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Update on the Groundwater Assessment in the Okanagan Basin Project

1. Introduction

Groundwater is an important water supply in the Okanagan Basin and provides drinking water to communities as well as water for irrigation and industry. The Okanagan is one of the driest regions in Canada and increasing population growth, accompanying developments and agricultural growth, has significantly increased demands on both surface and groundwater resources. Groundwater use in the Okanagan Basin is anticipated to grow as tributaries into the Okanagan Lake system are nearing complete allocation of surface water licences. Since there is no licensing requirement, groundwater is an attractive alternative and use could expand in the years to come.

In 2004 the Groundwater Assessment in the Okanagan Basin (GAOB) project was initiated with the objective to increase understanding of the groundwater resources in the Okanagan Basin. In order to better manage this important resource, more detailed information with respect to an aquifer's characteristics (e.g., groundwater flow directions, flow rates and sustainable capacities, interaction with surface water bodies, location of sensitive recharge areas, factors governing ambient groundwater quality, etc.) is needed. The GAOB project has brought together researchers from universities and governments to undertake the science to address the information and data gaps. In addition, one important component of GAOB is to ensure that the science is provided to the local decision makers in a form that they can effectively use.

2. Key Project Activities

Over the past two years, there have been a number of projects undertaken in different parts of the Okanagan Basin to address groundwater data and information gaps. These projects are described below.

<u>2.1 Canadian Water Network Projects - A Basin Approach to Groundwater Recharge in the Okanagan: Bridging the Gap Between Science and Policy</u>

In March 2005, a research proposal to study groundwater recharge in the Okanagan Basin was funded by the Canadian Water Network. This project is being led by Dr. Diana Allen from Simon Fraser University and involves a group of researchers from universities (faculty, post-doctoral fellows and graduate students), the Geological Survey of Canada and industry (Waterloo Hydrogeologic Inc.). This project will be completed in the spring of 2007. A sub-group of the project researchers, in addition to some new members, intend to re-apply to the CWN to extend the research in such a way that the results can be more readily incorporated into various planning initiatives throughout the valley, in particular the basin wide supply/demand project.

The overall objective of this project is to understand groundwater recharge in the Okanagan Basin through hydrogeological modelling, geochemical sampling and analysis, and field-based studies of highland to valley bottom recharge processes, including contributions of surface water to groundwater recharge. There are four sub-projects that will contribute to the project deliverables, which include a conceptual model for highland to valley bottom hydrologic processes that can be used as a basis for water budget assessments and water use planning; a groundwater vulnerability assessment that can be used in groundwater management planning to minimize development impacts on groundwater quality and quantity; and linking the scientific outcomes to local, regional and provincial decision makers.

Project 1 is being led by Dr. Diana Allen and involves gaining a better understanding of direct recharge to groundwater in the Okanagan Basin. There are three sub-projects.

One sub-project (Toews, M.Sc. candidate, SFU) uses numerical approaches to estimate recharge and groundwater conditions for current and future climate scenarios in the region between the Skaha Lake and Osoyoos Lake area. The sensitivity of groundwater recharge to climate change is being assessed using a recharge model, and the impacts of varying recharge on groundwater levels is being assessed using a 3-D groundwater flow model. Results have shown a general increase of annual recharge with the peak recharge shifting from March to February and lower recharge rates and higher potential evapotranspiration rates are expected in the summer (Toews et al, 2006). A smaller-scale 3D stochastic groundwater model has also been developed for the Oliver town area. This model is being used to predict capture zones for the municipal production wells.

Another sub-project (Voeckler, PhD candidate, UBC and SFU) investigates groundwater recharge into the fractured bedrock in the uplands area, and thereby provide an estimate of mountain block recharge to the valley bottom. The project involves mapping fractures (e.g., orientation and spacing), and using these data in a fracture network computer code (Fracman) to estimate permeability of the rocks in the upper watershed areas. These estimates will be incorporated into a catchment scale reservoir model using FRED. Ongoing research will aim to integrate the fractured reservoir model with a surface hydrologic model (DHSVM) for a larger scale watershed.

A third sub-project involves producing a set of intrinsic susceptibility maps for selected areas (Narramata, Vernon and Oliver) within the Okanagan Basin utilizing the GIS-based DRASTIC aquifer vulnerability method. The research aims not only to produce the maps, but also to critically evaluate the sensitivity of the results to uncertainty in input parameters. It is anticipated that these maps will be completed by the end of 2006. To date, the vulnerability map for the Oliver area has been incorporated into the Land Use Allocation Model, which was developed for the Greater Oliver area as part of the Smart Growth on the Ground initiative. When combined with hazard inventory maps and well capture zones, these maps have the potential to provide communities with a useful tool for guiding sustainable land use planning (Aller et al, 1987). Both the vulnerability maps and the well capture zone results for the Town of Oliver are being incorporated into the Oliver Concept Plan. A second component of this project is to evaluate the DRASTIC vulnerability maps against a more quantitative measure of vulnerability, that being direct recharge. Thus, datasets used to construct the DRASTIC maps will be used as input to a recharge model in combination with historic climate data to estimate groundwater recharge to Okanagan Basin. These maps will equip communities to consider aquifer vulnerability alongside other priorities as part of comprehensive land use planning processes.

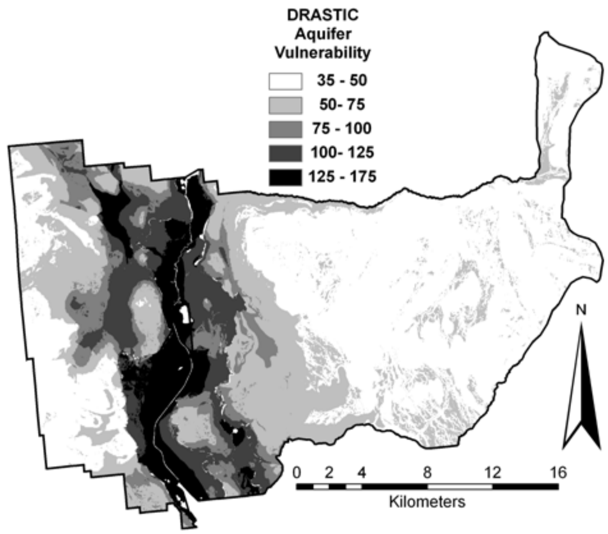

Figure 1. Relative intrinsic aquifer vulnerability in the Greater Oliver area (Electoral Area C) (Liggett et al, 2006).

Figure 1 illustrates the preliminary map of total vulnerability of Electoral Area C. Vulnerability ranges from 35 to 171 of a possible 230. Generally, the sand and gravel aquifers in the valley bottom are more susceptible to contamination than the igneous and metamorphic aquifers in the valley uplands. This is mainly controlled by the shallow depth to water in the valley bottom, along with high ratings assigned to aquifer media and aquifer conductivity.

Project 2 is being led by Dr. Steve Grasby from the Geological Survey of Canada and aims provide more information on potential source areas for recharge. This work is focussed on the BX Creek watershed in the North Okanagan and involves a geochemical/hydrologic approach to distinguish highland, benchland and valley bottom contributions to recharge. In the summer of 2005, thirty wells were sampled for major ions and stable isotopes of oxygen and hydrogen. Stable isotopes of oxygen and hydrogen typically show a systematic fractionation as a function of elevation (elevation effect), and can provide characteristic isotopic fingerprints for elevation of recharge. Isotope mixing models can help to estimate the relative contributions to valley bottom groundwater systems. As recharge waters from highland, benchland and valley bottom zones move through different geological materials, there will be different geochemical signatures in the waters. Thermodynamic modeling of water/rock interaction can be used to provide information on the flow path of groundwater (Grasby et al., 2000). Finally, groundwater age dating using ^{14}C and tritium will be used to estimate recharge rates and residence time of groundwater. The project also involves developing a surface water/groundwater integrated model (using MIKE SHE) for the BX Creek watershed. Groundwater recharge estimates from this model will be compared with those estimates from the direct recharge modeling studies in Project 1.

Project 3 is being led by Dr. Adam Wei and Dr. Jeff Curtis from the University of British Columbia – Okanagan and examines the surface groundwater interactions and the contribution of surface water to recharge in three different watersheds in the Okanagan - Vaseux, Upper Vernon, and Shorts Creek. The approaches to assess surface water-groundwater interactions include streamflow mass balances, use of natural tracers of source waters (hydrogeochemical), and numerical modelling (ie. MIKE SHE, MODFLOW). Field work has been done in the three watersheds to collect water balance on stream losses and water quality data (major ions, pH, and alkalinity).

Project 4 is being co-led by Dr. Murray Journeay and Shannon Denny from the Geological Survey of Canada, Dr. Nick Hedley from Simon Fraser University, and Dr. Craig Forester from the University of Utah. The objective of project 4 is to couple information and knowledge assets from projects 1, 2 and 3 with 3D visualization techniques, integrated resource assessment and scenario modeling tools to evaluate current groundwater quality and quantity and, to examine desirable future growth scenarios for the southern Okanagan. By furthering the integration of groundwater science with integrated modelling and visualization techniques, this project seeks to extend the reach of groundwater science knowledge into decision making and an understanding of complex systems.

In May 2006 researchers from project 4 were invited to engage in a community planning exercise taking place in the greater Oliver region. As a contribution to this exercise, a spatial allocation model (Land Use Allocation model (LUAM)) that ranks criteria based on its suitability to receive growth (i.e. residential, commercial, etc.) was developed. The LUAM incorporated datasets such as aquifer vulnerability maps, transportation routes and conservation areas to explicitly reflect suitable areas for future growth based on land use policy and community criteria. This type of modelling tool provides a mechanism for complex geologic and hydrogeologic information to be considered within a land use planning and design context to support community design and land use objectives. It is anticipated that the results of this sub-project will be applicable to other regions within the Okanagan and in regions across Canada.

2.2 North Okanagan Groundwater Characterization and Assessment Project

In April 2005, a proposal submitted to Agriculture Canada's Water Supply Expansion Program to characterize and assess the groundwater resources in the North Okanagan was funded. This project is being led by Des Anderson, the regional groundwater hydrologist for the Ministry of Environment and will be completed by the spring of 2008. The project involves staff from the University of BC – Okanagan, University of Manitoba, the Geological Survey of Canada, Ministry of Environment, consultants and a post doctorate. The project has two components: general groundwater characterization work for the North Okanagan and more detailed modelling work, including modelling surface /groundwater interactions in the Deep Creek Watershed.

To date, some of the outputs from this project include

- a regional fault fracture network map (1:100,000) for the entire Okanagan Basin,
- a 3-D geological model which identifies the significant aquifers in the North Okanagan (Monahan, 2006; Keller, 2006),
- a survey of irrigators (21 irrigators surveyed involving 88 wells),
- the collection and analysis of water quality in 68 wells and the collection,
- the analysis of 48 pumping tests to generate hydraulic properties such as hydraulic conductivity, transmissivity and specific capacity, and
- the compilation of historic water quality data.

A conceptual hydrogeological model is under development and modelling will include surface groundwater interactions.

Work is also being done with the North Okanagan Regional District and the City of Vernon to support the development of a Land Use Allocation Model (LUAM) to establish growth strategies for the North Okanagan region. To date, a contractor has created a data requirements document for the LUAM, a database of available spatial information sets has been compiled, the North Okanagan Regional District is compiling water use and water demand data for use in the LUAM and the criteria for the model are being developed through community consultation.

2.3 Osoyoos Nitrate Study

Research is being conducted by the University of Saskatchewan in the Osoyoos area, under the direction of Dr. Jim Hendry. Geochemical and isotopic techniques are being used to characterize regional impacts to groundwater and surface water as a result of agricultural activity. There are currently two areas being studied – one on the west side of Osoyoos Lake and the other in the highlands. The first study is in the valley bottom on the west side of Osoyoos Lake and involves characterizing the origin, fate and transport of nitrates in groundwater in the Osoyoos area (specifically, within and north of, the Osoyoos West Aquifer). A Masters student is conducting this research and is supported by a research grant from the Canada Center of Excellence in Water. To assist in this study, 9 piezometers have been installed to date. These multi-level piezometers, along with existing piezometers, will be used to assess groundwater chemistry and age, as well as nitrogen distribution, both spatially and with depth and will support future (long-term) monitoring. To date, groundwater sampling has been conducted at 33 wells in the study area and at two tile drainage systems, for analysis of geochemical parameters and stable isotopes of water and nitrate. In addition, surface water and precipitation samples have been collected and analyzed for water isotopes for comparison with groundwater isotope ratios to trace groundwater recharge, evaluate how much mixing occurs in the groundwater from precipitation and irrigation water, and estimate the depths at which irrigation water is circulating. The second study involves sampling bedrock wells and streams in the uplands areas for stable isotopes of water. The isotopic data will be used to characterize the potential sources of water adjacent to the valley bottom and assess groundwater recharge in the study area from the upland areas.

2.4 Okanagan Basin Waterscape Poster

The development of an Okanagan Waterscape Poster (Turner et al., 2006) co-led by Dr. Bob Turner from the Geological Survey of Canada (GSC) and Bill Taylor of Environment Canada and was initiated in the fall of 2005 and published in November 2006. The richly illustrated poster examines the geography, water cycle, lakes, groundwater, climate change, and ecosystems of the Okanagan Basin. It then goes on to explore human use and best practices for the household, urban development, and agriculture. The poster content is also available at http://geoscape.nrcan.gc.ca. Other waterscape posters are available for the Bow River Basin in Alberta, and the Gulf Islands and Bowen Island in British Columbia. The Waterscape poster is a means of reaching members of the community and to heighten awareness of water issues in the Okanagan.

The poster content was developed through a series of three workshops in 2006 attended by a broad representation of individuals and organizations in the Okanagan Basin and as a result, the Okanagan Waterscape Poster reflects water issues that are most relevant to the Okanagan and have a sound scientific and technical underpinning. There will be a launch event for the publication of the Okanagan Waterscape Poster in the January 2007 where posters will be distributed to communities and local organizations. There are also plans to work with teachers in the basin to develop a teacher resource kit for use in schools in the Okanagan. The poster is an excellent education and communication tool which will bring a greater understanding of the water resources to those living in the Okanagan Basin.

Figure 2. Okanagan Basin Waterscape Poster

2.5 Okanagan Basin Drinking Water System Inventory

In the fall of 2004, a pilot project was undertaken to inventory the 285 community drinking water supplies (both ground and surface water) in the Okanagan Basin (Carmichael and Allard 2006). Locations of system features such as wells and surface water intakes were determined through Differential GPS. Other information on the water system, such as points of extraction, storage and treatment facilities and monitoring locations were also collected at each site.

The collected information on the drinking water wells was cross-referenced with wells in the WELLS database. Only 48% of these field-inventoried wells were found in the database; new well record files were established for the other 52%. The cross referencing work resulted in the addition of 99 drinking water wells to the database. No cross referencing work has been done on the surface water systems to date.

The time required to cross-reference and update WELLS for each well ranged from 20 minutes to 7 hours of staff time. Searching the database and confirming a match between a field inventoried well and an existing Ministry well construction report was the most time consuming part of the cross-referencing process. This pilot project identified the importance of having sufficient well construction and location information to reduce the time required to cross reference the drinking water wells.

Figure 3. Capturing a differential GPS measurement at Kekuli Bay Provincial Park.

Well construction reports contain valuable information about the groundwater resource and are submitted to the province voluntarily by the well driller. This has presented challenges to the province and the most significant data issue facing the province is insufficient well location information (currently >20% of all the wells in the WELLS database do not have a georeferenced location). In order to assist all the research activities listed above, WELLS database records for the Okanagan were reviewed and verified to increase the robustness and utility of the database.

A consultant was first hired to confirm the accuracy of the existing ~ 5,000 located wells in the database and to identify where corrections were required. In many instances, there were incorrectly located wells, duplicate wells and more wells were found to exist in the database than were plotted on the map sheets. In addition, staff collected well construction reports and groundwater consultant studies. Wells from the provincial backlog of unlocated Okanagan wells were georeferenced. Local governments and well drillers in the Okanagan Basin were contacted to assist in this work. This resulted in the addition of over 1,000 new wells to the WELLS database. Another task addressed was the infilling of data, such as screen details, lithology, well location coordinates and other information previously not entered from the original hardcopy well records to the digital well construction report. Unfortunately, some wells could not be located due to incomplete well information provided on the well construction report. As of July 2006, there are over 6,200 wells in the Okanagan Basin – over 3800 drilled wells, ~1500 dug wells, ~250 with "other" construction method designation and about 700 wells where the construction type is unknown.

2.6 Collection and Compilation of Okanagan Groundwater Reports

The province maintains a library of groundwater reports called the NTS (National Topographic System) library. These reports vary from regionally based studies to site specific reports on individual wells and date back to the 1960's. At the inception of the GAOB project there were approximately 320 groundwater reports for the Okanagan Basin written by consultants or provincial employees; none were dated later than 1992. As a result, the NTS library was updated by collecting and compiling groundwater consultant or engineering reports that provided information and data on the groundwater resources in the Okanagan Basin. A Consent to Use form was developed and was used to acquire consent from the owner of the report for use in the GAOB project as well as to put the report in the NTS library and make it available to the public.

Over 300 groundwater reports were collected from local and regional governments and drinking water suppliers. These reports have been digitized and those that were accompanied with consent to use approval have been uploaded to the Ministry's ecological reports catalogue Ecocat and will be made available to the public.

2.7 Slug Testing of Provincial Observation Wells

A student from Simon Fraser University completed the slug testing of 14 different observation wells in the Okanagan Basin in the summer of 2004 (Liskop and Allen, 2005). Slug testing is a method of estimating physical properties of an aquifer using a well. The study was a preliminary investigation aimed at characterizing the aquifer media surrounding provincial monitoring wells in Okanagan Valley using slug testing methods, analyzing groundwater level fluctuations using a cumulative precipitation departure (CPD) graph, and using the hydrographs to estimate recharge using the water table fluctuation (WTF) method.

The hydraulic conductivities determined from slug testing range between $\sim 10^{-7}$ m/s for silty clay aquifers, and $\sim 10^{-3}$ m/s for gravel and sand aquifers (Liskop and Allen, 2005). The values obtained from slug testing correspond well with published values of hydraulic conductivities. The cumulative precipitation departure method indicated that six wells in the study area are primarily recharged by precipitation.

2.8 Map Compilation

Surficial geology mapping was conducted in the southern part of the Okanagan by H. Nasmith and in the northern part of the Okanagan by R.J. Fulton in the 1960s. This work has been digitized and work is underway to fine tune and join these two pieces of work into a surficial geology map for the basin.

Work is continuing on the compilation of bedrock geology maps for the Okanagan Basin by Dr. Andrew Okulitch from the Geological Survey of Canada. Bedrock maps will be compiled at a scale of 1:50,000.

Figure 4. An observation well with a protective housing at the top of the casing. A slug test was in progress at the time the photograph was taken.

3. Science-Policy Linkages

From the inception of the GAOB project, a primary goal was to ensure that science products developed during the project lifespan were shared with decision-makers and community members to support land use planning and policy development in the Okanagan Valley. Key activities to support this include the development of a web-based information sharing and project management portal, the establishment of a Land Use Allocation Modeling framework, and the design of the Waterscape poster. These activities aim to facilitate the use of science outputs (recharge maps and vulnerability maps) in support of planning and policy development activities that address issues of groundwater supply/demand and aquifer vulnerability throughout the Okanagan.

3.1 Web-based Decision Support System

A web-based decision support system called Phoenix has been developed to provide access to scientific data, reports and maps and to support collaboration among the many GAOB activities. Phoenix is being used within the GAOB project as a platform for collaboration between research partners by providing a workspace to create and share documents, search information collections and provide a central access point for project events, contacts and news.

3.2 Land Use Allocation Model (LUAM)

The modeling process integrates knowledge about a region and growth management to highlight areas on the landscape that are consistent with community priorities and that are aligned with regulatory controls. The Land Use Allocation Model allocates growth to land area based on a set of criteria that are used to determine and prioritize the issues that constrain or drive growth. The process involves ranking and weighting the suitability of a given land area to receive future growth. The result is a model that identifies overall suitability of a given location to receive new growth based on community preferences and regulatory controls. Used together with future population projections and growth rates, the model allocates population based on suitability (Liggett et al., 2006). The LUAM framework is being implemented in southern and northern regions of the Okanagan through planning activities with Regional District of Okanagan Similkameen, Town of Oliver, North Okanagan Regional District and the City of Vernon.

The coupling of Web-based knowledge integration systems and scenario modeling tools provides a venue for exploring viable sustainable development strategies and building coherence in policy negotiations across jurisdictional boundaries (Tansey et al., 2004). These tools will contribute to a wider and deeper understanding of environmental, social, and economic issues, and offer the potential for transforming the ways in which regional urban centres and surrounding rural communities in the Okanagan Valley use and share information to make decisions about their collective future.

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