12/04		
CHECK	JF		**FIGURE : 1**	
REVIEW				

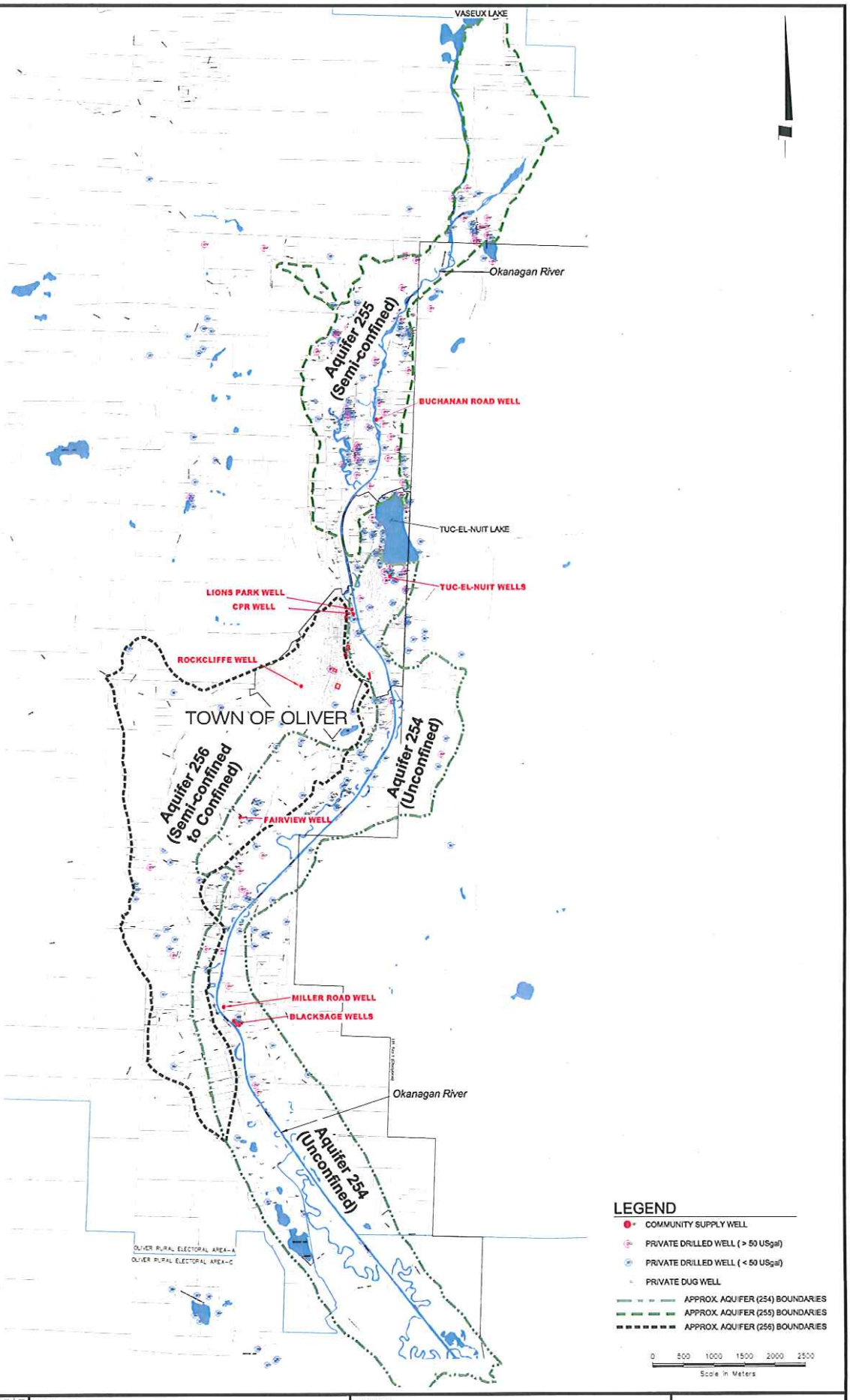


FIG. 2

PROJECT No. 03-1440-057
FILE No.
REV. 0 SCALE 1 : 60,000
DESIGN
CADD JG 21/JAN/02
CHECK
REVIEW

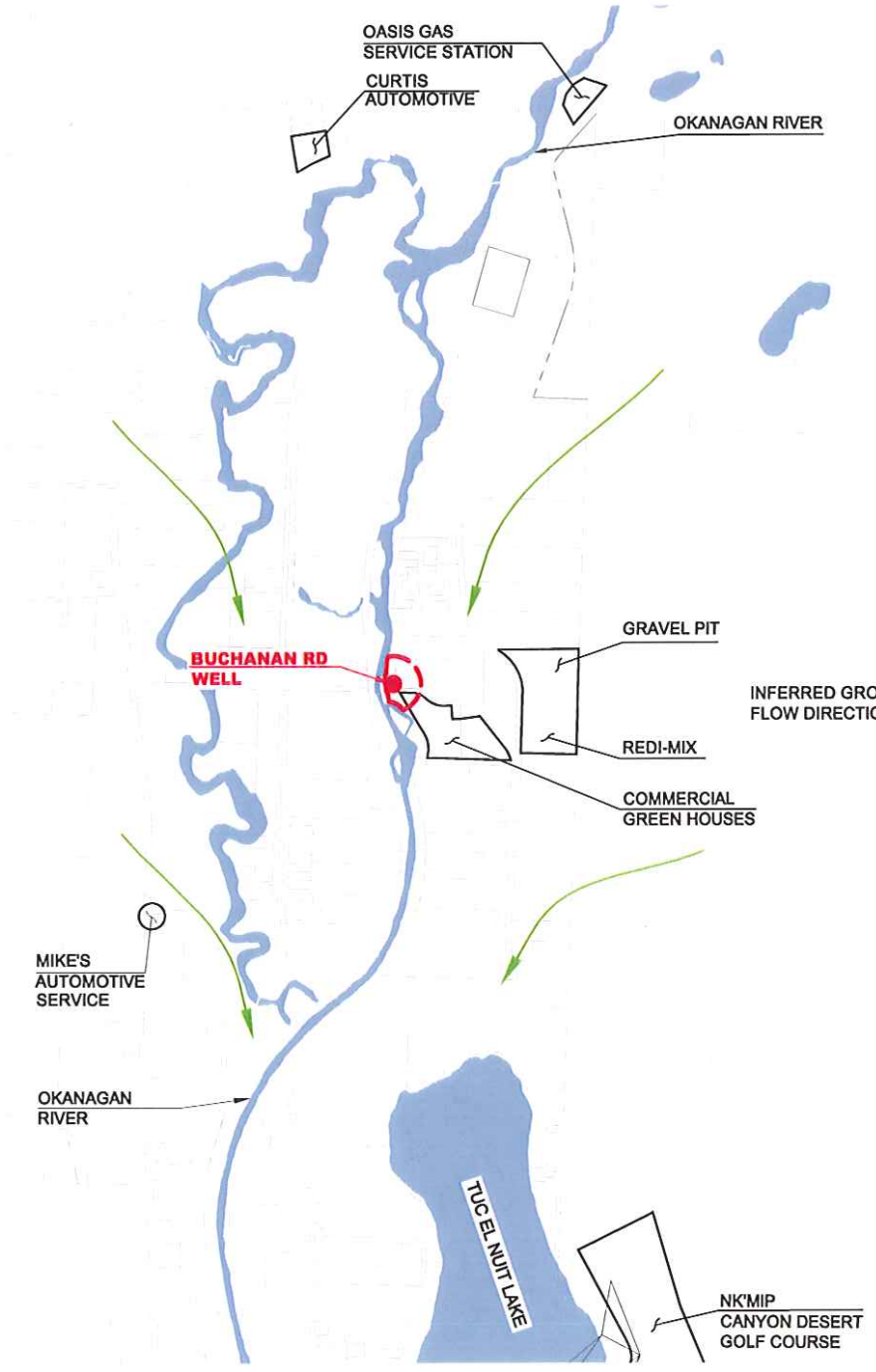
TITLE

AQUIFER AND WATER WELL LOCATION PLAN

PROJECT

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

Golder Associates
Kelowna, BC



LEGEND

- INFERRED GROUNDWATER FLOW DIRECTION
- COMMUNITY SUPPLY WELL
- APPROXIMATE LAND USE BOUNDARY
- CALCULATED FIXED RADIUS 60-DAY TIME OF TRAVEL ZONE

500 0 500
SCALE METRES

Golder Associates
Kelowna, B.C.

SCALE	1:25,000
DATE	09/FEB/05
DESIGN	DA
CADD	JG
CHECK	JF
REVIEW	

FILE No.
PROJECT 03-1440-057 REV. 0

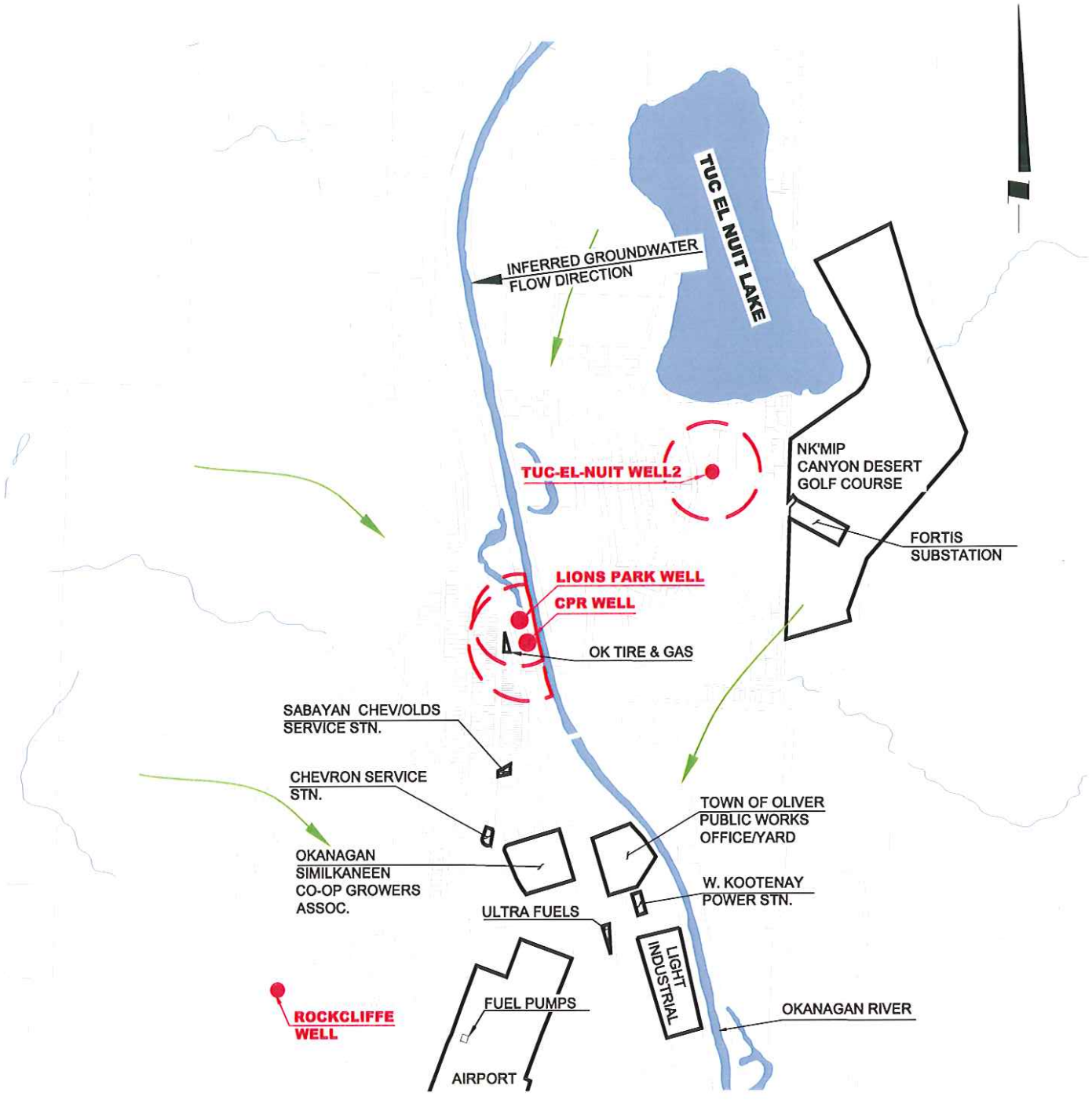
TITLE

EXTENT OF PRELIMINARY TIME OF TRAVEL ZONE
BUCHANAN WELL

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

FIGURE 3

N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Figures\Figure 3, 5-6.dwg Mar 30, 2005 - 9:49am



LEGEND

- INFERRED GROUNDWATER FLOW DIRECTION
- COMMUNITY SUPPLY WELL
- APPROXIMATE LAND USE BOUNDARY
- CALCULATED FIXED RADIUS 60-DAY TIME OF TRAVEL ZONE

400 0 400
SCALE METRES

Golder Associates
Kelowna, B.C.

SCALE	1:20,000
DATE	09/FEB/05
DESIGN	DA
CADD	JG
CHECK	JF
REVIEW	

FILE No.
PROJECT 03-1440-057 REV. 0

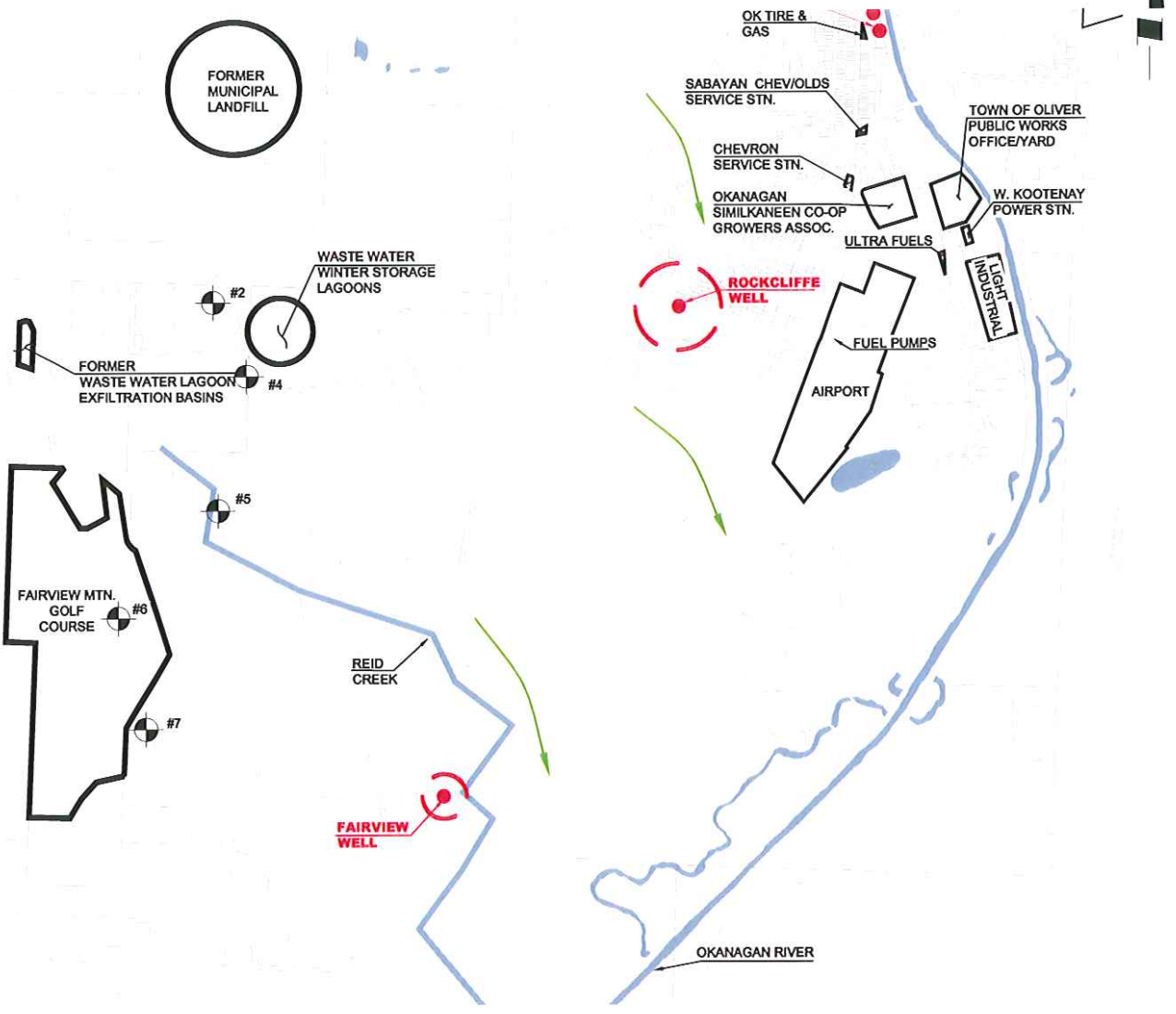
TITLE

EXTENT OF PRELIMINARY TIME OF TRAVEL ZONE
TUC-EL-NUIT, LIONS & CPR WELLS

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

FIGURE 4

N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Figures\Figure 4.dwg Mar 30, 2005 - 10:04am



LEGEND

- INFERRED GROUNDWATER FLOW DIRECTION
- COMMUNITY SUPPLY WELL
- APPROXIMATE LAND USE BOUNDARY
- CALCULATED FIXED RADIUS 60-DAY TIME OF TRAVEL ZONE
- #7 APPROX. TEST (MONITORING) WELL LOCATION

500 0 500
SCALE METRES

Golder Associates
Kelowna, B.C.

SCALE	1:25,000
DATE	09/FEB/05
DESIGN	DA
CADD	JG
CHECK	JF
REVIEW	

FILE No.
PROJECT 03-1440-057 REV. 0

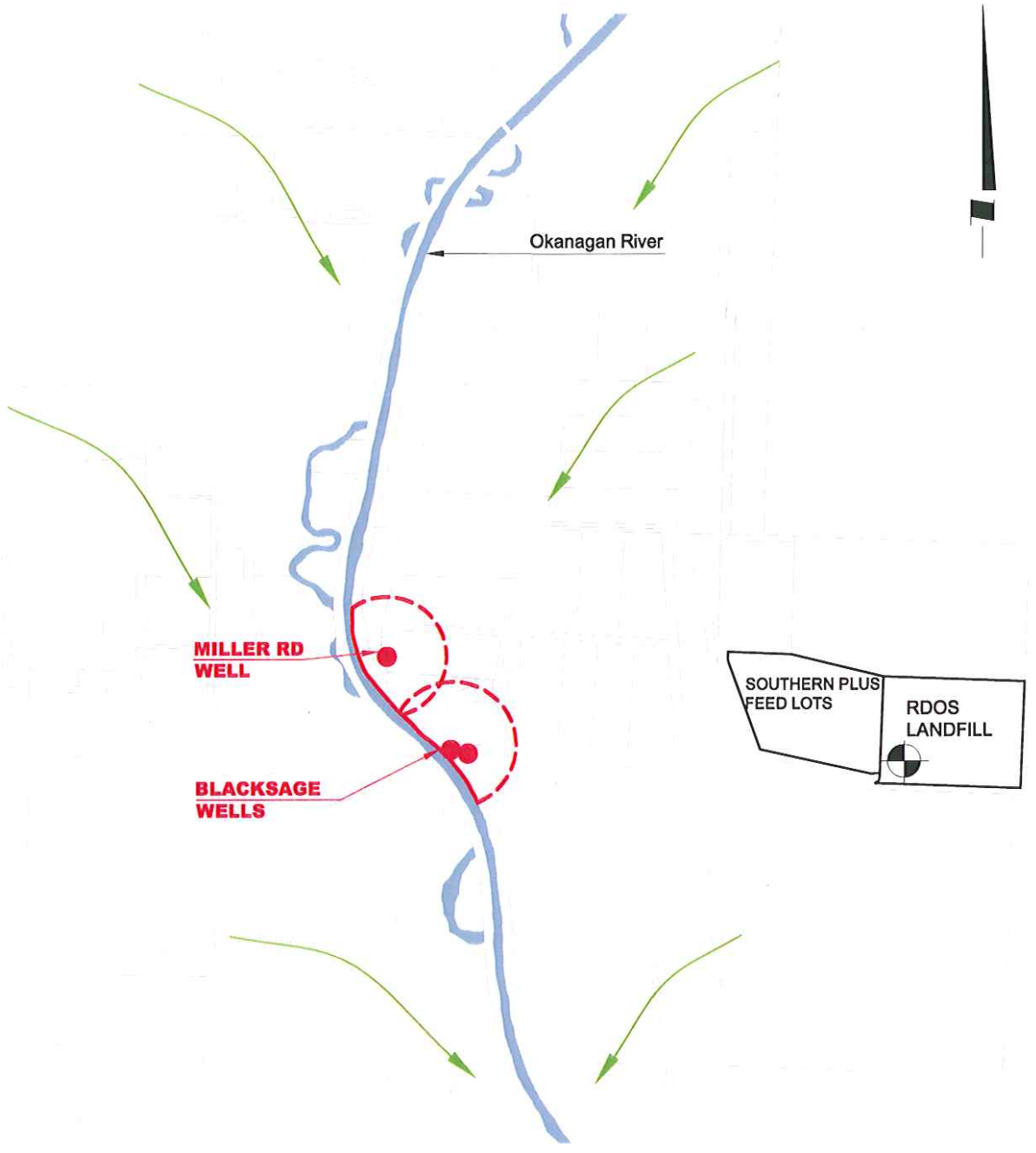
TITLE

EXTENT OF PRELIMINARY TIME OF TRAVEL ZONE
FAIRVIEW & ROCKCLIFFE WELLS

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

FIGURE 5

N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Figures\Figure 3, 5-6.dwg Mar 30, 2005 - 9:46am



LEGEND

- INFERRED GROUNDWATER FLOW DIRECTION
- COMMUNITY SUPPLY WELL
- APPROXIMATE LAND USE BOUNDARY
- CALCULATED FIXED RADIUS 60-DAY TIME OF TRAVEL ZONE
- APPROXIMATE LOCATION RDOS LANDFILL MONITORING WELL (E.B.A 1998)

400 0 400
SCALE METRES

Golder Associates
Kelowna, B.C.

SCALE	1:20,000
DATE	09/FEB/05
DESIGN	DA
CADD	JG
CHECK	JF
REVIEW	

FILE No.
PROJECT 03-1440-057 REV. 0

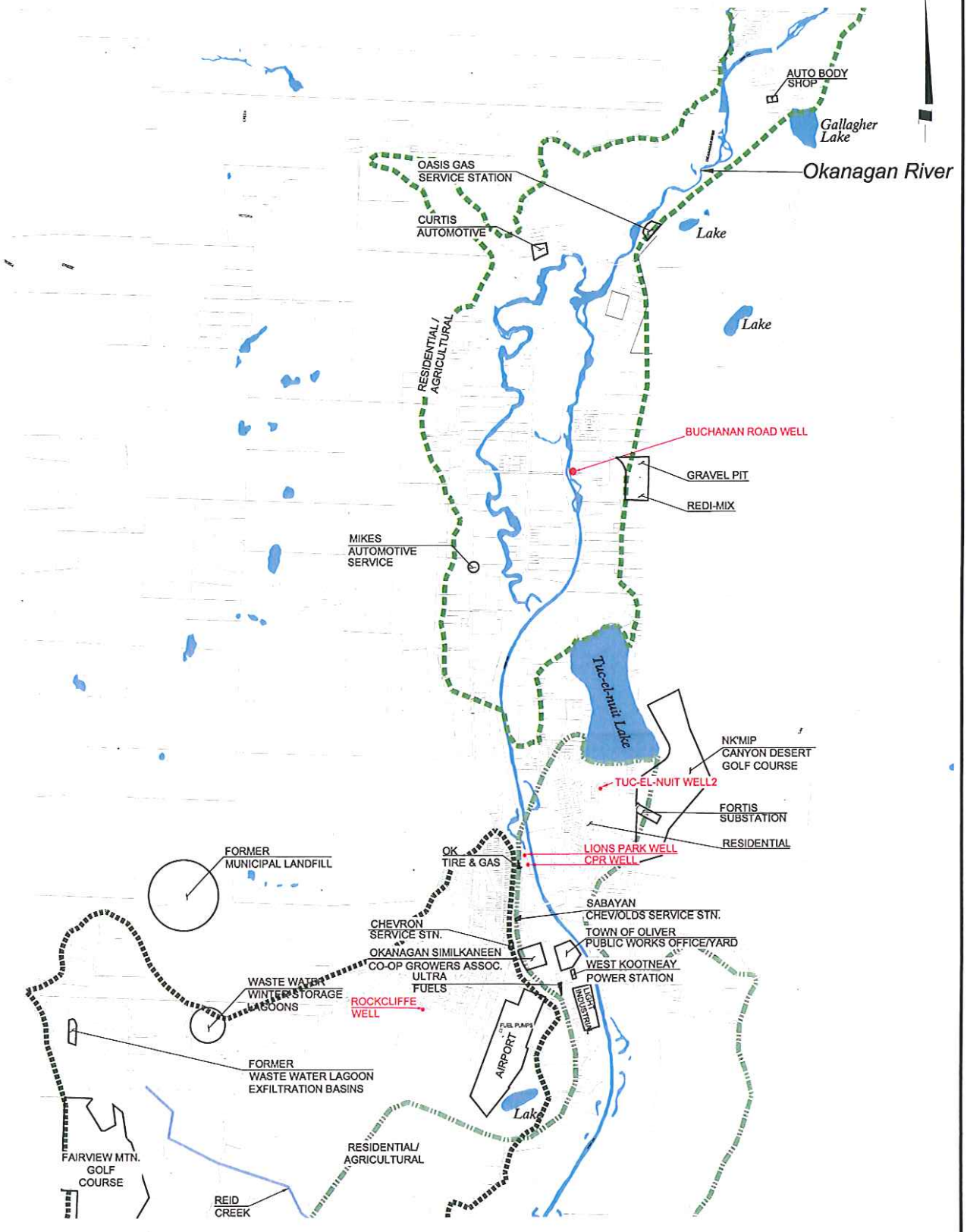
TITLE

EXTENT OF PRELIMINARY TIME OF TRAVEL ZONE
BLACKSAGE & MILLER RD. WELLS

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

FIGURE 6

N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Figures\Figure 3, 5-6.dwg Mar 30, 2005 - 9:43am



LEGEND

- COMMUNITY SUPPLY WELL
- APPROXIMATE LAND USE BOUNDARY
- APPROX. AQUIFER (255) BOUNDARIES
- APPROX. AQUIFER (254) BOUNDARY
- APPROX. AQUIFER (256) BOUNDARY

0 500 1000 1500 2000 2500
Scale in Meters

FIG. 7

PROJECT No.	03-1440-057
FILE No.	
REV. 0	SCALE 1 : 30,000
DESIGN	
CADD	JC 21/JAN/05
CHECK	JF
REVIEW	

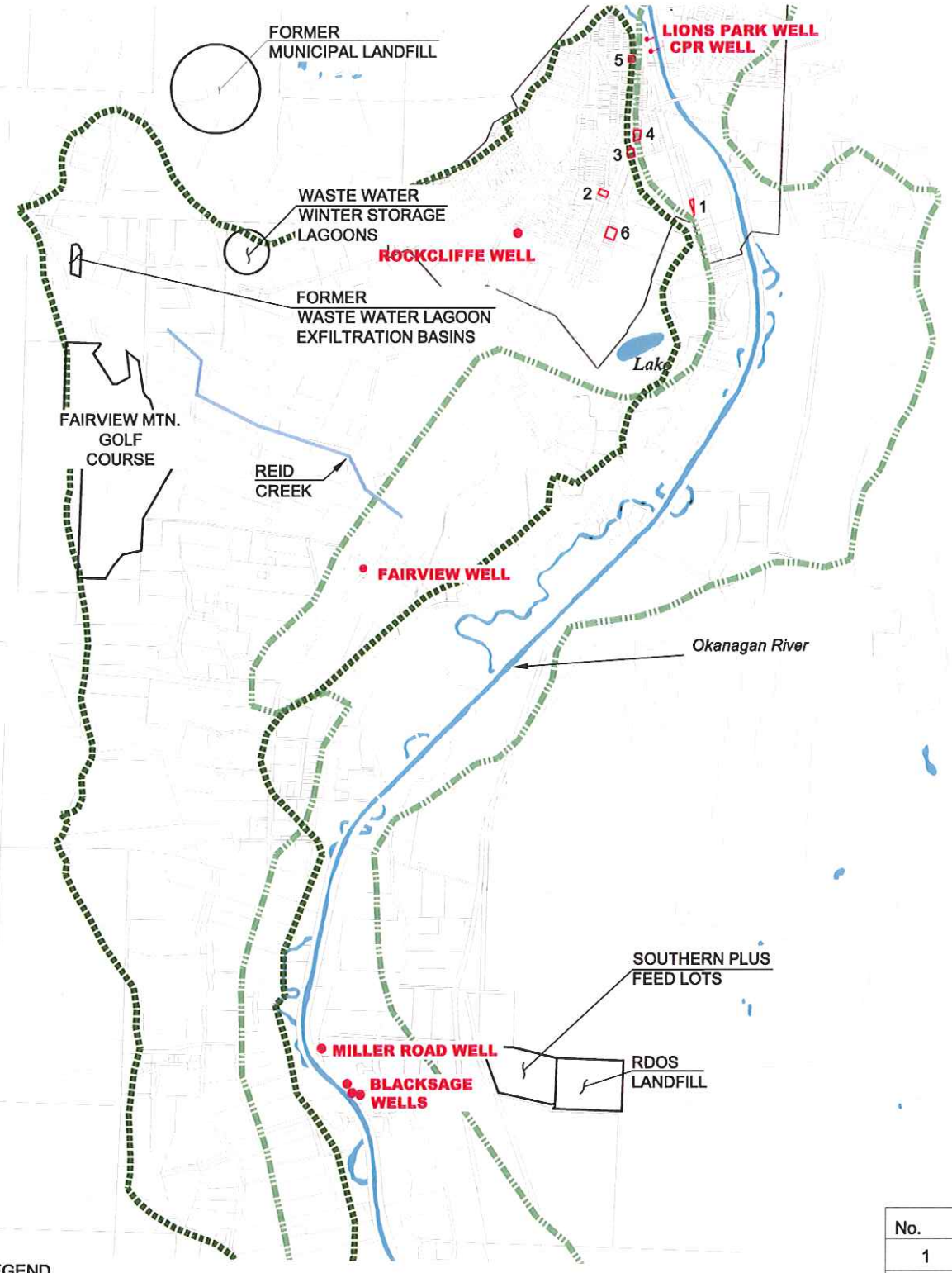
TITLE

LAND USE & CONTAMINATED SITE REGISTRY PROPERTY LOCATION PLAN

PROJECT

RESULTS OF CONTAMINANT INVENTORY FOR TOWN OF OLIVER & AREAS NORTH

Golder Associates
Kelowna, BC



No.	CIVIC ADDRESS
1	34718 - 91st STREET
2	34484 - 97th STREET
3	34817 - 97th STREET
4	34873 - 97th STREET
5	36216 - 97th STREET
6	34274 - 95th STREET

LEGEND

- APPROX. LAND USE BOUNDARY
- COMMUNITY SUPPLY WELL
- 4 MWLAP CONTAMINATED SITE REGISTRY (SEE INSERTED TABLE)
- APPROX. AQUIFER (254) BOUNDARY
- APPROX. AQUIFER (256) BOUNDARY

1 0 1
SCALE 1:40,000 KILOMETRES

Golder Associates
Kelowna, B.C.

SCALE	1:40,000
DATE	8/FEB/05
DESIGN	
CADD	JG
CHECK	JF
REVIEW	

FILE No.
PROJECT No. 03-1440-057 REV. 0

TITLE

LAND USE & CONTAMINATED SITE REGISTRY PROPERTY LOCATION PLAN

GROUNDWATER PROTECTION PLAN
TOWN OF OLIVER

FIGURE 8

N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Figures\Figure 2.7-8.dwg Mar 30, 2005 - 10:07am

APPENDIX I

MUNICIPAL WATER WELL LOGS

BRITISH COLUMBIA

Buchanan Rd. Well

Well Tag Number 000000021873

Owner: S.O.L.I.D.

Address:

Area: TUG-UL-NUIT LAKE

WELL LOCATION:
SIMILKAMEEN Land District
District Lot 2450S Plan 2280 Lot 718
Township Section Range
Indian Reserve Meridian Block
Quarter
Island
BCGS Number (NAD 27) 082E023123 Well 15

Well Use Unknown Well Use
Construction Method Drilled
Diameter 8.0 inches
Well Depth 114.0 feet
Elevation 0
Bedrock Depth UNK feet
Screen from 57 to 72 feet
Slot Size 1 0 Slot Size 2 0
Slot Size 3 0 Slot Size 4 0

Construction Date 19681009

Driller OSYOOS TILE WORKS
License Number

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield 402 USGM
Artesian Flow 0
Static Level 7 feet

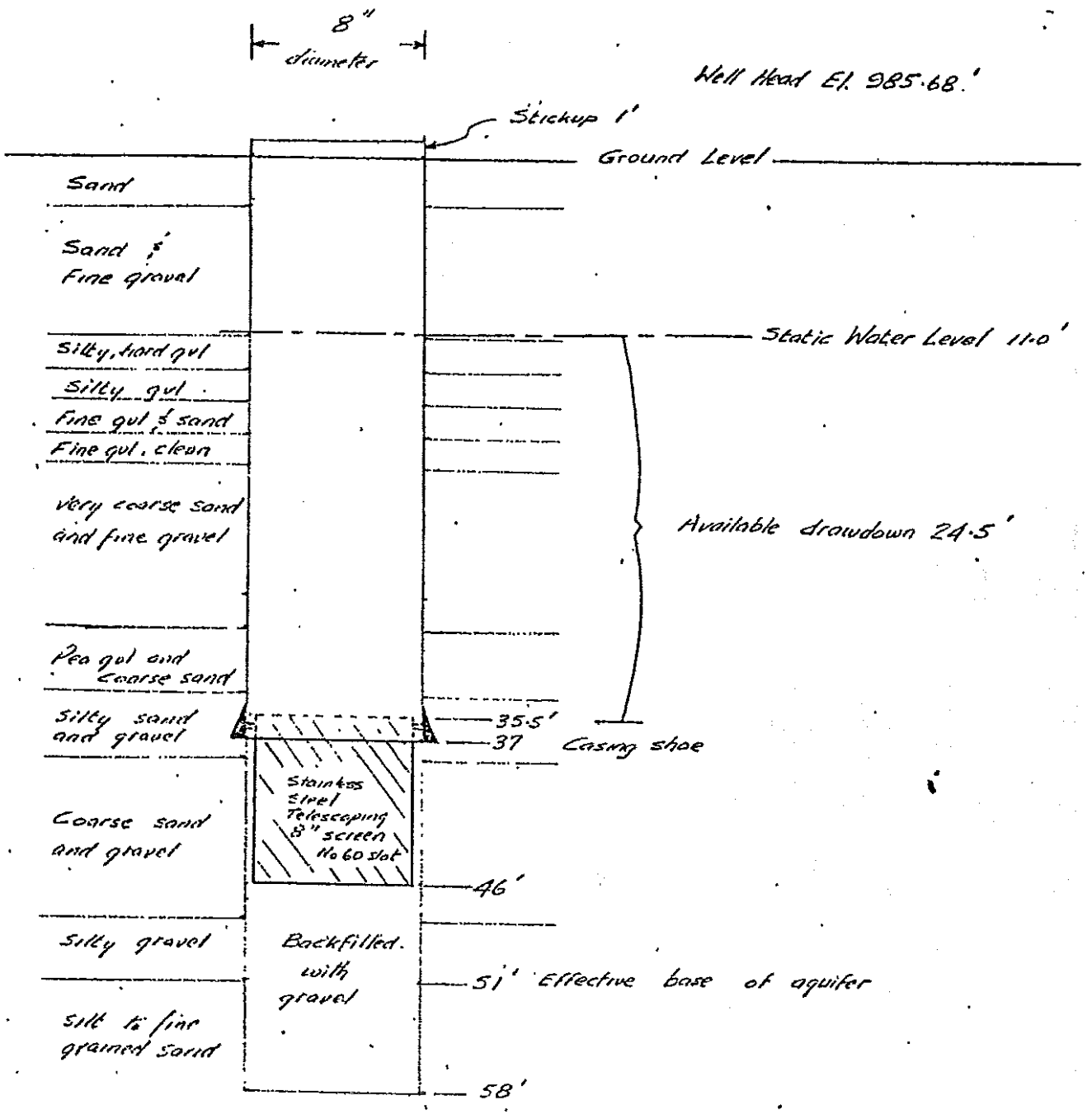
Water Utility
Lithology Info Flag Y
Pump Test Info Flag
File Info Flag
Sieve Info Flag
Screen Info Flag
Water Chemistry Info Flag
Field Chemistry Info Flag
Site Info (SEAM)
Other Info Flag

GENERAL REMARKS:
ANOTHER CARD ATTACHED

From	0	To	5 Ft.	compact clayish sand
From	5	To	24 Ft.	sharp gravel and sand (static 6'10" at
From	0	To	0 Ft.	24 ft.)
From	24	To	32 Ft.	sand and gravel, some silt (tight)
From	32	To	46 Ft.	sand and gravel, some silt (loose) (sta-
From	0	To	0 Ft.	tic 5'2" at 46 ft.)
From	46	To	74 Ft.	gravel and sand (loose and permeable)
From	74	To	95 Ft.	brown sandy silt
From	0	To	0 Ft.	
From	0	To	0 Ft.	Note: any gravel in the samples from
From	0	To	0 Ft.	80' to 100' is presumably caved down
From	0	To	0 Ft.	from the 74 ft. level.
From	0	To	0 Ft.	Caving stopped at 95 ft.
From	95	To	110 Ft.	blue silt
From	114	To	0 Ft.	? gravel
From	0	To	0 Ft.	
From	0	To	0 Ft.	Note: drilled open hole for 20 ft. to
From	0	To	0 Ft.	114 ft. Caving at 114 ft. S.W.L. (well
From	0	To	0 Ft.	depth 95 ft.) 6'3"

19 rows selected.

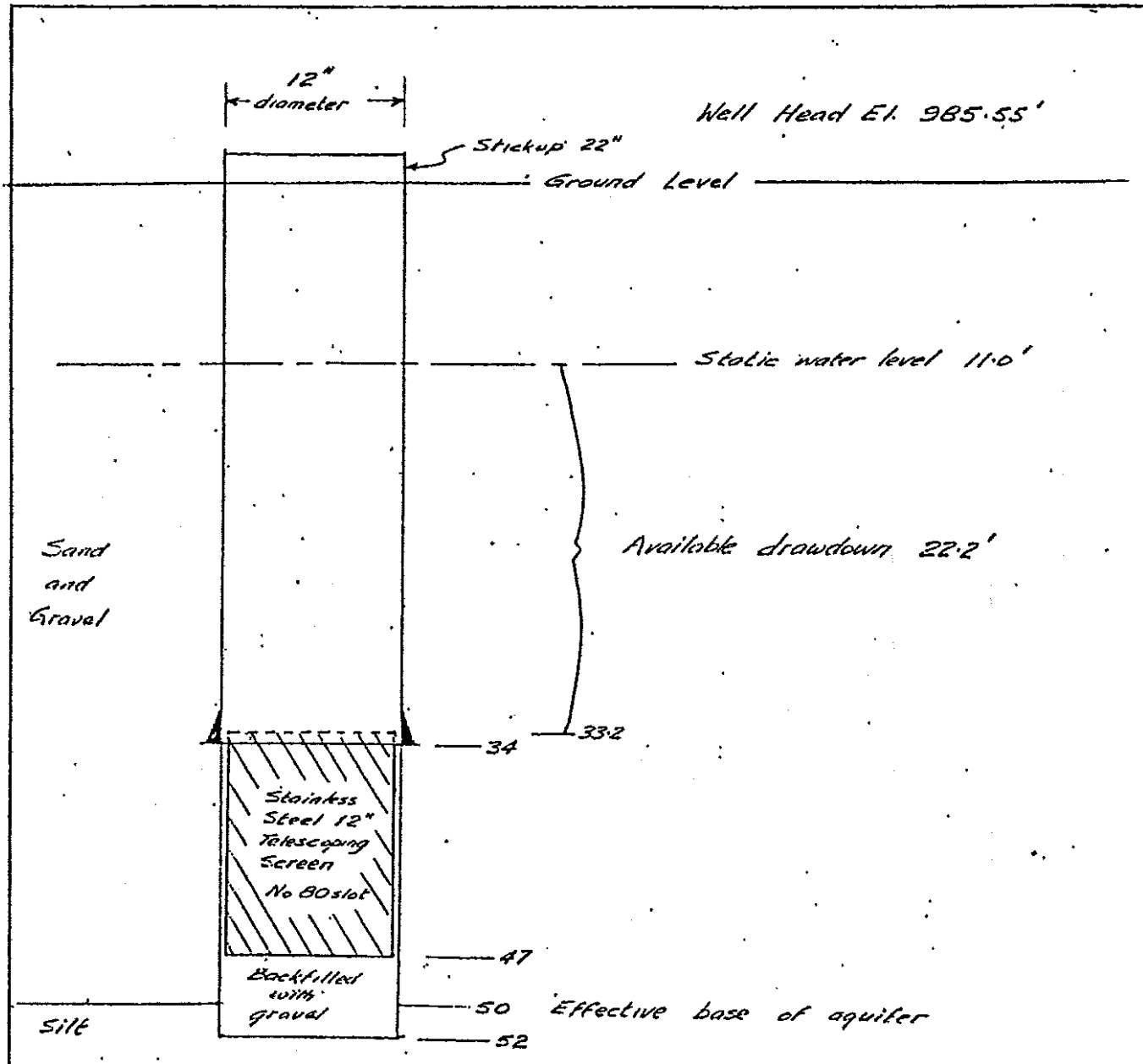
Date entered to WELL



SKETCH OF WELL CONSTRUCTION
SOLID No 3 SYSTEM
Tw-21-N1 WELL No 1

FIGURE 3

GROUNDWATER DIVISION
WATER INVESTIGATIONS BRANCH
DEPT. OF LANDS, FORESTS AND WATER RESOURCES
VICTORIA, B. C.



SKETCH OF WELL CONSTRUCTION

SOLID No. 3 SYSTEM

Tuc-El-Nuit WELL "No 2"

FIGURE 4

GROUNDWATER DIVISION
WATER INVESTIGATIONS BRANCH
DEPT. OF LANDS, FORESTS AND WATER RESOURCES
VICTORIA, B. C.

S.O.L.I.D.

System No. 3 Extension

Groundwater Development Program

Tuc-El-Nuit

Well Completion Diagram (No. 3).

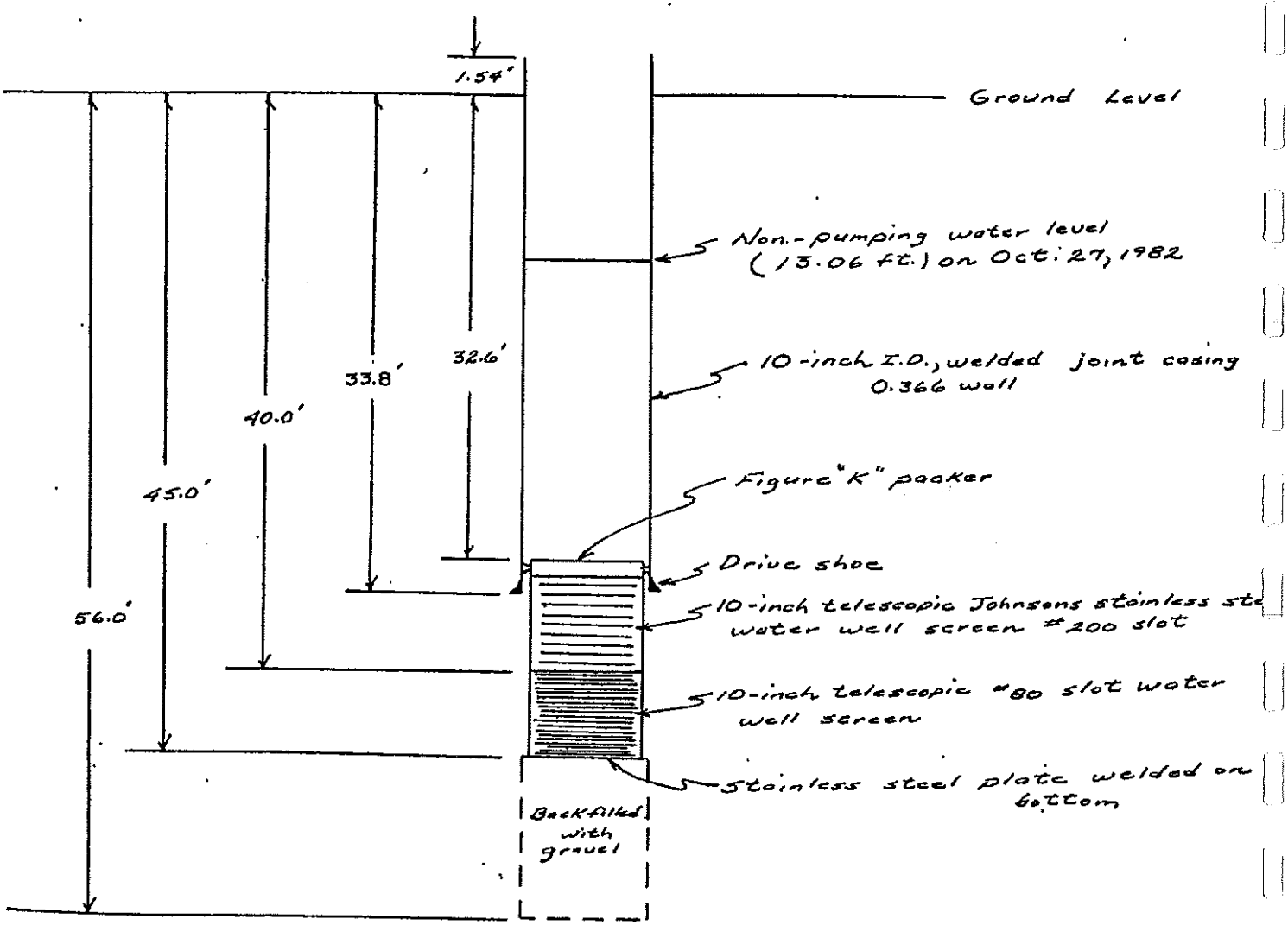


Figure 3

S.O.L.I.D.

System No. 3 Extension

Groundwater Development Program

DRILLERS LITHOLOG

Tul-El-Mait Well No. 3

Depth Interval (in feet)	Lithologic Description
0-2	Sandy top soil
2-8	Brown sand and coarse gravel
8-14	Gravel, pea to pebble size with coarse brown sand
14-16	Coarse clean sand with medium to small pebbles
16-18	Clean brown sand,finer than above with medium small cobbles
18-20	Brown sand, coarse with large cobbles and some fines
20-22	Clean brown sand with medium to large cobbles
22-24	Brown sand, becoming coarser, with small pebbles
24-28	Clean brown sand with small pebbles
28-34	Coarse clean sand with pebbles, polished
34-36	Medium to small gravel, polished,little sand fines 10-15%
36-38	Medium to small polished gravel, pea to pebble with little fines
38-40	Clean polished gravel, some fines
40-44	Coarser polished gravel and clean sand
44-46	Coarse brown sand, very clean with small pebbles
46-48	Coarse sand, very clean, some pebbles, little fines
48-50	Clean sand, coarse, some pebbles (20-30 slot)
50-56	Coarse clean sand with pebbles
56	Cemented lens

WELL LOG CONSTRUCTION RECORD

OWNER V. JAGE OF OLIVER

Address TEST HOLE # 6 CPR well.

Well Location 250' N OF FILTRATION GALLERY.

Date Started Feb. 21/80 Date Completed Feb. 22/80

QUALITY WATER WELLS LTD.
OKANAGAN FALLS, B.C.
BOX 159, PH. 497-5557
V0H 1R0

Drilling Method CABLE TOOL

Driller K. ROBBINS Helper R. RHODES

File _____ Folio _____

Signed By _____

LOG OF FORMATIONS

Depth		Descriptions
0	to	
1	to 4	SAND & GRAVEL
	to	COMPACT.
4	to 9	GREY SAND PASTE
9	to 15	GREY SAND DIRTY WITH PEBBLES
15	to 23	LOOSE PEBBLES & PEAS CLEAN BROWN (ACTIVE)
23	to 26	PEBBLES & PEAS VERY CLEAN ACTIVE
	to	POLISHED LITTLE SAND
26	to 44½	PEBBLES & PEAS BIG GRAVEL POLISHED ACTIVE VERY CLEAN
14½	to 45	CLAY LENS
15	to 50	GREY SILT WITH PEBBLES DIRTY

WATER BEARING — BEST

GENERAL REMARKS

CASING RECORD

Dia. 6 ins. Wt. ____ #/ft. From 0 to 50

Dia. ____ ins. Wt ____ #/ft. From ____ to ____

Dia. ____ ins. Wt. ____ #/ft. From ____ to ____

Shoe ____ Welded ____ Cemented ____

SCREEN RECORD

Make ____ Material ____

Slot opening ____ Length ____

Top ____ ft. Bottom ____ ft.

Fittings Top ____ Fittings Bottom ____

Gravel Pack ____ Natural ____

Development Method ____

ROCK WELL DATA

Open Bore Hole ____ Dia. ____ ins.

From ____ ft. to ____ ft.

PRODUCTION DATA

Static Level 3-11 ft.

Measured from GROUND

Pumping Level ____ ft. at ____ GPM

____ ft. at ____ GPM

Bail Test ____ ft. at ____ GPH

____ ft. at ____ GPH

Recommended Pump Setting ____ ft.

Recommended Max. Pump Output ____ GPM GPH

Duration of Test ____ Hrs.

PUMP DATA

Make ____ Type ____

Model ____ Serial No. ____

Size ____ HP ____ Drop Pipe ____ ins.

GPM ____ Head ____ ft. ____ RPM

Motor ____ Volts ____ PH ____

Well Seal ____

Water Analysis — Hardness ____ PPM

PH ____ Iron ____ PPM

WELL LOG CONSTRUCTION RECORD

OWNER VILLIAGE OF OLIVER

Address HOLE #7 - Lions Park Well.

Well Location 300'- N of #6 TEST HOLE

Date Started FEB 27/80 Date Completed MAR. 4/80

QUALITY WATER WELLS LTD.
OKANAGAN FALLS, B.C.
BOX 159, PH. 497-5557
V0H 1R0

Pg. 1

Drilling Method CABLE

Driller KEITH ROBBINS Helper L. PHODES

File _____ Folio _____

Signed By _____

LOG OF FORMATIONS

Depth		Descriptions
0	to 6	COMPACT SAND &
	to	GRAVEL DIRTY
6	to 13	GREY SAND DIRTY
13	to 17	GREY SAND & GRAVEL
	to	CLEANER
17	to 20	LARGE & SMALL GRAVEL
	to	WITH BR. SAND
20	to 24	LARGE & SMALL GRAVEL
	to	WITH LITTLE SAND BR. (CLEAN)
24	to 28	LARGE & SMALL GRAVEL
	to	POLISHED (ACTIVE)
28	to 30	LARGE & SMALL GRAVEL
	to	TIGHT WITH FINE BR SAND
	to	POLISHED GRAVEL
30	to 32	PEBBLES & PEAS LG & SMALL
	to	GRAVEL WITH LITTLE SAND
	to	LOOSE & ACTIVE
32	to 36	COARSE SAND BR. LOOSE
	to	& CLEAN WITH LG. GRAVEL
36	to 38	GREY SAND LITTLE DIRTY
	to	WITH SMALL GRAVEL
38	to 40	CLEAN PEBBLES & PEAS
	to	LOOSE & ACTIVE 5-10%
	to	SAND COARSE
40	to 48	PEBBLES & PEAS & SM.
	to	GRAVEL VERY LOOSE
	to	& POLISHED BIRDS EYES & LITTLE SAND.

GENERAL REMARKS

CASING RECORD

Dia. 6 ins. Wt. ____ #/ft. From 0 to 25

Dia. ____ ins. Wt ____ #/ft. From ____ to ____

Dia. ____ ins. Wt. ____ #/ft. From ____ to ____

Shoe ____ Welded ____ Cemented ____

SCREEN RECORD

Make ____ Material ____

Slot opening ____ Length ____

Top ____ ft. Bottom ____ ft.

Fittings Top ____ Fittings Bottom ____

Gravel Pack ____ Natural ____

Development Method ____

ROCK WELL DATA

Open Bore Hole ____ Dia. ____ ins

From ____ ft. to ____ ft

PRODUCTION DATA

Static Level 5'-11" ft

Measured from GROUND

Pumping Level ____ ft. at ____ GPM

____ ft. at ____ GPM

Bail Test ____ ft. at ____ GPH

____ ft. at ____ GPH

Recommended Pump Setting ____ ft

Recommended Max. Pump Output ____ GPM GPH

Duration of Test ____ Hrs

PUMP DATA

Make ____ Type ____

Model ____ Serial No. ____

Size ____ HP ____ Drop Pipe ____ ins

GPM ____ Head ____ ft. ____ RPM

Motor ____ Volts ____ PH ____

Well Seal ____

Water Analysis — Hardness ____ PPM

PH ____ Iron ____ PPM

WELL CONSTRUCTION RECORD

OWNER

Address

Well Location Bob #7 (Lions Park Well)

Date Started Date Completed

Drilling Method

Driller Helper

File Folio

Signed By

QUALITY WATER WELLS LTD.
OKANAGAN FALLS, B.C.
BOX 159, PH. 497-5557
V0H 1R0 g.2.

LOG OF FORMATIONS

Depth	Descriptions
0 to	
48 to 50	Pebbles Peas & Sm.
to	Gravel Loose (Wat. Good)
50 to 55	Pebbles & Peas Small
to	Gravel Clean & Loose
to	Active With Some Fines
55 to 60	Small Gravel & Peas
to	Loose & Polished Good
60 to 63	Large & Small Gravel
to	With Little Sand Clean (Active)
63 to 64	Big Gravel With Grey
to	Sand & Strip of
to	Cemented Gravel With
to	Clay (Drilled Hard)
64 to 68	Coarse Sand & Big Gravel
to	Clean With Little Fines
68 to 72	Loose Pebbles & Peas
to	Lg. & Sm. Gravel Very
to	Clean With Little Fines (Active/Polished)
72 to 76	Pebbles & Peas Coarse Sand
to	Lg. & Sm. Gravel, Some Fines
76 to 78	Grey Clay Firm With Gravel (Mixed)
76 to 85	Grey Sand Pasty
to	With Gravel (Dirty) (Not Making Water)
to	
to	
to	

GENERAL REMARKS

Att.
63 Good Wat'l.
76 Good Wat'l.

CASING RECORD

Dia. ins. Wt. #/ft. From to

Dia. ins. Wt. #/ft. From to

Dia. ins. Wt. #/ft. From to

Shoe Welded Cemented

SCREEN RECORD

Make Material

Slot opening Length

Top ft. Bottom ft.

Fittings Top Fittings Bottom

Gravel Pack Natural

Development Method

ROCK WELL DATA

Open, Bore Hole Dia. ins.

From ft. to ft.

PRODUCTION DATA

Static Level ft.

Measured from

Pumping Level ft. at GPM

ft. at GPM

Bail Test ft. at GPH

ft. at GPH

Recommended Pump Setting ft.

Recommended Max. Pump Output GPM GPH

Duration of Test Hrs.

PUMP DATA

Make Type

Model Serial No.

Size HP Drop Pipe ins.

GPM Head ft. RPM

Motor Volts PH

Well Seal

Water Analysis — Hardness PPM

PH Iron PPM

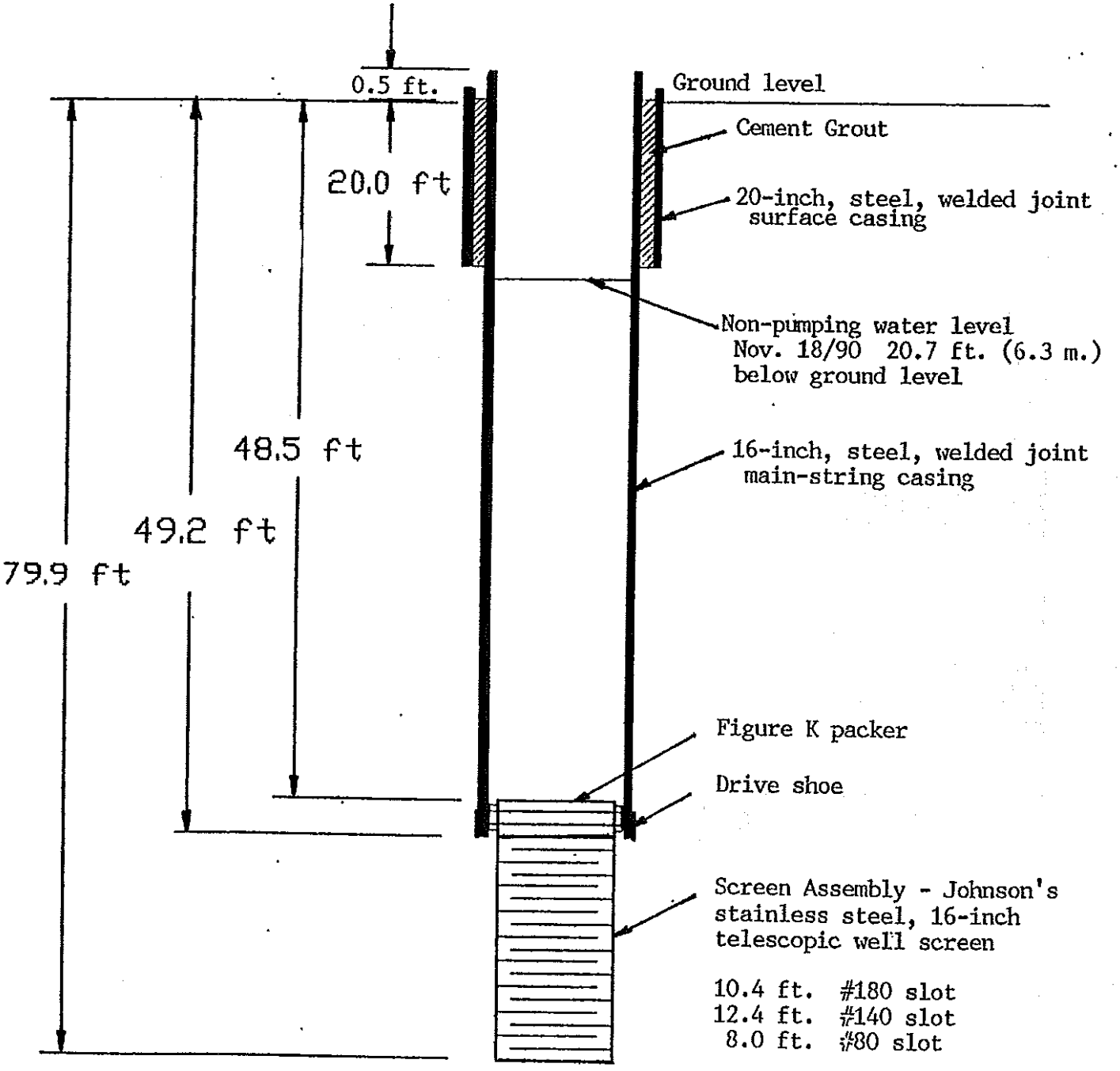


FIGURE 2

WELL COMPLETION DIAGRAM

Rockcliffe Well

BRITISH COLUMBIA

Fairview well

Well Tag Number 000000021867

Owner: S OKANAGAN LANDS IMM

Address:

Area:

WELL LOCATION:
SIMILKAMEEN Land District
District Lot 2450 Plan 4116 Lot 1
Township Section Range
Indian Reserve Meridian Block
Quarter
Island
BCGS Number (NAD 27) 082E013312 Well 11

Well Use Unknown Well Use
Construction Method Drilled
Diameter 8.0 inches
Well Depth 140.0 feet
Elevation 0
Bedrock Depth UNK feet
Screen from 88 to 93 feet
Slot Size 1 Slot Size 2
Slot Size 3 Slot Size 4

Construction Date 19681004

Driller OSYOOS TILE WORKS
License Number

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield 425 USGM
Artesian Flow
Static Level 30 feet

Water Utility
Lithology Info Flag Y
Pump Test Info Flag
File Info Flag
Sieve Info Flag
Screen Info Flag
Water Chemistry Info Flag
Field Chemistry Info Flag
Site Info (SEAM)
Other Info Flag

GENERAL REMARKS:
ANOTHER CARD ATTACHED

From	0	To	1	Ft.	topsoil
From	1	To	5	Ft.	compact sand
From	5	To	54	Ft.	gravel and sand (static 40')
From	54	To	68	Ft.	gravel and sand (some silt)
From	0	To	0	Ft.	static water level 30' attempted bail
From	0	To	0	Ft.	test, 100 gal in 10 min. Bottom heaving
From	0	To	0	Ft.	6'
From	68	To	76	Ft.	gravel and sand (some rocks)
From	77	To	0	Ft.	few clay lumps mixed with sand and gra-
From	0	To	0	Ft.	vel
From	77	To	104	Ft.	sharp sand and gravel (clean pea gravel)
From	0	To	0	Ft.	loose and permeable, some silt
From	104	To	0	Ft.	few lumps of hard clay to clean pea gra-
From	0	To	0	Ft.	vel and sharp sand
From	0	To	112	Ft.	sand and gravel (static 29'8")
From	112	To	117	Ft.	sand and gravel, some silt
From	117	To	0	Ft.	changing to silt (some clay)
From	118	To	140	Ft.	blue silt (impeameable)

18 rows selected.

Date entered to WELL

BRITISH COLUMBIA — WATER WELL RECORD

BC Environment — Water Management Branch, Groundwater Section

Date 04/10/21

BCGS MAP [ ] WELL No. [ ] ELEV [ ] Location Accuracy

UTM [Z] [ ] [E] [ ] [N] UTM Date 19 Well Type

Owners Name & Address: Town of Oliver Miller Rd. Well

Legal Description & Address

Descriptive Location

1 TYPE OF WORK: 1 [ ] New Well 2 [ ] Re-conditioned 3 [ ] Deepened 4 [ ] Abandoned

2. WORK METHOD: 1 [ ] Cable Tool 2 [ ] Auger 3 [ ] Jetting 4 [ ] Rotary 5 [ ] Hand 6 [ ] Dug 7 [ ] Driven [ ] Other

3 WATER WELL USE: 1 [ ] Domestic 2 [ ] Municipal 3 [ ] Irrigation 4 [ ] Commercial [ ] Other

4 DRILLING ADDITIVES

5 MEASUREMENTS from 1 [ ] ground level 2 [ ] top of casing

casing height above ground level

FROM ft	TO ft	6 WELL LOG DESCRIPTION	SWL ft
0	5	Br Sand w/gravel, mud to large rocks	
5	10	Large gravel w/ br Sand	
10	17	med to Small gravel with br Sand	
17	25	Small gravel w/ Sand gravel (clay)	
25	30	med to Small gravel w/ clean Sand	
30	36	clean coarse Sand w/ Small gravel Loose	
36	38	clean coarse Sand w/ Small gravel (polished w/ Active	
38	40	Coarse Sand w/ gravel Large Rocks	
40	44	Coarse br Sand with med to large gravel polished	
44	52	Coarse Sand w/ gravel very clean (Active)	
52	58	Clean coarse Sand w/ gravel (very wet)	
58	61	Coarse clean Sand w/ Small gravel (Very Loose)	
61	76	Grey clay (Firm) Drill you Here	

7. CONSULTANT

Address

8. WELL LOCATION SKETCH

9. CASING: Material: 1 [ ] Steel 2 [ ] Galvanized 3 [ ] Wood 4 [ ] Plastic 5 [ ] Concrete [ ] Other

	units
Diameter	ins
Diameter	ins
From	ft
To	ft
Thickness	ins
Weight	lb/ft

Perforations: ft 1 [ ] above 2 [ ] below ground level

[ ] Welded 2 [ ] Cemented 3 [ ] Threaded 1 [ ] New 2 [ ] Used

Perforations

Shoe(s)

Open hole, from to ft Diameter ins

Grout

10. SCREEN: 1 [ ] Nominal (Telescope) 2 [ ] Pipe Size

Type 1 [ ] Continuous Slot 2 [ ] Perforated 3 [ ] Louvre [ ] Other

Material 1 [ ] Stainless Steel 2 [ ] Plastic [ ] Other

Set from to ft below ground level

RISER, SCREEN & BLANKS						units
Length						ft
Diam I.D.						ins
Slot Size						ins
from						ft
to						ft

Fittings, top bottom

Gravel Pack

11. DEVELOPED BY: 1 [ ] Surging 2 [ ] Jetting 3 [ ] Air 4 [ ] Bailing 5 [ ] Pumping [ ] Other

12. TEST 1 [ ] Pump 2 [ ] Bail 3 [ ] Air Date

Rate USgpm Temp °C SWL before test ft

Water Level ft after test of hrs

[ ] DRAWDOWN in ft / [ ] RECOVERY in ft

mins	WL	mins	WL	mins	WL	mins	WL

13. PRODUCTION TEST TYPE | RECOMMENDED PUMP SETTING ft | RECOMMENDED PUMP RATE USgpm

14. WATER TYPE: 1 [ ] Fresh 2 [ ] Salty 3 [ ] Clear 4 [ ] Cloudy

colour smell gas 1 [ ] Yes 2 [ ] No

15. WATER ANALYSIS: 1 Hardness mg/l

2 Iron mg/l 3 Chloride mg/l

4 pH Field Date

SITE I.D. No Lab Date

16. FINAL WELL COMPLETION DATA

Well Depth ft Well Yield USgpm

Static Water Level ft Artesian Flow USgpm Pressure ft

Back filled

Well Head Completion

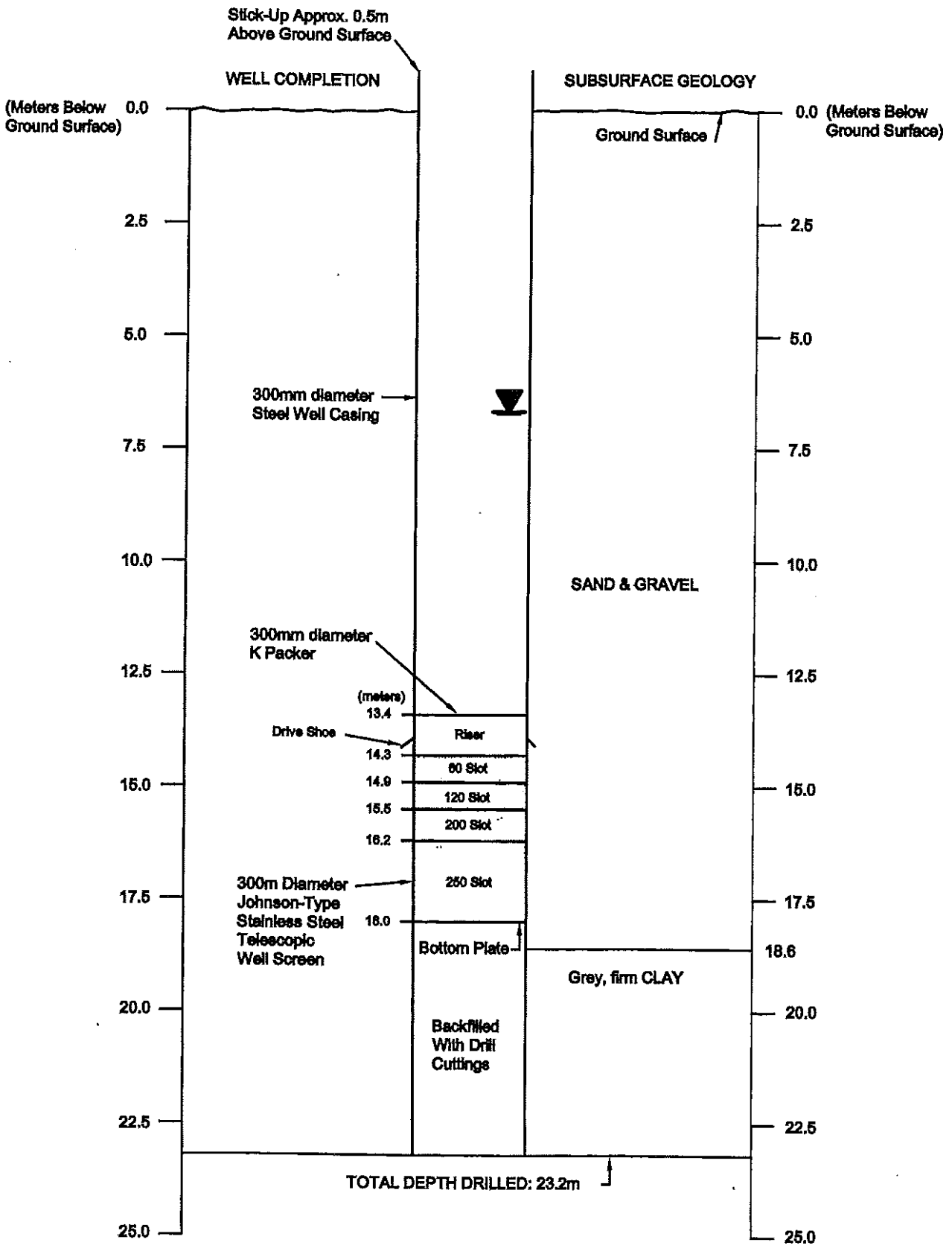
17. DRILLER (PLEASE PRINT) SURNAME | FIRST NAME | DATE

Signature

18 CONTRACTOR

Address

Minister, BC Gov't



Golder Associates
Kelowna, BC

FILE No.	Figure 3.dwg
PROJECT No.	04-1440-020
REV.	0
SCALE	NTS
DATE	26/10/04
DESIGN	D.A.
CADD	L.D.
CHECK	RA
REVIEW	RA

TITLE

PRODUCTION WELL PW04-01
WELL COMPLETION DIAGRAM

Miller Rd. Well

New Production Well (PW04-01) Construction,
TRUE Consulting Group, Oliver, B.C.

FIGURE 3

Drawing file: Figure 3.dwg Dec 16, 2004 - 9:36am

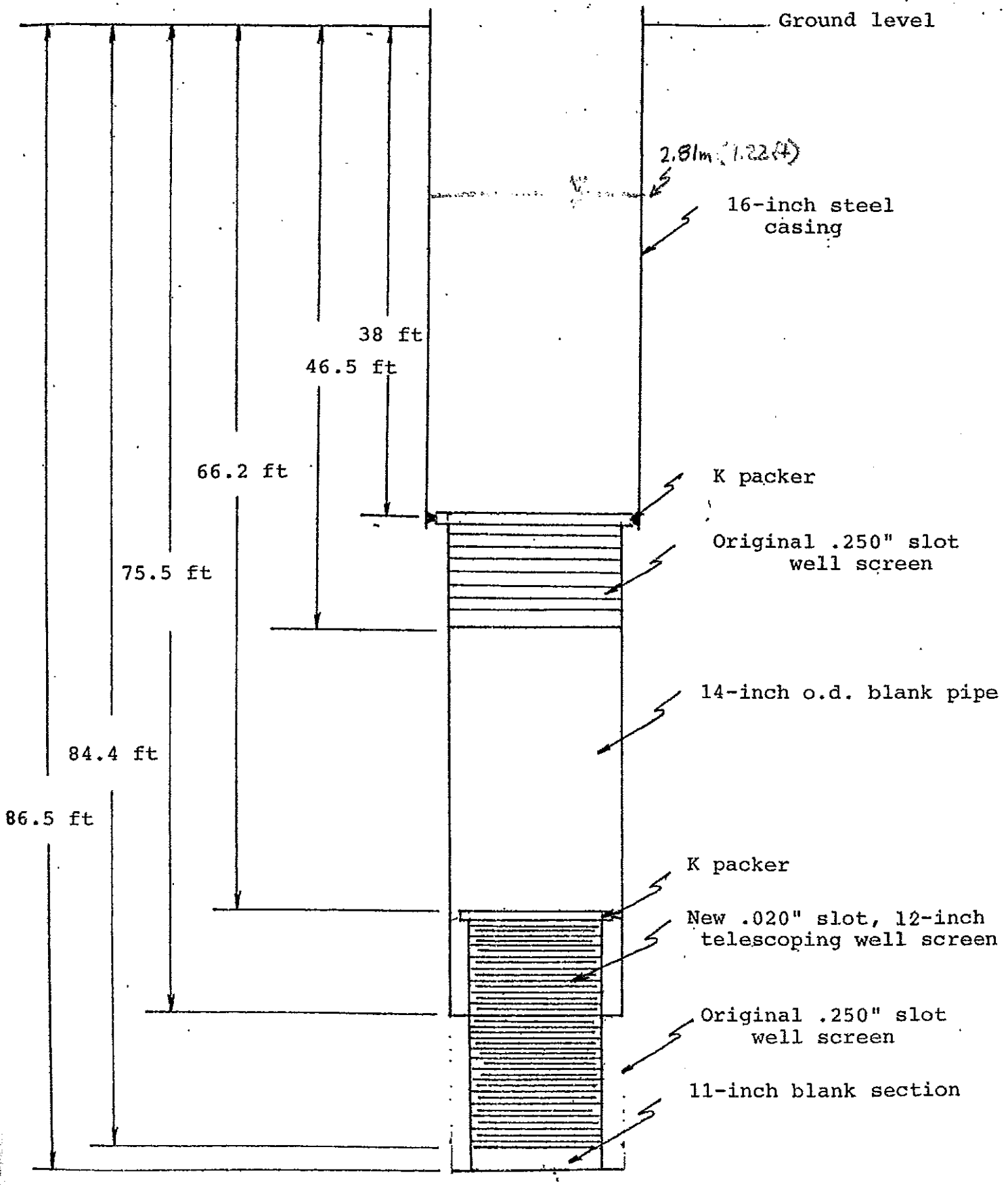


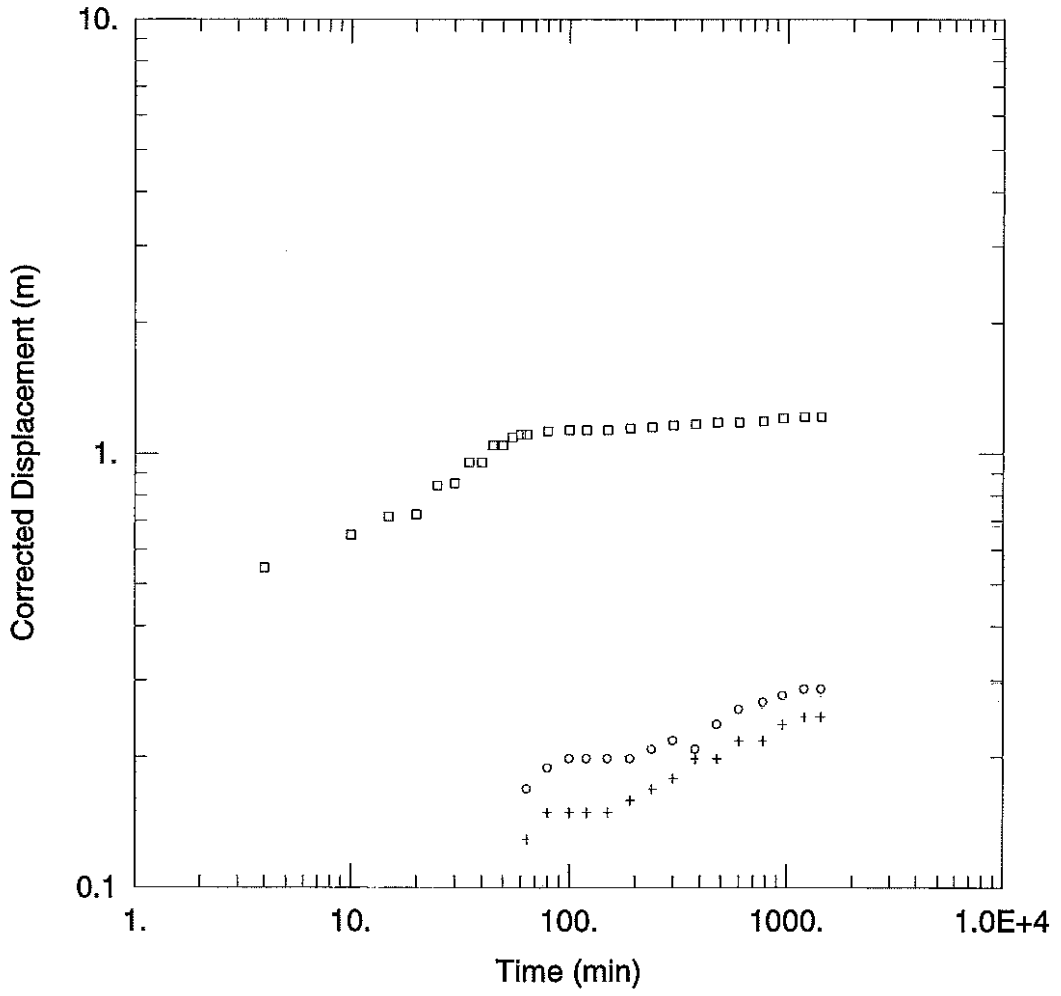
Figure 2

Well Completion Diagram

Black Sage Well

APPENDIX II

AQTESOLV PLOTS FOR SELECTED TOWN OF OLIVER WELLS



WELL TEST ANALYSIS

Data Set: N:\...\TEN Well 2 (Theis) Img Well jf.aqt
Date: 01/06/05 Time: 09:27:25

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: T-e-N #2
Test Date: Dec 1999

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well #2(P)	0	0
Img Well PW2	0	480

Observation Wells

Well Name	X (m)	Y (m)
□ pumping #2	0.15	0
+ OBS Well #3	13.4	-14.3
○ Obs well #1	0	-14.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 7.994 m^2/min
S = 0.1312
Kz/Kr = 1.
b = 10.9 m

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\TEN Well 2 (Theis) Img Well jf.a
Date: 01/06/05
Time: 09:31:36

PROJECT INFORMATION

Company: Oliver GWPP
Test Date: Dec 1999
Test Well: T-e-N #2

AQUIFER DATA

Saturated Thickness: 10.9 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: Well #2(P)

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.15 m
Wellbore Radius: 0.15 m

Partially Penetrating Well
Depth to Top of Screen: 7. m
Depth to Bottom of Screen: 10.9 m

No. of pumping periods: 6

Pumping Period Data

Time (min)	Rate (L/min)	Time (min)	Rate (L/min)
0.	2676.	35.	3782.
15.	3017.	45.	4164.
25.	3422.	55.	4259.

Pumping Well No. 2: Img Well PW2

X Location: 0. m
Y Location: 480. m

Casing Radius: 0.15 m
Wellbore Radius: 0.15 m

Partially Penetrating Well
Depth to Top of Screen: 7. m
Depth to Bottom of Screen: 10.9 m

No. of pumping periods: 6

Pumping Period Data

Time (min)	Rate (L/min)	Time (min)	Rate (L/min)
0.	-2676.	35.	-3782.
15.	-3017.	45.	-4164.
25.	-3422.	55.	-4259.

OBSERVATION WELL DATA

No. of observation wells: 3

Observation Well No. 1: pumping #2

X Location: 0.15 m
Y Location: 0. m

Radial distance from Well #2(P): 0.15 m
Radial distance from Img Well PW2: 480.0000234 m

Partially Penetrating Well
Depth to Top of Screen: 7.3 m
Depth to Bottom of Screen: 10.9 m

No. of Observations: 27

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
4.	0.56	100.	1.2
10.	0.67	120.	1.2
15.	0.74	150.	1.2
20.	0.75	190.	1.21
25.	0.88	240.	1.22
30.	0.89	300.	1.23
35.	1.	380.	1.24
40.	1.	480.	1.25
45.	1.1	600.	1.25
50.	1.1	780.	1.26
55.	1.15	960.	1.28
60.	1.17	1200.	1.29
64.	1.17	1440.	1.29
80.	1.19		

Observation Well No. 2: OBS Well #3

X Location: 13.4 m
Y Location: -14.3 m

Radial distance from Well #2(P): 19.59719368 m
Radial distance from Img Well PW2: 494.4815972 m

Partially Penetrating Well
Depth to Top of Screen: 6.39 m
Depth to Bottom of Screen: 10.19 m

No. of Observations: 15

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
64.	0.13	380.	0.2
80.	0.15	480.	0.2
100.	0.15	600.	0.22
120.	0.15	780.	0.22
150.	0.15	960.	0.24
190.	0.16	1200.	0.25
240.	0.17	1440.	0.25
300.	0.18		

Observation Well No. 3: Obs well #1

X Location: 0. m
Y Location: -14.3 m

Radial distance from Well #2(P): 14.3 m
Radial distance from Img Well PW2: 494.3 m

Partially Penetrating Well
Depth to Top of Screen: 7.74 m
Depth to Bottom of Screen: 10.77 m

No. of Observations: 15

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
64.	0.17	380.	0.21

Time (min)	Displacement (m)	Time (min)	Displacement (m)
80.	0.19	480.	0.24
100.	0.2	600.	0.26
120.	0.2	780.	0.27
150.	0.2	960.	0.28
190.	0.2	1200.	0.29
240.	0.21	1440.	0.29
300.	0.22		

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	7.994	m^2/min
S	0.1312	
Kz/Kr	1.	
b	10.9	m

K = T/b = 0.7334 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	7.994	0.275	m^2/min
S	0.1312	0.02133	
Kz/Kr	1.	not estimated	
b	10.9	not estimated	m

K = T/b = 0.7334 m/min

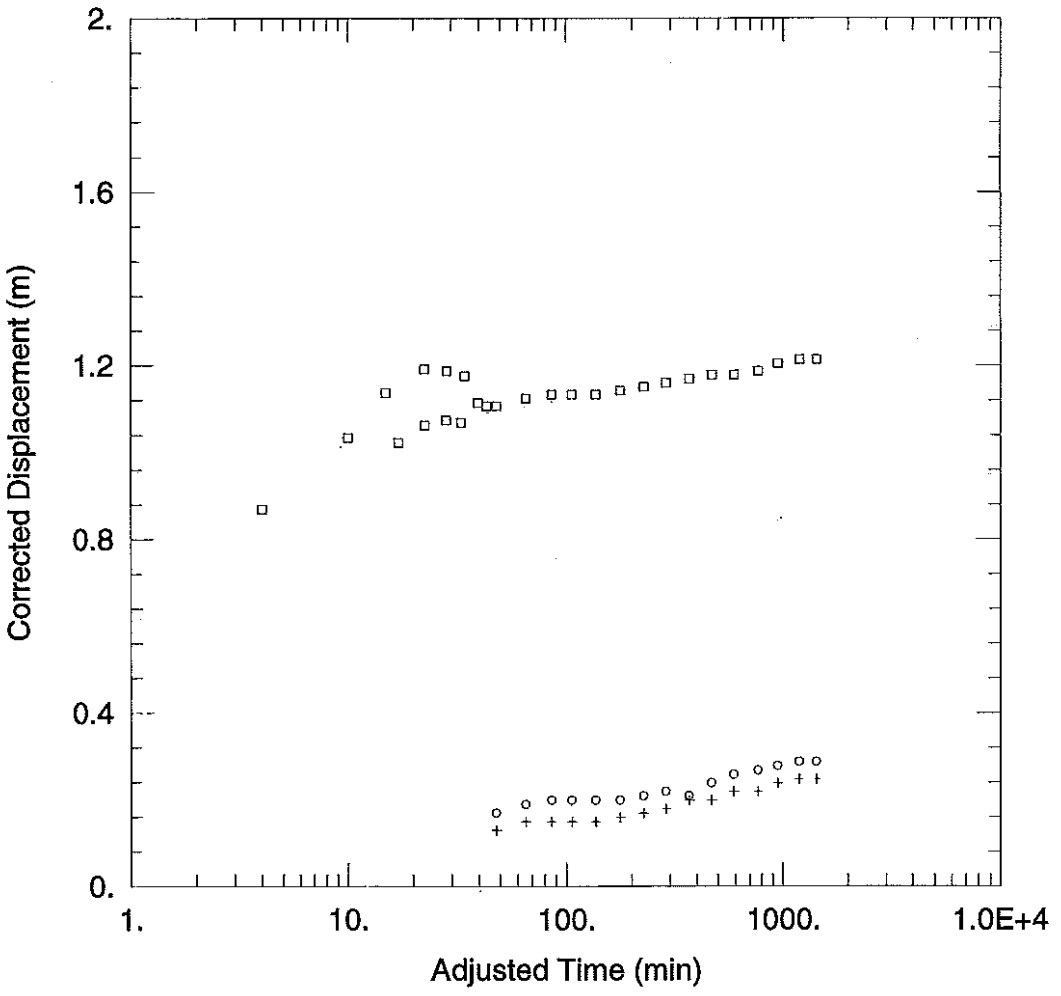
Parameter Correlations

	T	S
T	1.00	-0.90
S	-0.90	1.00

Residual Statistics

for weighted residuals

Sum of Squares. . . . . 0.00579 m^2
Variance. . . . . 0.0002068 m^2
Std. Deviation . . . . . 0.01438 m
Mean . . . . . 0.000341 m
No. of Residuals 30
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\TEN Well 2 (C-J) Img Well JF.aqt
Date: 01/06/05 Time: 09:32:58

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: T-e-N #2
Test Date: Dec 1999

AQUIFER DATA

Saturated Thickness: 10.9 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well #2(P)	0	0
Img Well PW2	0	480

Observation Wells

Well Name	X (m)	Y (m)
▫ pumping #2	0.15	0
+ OBS Well #3	13.4	-14.3
◦ Obs well #1	0	-14.3

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

$T = 9.123\ m^2/min$ S = 7.06E-9

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\TEN Well 2 (C-J) Img Well JF.aq
Date: 01/06/05
Time: 09:33:15

PROJECT INFORMATION

Company: Oliver GWPP
Test Date: Dec 1999
Test Well: T-e-N #2

AQUIFER DATA

Saturated Thickness: 10.9 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: Well #2(P)

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.15 m
Wellbore Radius: 0.15 m

Partially Penetrating Well
Depth to Top of Screen: 7. m
Depth to Bottom of Screen: 10.9 m

No. of pumping periods: 6

Pumping Period Data

Time (min)	Rate (L/min)	Time (min)	Rate (L/min)
0.	2676.	35.	3782.
15.	3017.	45.	4164.
25.	3422.	55.	4259.

Pumping Well No. 2: Img Well PW2

X Location: 0. m
Y Location: 480. m

Casing Radius: 0.15 m
Wellbore Radius: 0.15 m

Partially Penetrating Well
Depth to Top of Screen: 7. m
Depth to Bottom of Screen: 10.9 m

No. of pumping periods: 6

Pumping Period Data

Time (min)	Rate (L/min)	Time (min)	Rate (L/min)
0.	-2676.	35.	-3782.
15.	-3017.	45.	-4164.
25.	-3422.	55.	-4259.

OBSERVATION WELL DATA

No. of observation wells: 3

Observation Well No. 1: pumping #2

X Location: 0.15 m
Y Location: 0. m

Radial distance from Well #2(P): 0.15 m
Radial distance from Img Well PW2: 480.0000234 m

Partially Penetrating Well
Depth to Top of Screen: 7.3 m
Depth to Bottom of Screen: 10.9 m

No. of Observations: 27

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
4.	0.56	100.	1.2
10.	0.67	120.	1.2
15.	0.74	150.	1.2
20.	0.75	190.	1.21
25.	0.88	240.	1.22
30.	0.89	300.	1.23
35.	1.	380.	1.24
40.	1.	480.	1.25
45.	1.1	600.	1.25
50.	1.1	780.	1.26
55.	1.15	960.	1.28
60.	1.17	1200.	1.29
64.	1.17	1440.	1.29
80.	1.19		

Observation Well No. 2: OBS Well #3

X Location: 13.4 m
Y Location: -14.3 m

Radial distance from Well #2(P): 19.59719368 m
Radial distance from Img Well PW2: 494.4815972 m

Partially Penetrating Well
Depth to Top of Screen: 6.39 m
Depth to Bottom of Screen: 10.19 m

No. of Observations: 15

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
64.	0.13	380.	0.2
80.	0.15	480.	0.2
100.	0.15	600.	0.22
120.	0.15	780.	0.22
150.	0.15	960.	0.24
190.	0.16	1200.	0.25
240.	0.17	1440.	0.25
300.	0.18		

Observation Well No. 3: Obs well #1

X Location: 0. m
Y Location: -14.3 m

Radial distance from Well #2(P): 14.3 m
Radial distance from Img Well PW2: 494.3 m

Partially Penetrating Well
Depth to Top of Screen: 7.74 m
Depth to Bottom of Screen: 10.77 m

No. of Observations: 15

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
64.	0.17	380.	0.21

Time (min)	Displacement (m)	Time (min)	Displacement (m)
80.	0.19	480.	0.24
100.	0.2	600.	0.26
120.	0.2	780.	0.27
150.	0.2	960.	0.28
190.	0.2	1200.	0.29
240.	0.21	1440.	0.29
300.	0.22		

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	9.123	m^2/min
S	7.06E-9	

K = T/b = 0.837 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	9.123	17.	m^2/min
S	7.06E-9	4.092E-5	

K = T/b = 0.837 m/min

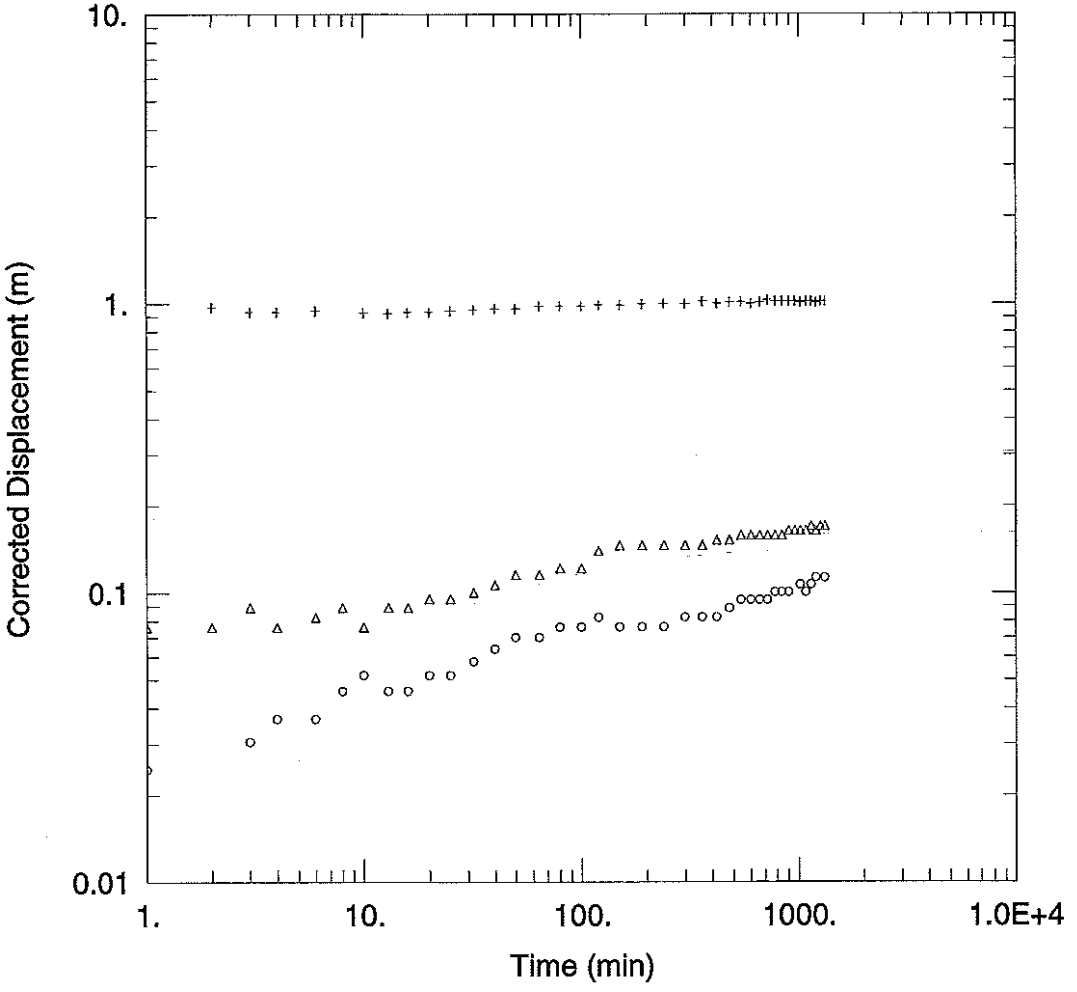
Parameter Correlations

	T	S
T	1.00	-1.00
S	-1.00	1.00

Residual Statistics

for weighted residuals

Sum of Squares. . . . . 5.537 m^2
Variance. . . . . 0.1978 m^2
Std. Deviation . . . . . 0.4447 m
Mean . . . . . -0.4294 m
No. of Residuals 30
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\TEN Well 3 (Theis) Img Well jf.aqt
Date: 01/06/05 Time: 09:32:03

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: Tuc-el-Nuit System 3

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pump Well3	0	0
Img Well PW3	480	0

Observation Wells

Well Name	X (m)	Y (m)
△ OBS1	-13.4	0
+ pumping well	0.5	0
○ OBS 2	-13.4	14.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 8.42 m^2/min
S = 0.02634
Kz/Kr = 1.
b = 13.09 m

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\TEN Well 3 (Theis) Img Well jf.aq
Date: 01/06/05
Time: 09:32:10

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: Tuc-el-Nuit System 3

AQUIFER DATA

Saturated Thickness: 13.09 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: Pump Well3

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.13 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 6.3 m
Depth to Bottom of Screen: 9.7 m

No. of pumping periods: 1

Pumping Period Data	
Time (min)	Rate (L/min)
0.	2373.

Pumping Well No. 2: Img Well PW3

X Location: 480. m
Y Location: 0. m

Casing Radius: 0.13 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 6.3 m
Depth to Bottom of Screen: 9.7 m

No. of pumping periods: 1

Pumping Period Data	
Time (min)	Rate (L/min)
0.	-2373.

OBSERVATION WELL DATA

No. of observation wells: 3

Observation Well No. 1: OBS1

X Location: -13.4 m
Y Location: 0. m

Radial distance from Pump Well3: 13.4 m
Radial distance from Img Well PW3: 493.4 m

Partially Penetrating Well
Depth to Top of Screen: 7.9 m

Depth to Bottom of Screen: 10.7 m

No. of Observations: 39

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.0762	240.	0.1463
2.	0.0762	300.	0.1463
3.	0.089	360.	0.1463
4.	0.0762	420.	0.1524
6.	0.0823	480.	0.1524
8.	0.089	540.	0.1585
10.	0.0762	600.	0.1585
13.	0.089	660.	0.1585
16.	0.089	720.	0.1585
20.	0.0954	780.	0.1585
25.	0.0954	840.	0.1585
32.	0.1006	900.	0.1646
40.	0.1067	960.	0.1646
50.	0.1158	1020.	0.1646
64.	0.1158	1080.	0.1646
80.	0.1219	1140.	0.1707
100.	0.1219	1200.	0.1646
120.	0.1402	1260.	0.1707
150.	0.1463	1320.	0.1707
190.	0.1463		

Observation Well No. 2: pumping well

X Location: 0.5 m
Y Location: 0. m

Radial distance from Pump Well3: 0.5 m
Radial distance from Img Well PW3: 479.5 m

Partially Penetrating Well
Depth to Top of Screen: 6.3 m
Depth to Bottom of Screen: 9.7 m

No. of Observations: 38

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.9388	240.	1.039
2.	1.009	300.	1.036
3.	0.9693	360.	1.061
4.	0.9693	420.	1.039
6.	0.9815	480.	1.052
10.	0.9662	540.	1.055
13.	0.9601	600.	1.039
16.	0.9693	660.	1.052
20.	0.9693	720.	1.07
25.	0.9815	780.	1.061
32.	0.9906	840.	1.061
40.	0.9997	900.	1.061
50.	0.9997	960.	1.061
64.	1.021	1020.	1.052
80.	1.021	1080.	1.061
100.	1.021	1140.	1.061
120.	1.03	1200.	1.052
150.	1.027	1260.	1.061
190.	1.036	1320.	1.061

Observation Well No. 3: OBS 2

X Location: -13.4 m
Y Location: 14.3 m

Radial distance from Pump Well3: 19.59719368 m
Radial distance from Img Well PW3: 493.6071819 m

Partially Penetrating Well
Depth to Top of Screen: 7.01 m
Depth to Bottom of Screen: 10.97 m

No. of Observations: 36

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.02438	190.	0.0762
3.	0.03048	240.	0.0762
4.	0.03658	300.	0.0823
6.	0.03658	360.	0.0823
8.	0.04572	420.	0.0823
10.	0.05182	480.	0.08839
13.	0.04572	540.	0.09449
16.	0.04572	600.	0.09449
20.	0.05182	660.	0.09449
25.	0.05182	720.	0.09449
32.	0.05791	780.	0.1006
40.	0.06401	840.	0.1006
50.	0.0701	900.	0.1006
64.	0.0701	1020.	0.1067
80.	0.0762	1080.	0.1006
100.	0.0762	1140.	0.1067
120.	0.0823	1200.	0.1128
150.	0.0762	1320.	0.1128

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	8.42	m^2/min
S	0.02634	
Kz/Kr	1.	
b	13.09	m

K = T/b = 0.6432 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	8.42	0.1752	m^2/min
S	0.02634	0.004323	
Kz/Kr	1.	not estimated	
b	13.09	not estimated	m

K = T/b = 0.6432 m/min

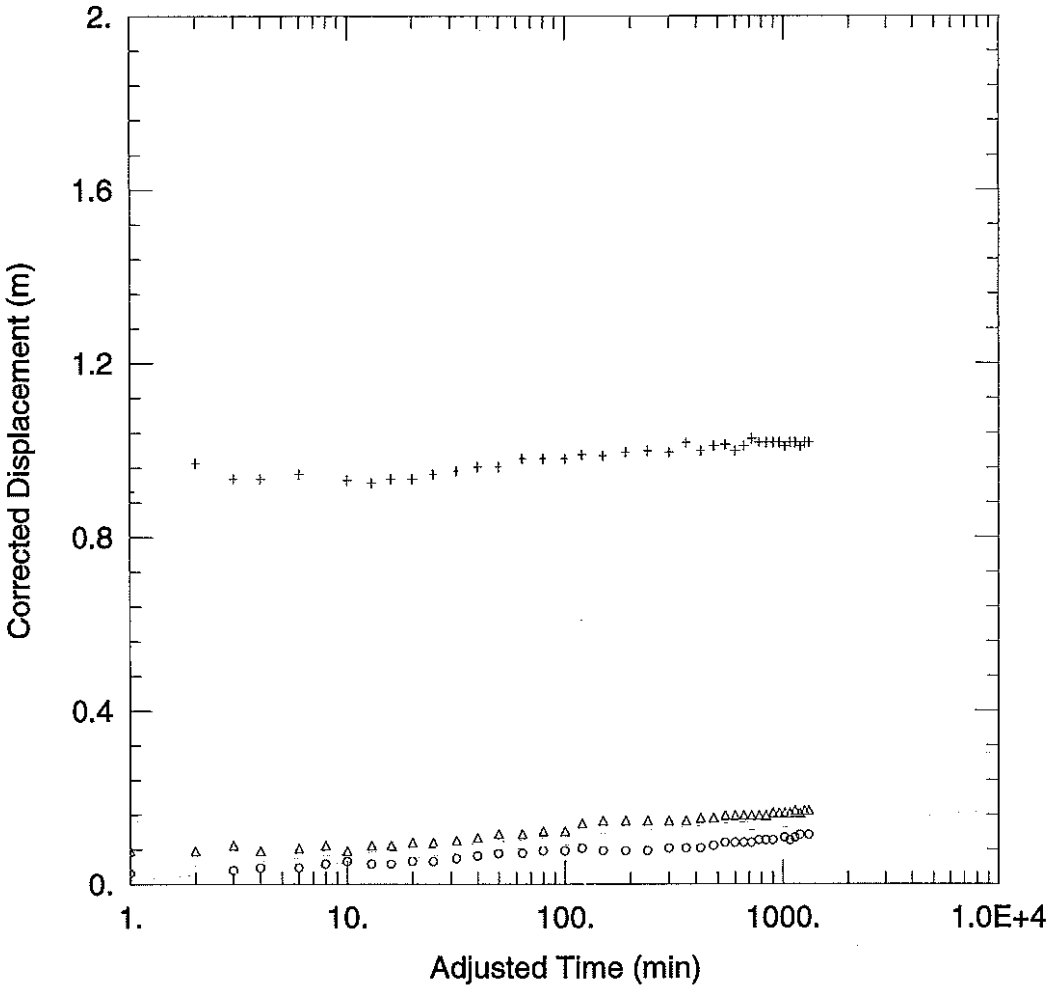
Parameter Correlations

	T	S
T	1.00	-0.64
S	-0.64	1.00

Residual Statistics

for weighted residuals

Sum of Squares. . . . . 0.005146 m^2
Variance. . . . . 0.000143 m^2
Std. Deviation . . . . . 0.01196 m
Mean . . . . . 0.00372 m
No. of Residuals 38
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\TEN Well 3 (C-J) Img Well jf.aqt
Date: 01/06/05 Time: 09:32:28

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: Tuc-el-Nuit System 3

AQUIFER DATA

Saturated Thickness: 13.09 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pump Well3	0	0
Img Well PW3	480	0

Observation Wells

Well Name	X (m)	Y (m)
△ OBS1	-13.4	0
+ pumping well	0.5	0
○ OBS 2	-19.5	13.4

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 10.83 m^2/min S = 0.02634

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\TEN Well 3 (C-J) Img Well jf.aqt
Date: 01/06/05
Time: 09:32:35

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: Tuc-el-Nuit System 3

AQUIFER DATA

Saturated Thickness: 13.09 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: Pump Well3

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.13 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 6.32 m
Depth to Bottom of Screen: 9.74 m

No. of pumping periods: 1

Pumping Period Data

Time (min)	Rate (L/min)
0.	2373.

Pumping Well No. 2: Img Well PW3

X Location: 480. m
Y Location: 0. m

Casing Radius: 0.13 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 6.32 m
Depth to Bottom of Screen: 9.74 m

No. of pumping periods: 1

Pumping Period Data

Time (min)	Rate (L/min)
0.	-2373.

OBSERVATION WELL DATA

No. of observation wells: 3

Observation Well No. 1: OBS1

X Location: -13.4 m
Y Location: 0. m

Radial distance from Pump Well3: 13.4 m
Radial distance from Img Well PW3: 493.4 m

Partially Penetrating Well
Depth to Top of Screen: 7.9 m

Depth to Bottom of Screen: 10.7 m

No. of Observations: 39

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.0762	240.	0.1463
2.	0.0762	300.	0.1463
3.	0.089	360.	0.1463
4.	0.0762	420.	0.1524
6.	0.0823	480.	0.1524
8.	0.089	540.	0.1585
10.	0.0762	600.	0.1585
13.	0.089	660.	0.1585
16.	0.089	720.	0.1585
20.	0.0954	780.	0.1585
25.	0.0954	840.	0.1585
32.	0.1006	900.	0.1646
40.	0.1067	960.	0.1646
50.	0.1158	1020.	0.1646
64.	0.1158	1080.	0.1646
80.	0.1219	1140.	0.1707
100.	0.1219	1200.	0.1646
120.	0.1402	1260.	0.1707
150.	0.1463	1320.	0.1707
190.	0.1463		

Observation Well No. 2: pumping well

X Location: 0.5 m
Y Location: 0. m

Radial distance from Pump Well3: 0.5 m
Radial distance from Img Well PW3: 479.5 m

Partially Penetrating Well
Depth to Top of Screen: 6.32 m
Depth to Bottom of Screen: 9.74 m

No. of Observations: 38

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.9388	240.	1.039
2.	1.009	300.	1.036
3.	0.9693	360.	1.061
4.	0.9693	420.	1.039
6.	0.9815	480.	1.052
10.	0.9662	540.	1.055
13.	0.9601	600.	1.039
16.	0.9693	660.	1.052
20.	0.9693	720.	1.07
25.	0.9815	780.	1.061
32.	0.9906	840.	1.061
40.	0.9997	900.	1.061
50.	0.9997	960.	1.061
64.	1.021	1020.	1.052
80.	1.021	1080.	1.061
100.	1.021	1140.	1.061
120.	1.03	1200.	1.052
150.	1.027	1260.	1.061
190.	1.036	1320.	1.061

Observation Well No. 3: OBS 2

X Location: -19.5 m
Y Location: 13.4 m

Radial distance from Pump Well3: 23.66030431 m
Radial distance from Img Well PW3: 499.6797074 m

Partially Penetrating Well
Depth to Top of Screen: 7.01 m
Depth to Bottom of Screen: 10.97 m

No. of Observations: 36

Observation Data

Time (min)	Displacement (m)	Time (min)	Displacement (m)
1.	0.02438	190.	0.0762
3.	0.03048	240.	0.0762
4.	0.03658	300.	0.0823
6.	0.03658	360.	0.0823
8.	0.04572	420.	0.0823
10.	0.05182	480.	0.08839
13.	0.04572	540.	0.09449
16.	0.04572	600.	0.09449
20.	0.05182	660.	0.09449
25.	0.05182	720.	0.09449
32.	0.05791	780.	0.1006
40.	0.06401	840.	0.1006
50.	0.0701	900.	0.1006
64.	0.0701	1020.	0.1067
80.	0.0762	1080.	0.1006
100.	0.0762	1140.	0.1067
120.	0.0823	1200.	0.1128
150.	0.0762	1320.	0.1128

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	10.83	m^2/min
S	0.02634	

K = T/b = 0.8271 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	10.83	1.004	m^2/min
S	0.02634	0.0141	

K = T/b = 0.8271 m/min

Parameter Correlations

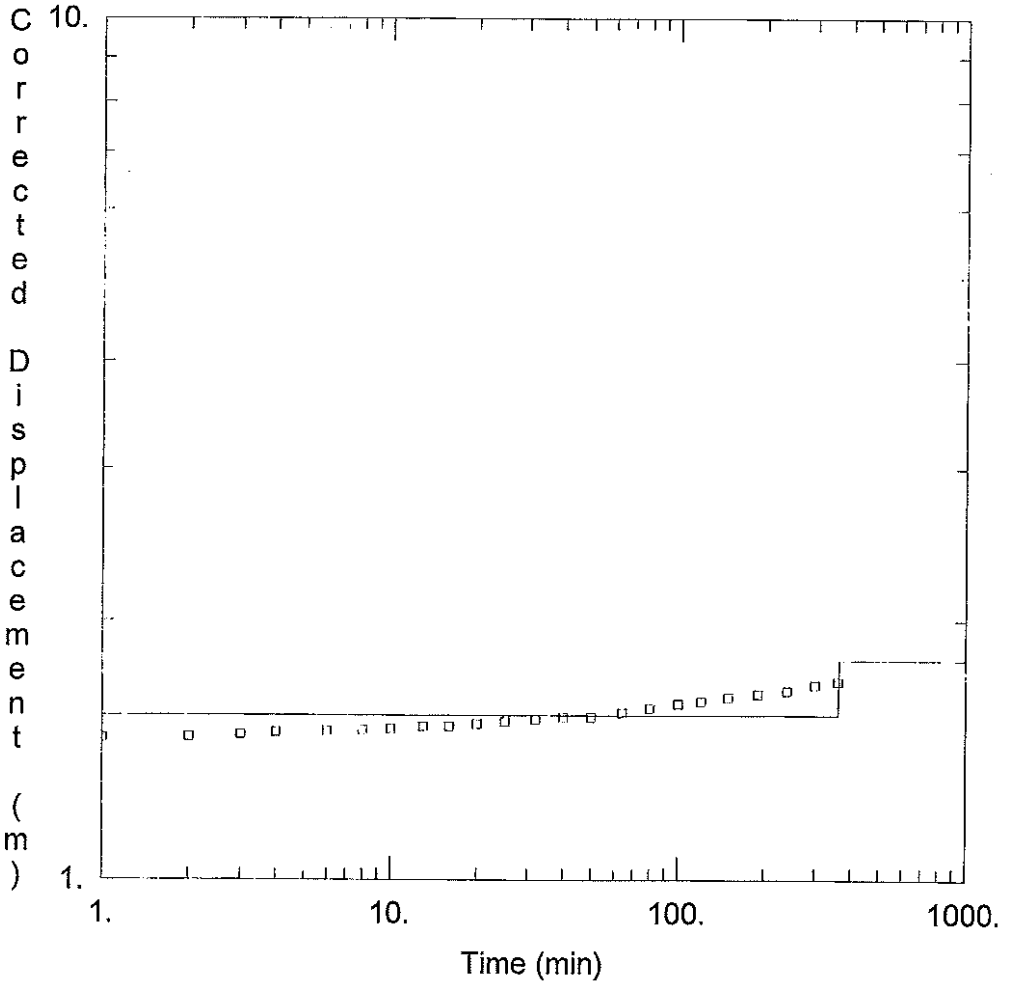
	T	S
T	1.00	-0.93
S	-0.93	1.00

Residual Statistics

for weighted residuals

Sum of Squares. . . . . 0.01589 m^2
Variance. . . . . 0.0004414 m^2
Std. Deviation . . . . . 0.02101 m

Mean . . . . . 0.01869 m
No. of Residuals 38
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\BS Well1 (Theis) Img Well jf.aqt
Date: 12/14/04 Time: 11:45:22

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: System 2
Test Date: Feb 1985

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
system 2	0	0
Img Well PW2	0	-100

Observation Wells

Well Name	X (m)	Y (m)
system 2	0.15	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 3.592 m^2/min
S = 4.065E-11
Kz/Kr = 1.
b = 23.55 m

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\BS Well1 (Theis) Img Well jf.aqt
Date: 12/14/04
Time: 11:45:28

PROJECT INFORMATION

Company: Oliver GWPP
Test Date: Feb 1985
Test Well: System 2

AQUIFER DATA

Saturated Thickness: 23.55 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: system 2

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.15 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of pumping periods: 2

Pumping Period Data

Time (min)	Rate (L/min)
0.	5394.
361.	6246.

Pumping Well No. 2: Img Well PW2

X Location: 0. m
Y Location: -100. m

Casing Radius: 0.15 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of pumping periods: 2

Pumping Period Data

Time (min)	Rate (L/min)
0.	-5394.
361.	-6246.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: system 2

X Location: 0.15 m
Y Location: 0. m

Radial distance from system 2: 0.15 m
Radial distance from Img Well PW2: 100.0001125 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of Observations: 23

Observation Data

Time (min)	Displacement (m)
1.	1.51
2.	1.515
3.	1.525
4.	1.535
6.	1.54
8.	1.545
10.	1.55
13.	1.56
16.	1.56
20.	1.57
25.	1.58
32.	1.59
40.	1.6
50.	1.6
64.	1.62
80.	1.64
100.	1.66
120.	1.67
150.	1.69
190.	1.705
240.	1.72
300.	1.75
360.	1.765

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	3.592	m^2/min

S	4.065E-11	
Kz/Kr	1.	
b	23.55	m

K = T/b = 0.1525 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	3.592	0.041	m^2/min
S	4.065E-11	0.0008283	
Kz/Kr	1.	not estimated	
b	23.55	not estimated	m

K = T/b = 0.1525 m/min

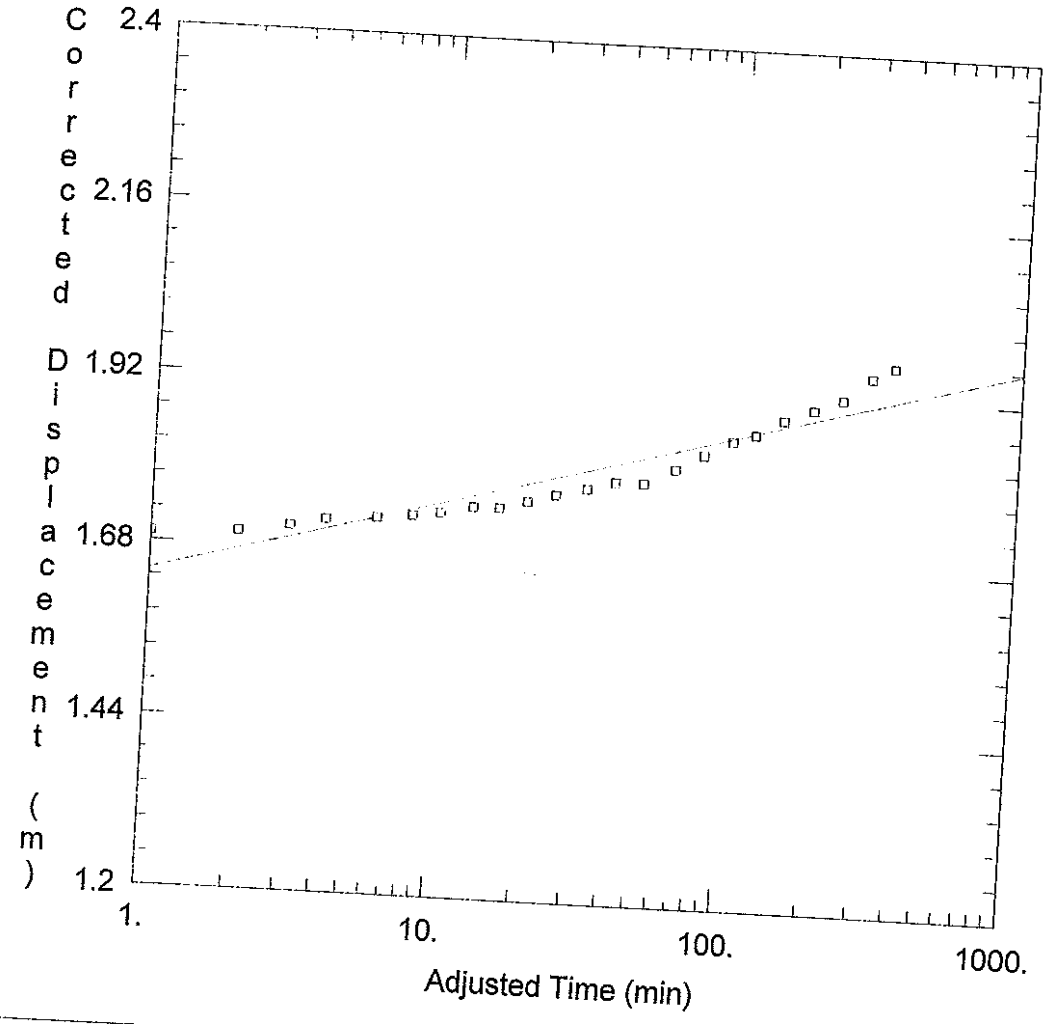
Parameter Correlations

	T	S
T	1.00	-0.49
S	-0.49	1.00

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 0.1309 m^2
Variance . . . . . 0.006234 m^2
Std. Deviation . . . . . 0.07896 m
Mean . . . . . -0.0002004 m
No. of Residuals. 23
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\BS Well1 (C-J) Img Well jf.aqt
Date: 12/14/04 Time: 11:43:50

PROJECT INFORMATION

Company: Oliver GWPP
Test Well: System 2
Test Date: Feb 1985

AQUIFER DATA

Saturated Thickness: 23.55 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
system 2	0	0
Img Well PW2	0	-100

Observation Wells

Well Name	X (m)	Y (m)
system 2	0.15	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 10.53 m^2/min
S = 8.494E-13

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\BS Well1 (C-J) Img Well jf.aqt
Date: 12/14/04
Time: 11:44:27

PROJECT INFORMATION

Company: Oliver GWPP
Test Date: Feb 1985
Test Well: System 2

AQUIFER DATA

Saturated Thickness: 23.55 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: system 2

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.15 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of pumping periods: 2

Pumping Period Data

Time (min)	Rate (L/min)
0.	5394.
361.	6246.

Pumping Well No. 2: Img Well PW2

X Location: 0. m
Y Location: -100. m

Casing Radius: 0.15 m
Wellbore Radius: 0.18 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of pumping periods: 2

Pumping Period Data

Time (min)	Rate (L/min)
0.	-5394.
361.	-6246.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: system 2

X Location: 0.15 m
Y Location: 0. m

Radial distance from system 2: 0.15 m
Radial distance from Img Well PW2: 100.0001125 m

Partially Penetrating Well
Depth to Top of Screen: 17.6 m
Depth to Bottom of Screen: 22.9 m

No. of Observations: 23

Observation Data

Time (min)	Displacement (m)
1.	1.51
2.	1.515
3.	1.525
4.	1.535
6.	1.54
8.	1.545
10.	1.55
13.	1.56
16.	1.56
20.	1.57
25.	1.58
32.	1.59
40.	1.6
50.	1.6
64.	1.62
80.	1.64
100.	1.66
120.	1.67
150.	1.69
190.	1.705
240.	1.72
300.	1.75
360.	1.765

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	10.53	m^2/min

S	8.494E-13

K = T/b = 0.4471 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	10.53	0.7449	m^2/min
S	8.494E-13	2.221E-12	

K = T/b = 0.4471 m/min

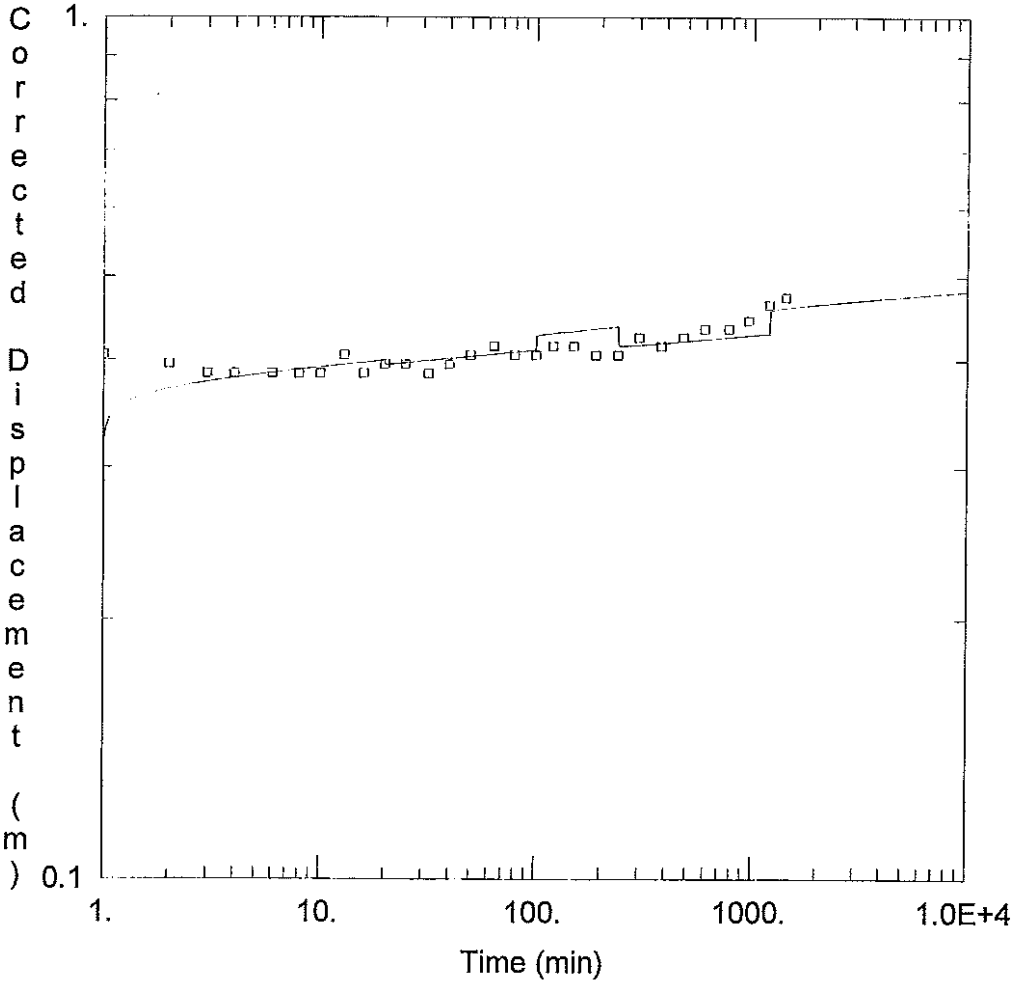
Parameter Correlations

	T	S
T	1.00	-0.00
S	-0.00	0.00

Residual Statistics

for weighted residuals

Sum of Squares	0.01221 m^2
Variance	0.0005816 m^2
Std. Deviation	0.02412 m
Mean	-1.213E-7 m
No. of Residuals	23
No. of Estimates	2



OLIVER GWPP 03-1440-057

Data Set: N:\...\Rockcliffe well (Theis) jf.aqt
Date: 12/14/04 Time: 13:28:41

PROJECT INFORMATION

Company: Rockcliffe Well
Client: Town of Oliver
Project: 03-1440-057
Test Well: Well #4
Test Date: Nov 1990

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Rockcliffe	0	0

Observation Wells

Well Name	X (m)	Y (m)
▫ Rockcliffe	0.2	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 40.83 m^2/min
S = 2.46E-13
Kz/Kr = 1.
b = 18.2 m

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\Rockcliffe well (Theis) jf.aqt
Title: Oliver GWPP 03-1440-057
Date: 12/14/04
Time: 13:28:47

PROJECT INFORMATION

Company: Rockcliffe Well
Client: Town of Oliver
Project: 03-1440-057
Test Date: Nov 1990
Test Well: Well #4

AQUIFER DATA

Saturated Thickness: 18.2 m
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: Rockcliffe

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.2 m
Wellbore Radius: 0.2 m

Partially Penetrating Well
Depth to Top of Screen: 8.7 m
Depth to Bottom of Screen: 18.1 m

No. of pumping periods: 5

Pumping Period Data

Time (min)	Rate (L/min)
1.	5166.
20.	5098.
100.	5318.
240.	5022.
1200.	5379.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: Rockcliffe

X Location: 0.2 m
Y Location: 0. m

Radial distance from Rockcliffe : 0.2 m

Partially Penetrating Well

Depth to Top of Screen: 8.7 m
Depth to Bottom of Screen: 18.1 m

No. of Observations: 29

Observation Data

Time (min)	Displacement (m)
1.	0.41
2.	0.4
3.	0.39
4.	0.39
6.	0.39
8.	0.39
10.	0.39
13.	0.41
16.	0.39
20.	0.4
25.	0.4
32.	0.39
40.	0.4
50.	0.41
64.	0.42
80.	0.41
100.	0.41
120.	0.42
150.	0.42
190.	0.41
240.	0.41
300.	0.43
380.	0.42
480.	0.43
600.	0.44
780.	0.44
960.	0.45
1200.	0.47
1440.	0.48

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	40.83	m^2/min
S	2.46E-13	
Kz/Kr	1.	
b	18.2	m

K = T/b = 2.244 m/min

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	
T	40.83	30.48	m^2/min
S	2.46E-13	7.298E-12	
Kz/Kr	1.	not estimated	
b	18.2	not estimated	m

K = T/b = 2.244 m/min

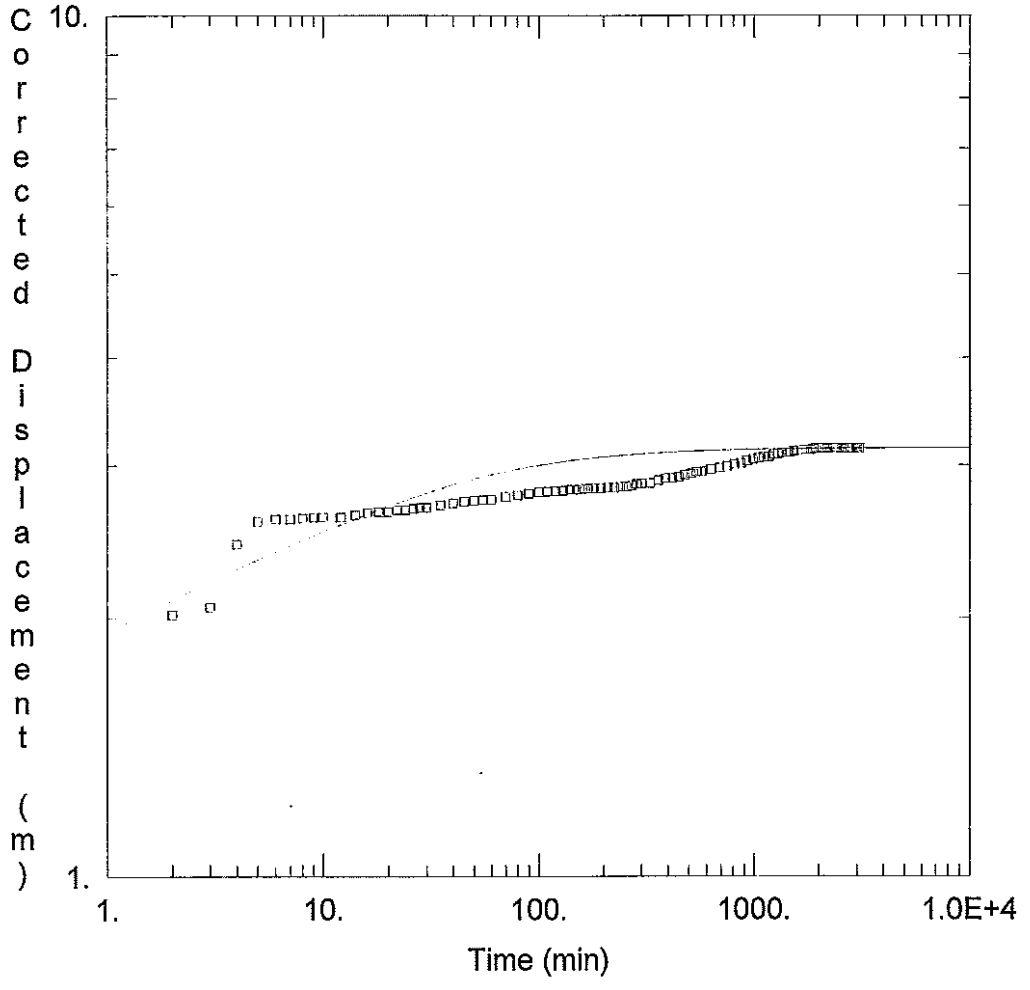
Parameter Correlations

	T	S
T	1.00	-0.00
S	-0.00	0.00

Residual Statistics

for weighted residuals

Sum of Squares . . . . . 0.1742 m^2
Variance . . . . . 0.006453 m^2
Std. Deviation . . . . . 0.08033 m
Mean . . . . . 0.01425 m
No. of Residuals. 29
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: N:\...\Miller Rd Well (Theis) Img Well jf.aqt
Date: 02/01/05 Time: 17:51:48

PROJECT INFORMATION

Company: Oliver GWPP

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
PW 1	0	0
PW 2	0	110

Observation Wells

Well Name	X (m)	Y (m)
PW 1	0.25	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 0.02042 m^2/sec
S = 0.0261
Kz/Kr = 0.04376
b = 11.6 m

Data Set: N:\Active\2003\1440 - Kelowna\03-1440-057 Oliver GWPP\Aqtesolv\Miller Rd Well (Theis) Img Well jf
Date: 02/01/05
Time: 17:51:57

PROJECT INFORMATION

Company: Oliver GWPP

AQUIFER DATA

Saturated Thickness: 11.6 m
Anisotropy Ratio (Kz/Kr): 0.04376

PUMPING WELL DATA

No. of pumping wells: 2

Pumping Well No. 1: PW 1

X Location: 0. m
Y Location: 0. m

Casing Radius: 0.25 m
Wellbore Radius: 1. m

Partially Penetrating Well
Depth to Top of Screen: 7.6 m
Depth to Bottom of Screen: 11.6 m

No. of pumping periods: 1

Pumping Period Data

Time (min)	Rate (gal/min)
0.	1050.

Pumping Well No. 2: PW 2

X Location: 0. m
Y Location: 110. m

Casing Radius: 1. m
Wellbore Radius: 1. m

Fully Penetrating Well

No. of pumping periods: 1

Pumping Period Data

Time (min)	Rate (gal/min)
0.	-1050.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: PW 1

X Location: 0.25 m
Y Location: 0. m

Radial distance from PW 1: 0.25 m
Radial distance from PW 2: 110.0002841 m

Partially Penetrating Well
Depth to Top of Screen: 7.6 m
Depth to Bottom of Screen: 11.6 m

No. of Observations: 98

Observation Data

Time (min)	Displacement (m)
1.	1.
2.	2.23
3.	2.28
4.	2.76
5.	2.96
6.	2.98
7.	2.98
8.	2.99
9.	2.995
10.	3.
12.	3.
14.	3.02
16.	3.04
18.	3.05
20.	3.05
22.	3.07
24.	3.07
26.	3.08
28.	3.09
30.	3.09
35.	3.115
40.	3.135
45.	3.15
50.	3.16
55.	3.165
60.	3.17
70.	3.2
80.	3.215
90.	3.23
100.	3.245
110.	3.25
120.	3.255
130.	3.26
140.	3.27
150.	3.27
160.	3.28
170.	3.28
180.	3.285
195.	3.285
210.	3.29
225.	3.29

Time (min)	Displacement (m)
240.	3.3
255.	3.3
270.	3.31
285.	3.33
300.	3.335
330.	3.34
360.	3.37
390.	3.39
420.	3.395
450.	3.405
480.	3.43
510.	3.445
540.	3.46
570.	3.465
630.	3.49
690.	3.51
750.	3.525
810.	3.55
870.	3.56
930.	3.59
990.	3.605
1050.	3.62
1110.	3.63
1170.	3.635
1230.	3.665
1290.	3.67
1350.	3.68
1410.	3.69
1440.	3.69
1470.	3.69
1530.	3.7
1590.	3.71
1650.	3.71
1710.	3.72
1770.	3.72
1830.	3.72
1890.	3.73
1950.	3.74
2010.	3.74
2070.	3.74
2130.	3.74
2190.	3.735
2250.	3.74
2310.	3.74
2370.	3.745
2430.	3.74
2490.	3.74
2550.	3.735
2610.	3.735
2670.	3.735
2730.	3.735
2790.	3.74
2850.	3.74
2910.	3.74
2970.	3.74

Time (min)	Displacement (m)
3030.	3.74
3090.	3.74

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

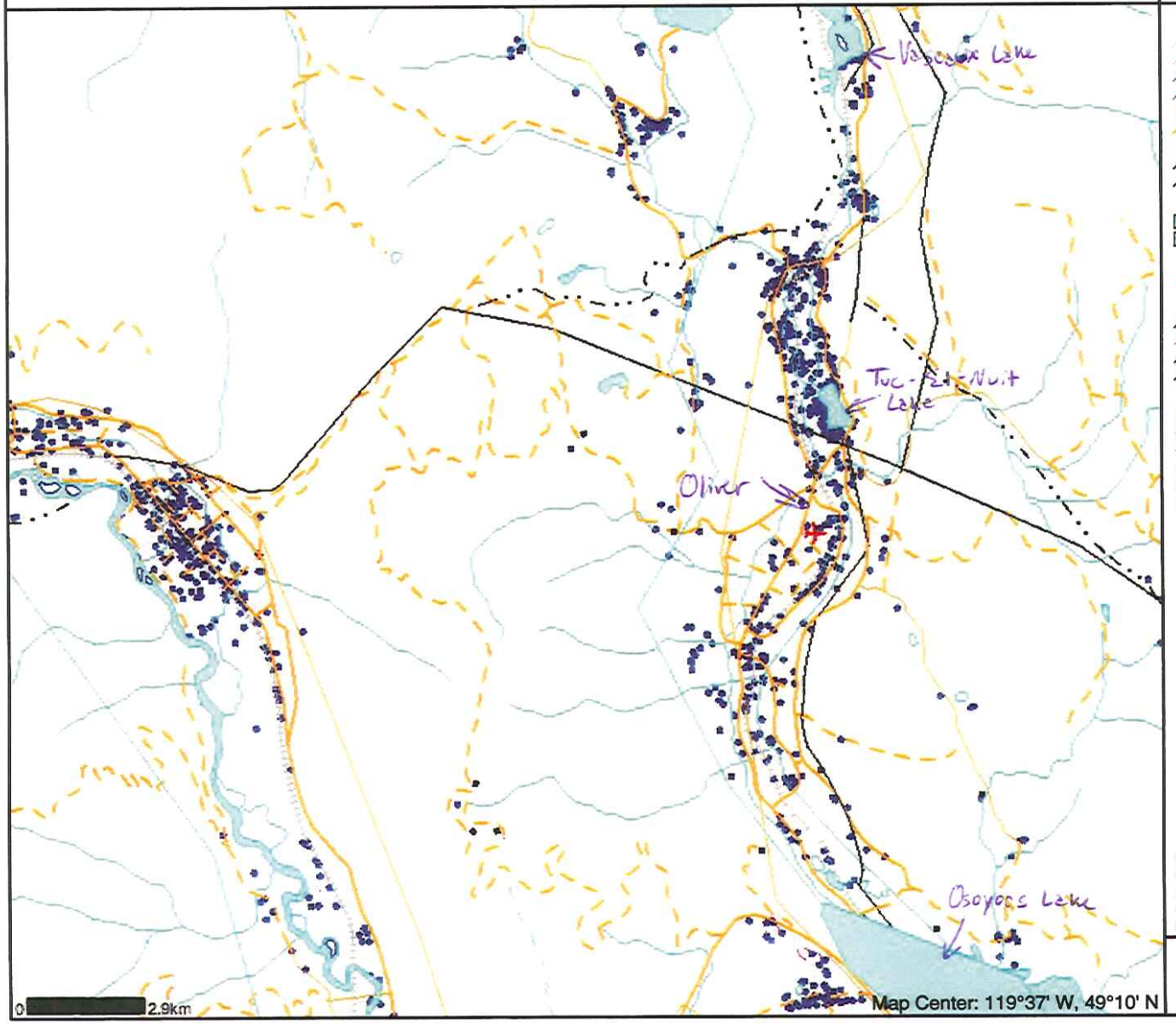
Parameter	Estimate	
T	0.02042	m^2/sec
S	0.0261	
Kz/Kr	0.04376	
b	11.6	m

K = T/b = 0.001761 m/sec

APPENDIX III

MINISTRY OF WATER, LAND AND AIR PROTECTION
WELL LOCATION PLAN

MWLAP Water Well Location Map



Legend

1:6M Lines
River/Stream - Definite
Lake - Definite
Island - Definite
Coastline - Definite
Road - Trunk
Road - Main
Rail Line
Boundary (International)
Boundary (Interprovincial)

1:6M Polygons
River/Stream - Definite
Lake - Definite

Landform - Points (1:250K)
Rock

Landform - Lines (1:250K)
Ledge
Cliff
Esker
Moraine

Landmark - Points (1:250K)
Mine - Abandoned
Campground/Campsite
Park
Ski Area
Park/Picnic Area
Campground Campsite
Town
Village
School
Fire Lookout - Tower
Ranger/Warden Station
Customs Office
Electric Facility/Transformer Station
Oil/Gas Facilities
Cabin/Hut/Shack
Terminal/Station - Railroad
Building
Tower/Mast
Tower/Mast - Microwave
Tower - Clearance(symbol)
Monument (Historical)
Beacon
Navigation Aid - Light(symbol)
Tank

Landmark - Lines (1:250K)
Mine (Underground)
Pit
Quarry
Sewage Leaching Field
Tailing Pile/Pond/Dump

Scale: 1:150,000

DO NOT USE FOR NAVIGATION

APPENDIX IV

MINISTRY OF WATER, LAND AND AIR PROTECTION
SITE REGISTRY PROPERTIES

11 records selected for 5.0 km from latitude 49 deg, 12 min, 53 sec
and Longitude 119 deg, 32 min, 45 sec

Site Id	Lastupd	Address / City
0002271	03MAY20	34718 91ST STREET OLIVER
0002278	01MAY03	33886 97TH STREET OLIVER
0002282		34484 97TH STREET OLIVER
0003033	03OCT09	34817 97TH STREET OLIVER
0005153	03OCT30	34873 97TH STREET OLIVER
0005159	03JAN09	36216 97TH STREET OLIVER
0006986		38686 97TH STREET OLIVER
0007499	04APR07	34274 95TH STREET OLIVER
0007729	04APR07	35470 - 89TH STREET OLIVER
0007913	04APR07	35470 - 89 STREET OLIVER
0008592		39044 HIGHWAY 97 OLIVER

As Of: JAN 23, 2005 BC Online: Site Registry 05/01/24
For: PE92096 GOLDER ASSOCIATES LTD. (KELOWNA) 15:11:27
Folio: Page 1

1 records selected for 5.0 km from latitude 49 deg, 7 min, 33 sec
and Longitude 119 deg, 34 min, 19 sec

Site Id	Lastupd	Address / City
0002278	01MAY03	33886 97TH STREET OLIVER

APPENDIX V

EXAMPLES OF GROUNDWATER PROTECTION MEASURES

EXAMPLES OF GROUNDWATER PROTECTION MEASURES

1.	Hazardous Waste Collection	✓	Drop-off at central depot outside of capture zone
		✓	Mobile units that travel to various locations
		✓	Collection days once or twice per year
2.	Technical Assistance	✓	Best Management Practices pamphlets
		✓	Training building and fire inspectors to recognize abandoned wells and USTs
		✓	Agricultural consultants
		✓	Septic system consultants
		✓	Training for commercial and industrial facilities
3.	Land Acquisition	✓	Donation
		✓	Land exchange
		✓	Land purchase
		✓	Purchase and lease back
4.	Cluster Development	✓	Encourage development in less sensitive areas
		✓	Encourage development where sewer extension is planned
5.	Stormwater and Sewage Control	✓	Integrated Water Management Plan
		✓	Design standards for drainage systems and catch basins
		✓	Regular inspection and maintenance
		✓	Upgrading and replacement
		✓	Testing of stormwater and sewage discharges
		✓	Permitting of stormwater and sewage discharges
		✓	Containment and treatment of discharges
		✓	Subdivision controls
		✓	Prohibit dry wells and infiltration trenches
6.	Septic System Controls	✓	Educational programs
		✓	Technical assistance
		✓	Water conservation
		✓	Siting control
		✓	Prohibition in sensitive areas
		✓	Minimum lot size requirements
		✓	Design control
		✓	Restrict use by industry
		✓	Extend sewer system
		✓	Use holding tanks
		✓	Operational permits
		✓	Regular inspection program and maintenance program
		✓	Inspection prior to property transfer
		✓	Ban cleaners with organic solvents

EXAMPLES OF GROUNDWATER PROTECTION MEASURES

7.	Agricultural Controls	✓	Educational programs (working groups)
		✓	Technical Assistance
		✓	Best Management Practices pamphlets
		✓	Restrict amount and type of chemicals stored
		✓	Pesticide/fertilizer application control
		✓	Prohibit/restrict agricultural activities in sensitive areas
		✓	Reporting requirements
		✓	Research
8.	Transportation Controls	✓	Designated truck route
		✓	Designated rail route
		✓	Warning signs
		✓	Speed limits
		✓	Education of delivery personnel
		✓	Training for emergency response personnel
		✓	Road and maintenance repair
9.	Well Drilling and Abandonment	✓	Siting guidelines/regulations
		✓	Construction guidelines/regulations
		✓	Maintenance guidelines/regulations
		✓	Guidelines/regulations for well abandonment
		✓	Identification of abandoned wells as a condition of site plan approval/property transaction
10.	Geotechnical Controls	✓	Guidelines/regulations for grouting boreholes
		✓	Limit depth of excavations in sensitive areas
11.	Forest Management	✓	Forest management plan
		✓	Management to reduce the risk of fire
		✓	Control of activities around streams
		✓	Cutting restrictions
		✓	Design controls for haul roads, skid trails and log landings
		✓	Control of pesticides and herbicides
		✓	Performance bonds
12.	Market Approaches	✓	Performance bonds
		✓	Surcharge on water use
		✓	Penalties/fines for non-compliance
		✓	Financial incentives through tax credits
		✓	Financial incentives through grants and loans

EXAMPLES OF GROUNDWATER PROTECTION MEASURES

13.	Groundwater Quality Guidelines /Regulations	✓	Non-degradation policy
		✓	Limited degradation policy
14.	Zoning	✓	Overlay zones
		✓	Prohibition of hazardous materials
		✓	Prohibition of land uses
		✓	Aquifer-wide protection area
		✓	Protection area around a well field
		✓	Large-lot zoning
15.	Facility Siting, Design and Operation Controls	✓	Best management plan
		✓	Siting Restrictions
		✓	Design and construction standards (i.e., secondary containment)
		✓	Operating standards
		✓	Permitting and licensing
		✓	Regular inspection and maintenance
		✓	Contingency plan
16.	Hazardous Materials Restrictions	✓	Control type and quantity of hazardous materials
		✓	Registration and tracking controls (i.e. business license renewal process)
		✓	Storage and handling controls
		✓	Disposal controls
17.	Underground Storage Tanks and Pipelines	✓	Operations standards
		✓	Secondary containment
		✓	Pressure testing
		✓	Groundwater Monitoring
		✓	Permitting
		✓	Fees
		✓	Prohibition in sensitive areas
18.	Above-ground Storage Tanks	✓	Operations standards
		✓	Secondary containment
		✓	Pressure testing
		✓	Groundwater Monitoring
		✓	Permitting
		✓	Fees
		✓	Prohibition in sensitive areas

EXAMPLES OF GROUNDWATER PROTECTION MEASURES

19.	Sand and Gravel Mining	✓	Security requirements
		✓	Drainage control
		✓	Mining restrictions
		✓	Prohibition in sensitive areas
20.	Inspection and Compliance	✓	Fire Inspectors

Adapted from (Environment Canada, 1995) Table 10: Detailed Summary of Groundwater Protection Measures