Re-evaluating the aquifer hydraulic properties within the Okanagan Valley, British Columbia, Canada

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ABSTRACT
This paper reports on the results of a comprehensive re-evaluation of available pumping test data collected within the Okanagan Basin in south-central British Columbia, Canada. As part of the Groundwater Assessment of Okanagan Basin (GAOB) project, well construction reports and consulting hydrogeology reports housed in local government offices were collected. These included close to 158 pumping test reports, which consisted of single well response tests, tests with one or more observation wells, or multiple tests conducted on the same well with a short time period or with an interval of years between the tests. These pumping tests were re-analyzed using a consistent methodological approach, involving use of the derivative method to identify the different flow regimes (e.g., radial, linear) and the application of appropriate analytical methods to estimate the hydraulic properties. In addition to estimating the aquifer hydraulic properties, specific capacity and long-term yield were evaluated, and potential boundary conditions identified. The resulting hydraulic properties were interpreted by relating them to the six main aquifer types identified in the Cordillera Region. The results from this work will be used by researchers doing hydrogeological modelling throughout the Okanagan Basin and to further general understanding of aquifer characteristics in the Okanagan.

RESUME
Ce document fait état des résultats d'une réévaluation en profondeur des données d'essais de pompage disponibles recueillies du bassin de l'Okanagan, dans le centre sud de la Colombie-Britannique, au Canada. Dans le cadre d'évaluation des eaux souterraines du bassin de l'Okanagan (communément appelé GAOB, pour Groundwater Assessment of Okanagan Basin), les rapports portant sur la construction de puits et les rapports de consultation en hydrogéologie conservés dans les bureaux des gouvernements locaux ont été utilisés. Ces documents comprenaient tout près de 158 rapports d'essais de pompage, lesquels consistaient en des tests d'intervention sur des puits uniques, des essais avec un puit d'observation ou plus, et des essais multiples menés sur le même puits sur une courte période, ou espacés de quelques années. Ces essais de pompage ont fait l'objet d'une nouvelle analyse suivant une approche méthodologique pour laquelle on a eu recours à une méthode dérivative pour déterminer les divers types d'écoulement (radial, linéaire et autres) et puis méthodes analytiques appropriées pour évaluer les propriétés hydrauliques. En plus d'estimer les propriétés aquifères hydrauliques, la capacité spécifiques et les apport à long-terme ont été évalués et les frontieres potentielles ont été établies. Les propriétés hydrauliques résultantes ont été interprétées en les reliant aux six grands types aquifères identifiés dans la région cordillère. Les résultats de ce travail seront utilisés par les chercheurs effectuant de la modélisation hydrogéologique dans tout le bassin de l'Okanagan et pour progresser dans la compréhension des caractéristiques aquifères de l'Okanagan.

1 INTRODUCTION

The Okanagan Basin is a north-south trending valley in the Interior Plateau of British Columbia, Canada (see Figure 1). The area of the Basin is 8046 km^2 (Neilson-Welch and Allen, 2007). Distinct physical features of the Basin include: the highland areas that form the boundaries of the Basin; the benchlands and kame and outwash terraces; and the base of the valley, consisting of a series of lakes (the largest ones being Okanagan Lake, Woods Lake, and Kalamalka Lake) and the Okanagan River floodplain, alluvial fans and deltas.

The Okanagan Basin has a dry continental climate with mild winters and hot summers (Cohen et al. 2004). The valley bottom is semi-arid, with a climate gradient trending along the length of the valley from north to south. On a basin-wide scale, annual precipitation averages approximately 600 mm/year (Summit, 2005), but varies within the base of the Valley from 410 mm/year in Vernon in the North Okanagan to 328 mm/year in Oliver in the South Okanagan. Precipitation also increases with elevation in the Basin.

Snow accumulations during the winter months are important for recharge during the spring and early summer as the snow melts. Groundwater recharge in the upland areas occurs primarily during spring snowmelt when evapotranspiration losses are at a minimum. In the valley bottom, groundwater recharge is primarily during the early spring. Overall, however, direct recharge to Valley bottom aquifers is limited (Liggett and Allen, 2008; Smerdon et al., 2008). High daily rainfall in the summer from local convection storms is recorded, but most of this precipitation is not available for recharge due to high evapotranspiration (Toews, 2007). Groundwater levels respond accordingly to seasonal recharge; they are at their lowest in the winter and highest in the late spring and early summer.

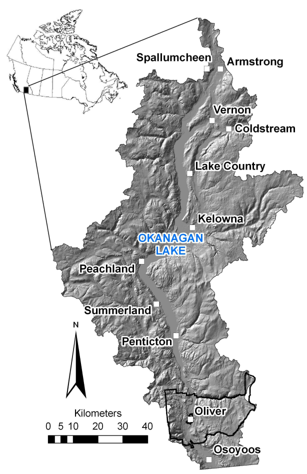

Figure 1. Location maps showing the Okanagan Basin in British Columbia, Canada (map courtesy of J. Liggett).

The Okanagan Basin is a well populated valley and the current population is greater than 350,000 and it is anticipated that the population will exceed 500,000 by 2020. The current and predicted water demand impart a considerable stress on the limited water resources in the basin, especially considering the competing demands between agricultural irrigation needs for crops such as grapes, and the potable water needs of an increasing urban population.

Having a better understanding of the occurrence and distribution of groundwater in the Basin is crucial to assisting communities with long-range planning and protection of their existing water resources. A regional partnership project, the Groundwater Assessment in the Okanagan Basin (GAOB) project, was initiated in 2004 to gain a better understanding of the groundwater resources in the Basin. The GAOB project involves federal, provincial and local governments as well as universities and professional organizations.

One component of the GAOB project has focussed on collecting and analyzing data from pumping tests conducted in wells throughout the Basin in order to characterize the hydraulic properties of aquifers in the region. This paper describes the methods used to re-evaluate existing well pumping test data, and summarizes the hydraulic properties of the main aquifer types that have been identified in the Okanagan Basin.

2 METHODOLOGY

Pumping test data (including recovery test data) were obtained from consultant's reports collected from local governments in the Okanagan Basin, as well as from the Ministry of Environment (MoE) well record and groundwater reports library for the period 1964 to 2004. The pumping tests were generally conducted in higher capacity wells serving multiple users, such as municipal drinking water supplies, water utilities or irrigation districts, but also in several private domestic wells. Not all pumping tests collected were analyzed due to the limited quality of some of the pumping test data, e.g. the pumping duration was too short or the extreme variability of the pumping rate rendered the data unusable. Constant pumping rates were observed in only 40% of the pumping tests. In tests where the pumping rate was not constant, a weighted average pumping rate was used for hydraulic property calculations.

Pumping test data and well information were recorded in a consistent format in Excel worksheets under the following categories: well and location information, aquifer classification information (including aquifer attributes and hydrogeological setting), summary of the well characteristics, interpretation of drawdown and recovery water level behaviour during and after the pumping test, pumping test calculation values, and summary results. Hydraulic properties such as transmissivity, storativity, hydraulic conductivity, specific capacity and long-term well capacity were included in the summary results. In addition to the summary data, each worksheet contained all the graphs used to estimate the hydraulic properties and were annotated to show the period(s) of radial flow and any other relevant points related to the analysis of the pumping test.

To facilitate the interpretation of the test data, time-drawdown data from pumping tests were first analyzed using the derivative method (Spane and Wurstner, 1993; Allen, 1999). Then, various analytical models were applied over the appropriate time periods following methods outlined in Allen (1999). The derivative method involves plotting the first derivative of drawdown versus time on a log-log plot (or semi-log plot). This curve can be used to identify the different flow regimes (e.g., radial, linear), and specifically the period(s) of infinitely acting radial flow to the well (Allen, 1999). Once the radial flow period is identified, standard analytical methods for radial-type flow in confined aquifers can be applied over the specific time interval identified from the derivative curve. Both curve matching (e.g., Theis) and straight-line (Cooper-Jacob) methods were used to calculate the transmissivity and storativity of the aquifer. Recovery data were analyzed using the same time period identified during the pumping part of the test.

Table 1. Types and sub-types of aquifers in British Columbia.

Type	Description of aquifer materials	Subtype description
Unconsolidated aquifers		
1	Predominantly unconfined aquifers of fluvial or glaciofluvial origin, along river or stream valleys[1]	1a. Aquifers along major rivers of higher stream order
		1b. Aquifers along rivers of moderate stream order[1]
		1c. Aquifers along confined, lower order (< 3-4) streams
2	Predominantly unconfined deltaic sand and gravel aquifers	
3	**Predominantly unconfined alluvial fan, colluvial sand and gravel aquifers[1]**	
4	Sand and gravel aquifers of glacial or pre-glacial origin[1]	**4a. Predominantly unconfined sand and gravel aquifers of glaciofluvial origin[1]**
		4b. Predominantly confined sand and gravel aquifers of glacial or pre-glacial origin[1]
		4c. Predominantly confined sand and gravel aquifers associated with glaciomarine environments
Bedrock aquifers		
5	Sedimentary rock aquifers	**5a. Fractured sedimentary bedrock aquifers[1]**
		5b. Karstic limestone aquifers
6	Crystalline bedrock aquifers	6a. Flat-lying or gently-dipping volcanic flow rock aquifers
		6b. Crystalline granitic, metamorphic, meta-sedimentary, meta-volcanic and volcanic rock aquifers[1]

[1]**Pumping test data were analyzed from this aquifer type in the Okanagan Basin study**.

In addition, other types of flow conditions were identified using the derivative plot (e.g. borehole storage, transition flow, and boundary conditions). The period over which borehole storage was observed was not considered during analysis. Similarly, transition flow was identified and used to constrain the analysis for unconfined aquifers using the Neuman method.

For the purposes of determining hydraulic conductivity from transmissivity estimates, the aquifer thickness for unconsolidated aquifers was assumed to be the screen length of the well. For fractured aquifers, hydraulic conductivity was calculated assuming 5% of the open hole thickness below the static water level as the effective aquifer thickness.

Long-term well yield was calculated utilizing the Ministry of Environment's method of extrapolating, on a semi-log plot, the drawdown trend at the end of the pumping test to 100 days and multiplying the specific capacity (pumping rate divided by drawdown) by 70% of the total available drawdown in the well (BCMoE, 1999). For a well completed in fractured bedrock, the total available drawdown was taken from the static water level to the upper-most major water-bearing fracture (usually determined from the driller's well construction report). For a well completed in unconsolidated materials, the total available drawdown was taken from the static water level to the top of the screen assembly. In cases where the calculated long-term well yield was higher than the rate at which the well was pumped, the pumping rate for the test was assigned as the calculated long-term yield for the well—there were 90 wells where this occurred.

In order to put the results of the pumping test analyses into a framework to allow comparisons, the pumping test wells were correlated to a provincially mapped and classified aquifer, where possible (Table 1). As well, tests were associated with aquifer types found within the Cordillera Region of Canada (Table 1). Wei et al. (2007) identified six main aquifer types (four with sub-categories) based on geologic and hydrologic considerations (Figure 2):

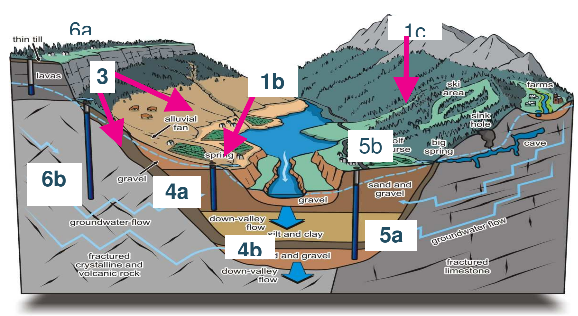

Figure 2. Aquifer types in a typical interior basin environment such as the Okanagan Basin (graphic courtesy of the Geological Survey of Canada).

3 RESULTS AND DISCUSSION

Data from 158 pumping tests were re-analysed to derive estimates of the hydraulic properties of the aquifer. At ten sites, two or more pumping tests were done (3 wells had 3 pumping tests completed). Repeat tests were completed on three wells in the same month. In seven wells, pumping tests were one to 20 years apart. One or more observation wells were used in 31 of the pumping tests—however, only four pumping tests had two or more observations wells.

3.1 Characteristics of Study Wells

A total of 44 (28%) of the wells investigated were completed in bedrock and 114 (72%) were in unconsolidated aquifers. Sixteen pumping tests involved flowing artesian wells, including 6 flowing wells completed into bedrock.

Summary statistics for well depth and static water level at the well site are reported in Table 2 according to aquifer type. Well depths varied according to aquifer type, with the deepest wells found in Type 6b (crystalline bedrock) aquifers and the shallowest wells found in Type 1b unconfined aquifers along mid-order streams. Static water levels also varied according to aquifer type, again with the deepest static water level being associated with Type 6b aquifers and the lowest with Type 1b aquifers. The large range of values for both well depth and static water level for bedrock aquifers is likely due to the differences in fracturing encountered during drilling. It is not uncommon to find two bedrock wells located in close vicinity to one another having different depths and static water levels.

Table 2. Number of wells, reported well depths and static water levels according to aquifer type.

	Aquifer Type					
	1b	3	4a	4b	5a	6b
# wells	11	6	43	62	3	44
Well depth (meters)						
Max	23	77	153	152	45	180
Min	11	27	9	9	34	30
Mean	17	56	36	55	40	105
Median	17	60	28	57	43	113
Static Water Level (meters)						
Max	7	10	153	85	37	73
Min	2	12	9	-6	-1	-14
Mean	4	8	36	14	15	18
Median	3	11	28	10	9	9

Estimated well yields were reported by the well driller at the time of well development for 86 of the study wells. A comparison was done between the driller's estimated well yield and the long-term well yield calculated from the pumping test. Long-term and driller estimated well yields are shown in Figure 3. The graph shows that for wells with long-term yield of <50 USgpm, the driller's estimated well yield tended to be higher than the calculated long-term yield, although there were several tests where the opposite occurred. For wells with higher long-term yield, there appears to be fairly good agreement between the driller's estimated yield and the calculated long-term yield. Although the driller's estimated yield may be a reasonable approximation of well productivity, a pumping test is still essential to determine hydraulic parameters and boundary conditions, both of which provide greater information to assess the long-term sustainable well yield.

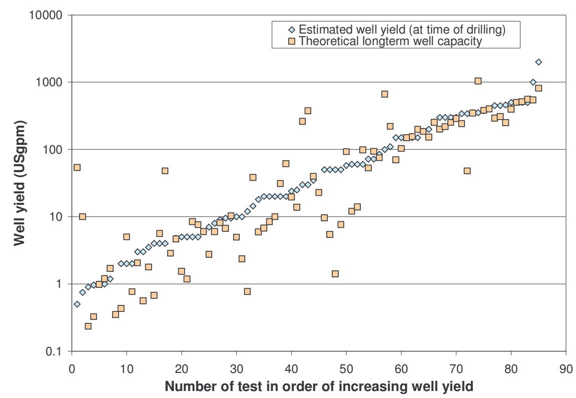

Figure 3. Comparison of driller's estimated well yield and calculated long-term yield (n=86).

3.2 Pumping Test Flow Conditions

Pumping test results are discussed below in order of the flow regimes typically encountered over the course of a pumping test.

Radial flow occurs when groundwater flows toward a pumping well radially from all directions in the aquifer (Driscoll, 1986). Common methods of analysis, including Theis and Cooper-Jacob for confined aquifers, assume that radial flow occurs over the duration of the test. Radial flow is also assumed to be infinitely acting because the conceptual model for these methods shows the aquifer to extend to infinity in all directions. Rarely, however, are these conditions met in a particular aquifer. Typically, there are borehole storage effects during the initial stages of a pumping test, in which drawdown in the pumping well may be influenced by the removal of water that is stored within the well casing (Driscoll, 1986). There may also be linear periods of flow associated with fractures (Allen, 1999), periods over which the flow approaches radial conditions, and boundary effects. As mentioned above, the derivative method was used to identify these various flow regimes.

Borehole storage was not observed during the pumping tests for 75 wells (22 bedrock and 53 unconsolidated). However, often data were missing at the beginning of the pumping test so it was hard to determine whether borehole storage effects occurred or not. Borehole storage intervals ranged from 0.25 to 200 minutes, with an average interval of 17 minutes. For some pumping tests, where the well had a large borehole storage volume (i.e., a large diameter), the pumping rate at the beginning of the test was increased to pump this storage volume and then decreased for the remainder of the test.

The percentage of the pumping test over which radial flow was observed is indicated for each of the aquifer types in Table 3. In 26 pumping wells radial flow occurred for 95-100% of the pumping test—16 of these wells were completed into confined glaciofluvial aquifers (Type 4), suggesting that these types of aquifers generally meet the assumptions inherent to the Theis and Cooper-Jacob methods of analysis (i.e., they are confined, of large extent, etc). The results show that pumping tests conducted in unconsolidated aquifers, in general, achieve radial flow over a longer proportion of the test, while radial flow occurs only over a relatively small proportion of the test in bedrock aquifers. This is not surprising given that pumping tests in fractured bedrock aquifers are commonly strongly influenced by major fracture zones that result in linear flow (Allen, 1999). It is unclear why Type 1a aquifers (adjacent to streams) have the greatest proportion of the pumping test with radial flow. Due to their proximity to streams, one might expect a positive (recharging) boundary effect (as discussed below) to dominate the later part of the test. These aquifers may simply be of larger extent, relative to the Type 3 and 4 aquifers, and thus, may approach infinitely acting radial flow.

Table 3. Summary of radial flow characteristics from pumping tests by aquifer type.

Aquifer Type	Average % of Radial Flow in a Pumping Test (min)	Median % of Radial Flow in a Pumping Test (min)
1b	70%	80%
3	49%	40%
4a	48%	42%
4b	52%	55%
5a	35%	10%
6b	26%	10%

There were eight wells where no radial flow was observed – these tests ranged from 660 to 27360 minutes (<0.5 to 19 days) in duration. In 45 wells, more than one period of radial flow was observed. Often, the establishment of a second period of radial flow was attributed to changes in the pumping rate. For example, these tests were similar to step tests in that radial flow was established over each interval in which the pumping rate changed. Fifteen (30%) of the wells that exhibited more than one period of radial flow were bedrock wells, indicating that potentially more than one water bearing fracture was encountered during the pumping test. In some pumping tests radial flow was hard to determine due to the pumping rate changing throughout the test or missing data at the beginning of the test.

There were several pumping tests for bedrock wells where linear flow was observed for the majority of the pumping test, indicating that the well was being influenced by a productive fracture zone. Linear flow results when drawdown effects propagate along the length of the fracture, as opposed to radially away from the well (Allen et al., 2003). This type of flow behaviour occurs because the fracture zone is more permeable than the surrounding rock matrix. For some tests, the derivative graph showed an early linear flow period transitioning into a radial flow period. There were also instances for bedrock wells where the entire pumping test was linear flow and no radial flow was observed.

Pumping test data were also examined to see if there was any evidence of hydraulic boundaries. The pumping tests analyzed in this study ranged in duration from 120 to 80,670 minutes (<0.5 to 56 days), with an average duration of 2,463 minutes (1.7 days). Thus, the majority of tests were considered to be of sufficiently long enough duration to look for evidence of boundary effects.

Within unconsolidated aquifers, an increase in the rate of drawdown may reflect a decrease in permeability of the aquifer materials, a decrease in the thickness of the aquifer, or that the area of drawdown has reached the edge of the aquifer. Such “negative” boundaries were observed in seven unconsolidated wells - two wells in unconfined glaciofluvial aquifers and five wells in confined glaciofluvial aquifers. The respective aquifers are small in aerial extent (e.g. 1.1 km^2 to 14.5 km^2) therefore, the response is likely the result of the drawdown extending to the limits of the aquifer. In the case of bedrock aquifers, negative boundaries can indicate dewatering of a fracture or the interception of a zone or fracture with lower transmissivity. There were two bedrock wells where such boundaries were observed

For 116 wells, stabilization of the pumping water level was reached during the pumping test. Stabilization was defined as less than 0.03 metres (or 0.1 feet) of drawdown fluctuation per hour in the last 4 hours of drawdown measurement. All wells completed in alluvial aquifers (Type 3) reached stabilization, but only 39% of the wells completed in bedrock reached stabilization during the pumping test.

For both unconsolidated and bedrock aquifers, a constant head boundary, during which there is no further drawdown observed in the well, indicates that aquifer recharge is occurring at the same or greater rate than the well is being pumped (Driscoll, 1986). Constant head or “positive” boundary conditions were observed in 43 wells—34 wells in unconsolidated aquifers and 10 wells in bedrock aquifers. For three of these bedrock wells, the constant head boundary condition was either temporary (likely a result of reduced pumping rates) or potentially influenced by a rainfall event. For the seven remaining bedrock wells exhibiting constant boundary conditions, it is possible that these wells intercepted a high yielding fracture zone (e.g., fracture zones of higher transmissivity that may correspond to major lineaments in the Basin). However, when calculated long-term yields for all bedrock wells are compared to yields from wells that displayed constant head boundaries, there is no significant difference between average and median well yields for these wells.

Recovery was monitored in 142 pumping tests (91% of the tests analysed); however, for two pumping tests the data were unusable. Recovery results were often the most useful data, especially for tests where the pumping rate varied (e.g., only 64 pumping tests reported a constant pumping rate). In a couple of pumping tests, it appeared that there was an inaccurate recording of the recovering water level in the well during recovery.

3.3 Hydraulic Properties

The Theis, Neuman and Cooper-Jacob methods of analysis are based on the premise that radial flow is achieved during the test (Theis, 1935; Cooper and Jacob, 1946; Neuman, 1972). Technically, these methods should only be used if all of the assumptions inherent to these methods are met. However, reasonable estimates of the hydraulic properties of the aquifer can be obtained if only the data from the radial flow period are used for analysis (Allen, 1999). Essentially, the curve-matching process of the Theis method or the construction of the best-fit straight line for the Cooper-Jacob method use only the data over the radial flow period. Using the sub-set of data, estimates of transmissivity and storativity can be made. The corresponding period of radial flow was identified on the recovery plot, but in many instances the period corresponding to the latter part of the recovery curve was used to estimate transmissivity as this portion of the curve was the least influenced by changes in pumping rates during the test.

Transmissivity was estimated using four different methods including, Theis, Cooper-Jacob, Theis recovery and Neuman (where appropriate). Transmissivity estimates from the Theis recovery method are presented in Figure 5. As expected, the most transmissive aquifer types are those associated with unconsolidated unconfined aquifers adjacent to surface water features (e.g., Type 1b). These higher transmissivity values for the Type 1b aquifers likely reflect the coarser and more permeable sands and gravels deposited in higher energy depositional environments in rivers of moderate order. The average transmissivity values are fairly consistent for the other unconsolidated aquifers (e.g. Types 3, 4a and 4b), but both the median and minimum transmissivity values show declining values from aquifer Type 3 to 4b. Transmissivity for bedrock aquifers is several orders of magnitude lower than values for unconsolidated aquifers (average).

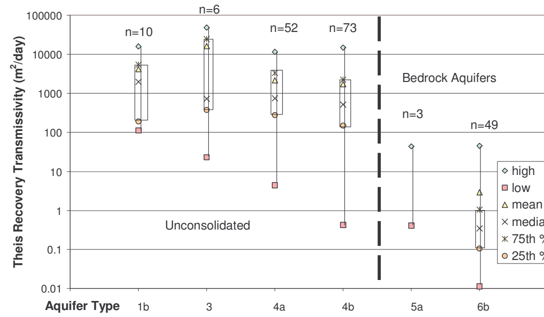

Figure 5. Transmissivity values by aquifer type for Theis recovery calculations.

Transmissivity values calculated from the four different methods were compared in Figure 6. In general, there was good agreement between methods for estimating transmissivity. However, at higher transmissivity values (>100 m^2/day), some pumping tests showed that transmissivity values estimated from the Theis recovery method were higher than those estimated from the other methods. The inverse was observed for lower transmissivity values (<1 m^2/day), where 12 Theis recovery values were lower than the other methods. In general, transmissivity calculated using the Neuman method was lower than the other methods. This is not surprising given that the volume of the aquifer which releases water during testing of an unconfined aquifer becomes smaller as the water table declines.

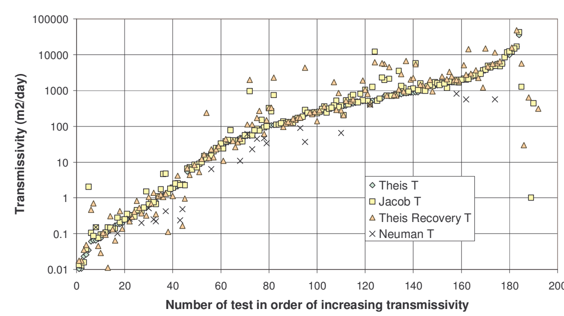

Figure 6. Comparison of transmissivity results (m^2/day) by method of analysis (n=192).

Hydraulic conductivity was determined using the estimated aquifer transmissivity divided by the aquifer thickness. Figure 7 shows conductivity values calculated using the Jacob method transmissivity values because there were more values generated through this method than for the other methods. The calculated values of hydraulic conductivity are in good agreement with published values for the different type of aquifer formations, e.g. for the unconsolidated sand and gravel aquifers, hydraulic conductivity ranges between >1 and 10^3 m/day (Heath, 1983). There was one hydraulic conductivity value for the Type 4b aquifer that was less than expected for an unconsolidated aquifer, e.g. 0.25 m/day. This well is confined and intersects a thin (1 m) layer of water-bearing gravel, between clay and till layers. Water-bearing sediments are heterogeneous and of variable thickness in this area. The low hydraulic conductivity and transmissivity values for this well reflect these conditions.

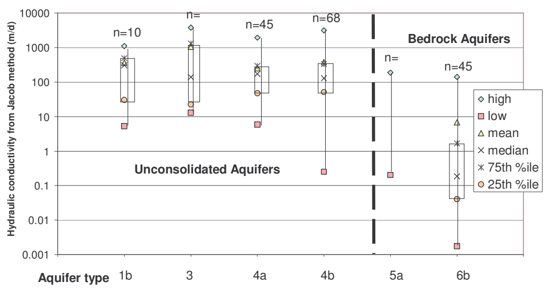

Figure 7. Boxplots of hydraulic conductivity values (m/day) for the different aquifer types.

Storativity estimates provide valuable information on the ability of water-bearing materials such as sands and gravels to store and release water. The magnitude of the storage coefficient or storativity depends on whether the aquifer is confined or unconfined. Storativity values were generated in 31 (20%) of the 158 pumping tests. This is because storativity values can only be reliably determined from observation well data. Of these 31 storativity values, two were rejected as unrealistic (>1). Boxplots in Figure 8 categorize storativity estimates into unconsolidated and bedrock aquifers and whether the well is confined or not. The highest storativity values are observed in unconfined unconsolidated aquifers and the range of these values is consistent with literature values of 0.01 to 0.3 for specific yield (Freeze and Cherry, 1979). Storativity values for bedrock aquifers were consistent with typical storage coefficients for a bedrock aquifers (10^{-3} to 10^{-5}) but there were only two test values in this category (Driscoll, 1986). The storativity values for confined unconsolidated aquifers also were higher, on average, than literature values of 0.005 to 0.00005 for confined aquifers (Freeze and Cherry, 1979).

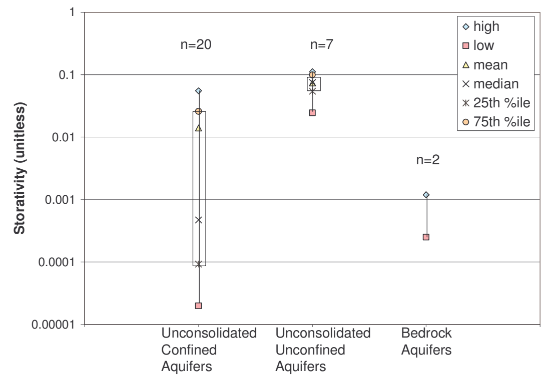

Figure 8. Boxplots of storativity values for different aquifer types.

4 CONCLUSION

The pumping test is a very important tool for evaluating groundwater resource potential. Proper pumping test practices are key to acquiring a high quality dataset that can be used for analysis. The majority of the pumping tests analyzed in this study (60%) did not achieve constant pumping rates for the duration of the testing and this greatly limited the usefulness of the full dataset. In tests where the pumping rate was not constant, a weighted average pumping rate was used for hydraulic property calculations, thereby contributing to additional error in parameter estimation. As well, only a few tests (20%) had one or more observation wells. Estimates of storativity, therefore, were limited to those tests where observation well data were available.

In addition to the collection of the data, the analysis of the pumping test is equally important in providing a meaningful interpretation of the aquifer hydraulic properties and for inferring the potential for well interference, the presence of aquifer boundary conditions, and the long-term yields of wells. Identification of the different types of flow regimes using the derivative method proved to be an effective way to interpret the data. As well, the derivative method allowed for the period of radial flow to be specifically identified. The data corresponding to this time period (over which radial flow occurs) could then be targeted for use of the Theis curve-matching or Cooper-Jacob straight line methods of analysis for confined aquifers, or the Neuman method for unconfined aquifers. The overall approach was consistent and yielded estimates of hydraulic property values that were comparable with literature, but that were also reasonably consistent between methods, including the Theis recovery method.

The results from this work will be made available to researchers for developing conceptual and numerical flow models for aquifer characterization throughout the Okanagan Basin. Such models will provide tools to support local planning and decision making, as well as to further the general understanding of aquifer characteristics in the Okanagan.

ACKNOWLEDGEMENTS

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