Golder Associates Ltd.

220 - 1755 Springfield Road
Kelowna, British Columbia, Canada V1Y 5V5
Telephone (250) 860-8424
Fax (250) 860-9874

**Golder
Associates**

REPORT ON

HYDROGEOLOGICAL EVALUATION
WELL FIELD CAPACITY
SOUTHEAST KELOWNA IRRIGATION DISTRICT
KELOWNA, BRITISH COLUMBIA

Submitted to:

Associated Engineering (BC) Ltd.
#420 – 1628 Dickson Avenue
Kelowna, B.C., V1Y 9X1

DISTRIBUTION:

1   Copy   -   Associated Engineering (BC) Ltd.
1   Copy   -   Southeast Kelowna Irrigation District
1   Copy   -   Golder Associates Ltd.

November 26, 2007   07-1440-0142

BEST
EMPLOYERS
IN CANADA
2006

50
BEST
MANAGED
COMPANIES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0   INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to provide this report to Associated Engineering (BC) Ltd. (AEBC), presenting the results of a hydrogeological evaluation of subsurface conditions in the area of three existing water wells operated by the Southeast Kelowna Irrigation District (SEKID) in southeast Kelowna, BC. The purpose of this assignment is to assess aquifer and well conditions within the Study Area to determine the feasibility of constructing additional well(s) to operate concurrently with the three existing wells. Based on these results, recommendations can be made regarding the viability and cost effectiveness of utilizing groundwater to increase SEKID's capacity to deliver high quality treated water for domestic consumption for a minimum peak water demand of 21.3 ML/d, and potentially as much as 30 ML/d.

It is understood that this investigation is part of a larger comprehensive study being completed by AEBC for SEKID regarding the assessment of water supply/treatment and system options.

Currently, SEKID operates three separate water wells in southeast Kelowna, which are used for both potable and irrigation demand in the immediate area. The wells are all completed in the same aquifer, which is locally known as the Greater Kelowna Aquifer. A summary of each of the wells is as follows:

- *O'Reilly Well: is located on O'Reilly Road within the Hall Road Subdivision Area. This 300 mm diameter well was drilled in 1981 to 59.5 m depth and is completed with a 7.3 m long screen assembly. The static water level in the well is generally within 16 m of ground surface and the sustainable yield for the well is in the order of 60 L/s. The well is currently pumped at approximately 38 L/s. The specific capacity of the well when it was constructed was approximately 3.1 L/s/m of drawdown.*

- *SEKID Well No. 1: is located approximately 450 m east of the O'Reilly Well on East Kelowna Road. This 300 mm diameter well was drilled in 1986 to 97.5 m depth and is completed with a 12.3 m long screen assembly. The static water level in the well is generally within 52 m of ground surface and the well is reportedly capable of delivering 125 L/s. The well is currently pumped at 60 L/s. The specific capacity of the well when it was constructed was approximately 4.3 L/s/m of drawdown.*

- *SEKID Well No. 2: is also located on East Kelowna Road, approximately 450 m north of Well #1 and 500 m northeast of the O'Reilly Well. This 300 mm diameter well was drilled in 1990 to 128 m depth and is completed with a 12.3 m long screen assembly. The static water level in the well is generally within 58 m of ground surface and the well is reportedly capable of delivering 125 L/s. The specific capacity of the well when it was constructed was approximately 4.9 L/s/m of drawdown. This well is currently pumped at 60 L/s.*

We understand that ongoing water quality testing in all three wells indicates that the source water quality from the aquifer meets the Guidelines for Canadian Drinking Water Quality (GCDWQ).

2.0 METHODOLOGY

In order to provide a preliminary feasibility assessment of the capacity of the local aquifer to provide additional water, Golder completed the following tasks:

Task 1: Information Review

To assess the local hydrogeology, Golder conducted a review of available information for the Study Area, including the review of i) data from available topographic and geological mapping, ii) the BC Ministry of Environment's (BCMoE) Water Resource Atlas (WRA), iii) reports for the Study Area completed by others, and iv) several wide-area hydrogeological reports authored by Golder for the City of Kelowna and the Kelowna Joint Water Committee.

Task 2: Data Analysis

Golder completed a detailed review of the available hydrogeological information to determine the physical characteristics of the aquifer including relative homogeneity and spatial variability in thickness, hydraulic conductivity, transmissivity and storage coefficient. Using these fundamental aquifer characteristics, Golder completed a preliminary assessment of aquifer yield, theoretical well yield, and spacing requirements for optimal well yield and limitation of mutual well interference effects for a well field capable of meeting the projected water demand.

Task 3: Infrastructure Costing

Based on current costs in the water well industry, along with standard maintenance and operational costs for water wells, Golder compiled an estimate of construction, maintenance and monitoring costs, as well as reporting costs, for the additional wells proposed. This information can be used for comparison against other water source options.

Task 4: Reporting

Provide an engineering report, complete with a summary of information reviewed and analysis completed, along with conclusions, recommendations, figures, tables and appendices.

3.0 REVIEW OF AVAILABLE INFORMATION

Golder has completed numerous wide-area hydrogeological studies, as well as site specific hydrogeological and geotechnical studies in the Kelowna area which contribute significantly to the understanding of the hydrogeology in the Study Area for this assignment. The most significant studies of relevance include the following:

- *"Initial Phase Groundwater Protection Planning, Greater Kelowna Aquifer, Kelowna, BC",* report for the Kelowna Joint Water Committee in August 2004 (Golder Project 03-1440-051).

- "*Phase II, Groundwater Protection Plan, Greater Kelowna Aquifer, Kelowna, BC",* report for Kelowna Joint Water Committee in September 2007 (Golder File 07-1440-0013).

- "*Preliminary Assessment of Using Groundwater to Irrigate Municipal Parks in the City of Kelowna*", report for the City of Kelowna Parks Department in September 2007 (Golder File 07-1440-0067).

A significant amount of information from these earlier reports has been incorporated into this report.

3.1   Description of Study Area

The Study Area is located in southeast Kelowna to the south and east of Mission Creek on a plateau formed by the Mission Creek Fan, which has been created by the down-ward erosion of Mission Creek (Figure 1). The topographic relief across the plateau is approximately 125 m, ranging from approximately 530 meters above sea level (masl) at the southeast (highest) portion of the Fan, to approximately 370 masl along the top of the erosional escarpment along the Creek at the northwest limits of the Study Area. The erosional escarpment averages approximately 10 m in height.

The area is predominantly flat and devoid of natural vegetation, owing to extensive agricultural activity. To the west, in the Hall Road Subdivision Area, the Study Area is more densely populated as and treed.

The Study Area represents only a small portion of the total service area covered by SEKID.

3.2   Surficial Geology

The following review is based primarily on previous work completed by Nasmith (1962), Fulton (1976), Roed et al (1995), and Shaw (1999). The surficial geology of the Okanagan Valley (the Valley) is predominated by glacial and post-glacial deposits derived from the erosion by glaciers of the bedrock in the Valley and adjacent upland areas, followed by various stages of deposition. The resultant landforms in the base of the Valley are complex and include alluvial fans, deltas and associated gullies and stream channels. The sediment types associated with the landforms include lacustrine silt and clay, glacial and glacial-fluvial deposits of till, clay, silty sand, sand and gravel and more recent fluvial and alluvial sediments.

Nasmith's paper on the *Late Glacial History and Surficial Deposits of the Okanagan Valley* (1962), is the most detailed paper known to exist for the area and describes the landforms, as well as sediment types, through a sequence of depositional events. The sequence of events is divided into pre-glacial, glacial advance/occupation/ retreat and post-glacial events.

Pre-glacial events in the Study Area include the deposition of sediments (the White Lake Formation) associated with a large river system which flowed through the Valley. The sediments buried a large portion of the existing volcanic terrain. This was subsequently followed by major tectonic activity including uplift and faulting, which created the Okanagan Fault and the complex bedrock geology of the area.

Additional volcanic activity (basalt flows) occurred after the faulting and uplift. Dissection (downward erosion) of the dominant stream channels along the edge of the Valley also occurred during this period.

Glacial advance and occupation was characterized by the buildup of ice across a large area which completely engulfed the Province of British Columbia. The thickness of ice reached as much as 3000 m and the weight of the ice caused scouring of the underlying bedrock. Ice movement in the Valley was influenced by gravity, primarily away from accumulation areas, generally from north to south and from higher to lower elevations.

Glacial retreat was characterized by "down-melting" within the upland areas first and subsequently in the Valley itself. Stagnant ice created blockages, both within the tributaries which drained into the Valley and within the Valley, which resulted in the creation of Glacial Lake Penticton.

Melt water from the glaciers, combined with runoff from creeks and streams draining the plateau, flowed along the margin of the Valley, eroding temporary channels and depositing gravels and sands, sometimes on the edge of the ice and sometimes in ponds blocked in the tributary valleys by the ice. The substantial gravel deposit located along the edge of the Valley to the west of the Kelowna Airport is such an ice-contact deposit.

Mission Creek played a dominant role in the late and post-glacial deposition of sediments in the Study Area, which is not surprising given the large upland area which is drained by the creek in comparison to the other creeks which drain into the Valley. The resultant Mission Creek Raised Fan, which is the dominant landform in the area, was initially formed during the inter-glacial period and subsequently modified during the late glacial and post glacial period. Sand and gravel dominate the proximal portion of the fan where Mission Creek enters the eastern portion of the Valley. Fine sand and silt become more prominent in the distal portion of the fan towards Lake Okanagan and the centre of the Valley. At one time the creek was diverted to the north of the present orientation and deposited sediments between Layer Cake Mountain and Mine Hill along the eastern edge of the Valley, extending to where Scotty Creek is presently situated. The current Mission Creek channel has down cut into the fan deposit.

Lacustrine (lake bottom) deposits associated with Glacial Lake Penticton predominate across the lowest portions of the Valley, where the glaciers remained for the longest time. Considerable re-working of the upper portions of the lacustrine sediments and subsequent mixing with fluvial sediments along the lower beaches of Kelowna Creek has created a fine-grained delta adjacent to Lake Okanagan.

The entire Study Area lies within the lower extremity of the Mission Creek Fan.

4.0   REVIEW OF HYDROGEOLOGY

The following presents a basic review of the hydrogeology in the area as described in the reports referenced in Section 3.

According to the WRA, a total of nine overburden aquifers are documented in the Kelowna Area, consisting of unconfined and confined aquifers. For the purpose of this study, two of the nine aquifers, consisting of Aquifer No. 463 and No. 464, have been collectively grouped into a single aquifer known as the Greater Kelowna (GK) Aquifer. The footprint area of the GK Aquifer is approximately 1,200 ha, and is generally classified by the BCMoE as "IC", indicating heavily developed with low vulnerability. The aquifer vulnerability rating is based on the risk to the aquifer from surface contamination and the low rating indicates the aquifer is confined.

Recharge to the GK Aquifer generally occurs in upland areas, where creeks discharge water into the eastern edge of the Valley. The entire Study Area, including the majority of the Mission Creek Fan, is underlain by the Greater Kelowna Aquifer. All of the SEKID wells are completed in this aquifer.

In addition to the SEKID wells, there are several other wells located to the north, west and southwest, which are completed in the same aquifer. These wells are shown in Figure 2 as Well Tag Number (WTN) 24382 and WTN 41319, as well as Rutland Waterworks District (RWWD) production wells 5, 8, 11, 15 and 16. It is understood that RWWD Wells 5, 11 and 16 are no longer in use by RWWD.

Based on a review of the lithology encountered in each of the above-referenced wells, the aquitard, or confining layer above the aquifer, consists of a sequence of silt, clay and clay till, generally present from 360 masl to 380 masl. The thickness of the aquitard generally increases to the west and the complexity of the aquitard sequence increases to the north.

The thickness of the aquifer is the greatest in the area of the existing wells and appears to diminish both to the southwest and northeast. This lateral trend is typical for fan deposits and suggests the main axis of deposition for the fan is oriented in a southeast-northwest direction as shown in Figure 2. For the three SEKID wells, the aquifer thickness encountered ranges from 26 m in the O'Reilly Well, which is at a lower elevation due to the proximity with Mission Creek, to 34 m at Well No. 2, which is located furthest north. Of particular note is that the driller's log for Well No.2 suggests that the aquifer was not fully penetrated at this location.

Golder has previously reviewed pumping test data for all of the municipal water supply wells completed in the Greater Kelowna Aquifer that are operated by the Kelowna Joint Water Committee (KJWC). A summary of hydraulic characteristics for the SEKID Wells is presented in Table 1, including values for transmissivity (T), aquifer thickness (b) and hydraulic conductivity (K). Values for "T" and "K" are assumed to be within an order of magnitude of the actual values, which is considered acceptable at this level of analysis.

Hydraulic conductivity values for the aquifer at each well location were calculated assuming that transmissivity is equal to the saturated thickness at that location multiplied by the hydraulic conductivity of the aquifer material. The calculated values range from a low of 1.1×10^{-3} m/s at Well #2, to a high of 1.6×10^{-3} m/s at the O'Reilly Well. These values are consistent with hydraulic conductivity data found in the literature for medium to coarse sand (Freeze and Cherry, 1980; Fetter, 1994).

Storage coefficients have been calculated for two of the wells only and range from a low of 6×10^{-4} to a high of 2×10^{-3} (dimensionless). These values fall in the upper range for a confined aquifer system and infer that the aquifer could be leaky.

Based on updated water levels for the wells, as provided by SEKID, the groundwater flow direction and hydraulic gradient within the Study Area has been assessed. The direction of flow is generally from the east and southeast, where Mission Creek enters the Study Area and the upper portion of the Mission Creek Fan exists, towards the west and northwest, at the lower portion of the Fan. The average flow gradient across the study area is 7×10^{-3} (dimensionless). Groundwater equipotentials and the direction of flow are shown in Figure 2.

A preliminary water balance for the Study Area was determined by calculating the approximate flow across the aquifer based on Darcy's Law. This provides an indication of the recharge required to sustain groundwater flow and the water levels in the aquifer. Darcy's Law is dependent on several aquifer characteristics, including hydraulic conductivity, aquifer width and thickness, and the hydraulic gradient, and is presented as follows:

$$Q = K \times W \times b \times i \qquad \text{where: } K = \text{hydraulic conductivity}$$
$$W = \text{aquifer width}$$
$$b = \text{saturated thickness}$$
$$i = \text{hydraulic gradient}$$

Using an aquifer width of 225 m, along with values for the previously determined aquifer parameters including a hydraulic conductivity of 1.3×10^{-3} m/s, a saturated thickness of 30 m and hydraulic gradient of 3×10^{-2}, the annual recharge to the aquifer in the Study Area is estimated to be in the order of 8.3×10^6 m^3/yr.

5.0   SUSTAINABLE YIELD OF EXISTING WELLS

5.1   Well Diameter and Screen Limitations on Sustainable Well Yield

As noted previously, all of the existing wells are completed with 300 mm diameter casing and telescopic well screens within a confined aquifer. Casing diameter can limit the size and capacity of a submersible or vertical shaft pump that can be installed in a well. However, for all wells, the 300 mm diameter casings are not expected to limit pump capacity to below 125 L/s.

The maximum laminar flow capacity for screens in a well, also referred to as the screen transmitting capacity, can also limit the capacity or sustainable yield of a well. Screen manufacturers provide specifications for intake area per unit length of screen as a function of diameter and slot aperture (opening) size. These specifications are used to calculate the maximum flow that can be pumped through the screen under laminar flow conditions, before turbulent flow and potential cavitation will occur.

The calculated laminar flow capacities for the O'Reilly Well, Well No. 1 and Well No. 2 are 91.4 L/s, 134.5 L/s and 100.5 L/s, respectively. The wells should not be pumped at rates exceeding these screen capacities.

5.2   Theoretical Well Capacity

In order to determine sustainable yield for a municipal water supply well, pumping tests should be conducted for a minimum period of 72 hours and the rate of drawdown extrapolated to a period of approximately 100 days (representative of a period where groundwater recharge is minimal) to determine specific capacity after this period. Furthermore, as per the MoE's requirement to comply with the guidelines for a Certificate for Public Convenience and Necessity (CPCN), it is necessary to apply a 30% safety factor, utilizing only 70% of the available drawdown, when estimating the well capacity. According to the CPCN, the theoretical well capacity, also referred to as sustainable yield, is normally estimated as follows:

Q = 0.7 x specific capacity at 100 days x available drawdown in the well

Golder reviewed the original construction and testing reports for the three existing SEKID wells to determine the available drawdown and specific capacity for each. Using this information, the theoretical sustainable yield for the O'Reilly Well, Well No.1 and Well No.2 are 71 L/s, 99 L/s and 188 L/s, respectively. These calculations do not account for mutual well interference created by adjacent wells being pumped concurrently, nor do they account for screen transmitting capacity.

6.0 WELL FIELD ASSESSMENT

It is understood that AEBC is considering expansion of the capacity of the well field to accommodate a peak summer demand of 21.3 ML/d. As such, Golder has conducted a preliminary well field assessment to estimate the number of wells and pumping rates required to meet this demand. The assessment is based on the prediction of drawdown in each pumping well and the drawdown created in the aquifer at the locations where other wells are present. Pumping drawdown and mutual well interference drawdown were then cumulatively added at each location to determine total drawdown.

The addition of wells to meet the projected demand was investigated, based on the limiting criteria that the total drawdown would not exceed 70 percent of the available drawdown in any given well, as per the CPCN methodology for determining sustainable well yield presented in the previous section.

The mutual well interference calculations assume *conservative* values for aquifer parameters, including a value of 0.037 m^2/day for transmissivity and a value of 6 x 10^{-4} (dimensionless) for storage coefficient. Furthermore, the calculations do not account for the influence of water level gradient on the symmetry of the well capture zone that is created. Typically, where a water level gradient is flat, drawdown extends equally (symmetrical) in all directions. Where a gradient exists, the capture zone extends predominantly in the up-gradient direction. Therefore, the methodology that has been used for this Study over-estimates drawdown interference in directions perpendicular to gradient and down-gradient.

Table 1 and Table 2 collectively present the results of the well field assessment. Table 1 is a summary of the existing and proposed well characteristics and Table 2 is a summary of expected mutual well interference with two additional wells (Well No.3 and Well No.4) added to the field.

It is our opinion that it will be possible for a well field in the area of the existing SEKID wells to cumulatively yield up to approximately 27.2 ML/d. Based on our estimates, the combined rate from the three existing wells can easily be increased from 158 L/s (13.7 ML/d) to 185 L/s (16 ML/d), simply by increasing the size of the pumps that currently are installed in these wells. It is also considered feasible to construct two additional wells 500 m and 1000 m to the north of Well No.2, each capable of supplying 65 L/s (5.6 ML/d). Assuming at least one well be out of service at any given time, the four remaining wells (3 existing and 1 new) will be capable of meeting the peak demand of 21.3 ML/d.

It is our understanding that peak demand will occur between mid-April to mid-October and that demand for the remainder of the year will be in the order of 5 ML/d to 6 ML/d.

With regards to meeting the additional demand plateau of 30 ML/d, this volume of extraction will approach or eclipse the annual recharge which occurs in the aquifer within the Study Area, and therefore more wells than the two already proposed in the immediate area are not considered feasible. However, it may be possible to construct one or two smaller capacity wells to the south of the Study Area, to the south of the KLO Bridge across Mission Creek.

7.0   PRELIMINARY GUDI ASSESSMENT

The Province of British Columbia does not have a formal regulation with respect to evaluating if groundwater is considered to be under the direct influence of surface water ("GUDI"). As such, the Ontario Ministry of Environment protocols were followed as outlined in the Ministry document entitled *"Terms of Reference for Hydrogeological Study to Examine Groundwater Sources Potentially Under Direct Influence of Surface Water"* dated October 2001. The document states that community wells are "flagged" as potentially under the direct influence of surface water if they satisfy the following criteria:

- The wells regularly contain Total Coliforms and/or periodically contain E. coli; or

- The wells are located within approximately 50 days horizontal saturated travel time from surface water, or are within 100 m (overburden wells) or 500 m (bedrock wells) of surface water (whichever is greater) **and** meet one or more of the following criteria:

    o Wells may be drawing water from an unconfined aquifer;

    o Wells may be drawing water from formations within approximately 15 m of surface;

    o Wells are part of an enhanced recharge/infiltration project;

    o When the well is pumped, water levels in surface water rapidly change or hydraulic gradients beside the surface water significantly increase in a downward direction;

    o Chemical water quality parameters are more consistent with nearby surface water than local groundwater and/or if they fluctuate significantly and rapidly in response to climatological or surface water conditions.

A GUDI designation would require that the water from the well receive chemically assisted filtration and disinfection (or equivalent treatment processes).

Based on the presently available physical and chemical information, it is our opinion that the existing SEKID wells would *not* be flagged as GUDI. Furthermore, the same confined aquifer, which has a relatively low vulnerability, is expected to exist at the proposed locations for the new wells.

8.0   ESTIMATE OF WELL CONSTRUCTION AND MAINTENANCE COSTS

To allow for a comparison of groundwater against other water source options, an estimate of costs to develop and maintain a network (field) of five wells, including the existing three SEKID wells and two new wells, has been completed. The analysis includes capital costs for construction and testing of two new production wells, and operational costs throughout the expected operational lifespan of the well field. Engineering costs for the supervision and testing of all wells, along with analysis and reporting has been included, as is an estimate of cost for an environmental impact assessment (groundwater), which will be required should the project proceed. A summary of costs is provided below and in the attached Table 3.

8.1   Production Well Construction and Testing

The construction and testing of the proposed production wells is relatively straight-forward. A cost for each well has been compiled based on a target yield of approximately 65 L/sec.

Assuming that roughly the same length of screen assembly that exists in Well No.2 will be required (11 m) and a similar target depth of 140 m, the estimated cost to construct and test a single 300 mm diameter production well, along with engineering supervision and reporting is approximately $155,000. The cost is broken down to approximately $110,000 for the construction of the well, $23,000 for yield testing and $22,000 for engineering supervision and reporting. These estimates must be considered as preliminary, and do not account for the cost of land, pumping equipment, ancillary facilities at the ground surface (i.e., pump house and controls), nor distribution piping from each well to a centralized location (i.e., treatment plant).

Should both of the new wells be constructed and tested as one project, with one drilling/testing contractor and under the supervision of one consultant, there may be some economies of scale realized. Furthermore, the cost of well casing is currently volatile and delays in proceeding with this initiative may result in higher material costs.

8.2   Operation and Maintenance Costs

The expected operational lifespan for a conventional water well is between 35 and 45 years. The lifespan of the well is limited by the corrosion of the steel casing due to oxidation and/or by the encrustation or corrosion of the well screens.

The corrosion of the well casing occurs in the "splash zone", which is the section of the water column inside the well casing between the pumping water level and the non–pumping (static) water level. Eventually, the oxidation in the splash zone will cause holes in the casing, which can allow for the potential contamination of the well.

Due to pressure, chemical and electrical process' which occur at the interface of the well screen with the aquifer, deposition of chemical precipitates is common. This deposition causes encrustation (clogging) to occur in the intake area of the screen, thereby reducing the flow transmitting capacity and the overall well efficiency. In addition to chemical precipitates, iron bacteria can also accumulate on a screen and reduce the intake area.

Corrosion of screens is also possible and this can occur in low pH environments (pH less than 7). Our understanding is that the pH for all of the SEKID wells is greater than 7.

There is little that can be done about corrosion of the well casing in the splash zone; however, regular maintenance of the well screen assembly in a well is critical for maintaining operational efficiency and optimizing the lifespan of a well.

For each of the new wells and the three existing wells, it is proposed to initiate a monitoring program to collect continuous water level and pumping rate data. The data should be analyzed on an on-going basis to determine well efficiency. The monitoring would be used to generate graphs which will summarize the impacts of drawdown on the safe pumping level and specific capacity (efficiency) for each well.

The general principal is to collect the required data, input the information into spreadsheets and look for visual trends to identify, at an early stage, if either the static water level in the aquifer is declining, or specific capacity for each well is declining. As a general rule, a drop in specific capacity exceeding 15%, with no corresponding drop in static water level in the aquifer, will trigger more detailed assessment of the well and likely rehabilitation to recover lost efficiency.

The monitoring program would incorporate a water level transducer and associated electronic data logger in each well to provide continuous level monitoring, and a flow meter such that the pumping rate can be associated with the water level.

The presented data can be used at the early stages of development to identify a significant decline in specific capacity, such that well maintenance can be completed when convenient rather than during a peak demand period. Furthermore, regular rehabilitation of wells to maintain optimum specific capacity (efficiency) can significantly improve operation costs, specifically minimization of power consumption. Driscoll (1986) suggest that maintenance for wells completed in sand and gravel aquifers should be done at a minimum every 2 to 5 years. Based on our knowledge of water quality and wells in the Okanagan Valley, we have assumed that every 5 years is a reasonable frequency.

The costs for implementing monitoring will be in the order of $2,000 per well for equipment and $5,000 per year to analyze data for all the wells.

Well maintenance on a more frequent basis than every 5 years may result in some benefits; however, at a minimum, each well should be done this frequently. Work should be scheduled for only one well at a time so the other three wells can continue to meet the majority of the demand.

While several methods for well rehabilitation exist, which use chemicals and high or low temperatures to shock bacteria growth which can accumulate on screens, we recommend that physical methods be used only. This may require more frequent rehabilitation, but we believe the overall costs will be less as there will be no requirements for mixing and disposal of used chemicals.

The estimated cost to do rehabilitation for a single well in today's dollars is approximately $30,000 to $40,000. This total includes contractor costs to complete a short pre-rehabilitation pumping test, pulling of the pump, high energy down hole air jetting in the screens, well re-development using conventional methods, re-insertion of the pump following the work, and a final short duration pumping test. This also includes engineering supervision and reporting.

Assuming each well will require rehabilitation 6 times over an average expected operational lifespan of 30 years and allowing for inflation, the total costs for maintenance of a single well over its lifespan is in the order of $240,000, not allowing for yearly inflation.

This does not include costs for replacement and maintenance of pumps, nor maintenance of electrical controls and the pump house. We have assumed these will be provided by AEBC.

9.0   GROUNDWATER ENVIRONMENTAL IMPACT ASSESSMENT

Should this project proceed, and the quantity of groundwater utilized by SEKID is increased by more than 63 L/s, an environmental assessment and approval process will be required as per the BC Environmental Assessment Act (BCEAA) – Reviewable Projects Regulation (BC Regs. 370/2002). The scope of work required for the environmental assessment is determined at the initial stages of the process through consultation with BCEAA office (BCEAO). The costs for corresponding with the BCEAO to establish the scope of work, the completion of the environmental assessment and any public consultation cannot be determined at this point; however a preliminary estimate is in the range of $30,000 to $50,000. It must also be noted that if funding is secured for the well construction or ancillary facilities through the Canada / British Columbia Infrastructure Program, or another Federal Government grant program, this may trigger the need for a parallel environmental assessment under the Canadian Environmental Assessment Act (CEAA). The requirements for scope identification, reporting and public consultation under the CEAA are relatively similar and the costs to complete the additional report are not expected to add more than $25,000.

Therefore, the total costs for environmental impact assessments for the project are expected to be in the range of $30,000 to $75,000. These estimates will need to be revised based on discussions with the provincial and federal governments.

The process can take between 6 months and 1.5 years to complete, depending on which provincial and federal agencies are involved.

10.0   RECOMMENDATIONS

Based on the information available, analysis completed and conclusions made in the previous sections, the following recommendations are made:

1. It is recommended to drill two new production wells at locations 500 m and 1,000 m north of the existing SEKID Well No.2. The target depth for the new wells is 140 m and the target design yield is 65 L/s.

2. Should SEKID determine that they are proceeding with the potential withdrawal of over 63 L/s, an environmental assessment would be required as per the BC Environmental Assessment Act. Costs for environmental assessment work will be a function of project-specific requirements outlined by the BCEAO.

Golder Associates

11.0 LIMITATIONS

This report was prepared for the exclusive use of the Southeast Kelowna Irrigation District and Associated Engineering (BC) Ltd. The report is intended to provide an assessment of groundwater availability in the area of the existing SEKID Wells in southeast Kelowna. Calculations for sustainable yield, drawdown and specific capacity have been made based on the condition of the wells at the time of construction. The actual drawdown measured in the wells will depend on well construction, pumping rate, and well efficiency in addition to aquifer hydraulics. It is typical for wells to realize decreasing efficiency over time due to precipitation of dissolved chemicals or sedimentation in the well. Periodic maintenance of wells may alleviate these problems. Golder makes no prediction concerning the effect of decreasing well efficiency on well yields.

The investigation was performed according to current professional standards and practices in the groundwater field. The assessment of groundwater conditions presented has been made using historical and technical data collected and information from sources noted in the report.

The predictions regarding potential impacts are based on a reasonably good understanding of the current conditions at the Site. If new information is discovered during future work, including excavations, borings or other studies, Golder should be requested to provide amendments as required.

In evaluating the groundwater resources in the area, Golder has relied in good faith on information provided by the drilling contractors, the pumping test contractors and other parties noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracies contained in this report as a result of omissions, misinterpretations or fraudulent acts of others.

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

12.0   CLOSURE

We trust the foregoing provides the information you need at this time. Should you have any questions or require additional information, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.
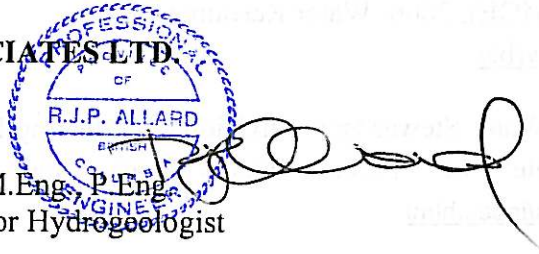
Remi J.P. Allard, M.Eng., P.Eng.
Associate and Senior Hydrogeologist

Don Chorley, M.Sc., P. Geo.
Principal and Senior Hydrogeologist

RA/DC/km

http://capws/071440042associatedEngineeringgroundwaterPotentialkelowna/Reports/WP_Final/SEKID Final report Nov 23-07.doc

REFERENCES

BC Ministry of Energy, Mines and Petroleum Resources,
http://webmap.em.gov.bc.ca/mapplace/minpot/bedrock_publications.asp

BC Ministry of Environment (MOE), 2006. Water Resources Atlas.
http://srmapps.gov.bc.ca/apps/wrbc/

BC Ministry of Environment, Water Stewardship Division, "Evaluating Long Term Well Capacity for a Certificate of Public Convenience and Necessity" - http://wlapwww.gov.bc.ca/wat/gws/index.html

Church, B.N. (1980) Geology of the Kelowna Tertiary Outlier (West Half), Province of British Columbia, Department of Energy, Mines and Petroleum Resources, Preliminary Map 39

Church, B.N. (1981) Geology of the Kelowna Tertiary Outlier (East Half), Province of British Columbia, Department of Energy, Mines and Petroleum Resources, Preliminary Map 45

Driscoll, Fletcher, Johnson Filtration Systems Inc., 1986, *"Groundwater and Wells, Second Edition"*

Energy, Mines and Resources Canada, Penticton 82 E/5, Edition 3, 1981

Environment Canada, Canadian Climate Normals or Averages 1971 - 2000 http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

EBA Engineering Consultants Ltd. (1997) Hydrogeological and Geotechnical Assessment for Stormwater Management and Planning, City of Kelowna, report for the City of Kelowna, 24 pages plus appendices and maps

Fetter, 1994. Applied Hydrogeology, 3rd Edition, Prentice-Hall, New Jersey, USA, 691 pages

Freeze and Cherry, 1979. Groundwater. Prentice Hall. Upper Saddle River, New Jersey, USA, 432 pages

Golder Associates Ltd. 2002. *"Initial Phase Groundwater Protection Planning, Greater Kelowna Aquifer, Kelowna, BC"* (Golder Project 03-1440-051).

Golder Associates Ltd. 2007. *Preliminary Assessment of Using Groundwater to Irrigate Municipal Parks in the City of Kelowna (*Golder Project 07-1440-0067).

Golder Associates Ltd. 2007. *Phase II, Groundwater Protection Plan, Greater Kelowna Aquifer, Kelowna, BC",* draft report for Kelowna Joint Water Committee in September 2007 (Golder File 07-1440-0013).

Health Canada, 2006. Guidelines for Canadian Drinking Water Quality. Sixth Ed., Updated Online March 2006. http://hc-sc.gc.ca/ewh-semt/pubs/water-eau/doc_sup-appui/sum_guide-res_recom/index_e.html

Kala Groundwater Consulting Ltd. (January 1991) South East Kelowna Irrigation District - East Kelowna Road - Well No. 2, report for South East Kelowna Irrigation District, 22 pages plus appendices (incomplete copy of report)

Kala Groundwater Consulting Ltd. (March 1986) South East Kelowna Irrigation District - East Kelowna Road - Well No. 1, report for South East Kelowna Irrigation District, 22 pages plus appendices

Lowen, D.A. and Letvak, D.B. (1981) Report on Groundwater-Surface Water Interrelationship, Lower Mission Creek, B.C., BC Ministry of Environment - Water Management Branch, Queens Printer Province of British Columbia, 19 pages plus maps

Naismith (1962) Late Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia, Department of Mines and Petroleum Resources, Queens Printer Province of British Columbia, 46 pages plus maps

Ontario Ministry of Environment, 2001. "*Protocol for Delineation of Wellhead Protection Areas for Municipal Groundwater Supply Wells Under Direct Influence of Surface Water.*" A Guideline Document for the Ontario Drinking Water Protection Regulation. 5 pages

Ontario Ministry of Environment, 2001. "*Terms of Reference – Hydrogeological Study to Examine Groundwater Sources Potentially Under Direct Influence of Surface Water.*" A Guideline Document for the Ontario Drinking Water Protection Regulation. 6 pages

Pacific Hydrology Consultants Ltd. (June 1981) Construction and Testing of 12 Inch (305 mm) Production Well Eldorado Estates Subdivision, report for Southeast Kelowna Irrigation District, 6 pages plus attachments

Roed et al (1995) Geology of the Kelowna Area and Origin of the Okanagan Valley, British Columbia, Kelowna Geology Committee, 183 pages

Shaw, J. (1998) Geomorphology and Sedimentary Sequences of the North Okanagan Valley/Okanagan Lake Area, Alberta Geomorphology Field Group - Annual Field Trip Notes for 1998, Department of Geology, University of Alberta, unpublished, 31 pages
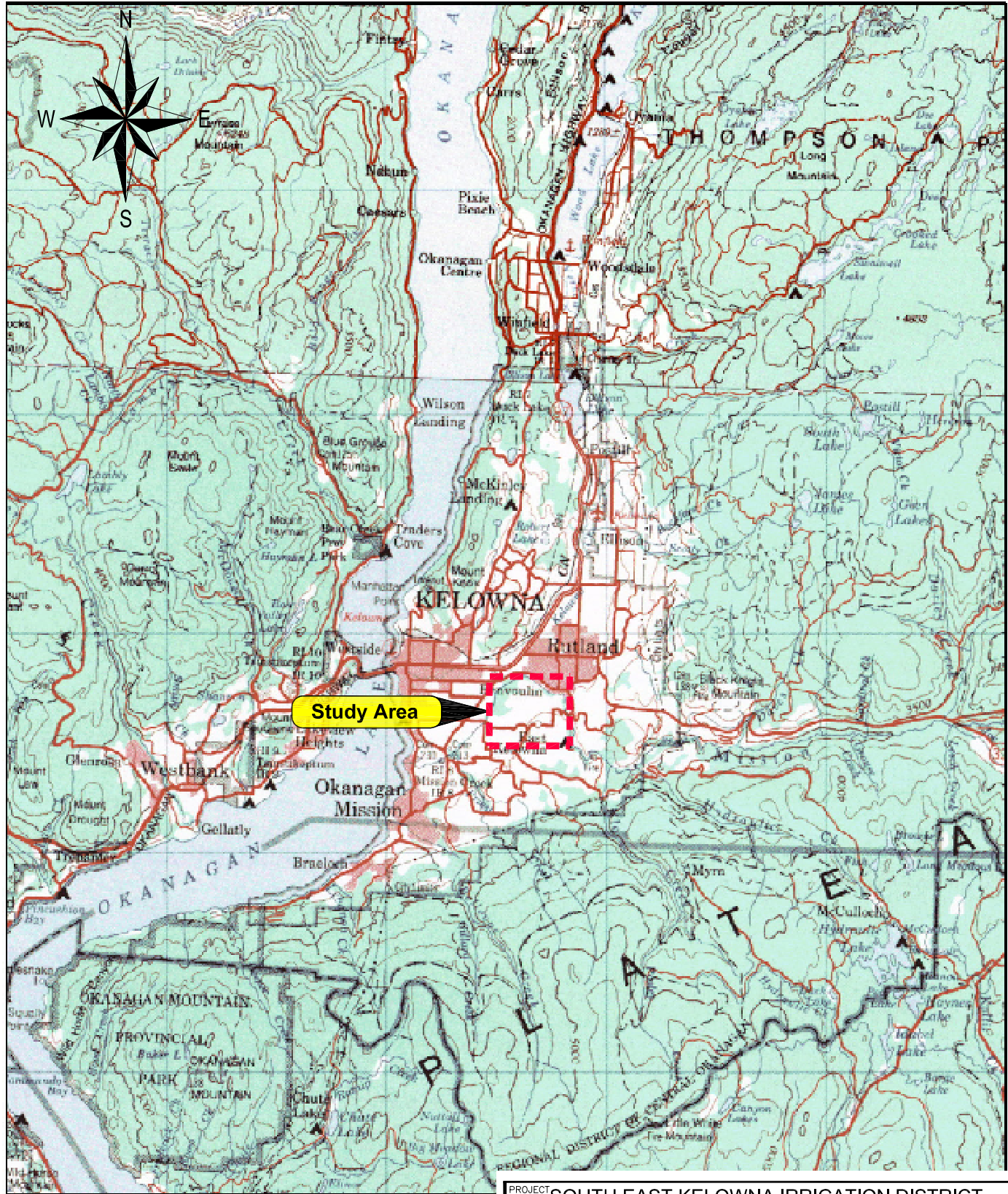
Study Area
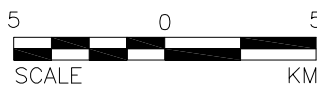
REFERENCE

Map reference: Produced under licenses granted by Her Majesty the Queen in right of Canada, represented by the Department of Natural Resources, and by SoftMap Technologies Inc.

5 0 5
SCALE   KM

PROJECT **SOUTH EAST KELOWNA IRRIGATION DISTRICT**
HYDROGEOLOGICAL ASSESSMENT
KELOWNA, B.C.

TITLE

KEY PLAN

Golder Associates
Kelowna, BC

PROJECT No. 07-1440-0142(2000)	FILE No. 0714400142_2000_1.dwg
DESIGN	RA	28/SEPT/07	SCALE	1:250,000	REV.	0
CADD	JG	28/SEPT/07				
CHECK			**FIGURE: 1**			
REVIEW						

LEGEND

- LOCATION OF MUNICIPAL WATER WELLS
- WTN   LOCATION OF PRIVATE WELLS (APPROX.) & WELL TAG NUMBER / IDENTIFICATION
- INFERRED AXIS OF MISSION CREEK FAN (THICKEST PART OF AQUIFER)
- INFERRED GROUNDWATER LEVEL EQUIPOTENTIAL (INTERVALS AS LABELLED)
- INFERRED 1 YEAR TIME-OF-TRAVEL CAPTURE ZONE
- INFERRED GROUNDWATER FLOW DIRECTION

REFERENCES

1.) GOOGLE EARTH IMAGERY
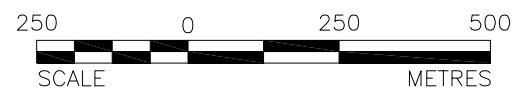
SCALE 250 0 250 500 METRES

PROJECT
SOUTH EAST KELOWNA IRRIGATION DISTRICT
HYDROGEOLOGICAL ASSESSMENT
KELOWNA, B.C.

TITLE
WELL LOCATIONS & WATER LEVEL EQUIPOTENTIALS IN GK AQUIFER IN SOUTH EAST KELOWNA

Golder Associates
Kelowna, BC

PROJECT No. 07-1440-0142(2000)		FILE No. 0714400142_2000_2	
DESIGN	RA	25/SEPT/07	SCALE 1:12,500 REV. 0
CADD	JG	25/SEPT/07	
CHECK			
REVIEW			**FIGURE: 2**

Table 1
Southeast Kelowna Irrigation District
Summary of Existing and Proposed Well Characteristics

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Well	Surface Elevation (masl)	Depth (m)	Static Water Level (m)	Saturated Thickness (m)	Hydraulic Conductivity (m/s)	Transmissivity (T=kb) (m²/s)	Storage Coefficient (dimensionless)	Specific Capacity (L/s/m)	Available Drawdown (m)	Max Rated Yield (L/s)	Screen Capacity (L/s)	Current Rate Pumped (L/s)	Recommended Future Rate (L/s)	Recommended Future Rate (ML/d)
O'Reilly	393	59.5	13.5	26	1.60E-03	0.0416	6.00E-04	3.1	33	60	90	38	45	3.89
Well #1	425	97.5	52	31	1.30E-03	0.0388	2.00E-03	4.3	33	125	135	60	65	5.62
Well #2	433	128	58	34	1.10E-03	0.0359	N/A	4.9	55	125	100	60	75	6.48
New Well #3		140	50	30	1.40E-03	0.035	6.00E-04		40				65	5.62
New Well #4		140	50	30	1.40E-03	0.03	6.00E-04		40				65	5.62

Total Current Withdrawls =	158
Total Proposed Withdrawls (l/s) =	315
Total Proposed Withdrawls (ML/d) =	27.22

Notes:

(1) Peak water demand is 21.3 ML/d, which can be met using 4 of the 5 wells, with the 5th out of service for maintenance or backup (if needed).

(2) Based on mutual well interference, all five wells could be used for very short periods, but not for the entire year due to the annual volume of water recharge to the aquifer in this area.

(3) Well construction details and hydraulic characteristics as reported in original well construction and testing report

(4) Screen capacity as calculated using manufacturers technical specifications. Note well yield should not exceed laminar flow transmitting capacity of the screen assembly.

(5) Current rates that wells are pumped are as reported by SEKID staff

(6) Proposed wells to the northwest of existing SEKID wells, with inferred characteristics based on trend in aquifer thickness, static water level and hydraulic conductivity

Table 2
Southeast Kelowna Irrigation District
Summary of Expected Mutual Well Interference with Additional Wells

Pumping Rate (L/s)	Well	Spec. Cap. (L/s/m)	CURRENTLY OPERATING WELLS						PROPOSED NEW WELLS			
			O'Reilly		WELL #1		WELL #2		WELL #3		WELL #4	
			Distance	Drawdown	Distance	Drawdown	Distance	Drawdown	Distance	Drawdown	Distance	Drawdown
Current Withdrawls												
38.0	O'Reilly	3.1	0.3	12.29	450	0.70	500	0.70				
60.0	Well #1	4.3	450	1.10	0.3	13.95	450	1.10				
60.0	Well #2	4.9	500	1.10	450	1.10	0.3	12.24				
Total Drawdown				14.49		15.75		14.04				
Available Drawdown				33.00		33.00		55.00				
70% Avail drawdown				23.10		23.10		38.50				
Drawdown Acceptable (Y/N)				Y		Y		Y				
Proposed Withdrawls												
45.0	O'Reilly	2.8	0.3	16.07	450	0.83	500	0.81	950	0.70	1400	0.62
65.0	Well #1	4.3	450	1.20	0.3	15.12	450	1.20	950	1.00	1400	0.90
75.0	Well #2	4.9	500	1.40	450	1.40	0.3	15.31	500	1.40	1000	1.15
65.0	Well #3	4.6	950	1.00	950	1.00	500	1.20	0.3	14.13	500	1.20
65.0	Well #4	4.6	1400	0.90	450	1.20	1000	1.00	500	1.20	0.3	14.13
Total Drawdown				20.57		19.55		19.52		18.43		18.00
Available Drawdown				33.00		33.00		55.00		33.00		33.00
70% Avail drawdown				23.10		23.10		38.50		23.10		23.10
Drawdown Acceptable (Y/N)				y		y		y				

Notes:
(1) All measurements for distance and drawdown are in meters
(2) Calculations based on relatively homgeneous aquifer characteristics, including transmissivity of 3.74E-02 m2/s, storage coefficient of 6.00E-4 and boundaries at infinite extent
(3) Calculation based on maximum pumping rate for 100 days duration with no recharge to aquifer
(4) Calculations do not account for directional influence of gradient and are therefore conservative with respect to predicted drawdown at right angles to gradient
(5) Calculations assume that new wells are at locations shown in Figure 2. Changes to the locations and rates pumped will require re-calculation of the mutual well interference.
(6) Specific capacities for existing wells are based on pumping tests completed when wells were constructed and do no account for diminshing specific capacity, which generally occurs over the lifetime of a well due to encrustation of precipitates and iron bacteria on well screens. Regular maintenance is required to minimize diminishing specific capacity
(7) Calculation based on maximum pumping rate for 100 days duration with no recharge to aquifer
(8) Drawdown in existing wells at current pumping rates is based on specific capacity information from original well construction reports
(9) Predicted drawdown at higher pumping rates is extrapolated assuming specific capacity (well efficiency) will decrease by the ratio of recommended (higher) pumping rate divided by current pumping rate
(10) Predicted drawdown for new wells based on conservative specific capacity (4.6 L/s/m), which is lower than the measured specific capacity in Well 2 (5.2 L/s/m) AND less than a projected specific capacity of 4.9 L/s/m at 75 L/s.
(11) Current conditions assume existing wells pumping at historical rates
(12) Recommended conditions assume existing wells pumped at recommended (higher than historical) rates and new wells pumped at recommended rates
(13) Available drawdown defined as height of water from top of screens to static water level, OR, bottom of aquifer confining unit to static water level
(14) Total drawdown is sum of drawdown produced by pumping well and interference drawdown produced by other wells operating simultaneously

Table 3
Southeast Kelowna Irrigation District
Summary of Well Construction, Maintenance and Environmental Assessment Costs

Task		Engineer Fees	Pumping Test Contractor	Drilling Contractor	Well Equipment and Chemical Analyses	Total Costs
Production Well Construction and Testing		$22,000	$23,000	$110,000	NA	$155,000 for single production well
Operation and Maintenance Costs	Well Monitoring Program	$5,000	NA	NA	$2,000 per well	$15,000 for five wells
	Rehabilitation	$30,000 to $40,000 per well			NA	$240,000 per well over the lifetime of a single well
Groundwater Environmental Impact Assessment		NA	NA	NA	NA	$30,000 to $75,000