FINAL REPORT

OKANAGAN BASIN WATER SUPPLY AND DEMAND STUDY: PHASE 1

Prepared for:

Land and Water B.C. Inc.
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Prepared by:

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Project 572-02.01

May 2005

SUMMIT
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May16, 2005

Reference: **572-02.01**

Dr. Wenda Mason
Business Programs and Policy Division
Land and Water BC Inc.
4th Floor, 1175 Douglas Street
Victoria, B.C. V8W 2E1

Dear Dr. Mason:

Re: Okanagan Basin Water Supply and Demand Study: Phase 1 Report

Summit Environmental Consultants Ltd. (Summit) is pleased to provide one unbound, three bound copies, and one digital copy of a final report on Phase 1 of the Okanagan Water Supply and Demand Study.

The Phase 1 report reviews the information we have assembled to conduct the water supply and demand analysis, and outlines a recommended strategy and work plan to complete the analysis in Phase 2. The report also identifies the minimum level of effort that we believe will allow LWBC to meet its objectives for the Phase 2 study, as well as an enhanced program which will deliver a value-added product.

The report outlines the recommended personnel required to provide optimal value in Phase 2. We have recommended a leadership core similar to our Phase 1 team, supported by a consortium that includes government and university researchers and local consultants. Each of these other agencies has confirmed their interest and capability to participate in Phase 2. I am confident that the integrated team recommended in this report has the capacity to deliver the Phase 2 program outlined herein.

Please call if you have any questions on the report.

Yours truly,

Summit Environmental Consultants Ltd.

Brian T. Guy, Ph.D., P.Geo., P.H.
Senior Geoscientist
President

Attachments: Final Report (3 bound, 1 unbound)

EXECUTIVE SUMMARY

Land and Water B.C. Inc. (LWBC) has initiated a two-phase study to develop current water supply and demand information throughout the Okanagan Basin. The first phase, which is the subject of the present report, consists of the collection and evaluation of all potentially relevant information, and the design of a water supply and demand analysis. The supply and demand analysis will be conducted in the second phase. The desired outcome of the analysis is a scientifically credible product that can be used to assist LWBC in fulfilling its water licensing mandate, and that can be used in an educational setting to assist in communicating with other agencies and water stakeholders.

The first phase of the study was led by LWBC and a Steering Committee comprised of representatives of LWBC, Environment Canada, and the Okanagan Basin Water Board. The function of the Steering Committee was to provide strategic advice and guidance to LWBC. LWBC was also supported by a Working Group, comprised of representatives of LWBC, Ministry of Water, Land, and Air Protection, Environment Canada, B.C. Ministry of Agriculture, Fisheries, and Food , and B.C. Ministry of Sustainable Resource Management. Its function was to provide technical guidance to LWBC and its consultants, in particular to help in identifying and obtaining relevant information. LWBC contracted the first phase of the study to a consulting team led by Summit Environmental Consultants Ltd. (Summit). Summit was supported by a network of associated individuals and firms with specific expertise useful to the study.

The Okanagan Basin as defined for this study includes the Okanagan River watershed upstream of the outlet of Osoyoos Lake, an area of 8,046 km^2. A very small amount of this area is located outside Canada, but has been included for technical reasons. Management recommendations will not be made for this area. The spatial scope includes specific tributary streams as well as Okanagan Lake and Okanagan River. The temporal scope for the study includes evaluation of current conditions, as well as providing forecasts of future demands and supplies.

A great deal of potentially relevant information exists for the Okanagan Basin. Efforts to collect data during Phase 1 focussed on current and forecast information relating to surface water supply, water use, and groundwater. Information on population, land use, recreation, and tourism was also obtained and reviewed. To facilitate the organization and review of the information, a database was developed in the Microsoft Access™ format. Information on 233 potentially relevant sources of information was entered into the database and classified according to several categories, including its potential usefulness to the supply and demand analysis. The database is included as an attachment to this report.

Notwithstanding the range of potentially useful information, some gaps in the information required to complete the supply/demand study were identified. The most significant data gaps include accurate information on evaporation and evapotranspiration, information on groundwater and groundwater/surface water interactions, and information on actual water use by water licensees. An interim design for the Phase 2 study was developed that makes optimal use of the available relevant information and focuses resources on filling the

information gaps necessary to conduct the analysis and ensure that LWBC's objectives will be met.

After most of the information evaluation work had been completed and an interim strategy for Phase 2 had been developed, a workshop was held on March 8, 2005 (with LWBC, the Steering Committee, the Working Group, other stakeholders, and the First Nations of the Okanagan) to review and obtain feedback on the work completed to date. Following the workshop, additional information was reviewed and the interim Phase 2 strategy was revised.

This report presents a strategy and workplan for Phase 2 that reflects the workshop input. A "recommended" study program is presented; as well as a "minimum" program, and an "enhanced" program. The recommended program is designed to fully achieve LWBCs objectives within an 18-month timeframe. On the basis of the Phase 1 work outlined in this report, it is strongly recommended that LWBC proceed with the recommended program.

The minimum program will minimally meet the technical objectives, but will not likely achieve the intended level of confidence in the study outcome. The enhanced program adds significant value, by adding components to the recommended program that will improve the technical robustness of the analyses and increase confidence in the outcomes.

The recommended program includes the following major tasks:

- Development of an Okanagan Water Model, which will automate the calculation of a monthly water balance at 79 points-of-interest (including tributary sub-basins, mainstem lakes and mainstem river locations), and produce output in a format useful for model calibration and examination of future scenarios;
- Scientific and engineering work necessary to identify values for water balance parameters and to properly calibrate and verify the model for average, dry, and wet years under current conditions - including additional work to obtain water use information from water purveyors, and groundwater work building on the GAOB project already underway;
- Development and delivery of a consultation program designed to provide necessary technical input and to achieve other objectives such as information sharing;
- Development of a suite of future scenarios based on the expected range of future variation in water supply and water demand, and running the Okanagan Water Model to evaluate each future scenario;
- Evaluation and presentation of the scenario output to illustrate parameter sensitivity and address LWBCs key questions related to licensing and allocation of water at each point-of-interest; and
- Development of recommendations to help LWBC develop an approach to future licensing and allocation decision-making in the Okanagan Basin.

The scientific and engineering work makes optimal use of existing information to ensure cost-effectiveness. The work program will result in achievement of a level of confidence in the results that meets LWBCs objectives.

The "minimum" program would include the same major tasks, but would rely on a significantly smaller effort. In particular, the minimum program would involve use of the information already obtained during Phase 1 from the water utilities, rather than obtaining additional information. The minimum program would direct a smaller effort at model calibration and verification, would restrict the development of the automated user interface to a very simple one useful mainly to the consultants, and will examine a smaller set of future scenarios. The minimum program is not recommended to LWBC, because whereas it will meet the technical deliverable requirements, it will not likely achieve the desired level of confidence in the results.

Similarly the "enhanced" program does not add major tasks, but instead adds some effort to the completion of each of the major tasks. Specifically, additional effort would be directed towards developing a significantly more robust and flexible database, linking model, and scenario driver through additional development, testing, and model calibration. Additional effort would be made in each of the water use, surface water and groundwater analyses to obtain the most accurate parameters for the model, and to run additional future scenarios. Furthermore, the enhanced program includes an expanded consultation program and development of a brochure for public distribution. This program would result in improved confidence in the Okanagan Water Model, would increase the user friendliness and the future utility of the model, and provide better tools to inform and educate the public.

The recommended Phase 2 study team organization includes a project manager who will direct the work of various specialists, including senior and junior hydrologists, computer programmers, water supply engineers, and groundwater hydrologists. In addition, we recommend including the UBC Faculty of Forestry (for improving the UBC Watershed Model), Agriculture Canada (for developing improved crop water demand information), and an economist. To guide and review the work of the consultants at key points during the study, a Local Advisory Council comprised of experienced local consultants, each with a long history in the water supply and demand field in the Okanagan, is proposed. The report makes specific personnel recommendations for each of the above-noted roles. Each identified firm or agency has reviewed their potential role in the Phase 2 study, and has confirmed their interest and capability to participate.

The recommended project organization includes an expanded Steering Committee and Working Group to assist LWBC and the consultants. In particular, we recommend adding the Okanagan Nation Alliance to the Steering Committee, and adding an urban planner, a representative of the Water Supply Association of B.C., and an agriculture industry representative to the Working Group.

The estimated cost of the recommended Phase 2 program is $1,096,865 (plus GST). The accuracy of this estimated is considered to be plus or minus 20 %. The estimated costs of the minimum and enhanced programs are $599,830 and $1,444,080, respectively. The benefits and limitations associated with each of these programs, and the assumptions underlying each of the cost estimates are described in detail in the report.

The report recommends that, following an internal decision on the scope of the Phase 2 work program, LWBC should request that the consultants refine the work program and budget contained herein, in preparation for establishing a contract for Phase 2.

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1.0 INTRODUCTION

1.1 BACKGROUND

This report outlines the results of the first phase of a water supply and demand analysis being undertaken by Land and Water B.C. Inc (LWBC), in collaboration with other partners. In the first phase of the study, the information available to conduct the supply and demand analysis has been evaluated, and a strategy and work plan for the analysis has been prepared. The supply/demand analysis will be completed in Phase 2 of the study.

The 1974 Okanagan Basin Agreement was the result of a comprehensive Okanagan water resources evaluation that took place in the early 1970s. That work produced a 50-year development plan with three economic growth projections and a conclusion that the existing available water supply was sufficient to meet all three scenarios. However, growth has proceeded at a higher rate than even the highest of the three projections, and in 1994, BC Environment concluded that only a small volume of water remained available to be licensed for offstream use.

Several water-related initiatives are underway in the Okanagan Basin, led by a variety of government, academic, and non-governmental organizations. These include a long-term groundwater study, ongoing research on climate change and climate change impacts, and efforts by the business community to improve basin-wide coordination of water management amongst local authorities. These groups, along with other agencies with water management responsibility, recognize that there is a need to gain an updated understanding of the current status of water supply and use in the Basin, to inform decision-makers about water availability for licensing and allocation, to facilitate economic growth and development, and to provide the basis for a more coordinated, effective, and sustainable approach to water management in the Basin.

LWBC on behalf of the Provincial Deputy Ministers' Committee on Drought, and in collaboration with the Okanagan Basin Water Board has taken the lead in completing this study. LWBC has divided the work into two phases:

- Phase 1: information identification, compilation, and evaluation; and gap analysis; and
- Phase 2: updated Okanagan water supply/demand analysis.

Phase 1 of the study has been completed, and is the subject of the present report.

1.2 SCOPE OF THE PROJECT

Consistent with the 1974 studies (Consultative Board, 1974), the geographic boundaries of the study area include the entire Okanagan River watershed upstream of Zozel Dam at the outlet of Osoyoos Lake (Figure 1.1 and Map 1). This area totals 8,046 km^2. Zozel Dam and the southern portion of Osoyoos Lake lie within the United States of America (USA), but the area of the watershed within the USA is very small (about 73 km^2). The small portion of the Basin that lies within the USA is included for technical reasons - to ensure a complete understanding of hydrologic processes to the outlet of the lake is achieved. However, recommendations will only be made for the Canadian portion of the Basin.

The study is intended to provide a comprehensive update of the supply and demand studies last done for the basin in the early 1970s (Consultative Board, 1974). Several studies with a smaller spatial scope have been conducted since that time, but with the exception of demand management studies in 1990 (KWL, 1990) no comprehensive basin-wide update has been done since the early 1970s work was published as part of the Okanagan Basin Agreement (Consultative Board, 1974). While available water quality and fisheries information will be considered in the study, new investigations on these topics are beyond the scope of the study.

The study will examine both surface water supply and use, and groundwater supply and use. It will estimate the current status of supply and use, and will also make future projections of both water supply and water use, by considering the implications of predictions of population growth and predictions of climate change.

1.3 PHASE 1 STUDY OBJECTIVES

The objectives of Phase 1 of the study were:

- To identify relevant information for conducting an analysis of the current status of surface water and groundwater supply and demand;
- To identify relevant information for providing forecasts of future surface water and groundwater supply and demand, by considering the likely effects of projected population and economic growth and climate change; and
- To develop a strategy and work plan for conducting the Phase 2 study.

The key tasks that were accomplished in Phase 1 included:

- Holding a meeting between the consultants, LWBC, the Steering Committee and the Working Group to discuss and scope the Phase 1 portion of the project;
- Identifying the information potentially relevant to conducting a supply/demand analysis for the Okanagan Basin;
- Assembling as much of this information as possible during the time frame available for the study;
- Assessing the information available with respect to its suitability for conducting the supply/demand analysis;
- Developing a database that lists and summarizes the potentially relevant information;
- Identifying gaps in current knowledge based on the information review and based on the Phase 2 needs;
- Developing an interim strategy for Phase 2 of the study;

- Developing and facilitating a workshop with major stakeholders in the Basin to familiarize them with the available data, its strengths and weaknesses, and the data gaps, and to review the proposed strategy for Phase 2 of the study;
- Finalizing the interim information review and Phase 2 strategy following the workshop; and
- Preparing a report that summarizes the available information and presents a strategy for Phase 2.

1.4 OVERVIEW OF THE BASIN

The Basin lies in the Thompson Plateau and Okanagan Highland physiographic regions (Holland, 1976) and is bounded on the east by the Kettle River Basin, on the west by the Similkameen River Basin, and on the north by the Shuswap River Basin. The Basin boundary is drawn eastward and westward from the outlet of Osoyoos Lake. The Canadian portion of the Basin encompasses the regional districts of North Okanagan, Central Okanagan, and Okanagan Similkameen and includes the cities of Vernon, Kelowna, and Penticton as well as several other smaller communities. The Basin is characterized by a high plateau averaging between 1,200 m and 1,500 m elevation bisected by a north-south oriented valley containing a series of lakes. Several major tributaries drain into Okanagan Lake including (from north to south): Vernon, Deep, Equesis (Six-Mile), Whiteman, Shorts, Lambly, Kelowna (Mill), Mission, Bellevue, Powers, Trepanier, Peachland, Trout, and Penticton Creeks. Mission Creek is the largest tributary, contributing an average of 21% of the total annual inflow to Okanagan Lake (Consultative Board, 1974). Okanagan Lake covers an area of 351 km^2 and contains roughly 24.6 billion m^3 of water (Consultative Board, 1974). At Penticton, Okanagan Lake flows into the Okanagan River, which empties into Skaha Lake. Downstream of Skaha Lake, the river flows through Vaseux and Osoyoos Lakes before entering the Columbia River at Brewster, Washington. Major tributaries downstream of Okanagan Lake include: Ellis, Shingle, Shuttleworth, and Vaseux Creeks.

The bulk of the land base (the mid and upper elevations) is managed by the provincial Crown, where land uses include forestry, agriculture (range), recreation, and mining. At lower elevations, land use includes urban development, First Nation communities (from north to south: Spallumcheen Indian Band, Okanagan Indian Band, Westbank First Nation, Penticton Indian Band, and Osoyoos Indian Band), and rural, residential, commercial, industrial, recreational, and agricultural areas. There are five biogeoclimatic zones in the Basin. Bedrock is typically of volcanic origin. Lower elevations are mantled by glaciofluvial and glaciolacustrine deposits, and higher elevations are typically mantled with colluvium and/or glacial till.

Annual precipitation in the Basin varies with elevation, and is relatively low, averaging about 600 mm per year throughout the Basin (it varies from north to south, east to west, and with elevation). Average annual runoff varies with elevation from about 120 to 230 mm. Inter-annual variation in annual runoff is significant in the Okanagan. Streamflows rise to a peak in spring in response to snowmelt, then decline through the summer to baseflow levels by late summer. These baseflows are maintained through the winter.

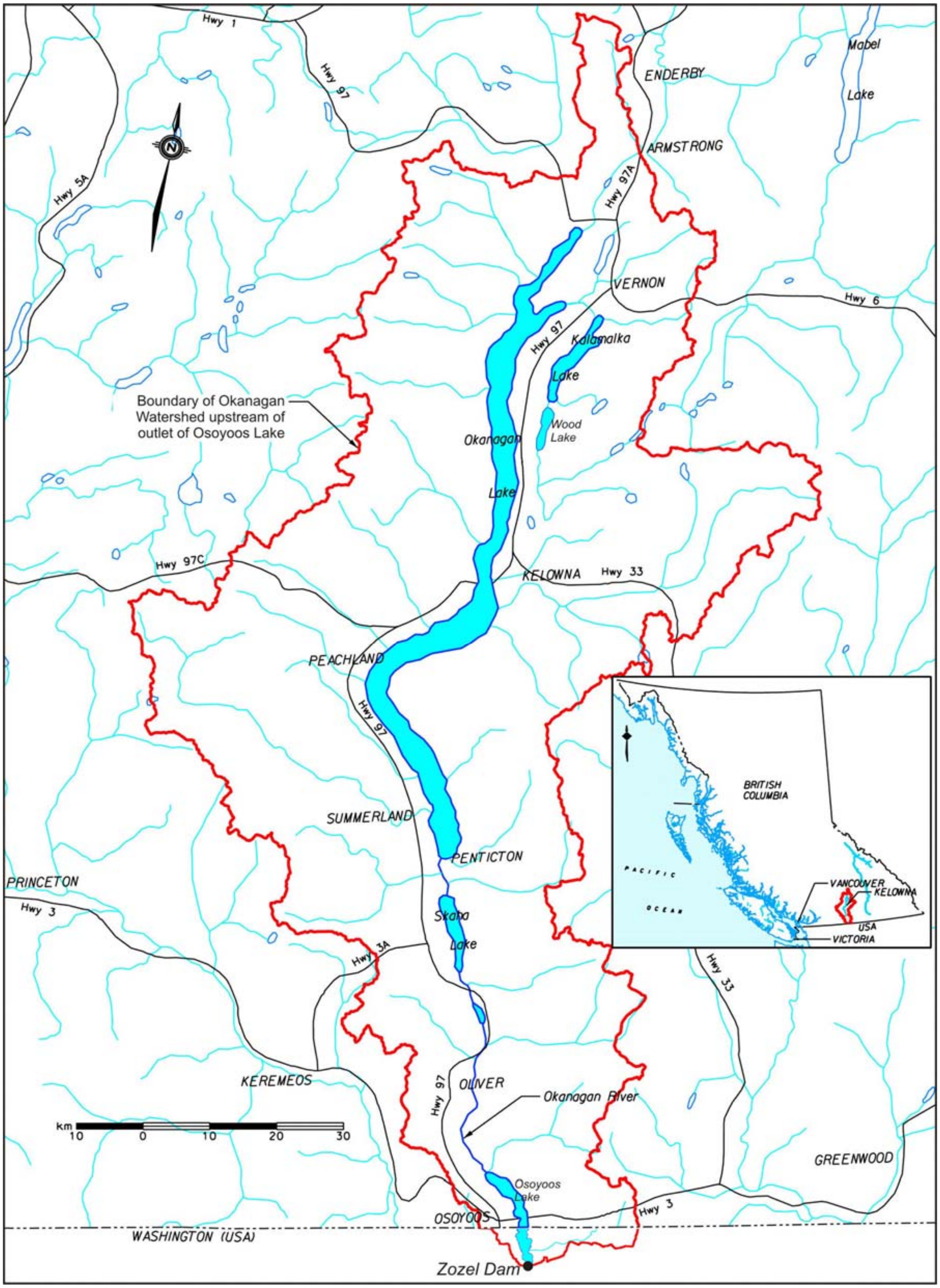


Figure 1.1 Location and boundaries of the Okanagan Basin.

1.5 PARTICIPANTS

The study is being led by LWBC. Dr. Wenda Mason is the Project Manager, assisted by Ms. Michele-Lee Moore. LWBC has formed a Steering Committee (Table 1.1) to provide guidance to LWBC on the project, to assist LWBC in dealing with significant issues, and to provide approval of the final report.

In addition, LWBC has created a broader Working Group (Table 1.2), whose mandate is to provide technical direction and guidance to the study, and to assist LWBC and its consultants with identifying and using relevant information.

Table 1.1 Membership of the project Steering Committee

Agency	Individuals
Land and Water B.C. Inc.	Jim Mattison Kevin Dickenson Glen Davidson
Environment Canada	Kirk Johnston
Okanagan Basin Water Board	Greg Armour

Table 1.2 Membership of the project Working Group

Agency	Individuals
Land and Water B.C. Inc	Wenda Mason Don McKee Michele-Lee Moore
Min. of Water, Land and Air Protection	Brian Symonds, P.Eng. Des Anderson, P.Geo.
Environment Canada	Bill Taylor
B.C. Ministry of Agriculture, Fisheries, and Food	Ted van der Gulik, P.Ag.
B.C. Ministry of Sustainable Resource Management	Ron Smith, P.Eng. Tony Cheong

Summit Environmental Consultants Ltd., in partnership with several others (Table 1.3), has completed the Phase 1 work.

Table 1.3 Phase 1 Consulting Team

Agency	Key Individuals	Role
Summit Environmental Consultants Ltd.	Brian Guy, P.Geo., P.H. Lars Uunila, P.Geo, P.H. Dan Watterson, P.Geo. Rebekka Lindskoog, R.P.Bio.	Project Management and Senior Technical Leadership Hydrology Groundwater Database
W. Obedkoff Consulting	William Obedkoff, P.Eng.	Senior Water Supply Expert
Agua Consulting Inc.	Bob Hrasko, P.Eng.	Senior Water Demand Expert
Alliance Professional Services Ltd.	Joanne de Vries	Workshop Facilitator
Okanagan Nation Alliance	Jillian Tamblyn	First Nations water use, workshop logistics
ESSA Technologies Ltd.	Clint Alexander	Database and modeling advisor
Water Management Consultants Ltd.	Dave Sellars, P.Eng. Rod Smith, P.Eng.	Water Management Expert Senior Groundwater Advisor

1.6 ORGANIZATION OF THIS DOCUMENT

This document presents the results of the Phase 1 study. The information database is described in Section 2.0 and provided digitally on CD1 (a summary of references in the database is presented in Appendix A). The preliminary information review and Phase 2 strategy results were discussed at a stakeholder workshop on March 8, 2005, and the workshop outcomes are summarized in Section 3.0. A summary of the results of the information review (incorporating workshop outcomes) is presented in Section 4.0. A strategy and outline for the Phase 2 study (incorporating workshop outcomes) is presented in Section 5.0. The components of the Phase 2 work program are outlined in Sections 6.0 through 12.0.

2.0 DESCRIPTION OF INFORMATION DATABASE

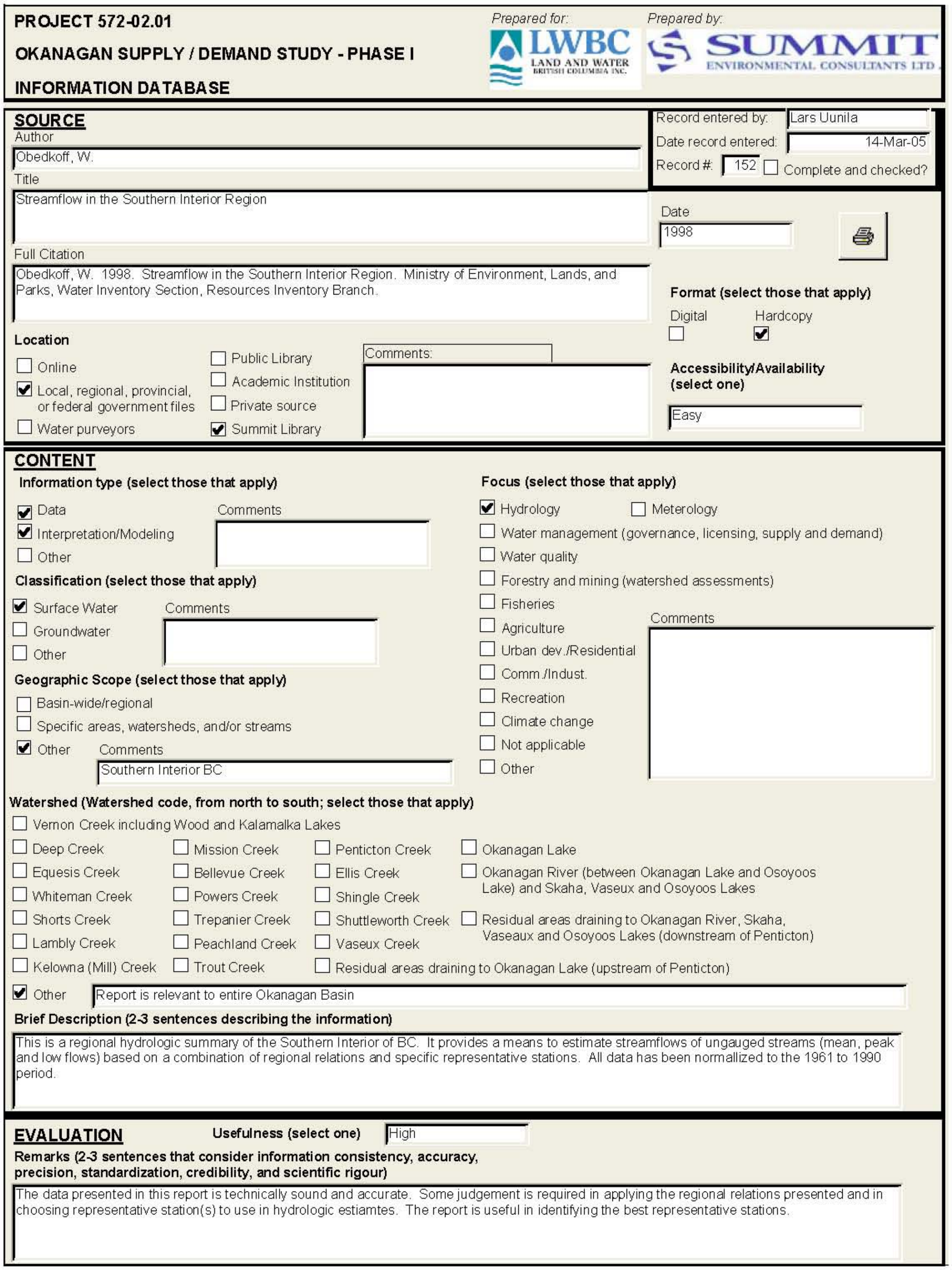
A straightforward and user-friendly information database was developed to facilitate organization, recording and summarizing of the information compiled. The database design is simple (Figure 2.1) and includes a user-friendly interface with the ability to create customized summary reports. This flexible design also allowed for the expansion of fields and the addition of extra features easily during the data entry phase.

Information on the content, a brief description, and an evaluation of the overall usefulness of each data source to the Okanagan Basin Supply/Demand Study has been recorded in the database. A total of 233 references were identified prior to the preparation of this report. A total of 152 references were reviewed for content and usefulness for Phase 2 of the study. The remaining 81 references were received late in Phase 1 and have not been reviewed, but citations for these have been entered to the database.

Three categories ("low", "moderate", and "high") of usefulness were developed in order to filter the available information for future use in Phase 2. Information sources deemed "high" and "moderate" were considered valuable for Phase 2 and comments are provided in the database to justify these decisions, which are based on consistency, accuracy, precision, standardization, credibility, and scientific rigour. Information sources deemed "low" usefulness are generally not relevant or valuable to Phase 2 and efforts are not generally required to review there sources further.

The information database is a useful tool for summarizing the variety of data sources and identifying the most useful resources for a given topic or geographic area within the Basin. Data gaps are also identifiable through simple queries.

A summary of the references contained in the database (and reference to the database record number) is attached as Appendix A. Since the database is fundamentally a digital tool, a digital copy is provided on CD1.



PROJECT 572-02.01

OKANAGAN SUPPLY / DEMAND STUDY - PHASE I

INFORMATION DATABASE

Prepared for: LWBC LAND AND WATER BRITISH COLUMBIA INC.

Prepared by: SUMMIT ENVIRONMENTAL CONSULTANTS LTD.

SOURCE

Record entered by: Lars Uunila
Date record entered: 14-Mar-05
Record #: 152 ☐ Complete and checked?

Author: Obedkoff, W.

Title: Streamflow in the Southern Interior Region

Date: 1998

Full Citation: Obedkoff, W. 1998. Streamflow in the Southern Interior Region. Ministry of Environment, Lands, and Parks, Water Inventory Section, Resources Inventory Branch.

Format (select those that apply)
- ☐ Digital
- ☑ Hardcopy

Location
- ☐ Online
- ☑ Local, regional, provincial, or federal government files
- ☐ Water purveyors
- ☐ Public Library
- ☐ Academic Institution
- ☐ Private source
- ☑ Summit Library

Comments:

Accessibility/Availability (select one): Easy

CONTENT

Information type (select those that apply)
- ☑ Data
- ☑ Interpretation/Modeling
- ☐ Other

Comments:

Classification (select those that apply)
- ☑ Surface Water
- ☐ Groundwater
- ☐ Other

Comments:

Geographic Scope (select those that apply)
- ☐ Basin-wide/regional
- ☐ Specific areas, watersheds, and/or streams
- ☑ Other

Comments: Southern Interior BC

Focus (select those that apply)
- ☑ Hydrology
- ☐ Meterology
- ☐ Water management (governance, licensing, supply and demand)
- ☐ Water quality
- ☐ Forestry and mining (watershed assessments)
- ☐ Fisheries
- ☐ Agriculture
- ☐ Urban dev./Residential
- ☐ Comm./Indust.
- ☐ Recreation
- ☐ Climate change
- ☐ Not applicable
- ☐ Other

Comments:

Watershed (Watershed code, from north to south; select those that apply)
- ☐ Vernon Creek including Wood and Kalamalka Lakes
- ☐ Deep Creek
- ☐ Equesis Creek
- ☐ Whiteman Creek
- ☐ Shorts Creek
- ☐ Lambly Creek
- ☐ Kelowna (Mill) Creek
- ☐ Mission Creek
- ☐ Bellevue Creek
- ☐ Powers Creek
- ☐ Trepanier Creek
- ☐ Peachland Creek
- ☐ Trout Creek
- ☐ Penticton Creek
- ☐ Ellis Creek
- ☐ Shingle Creek
- ☐ Shuttleworth Creek
- ☐ Vaseux Creek
- ☐ Residual areas draining to Okanagan Lake (upstream of Penticton)
- ☐ Okanagan Lake
- ☐ Okanagan River (between Okanagan Lake and Osoyoos Lake) and Skaha, Vaseux and Osoyoos Lakes
- ☐ Residual areas draining to Okanagan River, Skaha, Vaseaux and Osoyoos Lakes (downstream of Penticton)
- ☑ Other: Report is relevant to entire Okanagan Basin

Brief Description (2-3 sentences describing the information)

This is a regional hydrologic summary of the Southern Interior of BC. It provides a means to estimate streamflows of ungauged streams (mean, peak and low flows) based on a combination of regional relations and specific representative stations. All data has been normallized to the 1961 to 1990 period.

EVALUATION

Usefulness (select one): High

Remarks (2-3 sentences that consider information consistency, accuracy, precision, standardization, credibility, and scientific rigour)

The data presented in this report is technically sound and accurate. Some judgement is required in applying the regional relations presented and in choosing representative station(s) to use in hydrologic estiamtes. The report is useful in identifying the best representative stations.

Figure 2.1 Example form in the Okanagan Supply/Demand Study Phase 1 information database.

3.0 RESULTS OF STAKEHOLDER WORKSHOP

At a workshop conducted March 8, 2005, preliminary results of the information evaluation and Phase 2 program were presented and discussed by a group of stakeholders and First Nations chosen by LWBC with input from the consulting team. The workshop was facilitated by Joanne de Vries with help from Jillian Tamblyn. Dr. B. Guy of the consulting team presented results of the preliminary work completed to date. Participants are listed in Table 3.1.

The workshop was divided into two segments. The morning session focused on Phase 1 work completed to date, while the afternoon session promoted discussion of the future study direction, including key considerations for Phase 2.

Each session consisted of a formal presentation by the consulting team, followed by a break-out session during which grouped participants answered a series of questions. There were four groups of eight or nine participants each. Each group had a facilitator and a scribe, who was responsible for recording the consensus views of the group. These views were then presented to the whole group, after which the small groups reconvened to revise and reconsider their responses. The workshop outline is presented in Table 3.3.

Table 3.1 Participants in March 8 workshop.

Agency	Participants
Land and Water B.C. Inc.	Jim Mattison, Wenda Mason, Michele-Lee Moore, Glen Davidson, Don McKee
Environment Canada	Bill Taylor
Min. of Water, Land and Air Protection	Brian Symonds, Des Anderson, Phil Epp, Vicki Carmichael, Steve Matthews
Ministry of Agriculture, Fisheries, and Food	Ted van der Gulik
Ministry of Sustainable Resource Management	Ron Smith, Tony Cheong
Agriculture and Agri-Food Canada	Denise Nielson
Okanagan Basin Water Board	Greg Armour
Water Supply Association of B.C.	Bob Hrasko
Regional District of Central Okanagan	Leah Hartley
Regional District of Okanagan-Similkameen	Stephen Juch
Interior Health	Mike Adams
Greater Vernon Water	John Bartell
District of Peachland	Joe Mocilac
District of Lake Country	Mike Mercer, Jake Thiessen
Town of Oliver	Tom Szalay
City of Penticton	Carolyn Stewart
Penticton Indian Band/ONA	Chief Stewart Phillip
Okanagan Nation Alliance	Jillian Tamblyn, Howie Wright
UBC-Okanagan	Adam Wei
BC Fruit Growers Association	David Dobernigg
BC Agriculture Council	Hans Buchler
Summit Environmental Consultants Ltd.	Brian Guy, Lars Uunila
Alliance Professional Services	Joanne de Vries
ESSA Technologies Ltd.	Clint Alexander

Agencies which were invited but did not attend are listed in Table 3.2.

Table 3.2 Agencies invited to the March 8 workshop which did not attend

Agencies which were invited but did not attend	Agencies which were invited and registered but did not attend
Township of Spallumcheen	City of Kelowna - Don Degen
Town of Enderby	Land and Water B.C. - Kevin Dickenson
Town of Osoyoos	Village of Lumby - Roger Huston
Ministry of Forests	District of Summerland - Tim Palmer
Southern Okanagan Similkameen Conservation Partnership	
Osoyoos Indian Band	
Westbank First Nation	
Okanagan Indian Band	

Table 3.3 Outline of March 8, 2005 workshop.

08:00	Workshop Registration (coffee served)	
08:30 – 08:45	Introduction and Workshop Goals	Jim Mattison
08:45 – 10:00	Workshop Format Information Identification and Evaluation	Dr. Brian Guy
10:00 – 10:15	Break	
10:15 – 11:15	Break-out Groups and Discussion: Information availability, limitations, and value to Phase 2	Facilitator: Joanne de Vries
11:15 – 11:45	Plenary Session 1: Report on Break-out Group findings	Facilitator: Joanne de Vries
11:45 – 12:00	Reconvene Break-out Groups to finalize findings: Phase 1	Facilitator: Joanne de Vries
12:00 – 12:30	Lunch	
12:30 – 13:30	Phase 2 Strategy	Dr. Brian Guy
13:30 – 14:30	Break-out Groups and Discussion: Phase 2 Strategy	Facilitator: Joanne de Vries
14:30 – 15:00	Plenary Session 2: Report on Break-out Group findings	Facilitator: Joanne de Vries
15:00 – 15:15	Break	
15:15 – 15:30	Reconvene Break-out Groups to finalize findings: Phase 2	Facilitator: Joanne de Vries
15:30 – 16:00	Next steps and Summary Wrap-up	Dr. Brian Guy, Jim Mattison

The first presentation by the consultants addressed information assembly, review, evaluation, and gap analysis. During the small group discussion sessions that followed, participants were asked to discuss and record their answers to the following questions:

- Is there other information relevant to Phase 2 that we have not identified?
- Are there any significant data gaps that we have not already identified?
- Have we underrated some sources of information and overrated others in terms of potential usefulness to Phase 2?

Answers to these questions provided by each of the small groups are provided in Appendix B.

The second presentation by the consultants covered the preliminary Phase 2 strategy. The following questions were addressed in the small groups:

- Considering your own interests and needs, is the Phase 2 scope as outlined herein appropriate? If not, what additions to or deletions from the proposed scope would you suggest?
- Does the general approach to Phase 2, as presented, make sense? If not, what alternative approach(es) should be considered?
- Are the proposed Phase 2 objectives achievable? If not, which of the specific objective(s) is (are) not achievable? What alternative and/or additional objective(s) would be more appropriate?
- The proposed Phase 2 methodology includes technical and consultation components. Is the proposed methodology reasonable? If not, how would you improve it?
- The proposed Phase 2 methodology includes technical and consultation components. Is the proposed methodology reasonable? If not, how would you improve it?
- In what format(s) should the final report be presented (e.g. paper report, CD, on website)?

- Other than a report, are there other products related to an updated supply/demand analysis that would be useful to you? If so, please provide details.
- What barriers could prevent the Phase 2 report from getting the exposure it deserves? How could these barriers be removed?

Responses provided by each group are provided in Appendix B.

The workshop was a valuable exercise in that it:

- generated input from a broad cross-section of water professionals throughout the Okanagan;
- generated information useful for refining Phase 1 reporting;
- provided useful input for refining the proposed Phase 2 approach; and,
- helped promote a regional, integrated approach to water management in the Okanagan Basin.

4.0 INFORMATION EVALUATION

This section presents the results of the information identification, review, evaluation, and gap analysis. It incorporates the views of stakeholders expressed at the March 8, 2005 workshop.

4.1 CURRENT SURFACE WATER INFORMATION

A large volume of technical and planning information on surface water resources in the Okanagan is available (Appendix A). About 115 of the 152 identified information sources relate to surface water. However, the relevance of these sources to the current study varies widely, and they vary in geographic scope as well as focus. This section summarizes the work completed in Phase 1 to assemble and review relevant information and identify data gaps, and strengths and weaknesses for Phase 2.

4.1.1 Information Identification and Collection

The process of information identification and collection began with the compilation of key information sources known to the study team. A list of key sources was initially introduced to the Steering Committee in Table 4.1 of Summit's proposal (Summit, 2004b) and was reviewed and refined during the start-up meeting on December 8, 2004. The refined list provided a means to focus the efforts of the study team towards key information sources and areas where available information are particularly weak.

The following list outlines the major types of information that were compiled and reviewed for the project:

- Peer-reviewed papers;
- Presentations and papers;
- Provincial government reports;
- Provincial government databases and files;
- Regional district reports and information;
- Water utility reports and information;

- Environment Canada databases;
- Agriculture Canada research data;
- University research; and
- Multi-agency studies.

A summary of each information source reviewed is provided in the database on CD1. The discussion below focuses on sources deemed relevant and useful for Phase 2 and identifies strengths, weaknesses and gaps in the information.

4.1.2 Surface Water Use

In most portions of the Basin there is a significant difference between licensed water quantities and actual water use in the Okanagan Basin. In order to begin the evaluation of this difference, basic information on licensed quantities and actual water use was assembled.

Licensed water

Licensed water use for the Okanagan Basin was extracted from Water Licence Information System (WLIS) reports (in Demand Report #2 format) prepared by Don McKee of LWBC for 24 points-of-interest, including 18 major tributaries, 4 main valley lakes, Okanagan River, and the entire Okanagan Basin upstream of the Canada-US border. Water licences were classified according to their reported use. These were subsequently summarized into four categories:

1. Offstream use (not returned to point-of-diversion) - this refers to water that is withdrawn at points-of-diversion for the following uses: waterworks (local authority), waterworks (other than a local authority), domestic, incidental-domestic, processing, enterprise, watering, camps, dust control, fire protection, frost protection, institutions, public facilities, stockwatering, swimming pool, water delivery, amusement park, residential lawn/garden watering, irrigation local authority, and irrigation. In special cases, licences for land improvement were

classified in this category if it was clear that flows were not returned to the point-of-diversion (e.g., flood control channel). While a portion of the flow withdrawn for these purposes is returned to the basin, it is usually at a location considerably downstream of the point-of-diversion and/or after some period after withdrawal;

2. Offstream use (returned to point-of-diversion) – this refers to water that is withdrawn for purposes that result in complete or nearly complete return flow near the point-of-diversion. This category includes cooling, ponds, land improvement (with some exceptions), power-residential, and power-commercial;
3. Conservation – this refers to flows for instream uses to maintain fisheries and wildlife values. This category includes conservation – use of water and conservation – construct works; and
4. Storage (non-power and conservation) – this refers to water that is captured for storage usually in upland reservoirs and released based on required demands. This category includes storage (non – power) and conservation – stored water.

An annual summary of this information is provided in Figure 4.1. All reported values have been converted to metric equivalents to permit direct comparison. A detailed summary table of water licences in provided in Appendix C. Total annual licensed offstream use (not returned at the point-of-diversion) is currently approximately 753 million m^3. Roughly 37% (282 million m^3) of this total is associated with a licence for a flood control channel on Kelowna Creek that is used only if necessary. Annual licences for the remainder of the basin therefore total approximately 471 million m^3.

Supplementing this information are files documenting water restrictions and stream notations maintained by LWBC. These files are particularly useful in identifying those streams where water quantity issues exist or are possible in the future. Most streams documented in these files have supporting information maintained in the offices of LWBC. These supporting documents were not obtained for review during Phase 1 but are available upon request.

The WLIS system used to obtain summaries of water licences above points-of-diversion is accessible only to LWBC staff. This means that obtaining information requires a request be made for each query. Additionally, the information can only be delivered as hardcopy output, thus requiring manual entry to a spreadsheet for further analysis. For the Okanagan Basin, this can be a time-consuming task. So for the purpose of Phase 1, queries from the WLIS system were made only for selected major tributaries, and mainstem lakes and river[1]. A limitation of the WLIS system (Demand Report #2) is that it is based on stream hierarchy and this means that licences that are not located on the stream network (e.g., a disconnected spring) are potentially not reported. However, the total volume of such licences is believed to be insignificant on a basin-wide scale (McKee, pers. comm., 2004).

Water use – primary sources

In order to collect primary information on surface water use in the Okanagan, a questionnaire and information request was prepared and sent to 45 water purveyors known to the study team as well as water suppliers on First Nation lands Table 4.1. Particular efforts were made to assemble information from the largest water purveyors. According to Adams, pers. comm. (2004) 22 of the largest water purveyors supply roughly 90 percent of the water used in the Okanagan. Written responses and/or supporting information were obtained for 28 of the purveyors as of the date of reporting. Information from four non-respondents was obtained by other means so that basic information on water supply and distribution was found for a total of 32 water purveyors. A report on First Nations water use was submitted by the Okanagan Nation Alliance (ONA) following preparation of the draft Phase 1 report. The ONA report has been entered into the project database (Appendix A) but the results have not been considered in this final Phase 1 report. The results should be developed further in Phase 2 to achieve an increased understanding of water use by First Nations communities.

[1] Additional WLIS queries will be required if additional tributaries or points-of-interest are required.

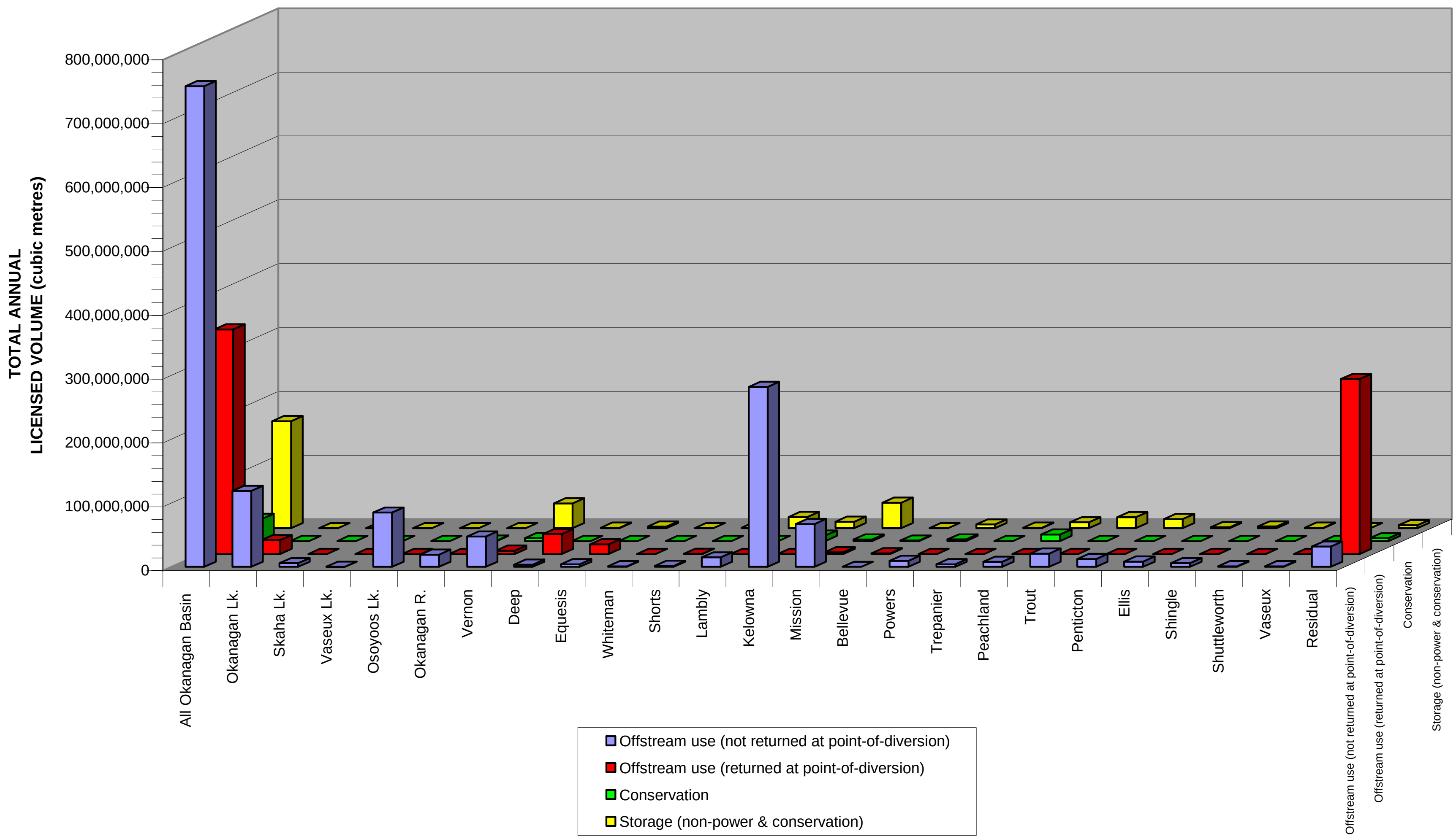


Figure 4.1 Annual summary of water licences in the Okanagan Basin organized by source and general purpose.

Table 4.1 List of water utilities in the Okanagan Basin that were contacted for information on water supply and distribution systems.

Rank	**Water Supplier**	**Approximate number of connections**	**Approximate Population served**	**Basic information of water supply and distribution obtained**
Utilities that have been contacted for information or for which information is available				
1	City of Kelowna	25,000	55,000	Yes
2	Greater Vernon Water	16,000	43,000	Yes
3	City of Penticton	10,000	25,000	Yes
4	Black Mountain Irrigation District	7,000	20,000	Yes
5	Westbank Irrigation District	4,200	11,000	Yes
6	District of Summerland	5,140	11,000	Yes
7	Glenmore Ellison Improvement District	4,245	12,000	Yes
8	Lakeview Irrigation District	3,500	9,000	Yes
9	Rutland Waterworks District	5,400	14,000	Yes
10	District of Lake Country (includes Winfield/Okanagan Centre, Wood Lake, Okanagan Lake, Oyama, Coral Beach, and Ponderosa Water System)	2,900	6,000	Yes
11	District of Peachland	2,200	5,000	Yes
12	Town of Oliver	2,000	4,500	No
13	South East Kelowna Irrigation District	1,400	4,000	Yes
14	West Kelowna Estates	700	1,700	No
15	Naramata Water Utility	600	1,500	No
16	Sunnyside Water Utility	500	1,200	No
17	Kaleden Improvement District	400	1,000	Yes
18	West Bench Irrigation District	400	1,000	Yes
19	Alto Utility	400	1,000	Yes
20	Okanagan Falls Irrigation District	300	750	No
21	Osoyoos Irrigation District	<300		No
22	Sunset Ranch Water Utility	<200		No
23	Falconridge Water Utility	150	350	No
24	Shamboolard Water Utility			No
25	Town of Osoyoos		4,500	Yes
26	Rolling Hills Waterworks Improvement District	<300		Yes
27	Boundary Line Irrigation District	<300		Yes
28	Lakeshore Highlands Irrigation District	<100		Yes
29	South Okanagan Mission Irrigation District	<100		Yes
30	Vaseux Lake Irrigation District			Yes

Table 4.1 cont'd/

Rank	Water Supplier	Approximate number of connections	Approximate Population served	Basic information of water supply and distribution obtained
31	Canyon WWD	<100		No
32	Eagle Rock Irrigation District	<100		No
33	Grandview WWD	<100		No
34	Highlands Park WWD	<100		No
35	Laird Improvement District	<100		Yes
36	Landsdowne WWD	<100		No
37	Larkin WWD	<100		Yes
38	Mountain View Water District	<100		Yes
39	Otter Lake WWD	<100		Yes
40	Silver Star WWD	<100		No
41	Stardel WWD	<100		No
42	Steele Springs WWD	<100		Yes
43	Stepney WWD	<100		No
44	Lower Nipit Irrigation District	<100		Yes
45	Sun Valley Irrigation District	<100		No
46	Traders Cove Waterworks District	<100		Not contacted; info is available
47	Wilson's Landing Utilities Inc.			Not contacted; info is available
48	Casa Loma			Not contacted; info is available
49	Jennens Road Water Users			Not contacted; info is available
First Nations:				
50	Westbank First Nation			No
51	Penticton Indian Band			No
52	Okanagan Indian Band			No
53	Osoyoos Indian Band (Vincor)			No
Utilities that have not been contacted – no information available				
54	Apex Mountain Resort			Not contacted
55	Meighan Creek			Not contacted
56	Woodsdale Utility	<300		Not contacted
57	Lakepine Utility	<300		Not contacted
58	Eastside Utility	<300		Not contacted
59	Greystoke I.D.	<100		Not contacted
60	Skaha Estates Water Utility	<300		Not contacted
61	Meadow Valley Irrigation District	<100		Not contacted

Note: Water suppliers are ordered by approximate number of connections and population served.

The vast majority of water purveyors have some information on water use and the distribution of its use by source and land-use. The larger utilities have this information well documented within files or planning documents. Particularly useful information on water use by land-use covering a considerable period was identified from the following major water utilities:

- Black Mountain Irrigation District;
- City of Kelowna;
- Lakeview Irrigation District;
- Peachland
- City of Penticton;
- South East Kelowna Irrigation District;
- District of Summerland;
- Westbank Irrigation District;
- Glenmore-Ellison Irrigation District; and
- Greater Vernon Water.

The remaining utilities that information is available for generally had some estimate of water use under typical years but less information on the actual distribution of water use amongst users was available. In addition, less information on the distribution of water use by month was available from the remaining utilities.

Overall, there is a wealth of primary water use information available from the major water utilities and at least some information on smaller utilities to provide a solid basis for estimating basin-wide water use. Difficulties in comparing the various records will however arise from the varying periods of record available that do not necessarily include estimates during dry and wet years in addition to average years.

In terms of agricultural water use, there are a substantial number of agricultural water users that are not currently irrigating parcels of land, but that could potentially irrigate in the future. This is because the land still has an associated water right. This has direct implications when assessing long-term water use trends. Information on the distribution of irrigated versus non-irrigated agricultural lands was not identified in Phase 1, but it would be particularly useful to assess this topic in Phase 2. This information is generally available from water utilities, since most assign and manage water rights based on a land grading system (Hrasko, pers. comm., 2005).

Water Use – secondary sources

Early in Phase 1 a request was made for information maintained by the financial department of LWBC on water usage by the major utilities. This would provide a secondary check of the water use quantities. However, these records were not forwarded to the study team prior to the completion of Phase 1.

In Obedkoff's (1971) report titled "Inventory of storage and diversion and their effect on flow records in the Okanagan Basin" some very useful background information is provided on water diversions and use and this is a good basis for evaluating water use in the Okanagan. However, the information is now dated and therefore must be confirmed with up-to-date information from the major utilities.

In a relatively comprehensive demand management study of irrigation district water supplies in the Okanagan Valley, KWL (1990) presents a useful analysis of water use by utility, organized by irrigation and domestic uses. Supporting information on water use by crop type and irrigation system is also provided. Overall, the information is highly relevant to Phase 2 and would provide a solid basis for evaluating water use throughout the basin. Nevertheless, it must be recognized that the data is roughly 15 years old and may or may not be representative of current conditions. In fact, it is expected that conditions have changed since 1990 as many orchards have been abandoned since then due to weak economic conditions.

4.1.3 Surface Water Supply

Relevant data, reports, and models

On the topic of surface water supply, the studies conducted under the Canada-BC Okanagan Basin Agreement (Consultative Board, 1974) remain the most comprehensive to date. Hydrologic investigators evaluated the water balance for the entire basin and investigated eight major tributaries in detail. A large amount of basic watershed information was presented and still remains valid. However, while the framework of the climatic and hydrologic analyses [e.g., Obedkoff's (1973a) report titled "Regionalization of sub-basin hydrology"] is technically sound, the results are dated and do not necessarily represent current conditions. This is particularly true given the climatic and hydrologic changes that have been identified since mid-1980s (Whitfield, 2001). Furthermore, over 30 years of additional streamflow information has now become available to refine or calibrate models since the Okanagan Basin Agreement reports were produced.

Obedkoff's (1994) report titled "Okanagan Basin Water Supply" is the most recent water quantity study of the mainstem of Okanagan River, however the results are over 10 years old and may not necessarily be representative of current conditions. Obedkoff's analysis is based on applying drought scenarios (based on the 1929-31 period) to a model designed to simulate monthly operation of Okanagan Lake and Okanagan River to Oliver. The framework of the model remains valid and is applicable in Phase 2 investigations. The usefulness of the model is that any scenario (e.g., multi-year drought) may be used as input to evaluate water supply conditions in Okanagan Lake and along the mainstem of Okanagan River.

The recently completed Trepanier Landscape Unit (TLU) Water Management Plan (Summit, 2004a) provides a thorough assessment of the TLU and several major tributaries: Lambly, Powers, Trepanier, Peachland, and McDougall Creeks. The assessment provided estimates of current and future (2020 and 2050) streamflows under a number of climate change and population change scenarios. The report provides a solid basis for evaluating the streamflows on the west side of Okanagan Lake. However, natural streamflows in the plan were based on estimates reported by NHC (2001). While these estimates are reasonably accurate they are considered first approximations given some assumptions and methods used in the analysis.

NHC's (2001) assessment of 21 tributaries of the Okanagan presents an approach to estimating naturalized flows that remains valid and remains reasonable for several streams in the Okanagan. However, the estimates they produced could be refined with additional effort. A key assumption used by NHC was that licensed quantities reasonably well represented actual use estimates. However, since it is unlikely true in many streams, efforts to estimate natural flows should strive to evaluate actual water use (e.g., diversions and withdrawals). The applicability of NHC's (2001) framework to naturalize streamflow records will primarily depend on available streamflow records and the nature and magnitude of water use in the watershed of interest. Since these vary throughout the Basin, its application will be limited to a select number of streams. A secondary issue associated with NHC's (2001) is the use of the reference period 1961-1995, which is dissimilar from the period proposed for Phase 2 (1971-2000).

Several Hydrology Section reports maintained by the Ministry of Sustainable Resource Management (MSRM) are focused on specific water management issues in specific streams and are generally not applicable to basin-wide studies. While the information is generally accurate and the sources credible, this information is best suited as secondary information to ensure estimates by other means are reasonable. Examples of such reports include: "Water Supply Hydrology of Powers Creek Basin and the Westbank Irrigation District" by Letvak (1981); "South East Kelowna Irrigation District Watershed Hydrology by Obedkoff (1978); "Trepanier Creek water yield" by Hunter (1978); and "Runoff in Okanagan Valley 1983-87" by Letvak (1988).

Letvak (1980a and 1980b) outlines a method to estimate annual runoff in tributaries on the west and east side of Okanagan Lake based on multiple regression analysis of physiographic variables and annual runoff in 1977. While it is one of a few regionally applicable methods, it is dated and should only be used as a rough first approximation. Letvak's relations have been used throughout the basin and have been quoted several times in water supply reports commissioned by water utilities. This means that water supply estimates based on these relations should be viewed with caution.

Obedkoff (1998 and 2000) provides the most recent and comprehensive sub-regional relations to estimate natural hydrologic characteristics of ungauged basins in the Southern Interior. While the information is technically sound and credible it is slightly dated and more importantly requires sound judgment in its application. It nevertheless provides a relatively straightforward means to arrive at natural streamflow estimates in ungauged basins.

Obedkoff's (1973b) report titled "Similkameen Basin Hydrology" presents a useful model of estimating runoff from ungauged basins based on a modified grid-square method. According to Obedkoff it is feasible to adapt this model to the Okanagan in order to provide an independent check of runoff estimates based on other regional relations [e.g., Obedkoff's (1998 and 2000) sub-regional relations]. However, the level of effort required to revise this model for application may not be justified in light of the other available information sources.

Another independent source of streamflow estimates for all major tributaries in the Okanagan is that presented in Cohen et al. (2004) using the UBC Watershed Model. While the methods used are scientifically rigorous, the objective of the modeling effort was not to best represent the current conditions in each tributary but to reasonably represent current conditions in order to evaluate the effects of climate change scenarios. An independent check of the model output by the study team (for the base case 1961 to 1990) against actual natural streamflow records collected by Water Survey of Canada (WSC) suggests that there may be some bias in these UBC Watershed Model results. Hydrographs from the model appears to rise earlier, have relatively lower peaks and have slightly higher fall and winter base flows versus the WSC records. Nevertheless, the modellers appear to have reasonably calibrated the model and actual records in terms of overall annual runoff, a parameter which was of particular interest to the modelling team (Alila, pers. comm., 2005). Output from the UBC Watershed Model used by Cohen et al. (2004) for the base case (1961-1990) and future climate change scenarios for mid-2020s, mid-2050s, and mid-2080s is available and has been obtained by the study team for 21 tributaries entering the main stem lakes and Okanagan River.

All models noted above utilize or require streamflow records to operate or calibrate. Such principal data to 2001 is available from Hydat (Environment Canada, 2003). Preliminary data to end-2004 is also available upon request. A total of 179 hydrometric stations have been established in the Okanagan Basin, with 150 measuring stream level/flow and 29 measuring lake levels. Currently, 18 stream locations and 6 lake locations are actively gauged. Supplementary streamflow information for recent years has also been collected for the Ministry of Water Land and Air Protection (Matthews, pers. comm., 2005). Unfortunately the majority of streamflow records are affected by regulation and thus do not directly represent natural streamflow conditions. Additionally, no continuous records are available for the period 1971-2000 at the mouths of the major tributaries. This means that streamflow estimation and regionalization will necessarily be a major component in Phase 2.

Surface groundwater interactions

Particularly in the lower reaches of Okanagan tributaries, interactions between surface flow and groundwater can be significant. However, the extent of losses to groundwater from surface streams during dry years and possibly gains during wet years is largely unknown. The magnitude of these interactions has been identified as potentially significant in at least Peachland, Trepanier, Trout and Lambly Creeks (Obedkoff, 1990). Based on the synopsis of a report that was unavailable for full review by the study team prior to reporting, losses of streamflow to groundwater may be relatively minor in some tributaries (e.g., Mission Creek) (Lowen and Letvak, 1981). However, the study team is aware of additional work in 2003 that indicated that losses to groundwater could be significant during dry years (roughly 10-20%) in Mission Creek. Work is currently in progress to summarize these results for the Black Mountain Irrigation District (Hrasko, pers. comm., 2005).

Effects of Timber Harvesting

Timber harvesting is widespread in the higher elevations of the Okanagan Basin. While Okanagan Basin Agreement reports concluded that forestry has a relatively minor effect on water supply at the time (1970s), its effect may be greater at present due to increased levels of harvesting. Scherer and Pike (2003) provide a primer for understanding the effects of forestry on water resources in the Okanagan and the research conducted by the Ministry of Forests in the Upper Penticton Creek watershed has provided insight to the hydrologic effects of forest harvesting. Preliminary analyses from the Upper Penticton Creek watershed indicate that logging 20% of the treatment watershed increases peak flows and decreases low flows, but does not affect average flows (Winkler, et al., undated) – a conclusion similar to the Okanagan Basin Agreement studies. These conclusions however should be further evaluated in Phase 2 in light of climate change effects on hydrology, since climate change and harvesting tend to have opposing influences on water yield.

The effects of existing timber removal are incorporated into the UBC Watershed Model results presented by Cohen et al. (2004). Therefore comparison of streamflow estimates with UBC Watershed Model estimates provides a basic means to ensure on a tributary by tributary basis that the effects of timber harvesting are reasonably well accounted for.

Water balance information

In developing an updated water balance for the Okanagan Basin (tributaries and mainstem lakes and river), it is essential to have reliable information on which to base estimates of each component of the water balance (see Section 6.2 for discussion of the general water balance). In order to assess rainfall, snowmelt, and evapotranspiration, climate information is needed. Climate normals are available from Environment Canada for 1971-2000 for 18 stations in the Okanagan. Unfortunately the majority (16) of the stations are located at relatively low elevations in the basin, while only two stations (McCulloch and Peachland-Brenda Mines) are on the plateau. Fortunately snow course data from the River Forecast Centre (MWLAP) is available for 20 active and 6 inactive locations throughout the Okanagan at relatively high elevations.

As discussed in Section 4.2, there is limited knowledge of groundwater availability and hydrogeology. Therefore, a water balance approach to estimating groundwater supply and demand is likely an effective way to develop broad knowledge of groundwater availability in the Basin where limited aquifer data exists. Where aquifer data does exist, a water balance approach would confirm estimates of groundwater availability based on the aquifer data.

Relatively little information is available on lake evaporation and evapotranspiration in the Okanagan, particularly at higher elevations. Initial estimates provided in the Okanagan Basin Agreement reports and a relatively comprehensive study of lake evaporation by Trivett (1984) are the primary sources identified. Other sources include reports by the staff of Agriculture and Agri-Food Canada in Summerland, and the website Farmwest.com.

4.1.4 Surface Water Data Gaps

The following summarizes the key information gaps associated with evaluating surface water supply and demand in the Okanagan:

- Information on actual use in the basin is available from individual utilities but no current summary for the basin is available. This information is of paramount importance to Phase 2 and compiling and consolidating this information [from the various sources (e.g., water utilities, LWBC financial department) will be necessary in order to assess actual use versus licensed quantities;
- A considerable amount of primary hydrometric data is available but no continuous record is available for 1971-2000 for the mouths of major tributaries.

The lack of natural streamflow data means that methods of naturalizing streamflow records and developing regional streamflow estimating procedures will be necessary in Phase 2;

- Most models to estimate water supply are dated, however the scientific framework behind several models is sound. Those most relevant to Phase 2 include Obedkoff's (1998 and 2000) sub-regional relations, Obedkoff's (1994) model to estimate water supply along the mainstem of Okanagan River, NHC's (2001) framework to naturalize streamflows, and the UBC Watershed Model;
- Several stream-specific studies can be used as independent checks to ensure estimates are reasonable;
- Information on lake evaporation and evapotranspiration (particularly at higher elevations) is generally limited; and
- Losses of streamflow to groundwater during drought years are largely unknown but are suspected to be significant (e.g., 10-20%) in some major tributaries. Very limited site-specific information is available on this topic.

4.2 CURRENT GROUNDWATER INFORMATION

4.2.1 Introduction

At present, insufficient knowledge exists to develop accurate measurements of available groundwater production and supply for the Okanagan Basin. For most of the Basin, groundwater use is not monitored. Basic well data including number of wells, their location, and production is lacking. In addition, insufficient knowledge is currently available for development and implementation of science-based legislation governing the sustainable development of groundwater resources in the Okanagan Basin.

Historically, groundwater information collected by the Province has mainly been in the form of basic data such as well records, water chemistry, or water levels, or in site-specific studies. In view of growing groundwater information needs, efficient and effective long-term groundwater management requires this basic data to be interpreted and synthesized into more usable and accessible information.

4.2.2 Groundwater Data Sources

As presented below, a large quantity of information regarding groundwater provenance, supply, and demand is available for the specific areas in the Okanagan Basin. Most of this data is contained within a relatively few sources. Additional information is likely available from sources other than those described below, but focusing on obtaining data and interpretations from these primary sources will help guide and focus the Phase 2 study. Key groundwater data sources for the Okanagan Basin were identified as follows:

- B.C. Aquifer Classification Maps developed by MWLAP;
- 1974 Okanagan Basin Study;
- MWLAP Well Database;
- MWLAP NTS Reference Library;
- MWLAP Observation Well Network; and
- Irrigation/Water District Capital Improvement Plans.

Provided below are brief summaries of information and analyses provided in each data source; limitations in the available data or data that is generally not included is also identified. Data which is not included within the information sources, limitations in the available data, and deficits in our understanding of hydrogeologic conditions in the Basin comprise groundwater data gaps, which are further discussed in Section 4.2.3.

MWLAP Aquifer Classification Maps

The MWLAP aquifer classification system is intended to inventory and prioritize aquifers for planning, management and protection of the Province's groundwater resource. The MWLAP aquifer database was designed to provide a tool to assist with effective aquifer management. This tool was required to assist resource managers in establishing, for each aquifer, its use and vulnerability to contamination, and an indication of the importance or priority to manage and protect an aquifer. The BC aquifer classification system systematically identifies and groups aquifers with similar attributes into categories suitable to support resource managers with aquifer protection and management activities.

Over 700 aquifers province-wide, with 65 located in the Okanagan Basin, have been identified and classified. A comprehensive suite of information is incorporated within the aquifer database. Each mapped aquifer includes:

- Based on available well data, geology and stratigraphic data, water quality, and supply/demand data;
- Aquifer assessment, classification and ranking by vulnerability, development, productivity, and demand, also several with quality and quantity evaluations; each of these have sub-criteria for assessment and ranking;
- Maps of aquifer extent including well-defined and estimated boundaries; the maps are based on available well location and depth data, air photos, topographic maps, geologic and stratigraphic data, water chemistry, and water level data;
- Aquifer maps of bedrock aquifers - based on springs, wells, and geologic data including rock type, fracture, and rock unit boundaries; and
- Several base map layers information, including TRIM Orthomosaics, computer-generated hillshade maps, as well as numerous map features including elevation contours, landforms, transportation, water features, and map annotations.

However, with respect to the Phase 2 assessment of groundwater data for the Okanagan Basin, substantial aquifer and hydrogeologic information is not available from the MWLAP aquifer database. This information includes:

- The data used to identify, map, and assess each aquifer has not been rolled up into summary statements about the groundwater resource for a watershed or region;
- Specific supporting data for each aquifer including interpretations and notes, maps/cross-sections, aquifer and well testing reports, well location and construction information, water level data, geologic mapping and stratigraphic data, water quality data, and demand and production data are not available;

- Some aquifer maps and rankings are supported by substantially less data than others; all classifications are subjective based on the mapper's interpretation and evaluation of available data;
- Not completed for aquifers less than 1 km^2 in area;
- Not completed for aquifers where negligible or no groundwater use exists;
- Not designed to answer most site-specific water supply, water quality, or potential well interference questions;
- Many more wells are actually present and in use than were used by aquifer mappers, thus the aquifer maps, classifications, and rankings may not be entirely correct, or may be incomplete. Also new data has been compiled since the aquifers were originally mapped and classified, thus many aquifers may require remapping and reclassification;
- Aquifer classifications are for the entire aquifer; local variability in aquifer parameters or classifications may exist;
- No information regarding specific aquifer production capacity is provided; and
- No information regarding specific aquifer demand is provided.

MWLAP cautions that the aquifer identification and classification system is intended for Basin-wide, regional, and local use; the maps and classifications are not intended to replace more detailed aquifer assessment required to manage the resource.

1974 Okanagan Basin Water Study

The 1974 Canada-British Columbia Okanagan Basin Agreement Report was the culmination of a 4-year study intended to develop a "*comprehensive framework plan for the development and management of water resources for the social betterment and economic growth of the Okanagan community*". With respect to increasing knowledge and understanding of Basin-wide groundwater issues, significant groundwater assessment work was completed in limited areas within the Okanagan Basin. Included information consists of a detailed hydrogeologic assessment of the north Okanagan area, and reconnaissance-level assessments of six sub-basins. Specific hydrogeologic data provided in the report includes:

- Presentation of an overall conceptual diagram of Okanagan Basin hydrogeology with limited flow and water budget information;
- Seismic profiles of unconsolidated sediments with interpretations of the north Okanagan area, and limited seismic data in the south Okanagan;
- Discussion and analysis of a rotary drilling exploration program conducted in the north Okanagan area; this exploration program was used to identify aquifer stratigraphy, validate seismic interpretations, conduct aquifer tests, and identify aquifer parameters;
- Rough maps and geologic cross-sections of unconsolidated aquifers in the north Okanagan area;
- Limited data and interpretations regarding basin recharge and discharge areas for the north Okanagan area;
- Limited data and interpretations on groundwater mining in the north Okanagan area;
- A small amount of data regarding surface-groundwater interactions at Vaseux Creek; this data was apparently used to validate north Okanagan area seismic data and interpretations;
- Limited reconnaissance-level hydrogeologic data for six Okanagan Basin sub-basins, including sub-basin maps, geology and stratigraphy, hydrology and climatic/precipitation data, summaries of previously collected hydrogeologic data as available, local water quality data, and minor bedrock aquifer data;
- Substantial groundwater data for the Penticton Creek area, and substantial geologic data available for Lambly Creek area; and
- Some indirect water quality and septic data that could be used for groundwater recharge estimates in populated areas.

However, with respect to the Phase 2 assessment of groundwater data for the Okanagan Basin, substantial aquifer and hydrogeologic information was not included in the 1974 groundwater study. This information includes:

- No basin or region-wide synthesis of the north Okanagan and sub-basin groundwater data;
- No explanation is provided for why the north Okanagan was selected for detailed hydrogeologic analysis compared to other known and/or heavily used aquifers in the Basin – such as those beneath Kelowna, Vernon, or Westbank;
- The report authors did not extrapolate the north Okanagan hydrogeologic findings to other parts of the Basin;
- No water balance or water budget calculations that include groundwater are provided;
- No explanation for why the reconnaissance studies were performed on the six sub-basins, nor why those specific sub-basins were selected; and
- The report authors selected sub-basins where little or no hydrogeologic data was available to validate reconnaissance observations and findings.

Although some of the groundwater data is dated, much may still be useful for current and future site-specific, watershed, and basin-wide hydrogeologic analyses.

MWLAP Well Database

The MWLAP Well database is intended to provide an easily accessible resource of wells in the province. Specific well records are searchable by several criteria including location, well tag number, and lithology. Included within the database is:

- Drilling information including well tag number, drilling company, well owner, and well location;
- Well records including stratigraphy, depth, static water levels, estimated production rate, and well completion/design data for many wells; and
- Base map layers that are useful for hydrogeologic interpretations of well data, including TRIM Orthomosaics, computer-generated hillshade maps, as well as

numerous map features including elevation contours, landforms, transportation, water features, and map annotations

However, many aspects of the well database limit its usefulness for the Phase 2 objectives. These include:

- The well data is only as good as supplied driller's logs, and this information is commonly highly incomplete or inaccurate;
- Many well records supply no stratigraphy, static water level, or well production rate data;
- Well location data is commonly very poor;
- Many wells, especially older wells, are not included in the database, and only 60% of wells on file in the province are displayed.

This database is continually being updated with additional well records and corrections to existing well data which should increase its usefulness for hydrogeologic analyses of the Okanagan Basin.

MWLAP NTS Reference Library

This online reference library provides digital access to many groundwater reports and groundwater data for the Province. A wide variety of reports are available for many aspects of groundwater supply, management, and quality in the Province. The Library contains over 320 Okanagan Basin groundwater or groundwater-related references, almost all comprised of site-specific reports generated to address specific issues. These reports have been developed by both public and private organizations.

The reference library can be characterized as follows:

- Documents organized by NTS map reference number, which are somewhat organized by location, municipality, or resource; listed references generally include most or all of report title, author and publication date;

- The list of reports appears very comprehensive; probably most groundwater research conducted within the Okanagan Basin is included in this list;
- Reports dated from approximately 1960 to 1992 are included; and
- The reports apparently address diverse groundwater assessment and analysis projects including aquifer tests and analyses, well drilling and log data, local groundwater evaluations, groundwater quality data, shallow groundwater and groundwater drainage problems, geologic analyses, and many other topics.

However, several limitations reduce the usefulness of the reference library resource for Basin-wide groundwater assessments. These include:

- The documents are loosely sorted by location, and no more rigorous organization exists;
- No reports later than 1992 are listed;
- The report list is only crudely searchable by key word, and the reports are not organized by date or topic;
- The list also contains references to both available reports, and reports where permission by the report owner is required to review the data, with no easy way to discriminate between these types;
- Limited access to private or consultants reports is available. Authorization from the report author is required to access the report and included data;
- The reports address mostly site-specific topics or issues, very few reports presenting regional analyses or syntheses are included;
- Included data is apparently of variable quality and thoroughness and ranges from incidental field notes to comprehensive and apparently rigorous aquifer analyses;
- Substantial effort will be required to extract, assess, compile and interpret the available groundwater data; and
- Most reports are only available in hard copy form, with access limited solely to the MWLAP library.

In general, although extracting and organizing useful information from these reports will be time-consuming and labour-intensive, as a whole these reports contain the vast majority of Okanagan Basin groundwater knowledge.

MWLAP Observation Well Network

The primary purpose of the MWLAP Observation Well Network is to collect, analyze and interpret ground water hydrographs and ground water quality data from various developed aquifers in BC. This data is used to characterize, monitor and manage the available groundwater resource in a sustainable manner.

The observation well network database includes the following information:

- Water level information for approximately 29 wells located in the Okanagan Basin;
- Water level data collected from early 1960's to the present;
- Water level hydrographs;
- Driller's well logs which generally include location, stratigraphy, well construction, and estimated water production potential;
- "Natural" changes in static water level since wells are generally located in areas where little human influences on water levels can be expected; and
- Selected database records include precipitation and cumulative precipitation departure information, basic well construction information, stratigraphic data, and brief interpretations of hydrograph data.

However, this resource also has limitations which reduce its usefulness to the groundwater supply/demand component of Phase 2. These include:

- Only 29 wells are used for the entire Okanagan Basin and most wells are located in valley areas;
- Some wells are inactive, and water level data is no longer recorded in these wells;
- Many wells only have data since the late 1970s or 1980's;

- Many well driller's logs commonly include only minimal well construction, stratigraphy, or production data; and
- Many database records only contain basic hydrograph data with no interpretations or climatic information.

Groundwater Supply/Demand Information

Groundwater supply and demand information may be obtained from Okanagan Basin water purveyors. Approximately 56 public water purveyors currently provide water services in the Okanagan Basin. We contacted 45 of the largest water utilities and requested general information regarding operation of their water system. A total of 32 utilities responded, and many obtain some or all of their water from groundwater sources. According to Hrasko (pers. comm., 2005), approximately one-half of the 56 water purveyors use groundwater for some or all of their water production.

Information resulting from our query to Basin water system operators includes:

- Available groundwater data from individual irrigation and water districts varies from basic annual production/consumption rates to comprehensive analyses of water production by month and year;
- The amount of groundwater production data is generally related to the size of the water purveyor, with larger districts having more data available;
- A few purveyors provide water use totals by business type;
- Some purveyors provide limited well data, usually just the number of wells providing water to their system;
- Limited data regarding the number of connections and water system design data is available;
- There is some domestic and irrigation water use and irrigation acreage data; and
- Some consumption forecast data is available.

Substantial groundwater supply and demand information available from local water system operators can be totalled into Basin-wide estimates of overall current and projected groundwater use. However, limitations to information collected from water purveyors include:

- Water purveyors who obtain their supply from both surface and groundwater may have limited groundwater-only information;
- No information or analyses regarding long-term impacts to their water supply from continued or increased well drawdown is readily available;
- Limited data regarding domestic vs. irrigation or agricultural use is commonly available;
- Limited data is available regarding the water systems projected impacts to water supply from climate change is available; and
- No well construction, testing, or analysis data is readily available as this information in commonly proprietary, although this information may be obtained upon approval from the data owners.

Although only a few Water District Capital Plans were submitted in response to our inquiry, substantial information regarding current and future water supply is available in some of these plans. Capital Plans that include useful groundwater information include those generated by the following Water Districts:

- Greater Vernon Water District;
- Glenmore-Ellison Improvement District;
- Rutland Waterworks District;
- District of Summerland;
- Osoyoos Irrigation District;
- The Town of Osoyoos; and
- Southeast Kelowna Irrigation District.

Numerous additional districts also obtain some or all of their water from groundwater wells. As the total number of connections for these districts is generally less than 300, in general the total amount of groundwater use is limited. However, some smaller water system purveyors may provide relatively small quantities of water to domestic users, and provide a much greater amount for agriculture for irrigation.

4.2.3 Groundwater Data Gaps

Data gaps were identified coincident with identification and evaluation of available groundwater information. As discussed above, abundant site-specific groundwater data is generally available for more intensively developed areas within the Okanagan Basin. However, extrapolation of this data into less well known areas, synthesizing available data into watershed or basin-wide understandings, or integrating multiple sources and types of data into usable databases suitable for effective water management has not been completed.

Substantial gaps or limitations in our technical understanding of groundwater in the Okanagan Basin exist. These include:

- Significant uncertainties exist with respect to fundamental aquifer characterization in the basin including identification of aquifer hydrogeologic parameters, groundwater recharge and discharge areas, development of accurate water budgets, and evaluation of water quality;
- No regional analysis of surface/groundwater interactions has been completed, nor has any correlation between existing aquifer data and abundant surface water data been made;
- Limited evaluation of the impacts of climate change on groundwater resources has been completed;
- Few estimates of sustainable groundwater production from aquifers have been completed; and
- Although substantial data and analyses are available for heavily used aquifers, limited data is available regarding the nature and extent of most aquifers in the Okanagan Basin.

Significant gaps in available groundwater data are also present. These include:

- With the exception of focused investigation in the north portion of the Basin, the 1974 Okanagan Basin study selected relatively unpopulated and inaccessible watersheds to evaluate; no attempt was made to extrapolate the study findings to more populated parts of the basin;
- Limited data sets are available for less populated areas and higher basin elevations;
- Although some continuous groundwater elevation data exists from the early 1960's in certain parts of the Basin, very little other groundwater data which has been continuously collected for many years is present;
- Almost all Okanagan Basin groundwater data is site-specific; no attempt has been made to generalize from local information to watershed or basin-wide scales; no regional synthesis of existing data into a regional summary of existing hydrogeologic aquifer conditions has been completed;
- Few groundwater resource evaluations have been completed for the major aquifers, few or none have been completed for smaller or less well-defined aquifers;
- No information regarding data quality, including review, testing or validation, is available for most readily available groundwater data;
- Although some well data is available for some wells in the Basin, many if not most wells have not been included in the MWLAP well database, resulting in significant uncertainty with identifying the number of wells presently utilizing groundwater; and
- Limited communication or transfer of critical groundwater data and issues has been made to basin water managers or the public.

The fact that there are over 320 entries in the MWLAP NTS reference database suggests that there is substantial groundwater knowledge for the Okanagan Basin. However, the great majority of this data is highly focused on specific areas and issues. Not even the 1974 Okanagan Basin Water Supply Evaluation attempted to comprehensively develop a synthesis of available groundwater data and develop useful groundwater management tools.

In addition, insufficient data are available to develop accurate groundwater supply and demand estimates for the Basin. Although individual water and irrigation providers may have developed district-specific estimates of future groundwater demand as part of their capital planning efforts, only rough estimates of groundwater production from private wells can be made and these estimates have not been combined into groundwater supply and demand estimates for the large aquifers or for the entire basin.

A further difficulty with estimating Basin-wide groundwater supply and demand arises due to the fact that the actual number of wells presently in use in the Basin is unknown (because records of well construction and abandonment have not historically been required to be supplied to the Province). Thus only rough estimates of groundwater production from individual wells can be made. Secondly, as no records of groundwater use are required by the Province, the amount of water that is being used from these wells can only be roughly estimated. Where well production data is known, accurate volume records are generally not kept.

4.2.4 GAOB Project Overview

A substantial long-term Basin-wide groundwater data compilation, evaluation, and collection project, led by MWLAP and several associated organizations, is presently underway. This effort, called the Groundwater Assessment of the Okanagan Basin (GAOB) project, is intended to develop a better understanding of groundwater resources in the Okanagan Basin in order to apply a more coordinated and effective approach to water management in the area. The overall focus and goals of the GAOB project are highly complementary to those of LWBC. In Section 6.0, we describe a plan to make use of those GAOB results that will provide useful input to the Phase 2 study, and will be available in 2005 and 2006.

The GAOB project is intended to characterize and assess the groundwater resources within the Okanagan Basin's unconsolidated and alluvial aquifers. The scope of the project will include a regional assessment of hydraulic properties, recharge, selected water quality parameters, water budgets and more detailed assessments of specific areas such as the development of numerical models for the Southern Okanagan and Kelowna. Key major objectives for the project include:

Aquifer Characterization

- Assess the hydraulic properties of unconsolidated and bedrock aquifers;
- Identify groundwater recharge and discharge areas for aquifers and select community wells;
- Describe the hydrogeology of the major Basin aquifers;
- Characterize groundwater flow directions and rates in major aquifers;
- Estimate the variability in vulnerability across key aquifers; and
- Develop standard approaches for aquifer characterization.

Water Budgets

- Calculate recharge rates for headwater, benchland and valley bottom areas;
- Assess the water budget and sustainable yield of key aquifers;
- Develop a greater understanding of the regional water budget for the Okanagan Basin;
- Develop an estimate of groundwater supply and demand for the Okanagan Basin;
- Gain a greater understanding of the surface water contribution and the irrigation return flows to the local and regional water budgets; and
- Develop standard approaches for estimating water budgets.

Groundwater / Surface Water Interactions

- Assess the groundwater / surface water interactions in key locations;
- Provide a greater understanding of the regional surface water contribution to the groundwater resources in the Okanagan Basin; and

- Develop standard approaches for assessing groundwater and surface water interactions.

Water Quality

- Characterize water quality in key aquifers and assess the origin of specific contaminants in groundwater;
- Examine water quality trends for selected parameters;
- Understand and determine background water quality as well as anthropogenic effects such as nutrient loadings on water quality;
- Provide a regional assessment of key water quality parameters such as nitrates; and
- Determine if any trans-boundary water quality impacts are present.

Climate Change

- Research potential impacts of climate change on the groundwater resource in the Okanagan Basin.

Significant additional effort will be made in developing partnership initiatives with key groundwater users in the Basin, and actively pursuing community outreach programs to assist with understanding of groundwater issues and management.

Specific major outcomes for the GAOB project will include:

- A quantitative and qualitative assessment of the groundwater resource in the Okanagan Basin;
- An increased understanding of groundwater / surface water interactions in key locations in the Okanagan Basin;
- The development of an interactive GIS database and numerical models for key Okanagan Basin aquifers and groundwater characteristics as part of the national and provincial databases;

- Outreach activities for increasing groundwater awareness of the groundwater resource; and
- Development of a process to incorporate the science-based results into sustainable water management practices for communities in the Okanagan Basin.

In addition, Dr. Diana Allen of Simon Fraser University, in collaboration with numerous other individuals and scientific organizations, has submitted a strategic research proposal to the Canadian Water Network (CWN) to complete a basin-wide assessment of groundwater recharge in the Okanagan Basin (Allen, 2004) as part of the GAOB effort. Dr. Allen's proposal includes four integrated projects:

- Characterize direct groundwater recharge and define aquifer vulnerability zones in the basin to aid with land use planning;
- Define the relative contribution of potential source areas of groundwater recharge including highlands, benchlands, and valley bottoms;
- Define surface/groundwater interactions within the watershed and the contribution of surface water to groundwater recharge; and
- Develop decision support tools for strategic planning and policy development as a PATHWAYS[2] project.

The CWN projects will substantially support LWBC and GAOB objectives by providing a more comprehensive analysis of the Okanagan watersheds where past research efforts have focused entirely on surface water resources or local groundwater issues. The CWN projects will also increase our knowledge of groundwater recharge at the basin scale, developing methodologies for undertaking comprehensive groundwater assessments of a large and complex region, and developing decision support tools that can be used to effectively manage groundwater resources.

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[2] PATHWAYS is part of a broader Natural Resources Canada program aimed at developing spatial decision support systems to help promote and facilitate the integration and use of earth science information.

The GAOB and CWN effort will be completed as funding and support allow over the next seven to ten years, much longer than LWBC's time frame for completing the Phase 2 water supply and demand evaluation. However, several individual GAOB projects that will support LWBC's Phase 2 objectives are presently underway, and scheduled to be completed during 2005 and 2006. Coordination of LWBC Phase 2 objectives and the GAOB project is discussed in Section 6.0.

4.3 CURRENT POPULATION AND LAND USE

Current population estimates and projections are available from BC Stats on a regional district basis (Table 4.2). These population statistics are based on the 2001 census and are organized by municipality and electoral area. Further details (e.g., by community or neighbourhood) on population distribution are available but would involve reviewing land-use information, official community plans (OCPs) and contacting individual municipalities, health authority, and school districts throughout the Okanagan (Hartley, pers. comm., 2005). Such a process was followed in Summit (2004a) to arrive at detailed population estimates in the Trepanier Landscape Unit. This process was beyond the scope of Phase 1 but will be required in Phase 2.

Table 4.2 Census results for the Okanagan region in 2001 by regional district.

Regional District	2001 Population	1996 Population	1996-2001 Growth (%)
CENTRAL OKANAGAN			
Kelowna	96,288	89,442	7.7
Lake Country	9,267	9,007	2.9
Peachland	4,654	4,524	2.9
Indian Reserves	7,857	7,221	8.8
Central Okanagan G	10,066	9,264	8.7
Central Okanagan H	15,935	13,637	16.9
Central Okanagan I	3,672	3,446	6.6
Total:	**147,739**	**136,541**	**8.2**
NORTH OKANAGAN			
Armstrong	4,256	3,906	9
Coldstream	9,106	8,975	1.5
Enderby*	2,818	2,754	2.3
Lumby*	1,618	1,689	-4.2
Spallumcheen	5,134	5,322	-3.5
Vernon	33,494	32,165	4.1
Indian Reserves	2,474	2,130	16.2
North Okanagan B	3,067	3,113	-1.5
North Okanagan C	3,627	3,587	1.1
North Okanagan D	2,840	2,982	-4.8
North Okanagan E	938	987	-5
North Okanagan F	3,855	3,997	-3.6
Total:	**73,227**	**71,607**	**2.3**
OKANAGAN-SIMILKAMEEN			
Keremeos*	1,197	1,167	2.6
Oliver	4,224	4,285	-1.4
Osoyoos	4,295	4,127	4.1
Penticton	30,985	30,987	0
Princeton*	2,610	2,826	-7.6
Summerland	10,713	10,584	1.2
Indian Reserves	1,729	1,743	-0.8
Okanagan-Similkameen A	1,897	1,845	2.8
Okanagan-Similkameen B	1,122	1,064	5.5
Okanagan-Similkameen C	4,154	4,077	1.9
Okanagan-Similkameen D	5,703	5,315	7.3
Okanagan-Similkameen E	1,996	1,998	-0.1
Okanagan-Similkameen F	1,989	1,903	4.5
Okanagan-Similkameen G	2,052	1,959	4.7
Okanagan-Similkameen H	1,969	2,053	-4.1
Total:	**76,635**	**75,933**	**0.9**

* outside or partially outside the study area

4.4 FUTURE PRESSURES

The principal factors that will influence water resources in the Okanagan in the future include climate change, population change and land-use change. Population and land use changes will influence demands for water while climate change will affect the water supply as well as influence water demand, because the growing season will likely be longer, warmer, and drier. Finally, economic forces will also play a role in determining future water demands. The economy is a direct driver of demand, and land and water prices and price elasticity will also affect water use. The following sections review some of the key pressures and principal information sources that are available and can be used to assess these pressures on water resources.

4.4.1 Population Change

Estimates of future changes in population are available from BC Stats 20-year growth predictions, OCPs from individual municipalities, and regional growth assessments (RDCO, 2001). The distribution of these future changes would require reviewing population projections from individual municipalities, health authorities, and school districts throughout the Okanagan. Population projections beyond the 20-year BC Stats projections are generally not available given the level of uncertainty in the controlling factors (e.g., future economic conditions).

4.4.2 Climate Change

Climate change in the Okanagan and its likely effects on water management have been recently investigated and reported by Cohen et al. (2004). Cohen et al. (2004) has forecast potential temperature and precipitation change for the Okanagan Basin using three different Global Climate Models (CGMs): the Canadian global coupled model (CGCM2), the UK's Hadley Centre model (HADCM3), and the Australian model from the Commonwealth Scientific and Industrial Research Organization (CSIROMk2). All three models were used by Cohen et al. (2004) in order to evaluate the climate change effects, and none was identified as being superior over the others. All three models were run using a high and low emissions scenario for the mid-2020s, mid-2050s, and mid-2080s[3] for a total of six scenarios for each period. For each climate change scenario changes in winter, summer, and annual temperature and precipitation were projected. The modeling results suggest that winter, summer, and annual temperatures will increase over the next 80 years. Seasonal precipitation is expected to change, with winter precipitation increasing gradually and summer precipitation decreasing. Increased winter precipitation along with increased within temperatures will result in less precipitation as snow, and the snowpack that does develop will be located at relatively higher elevations than at present. Warmer drier conditions are forecast for the summer which will increase the pressure on water resources in the Okanagan.

The recent research by Cohen et al. (2004) provides a thorough and credible assessment of climate change in the Okanagan and is the current recommended primary reference for likely future climate change in the Okanagan.

4.4.3 Land Use Change

Water Demand

The land-use changes that will have the greatest affect on demand in the Okanagan Basin are associated with agriculture and domestic use. Agricultural water use in 1990 accounted for 77% of total annual water use in the 17 irrigation districts and 3 municipalities in the Okanagan studied by KWL (1990). While the Agricultural Land Reserve (ALR) provides a means to restrict conversion of agricultural land to other uses, several changes in the agricultural land base have occurred and may continue to occur into the future. Over the last several decades, a generally slow decline in agricultural water use has been reported by several water utilities, which reflects several factors including:

- Improved irrigation methods (e.g., drip irrigation);

[3] The term "mid- 2020s" refers to the mid-point of a 30-year period centred on 1925, "mid- 2050s" refers to the mid-point of a 30-year period centred on 1955, and "mid- 2080s" refers to the mid-point of a 30-year period centred on 1985.

- Conversion to crops with lower water requirements (e.g., vineyards); and
- Reductions in irrigated land (e.g., where fruit trees have been pulled out and nothing planted as a replacement).

Changes to the agricultural land base and water demand have been assessed by Denise Neilsen of Agriculture and Agri-Food Canada and are summarized in Cohen et al. (2004). A considerable amount of information is also available directly from water utilities, the B.C. Ministry of Agriculture, Fisheries, and Food, and the agricultural community (e.g., B.C. Agriculture Council, B.C. Fruit Growers).

Irrigated areas associated with golf courses are also an important factor in future demands for water. Areas for likely or potential golf course development or expansion may be identified through review and discussion with regional planners and existing golf course managers.

The increase in domestic water demand is closely linked with population growth, but is also affected by the type of future residential development. Densification versus urban expansion will have varying impacts as densification will only increase the indoor water demands with typically reduced outdoor water demands. Urban expansion, which can result in both increased indoor and outdoor water uses of lands that are currently dry, will be one of the largest impacts on current water demand in the valley. The type of future development in the Basin may vary by community and must be projected based on a thorough review of official community plans and discussions with regional and municipal planners.

Water Supply

The majority of the water supply is associated with hydrologic processes occurring at relatively higher elevations in the Basin. While there is some potential for land-use changes (e.g., timber harvesting, recreation, mining) to affect these hydrologic processes and water quality, the available information suggests that the effects from these land uses on water quantity are relatively small or negligible. In 1974, the Okanagan Basin Study determined that impacts from forestry on water supply were projected to be minimal. These impacts appear to be confirmed by research in the Upper Penticton Watershed where despite effects on peak and low flows (which may significantly impact water supplies), annual water yield was not noticeably changed after harvesting 20% of the experimental watershed. Given these conclusions, there is some potential that future harvesting levels (particularly in light of the potential impacts of mountain pine beetle and forest fire) could affect, if not total annual water yield, the timing of water yield. While it is expected that harvest levels will remain relatively constant until about 2050 on the west side of Okanagan Lake (Summit, 2004a), we have yet to receive information on future harvesting levels in the remainder of the basin. Although we do not anticipate substantial increases in forest development above current levels, this remains to be confirmed in Phase 2 based on information from the Ministry of Forests and forest licensees. No information on the affects of mining, tourism and recreational on water supply and demand was identified in Phase 1. While it is speculated that these effects are generally minor, some effort in Phase 2 should be made to confirm this.

4.4.4 Economic Forces

Local, regional, provincial, national, and international economic forces will continue to shape land and water demand in the Okanagan in future.

In addition, increased costs for water will accompany expanded water supply and treatment systems. It is expected that in future the cost of new infrastructure will exceed the cost of additional treatment capability. The characteristics of water price elasticity will determine the degree to which the increased costs result in reduced demand.

5.0 PHASE TWO STRATEGY

5.1 OBJECTIVES

The overall objectives of Phase 2 of the Okanagan Basin Supply / Demand Study are to:

- Identify the current status of water supplies [from surface water (i.e., streams), groundwater, and mainstem lakes] and water use in the Okanagan Basin;
- Estimate future supply and demand under a range of possible future conditions; and
- Recommend an approach to future allocation decision-making.

In particular, it is required to determine the status of both surface water and groundwater resources in several major tributaries and along the mainstem of the Okanagan valley, and to utilize available forecasts of population growth and climate change to provide forecasts of future water supplies and water use. In both cases (supply and demand), forecasts of the future will account for a range of realistic future scenarios. For example, with respect to water supply, changes to water supply due to climate change depend on the future CO_2 concentrations in the global atmosphere, so there is a range of possible future effects on water supply. With respect to water demand, future changes in crop type, irrigation efficiency, conversion of agricultural land to urban land, feedback mechanisms that could reduce population growth in response to increasing water prices, or reductions in use due to conservation measures or land use change should be accounted for in defining future scenarios.

In some locations, the state of the available technical information will be such that determinations of water supply and current use will be possible with a high degree of confidence. In other areas, it will be possible only to make broad statements with a large associated uncertainty.

Some of the desired outcomes of Phase 2 include the following:

- A sound, transparent and verifiable science-based analysis of water supply and use in the Okanagan Basin;

- A decision-making tool for LWBC and other agencies to use in the future to obtain answers to questions such as:
    - How much water is licensed upstream of a point-of-interest (for offstream use, for instream use, for storage)?
    - How much water is currently being used upstream of this point?
    - Is it possible to license additional water at this point (considering the suite of potential downstream consequences)?
    - What are the downstream consequences of future additional licences?
    - What are the monthly average flows and the monthly flows in a 1 in 5 and a 1 in 10 year drought year at this point?
    - Would there be enough water for a proposed development to withdraw water at this point?
    - What is the long-term sustainable rate of groundwater extraction from each aquifer?
    - What is a practical upper limit to plateau storage in the Basin?
- An easily understood public educational tool that can be used to demonstrate options, sensitivities, and likely outcomes of a range of actions.

In order to achieve these broad objectives, a complex set of technical and other steps are recommended, as outlined below.

5.2 OVERALL APPROACH

The study design outlined in this section has been developed using the basic approach outlined in the following steps:

- Clearly identify the goals for Phase 2 of the water supply and demand study (completed in Phase 1);
- Identify and assess the information available to meet those goals, and determine where the information is weak or lacking (completed in Phase 1);
- Propose a study design that makes optimal use of the available information to fill the data gaps as needed to meet the study goals (completed in Phase 1); and

- Use high value information first, secondary information when needed, and tertiary information only to check if necessary or if no primary or secondary information is available.

The overall strategy for Phase 2 involves developing an updated water balance for the Okanagan Basin, including its tributaries and mainstem lakes and river (Section 6.0). This water balance model would be used to assess current water supply and demand conditions in the Basin, and following the identification of a large suite of reasonably possible future scenarios, would be used to forecast future conditions.

In developing the model, standard time periods should be chosen *a priori* in order to ensure scientifically valid comparisons. For both water supply and demand, it is recommended that the period 1971-2000 be adopted as the period which represents current conditions, since this is consistent with the most recent climate normal period. This means that available records (e.g., Okanagan Lake levels for 1922-present) will be standardized to the 1971-2000 time period. Efforts should be made to use the most recent and all relevant available information from each source. Forecasts of future conditions can be facilitated by the recent climate change investigations by Cohen et al. (2004). In their studies, climate change predictions are made for mid-2020s, mid 2050s, and mid-2080s. These dates for future water supply and demand projections should be adopted in Phase 2.

The overall water balance model adopted for the Basin should be sub-divided by discrete areas above points-of-interest. A total of 79 points-of-interest and areas-of-interest have been initially identified (Table 6.1 and Map 1), which includes all major and some small but relatively important tributaries (from water supply and or demand perspectives), residual areas draining to the mainstem lakes and Okanagan River, all mainstem lakes, and the Okanagan River at three locations. Water balance analyses will cover the range from individual tributaries and residual areas to the entire Okanagan Basin in B.C.

Surface water and groundwater supply and demand analyses should be conducted to assess the parameters of the water balance models for each of the 79 areas-of-interest.

Once the framework of the Okanagan water balance model is developed, it can be used to evaluate current conditions not only during average water years, but also during dry and wet years. These dry and wet years will be statistically defined and should include the 1 in 5 and 1 in 10 dry year as well as the 1 in 10 year wet year. However the precise return periods and duration (e.g., 1-, 2-, 3-year drought conditions) will be identified during the Phase 2 work.

In outlining the Phase 2 strategy in this report, three work programs have been identified, as follows:

- The **recommended program**, which will satisfactorily meet all Phase 2 objectives and desired outcomes identified in Section 5.1, and provide a reasonable level of confidence in the outcomes;
- The **minimum program**, which will minimally meet project objectives, but will result in uncertainty that may affect agency and public confidence in results; and
- The **enhanced program**, which will meet or exceed project objectives and reduce the level of uncertainty by further improvements (usually in modelling accuracy) and improve the ease of use of the Okanagan Water Model.

Most of the text is devoted to describing the "recommended" program since this is the program needed to achieve LWBC's objectives with the desired levels of accuracy and confidence. Reductions from the recommended program could be made, but these would be accompanied by losses of certainty and confidence. The minimum program has the smallest possible scope that could still be considered to meet the technical requirements of the Phase 2 study, although the associated losses in certainty and confidence could be significant.

5.3 STUDY ORGANIZATION

Figure 5.1 outlines the recommended organizational chart for the Phase 2 study. The overall organization is consistent with that in Phase 1, with some additions to increase the expertise and capacity of the study team in certain areas, and to ensure an efficient and effective execution of the Phase 2 strategy. An addition of the Okanagan Nation Alliance to the Steering Committee is recommended. Recommended additions to the Phase 1 consulting team include: UBC Faculty of Forestry to provide input to water supply modelling; Agriculture and Agri-Food Canada to provide input to agricultural water demand analyses; a land-use economist to provide advice on price elasticity with respect to future scenarios; five local water supply engineers to facilitate additional information collection from the large number of utilities; and a computer programmer to develop code to represent the Okanagan Water Model and in order to efficiently run the model in calibration mode and to run multiple future scenarios. A local consulting advisory group consisting of local individuals and firms with broad supply and demand expertise in the Okanagan is also recommended as an addition to the study team. Finally, for broader representation of water users in the Basin, it is recommended that the Phase 1 Working Group include a Water Supply Association representative, an agriculture industry representative, and a representative of the urban planning profession. The recommended composition of the consulting team is outlined in Table 5.1. An organization chart for the recommended consulting team is shown in Figure 5.2. The recommended study team presented in Figure 5.2 has the capacity to complete the study in the timeline identified in Section 11.0.

Table 5.1 Recommended Phase 2 study organization, including suggested additions to the Phase 1 team.

Study Team	Description
Project Leader	Land and Water B.C. Inc.
Consulting team	Same as Phase 1 plus: • UBC Faculty of Forestry (Younes Alila and assistant); • Agriculture and Agri-Food Canada (Denise Neilsen and assistant); • Land-use Economist (e.g. Dan Schroeter); • Local Water Supply Engineers (Associated Engineering, Kerr Wood Leidal Associates, True Consulting, Urban Systems Ltd., and Mould Engineering); • Computer Programmer (ESSA Technologies Ltd.).
Local Consulting Advisory Group	Local individuals / firms with broad supply / demand expertise in the Okanagan (e.g. Dobson Engineering, Mould Engineering, Golder Associates).
Working Group	Same as Phase 1 plus: • Water Supply Association of B.C. representative; • Agriculture industry representative (e.g., B.C. Tree Fruit Authority); and • Representative of urban planners (e.g., Leah Hartley).
Steering Committee	Same as Phase 1 plus: • Okanagan Nation Alliance

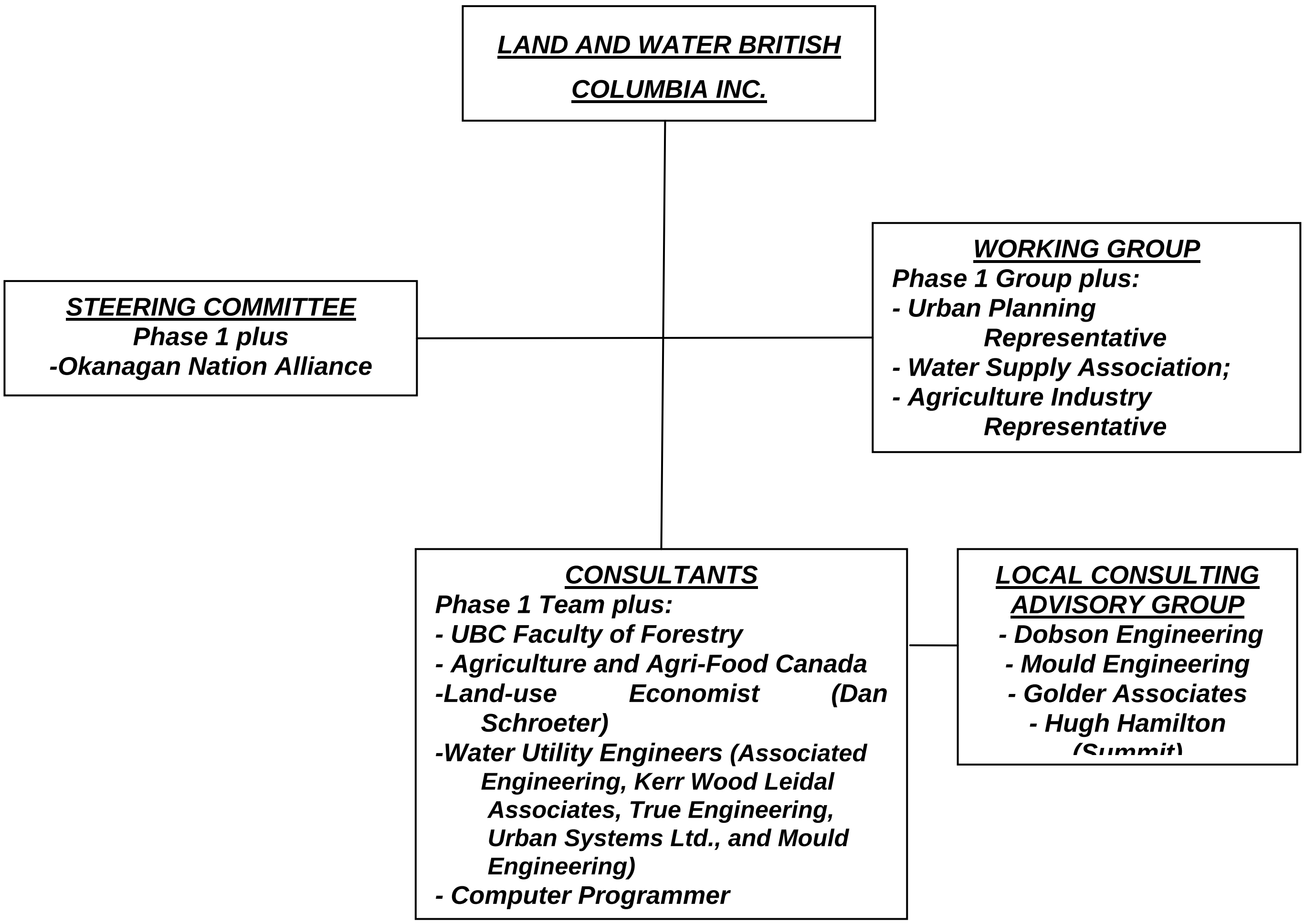

Figure 5.1 Recommended organization of study team for the "recommended" program of study.

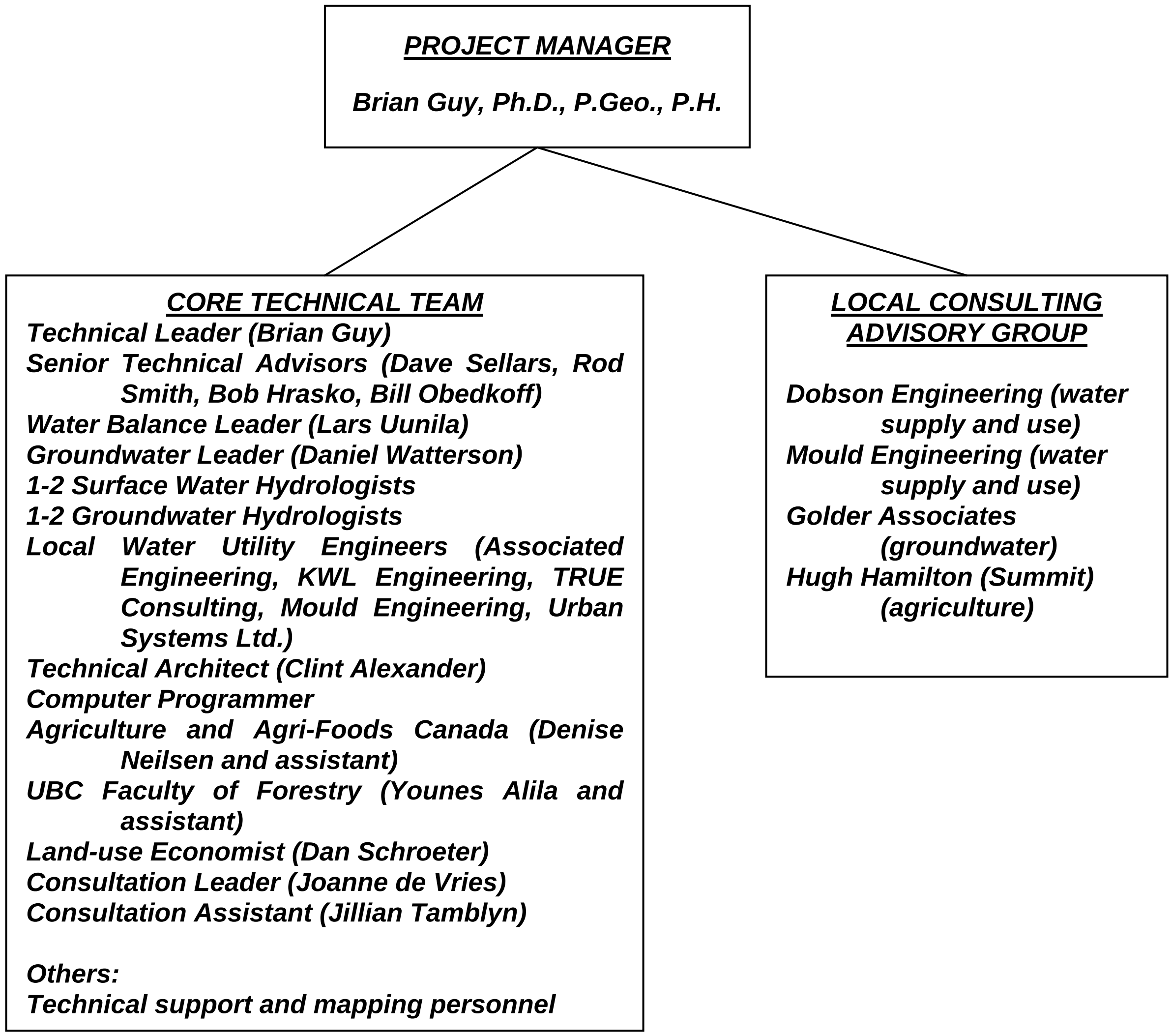

Figure 5.2 Recommended organization of Phase 2 consulting team for completing the "recommended" program of study.

5.4 PROJECT MANAGEMENT

LWBC is the project leader and will be formally responsible for overall financial administration of Phase 2. The lead consultant should provide overall management of the Phase 2 study and be in close communication with LWBC throughout the duration of the project. To ensure the overall study is successfully completed on schedule and budget, several management steps should be taken:

- The project manager should establish a study schedule, with corresponding budgets, personnel assignments, and deadlines;
- The project manager should establish sub-contracts with each of the independent parties within the consulting team. These sub-contracts should outline the specific scope, tasks, schedule, timing, and budget that each sub-consultant is responsible for;
- Information should be relayed to independent parties throughout the study to ensure that communication occurs smoothly within the team, and between the team and LWBC;
- The team should be regularly consulted by the project manager to assist in decision-making and to ensure the work proceeds in an efficient manner;
- Regular technical meetings should be held with project team members to ensure that each team member is aware of his or her responsibilities, and continues to meet them throughout the course of the study;
- The project manager should track study progress and budgets on a monthly or biweekly basis. Sub-consultants should be asked to provide monthly progress reports to the Project Manager, outlining work completed, comparing work completed against the schedule, and estimating the time required to complete tasks. This regular project status monitoring approach will ensure that the study proceeds according to plan, and will allow identification and correction of any difficulties quickly.

5.5 OUTLINE OF SPECIFIC TASKS IN PHASE 2

The following sections of this report lay out the tasks under the recommended and enhanced Phase 2 work programs. The minimum work programs includes the same tasks outlined below with the exception that the number of technical meetings would be reduced from four to two. In summary these tasks include the following which are listed in approximate chronological order (although there is overlap between them):

1. Following contract signing, the consultant reviews the Phase 1 report, confirms the approach, and develops a detailed work plan and cost estimate. If different from the approximate cost estimate developed in this report, this detailed cost estimate is the basis for an amended contract for Phase 2;
2. The Technical Working Group reviews the detailed work plan and cost estimate and provides feedback to the consultant;
3. The consultant obtains, reviews and evaluates all relevant information either not yet received or received late in Phase 1, and new information deemed necessary to Phase 2 through the gap analysis completed in Phase 1 (and adds this new information to the database developed in Phase 1);
4. A user-needs assessment is initiated at a meeting with LWBC, the Steering Committee and possibly the Working Group and other stakeholders to discuss desired characteristics of the Okanagan Water Model (technical meeting 1);
5. The consultant develops a computerized Okanagan Water Model that includes all components of the Okanagan Basin water balance and which provides an effective way to provide model input; to spatially and temporally link all technical analyses; and to produce output. The model can be used both for calibration of water balances as well as running future supply and demand scenarios at multiple points in the basin;
6. Scientific and engineering studies are completed to estimate the components of the water balance including:
    a) Water use/demand analyses are conducted by the consultant;
    b) Surface water supply analyses are conducted by the consultant;
    c) Groundwater analyses are conducted by the consultant;

7. The water balance model and the assessment of current water use and supply are reviewed with LWBC, the Steering Committee, and the Working Group (technical meeting 2);
8. The consultant develops a suite of scenarios for future water use and supply analysis, and an outline of a new input form and list of output options;
9. The suite of future scenarios and the input and output options are reviewed with LWBC, the Steering Committee, and the Working Group (technical meeting 3);
10. A meeting with stakeholders and First Nations is held to present the analyses of current conditions and the proposed approach to forecasting future conditions, which is then refined based on all this input (consultation meeting 1);
11. The consultant conducts the technical analyses using the agreed suite of future scenarios;
12. The consultant synthesizes the analyses and develops conclusions and recommendations for LWBC;
13. The consultant prepares and submits a draft report for review by LWBC, the Steering Committee, and the Working Group;
14. A meeting is held between the consultant, the Steering Committee, and the Working Group to review and discuss the report (technical meeting 4);
15. The consultant refines the draft report as necessary;
16. A meeting with other stakeholders and First Nations is held to review the study findings (consultation meeting 2);
17. The consultant provides training of LWBC staff in use of the model; and
18. The consultant refines the draft report as necessary and prepares a final report and deliverables for submission.

In response to feedback received at the March 8, 2005 workshop, a comprehensive consultation program should be developed and implemented during Phase 2 of the study (Section 8.0). Although the comprehensive consultation program has not been fully developed, the consultation steps outlined above (i.e. two meetings with other stakeholders and First Nations) is recommended under all three work programs. Under the recommended and enhanced work programs, we recommend the addition of a parallel consultation program with a broader audience. We have assumed that this parallel program would consist of three meetings under the recommended program and six meetings under the enhanced program. No parallel consultation program (in addition to the two stakeholder meetings listed above) is recommended under the minimum work program.

6.0 OKANAGAN WATER MODEL

6.1 OVERVIEW

The primary objective of Phase 2 of the study is to provide a statement of the current and likely future status of water supplies and water use in the Okanagan Basin. In order to address this objective an integrated approach is required that considers all water sources and all water demands. Analyses of water sources must include consideration of all surface water, groundwater, storage reservoirs and lakes and their interrelationship, and the potential effects of climate change. Demand analyses must consider the way in which irrigation and residential/commercial demands are affected by demand management strategies and changes in land use. The approach should ensure that First Nation water supplies and demands are explicitly assessed within the context of the overall Basin.

The integrated approach will be implemented by developing a comprehensive water balance model of the Okanagan Basin, similar to that developed by the Okanagan Basin Study in 1974. The model will be developed for each sub-basin and residual area and aggregated to provide a complete picture of water supply and use in the Okanagan Basin (at selected points-of-interest). The model will include the following principal components:

- Precipitation;
- Evapotranspiration;
- Surface water flows;
- Lake evaporation;
- Groundwater recharge, discharge, and storage;
- Reservoir operation (i.e., storage);
- Water use by land use and source (including return flows); and
- Streamflows.

The model will use a monthly time step, and the current or base-case will be based on the period 1971 to 2000. Average as well as dry and wet years will be modelled. The model will be calibrated using natural or naturalized streamflow records where available, and in particular the records of discharge on the Okanagan River. Descriptions of work required to define the major model components and calibrate the model are provided in the following sections.

Once calibrated, the model will represent water inputs and outputs from each major tributary to Okanagan Lake and River and will represent conditions in Okanagan Lake and on Okanagan River. In addition to reflecting current conditions, this calibrated model will be useful for both hindcasting and forecasting. For example, it could provide an indication of water availability for a given historic condition such as the 1929 to 1931 drought (i.e., a hindcast). The model will also be useful for simulating a number of different future scenarios which will include at least the following parameters:

- Climate change;
- Alternative population growth rates;
- Changes in irrigation technologies and application techniques;
- Changes in land use;
- Economic changes;
- Alternative demand management strategies;
- Opportunities for conjunctive use of groundwater and surface water; and
- Changes to fish flow requirements.

The scenario analyses will provide information on the relationships between the parameters and provide an indication of the sensitivity of water availability in the sub-basins, residual areas, and in the overall basin to changes in the parameter values. The relative importance of the parameters will be determined in the modelling analysis. Families of curves will be developed illustrating these relationships. This information will provide the basis for a future unidentified public process potentially leading to revised rules and constraints for water allocation.

The model will be designed to facilitate input and analyses of the complex hydrologic environment, and to ensure that a large suite of future scenarios can also be efficiently analyzed. The model will be designed to ensure that non-technical individuals can use the model effectively with little training.

In summary, the Okanagan Water Model will provide information on the current situation regarding water availability and the amount of water available for alternative futures.

6.2 POINTS-OF-INTEREST

As outlined in Table 6.1 and Map 1, a total of 79 areas located above points-of-interest have been identified by the study team following the March 8, 2005 workshop. These include major sub-basins (i.e., tributaries), relatively small but significant sub-basins, residual areas[4] (organized by west and east side of the Basin and from north to south), mainstem lakes, and Okanagan River at three (3) locations. It is recommended that these points-of-interest provide the geographic basis for the technical analyses required to develop the Okanagan Water Model. It is recommended that the Corporate Watershed Base (CWB) available from Base Mapping and Geomatics Services (MSRM), be used throughout the Basin. While the CWB is currently under development, the watershed linework is available to the study team (Von Ratenberg, pers. comm., 2005).

It is noted that whereas the drawing of surface contour-based boundaries provides a generally correct representation of water flow patterns, there are exceptions. For example, surficial groundwater flow patterns can generally be assumed to reflect surface drainage divides, but bedrock groundwater flow cannot. In addition, there are several locations in the headwaters of the Okanagan where water is routed for human use into or out of the Basin. Examples include Alocin Creek (diverted into the Lambly Creek basin from the Nicola River watershed) and Duteau Creek (diverted from the Shuswap River drainage into the Vernon Creek drainage). Furthermore, there is potential for major flow

[4] Residual areas are areas adjacent to the mainstem lakes and river where no distinct sub-basins have been defined. They include minor tributaries and areas with no mapped drainage patterns.

diversions within the Okanagan Basin, such as the Hiram Walker pump station (currently managed by the District of Lake Country) that has the ability to pump water from Okanagan Lake to the Vernon Creek drainage. Knowledge of these realities will be reflected in the model.

Table 6.1 Proposed points-of-interest (organized roughly from north to south)

ZONE[1]	No.	POINTS-OF-INTEREST	
		West side of Okanagan Basin	***East side of Okanagan Basin***
A	1		**Vernon Creek at outlet of Kalamalka Lake**
	2		**Kalamalka – Wood Lake**
B	3	**Deep Creek (mouth)**	
	4	Residual area W-1	
	5	**Irish Creek (mouth)**	
	6	Residual area W-2	
	7		Residual area E-1
	8	**Equesis Creek (mouth)**	
	9	Residual area W-3	
	10	**Nashwhito Creek (mouth)**	
	11	Residual area W-4	
	12		**Vernon Creek (mouth); includes Zone A & B**
	13		Residual area E-2
	14	**Whiteman Creek (mouth)**	
	15	Residual area W-5	
	16	**Shorts Creek (mouth)**	
	17	Residual area W-6	
	18	**Lambly Creek (mouth)**	
	19	Residual area W-7	
	20		**Kelowna (Mill) Creek (mouth)**
	21		Residual area E-3
	22		**Mission Creek (mouth)**
	23		Residual area E-4
	24		**Bellevue Creek (mouth)**
	25		Residual area E-5
	26	**McDougall Creek (mouth)**	
	27	Residual area W-8	
	28	**Powers Creek (mouth)**	
	29	Residual area W-9	
	30	**Trepanier Creek (mouth)**	
	31	Residual area W-10	
	32	**Peachland Creek (mouth)**	
	33	Residual area W-11	
	34		**Chute Creek (mouth)**
	35		Residual area E-6
	36	**Eneas Creek (mouth)**	
	37	Residual area W-12	
	38		**Robinson Creek (mouth)**
	39		Residual area E-7
	40		**Naramata Creek (mouth)**
	41		Residual area E-8
	42	**Trout Creek (mouth)**	
	43	Residual area W-13	
	44		**Turnbull Creek**
	45		Residual area E-9
	46		**Penticton Creek (mouth)**
	47	**Okanagan Lake**	
	48	**Okanagan River at Penticton**	

Table 6.1 Proposed points-of-interest (cont'd).

ZONE[1]	No.	POINTS-OF-INTEREST	
		West side of Okanagan Basin	***East side of Okanagan Basin***
C	49	Residual area W-14	
	50		Residual area E-10
	51	**Shingle Creek (mouth)**	
	52		**Ellis Creek (mouth)**
	53	Residual area W-15	
	54		Residual area E-11
	55	**Marron River**	
	56	Residual area W-16	
	57	**Skaha Lake**	
	58	**Okanagan River at Okanagan Falls**	
D	59		**Shuttleworth Creek (mouth)**
	60	Residual area W-18	
	61		Residual area E-12
	62	**Vaseux Lake**	
	63		Residual area E-13
	64		**Vaseux Creek (mouth)**
	65	Residual area W-19	
	66		Residual Area E-14
	67	**Park Rill (mouth)**	
	68	Residual area W-20	
	69		**Wolfcub Creek (mouth)**
	70		Residual area E-15
	71	**Okanagan River near Oliver**	
E	72	Residual area W-21	
	73		Residual area E-16
	74	**Testalinden Creek (mouth)**	
	75	Residual area W-22	
	76		**Inkaneep Creek (mouth)**
	77		Residual area E-17
	78	**Osoyoos Lake**	
A,B,C,D,E	79	**Okanagan Basin within British Columbia**	

Notes: 1. Refer to Map 1 for zone boundaries and locations of points-of-interest.

6.3 GENERAL WATER BALANCE

As outlined in Section 6.1, a comprehensive water balance model of the Okanagan Basin should be developed in order to properly assess current and future water supply and demands. The overall model should consist of a suite of linked water balances for each contributing area above points-of-interest (identified in Section 6.2). These water balances should first be developed on an annual time step, then disaggregated into a monthly time step. The framework for the water balance accounts for all inputs, outputs and changes in water storage above each point-of-interest. Since these components differ between the sub-basin (i.e., tributaries) or residual points-of-interest and the mainstem valley (lake and river), these are described separately below with a brief summary of how each component will be estimated. Further detail on the recommended strategy is provided in Sections 6.4 to 6.6. A summary of how each component of the water balance model and the overall model will be calibrated is provided in Section 6.8.

The general water balance for a tributary or a residual area can be represented by the following equation:

$$P - \Delta S - ET - G - WD + RF = Q_{out} \quad \text{..... [eq. 1]}$$

where,

P = precipitation (rainfall plus snowmelt);

ΔS = change in tributary storage;

ET = evapotranspiration;

G = infiltration to groundwater (groundwater recharge is positive and discharge is negative in equation 1);

WD = withdrawal (from all sources);

RF = return flow (accounting for any recycled water use); and

Q_{out} = total tributary flow at mouth in the case of a tributary watershed, or total surface flow from all streams in a residual area.

Each component of equation 1 is expressed in units of volume. For example, evapotranspiration is converted from a depth to a volume by multiplying by the relevant area; streamflow is converted from a rate to a volume by multiplying by the relevant time interval.

Estimates of P can be independently estimated based on meteorological data from Environment Canada (2 high elevation stations and 16 low elevation stations within the Basin, as well as other relevant stations outside the Basin), historic snow course data, regional precipitation estimates, information presented in Okanagan Basin Agreement studies, Cohen et al. (2004), several Hydrology Section reports, and MOF research reports. Estimates of ΔS can be estimated based on lake and reservoir records and other operational information from water utilities and provincial agencies (e.g., MWLAP).

Estimates of ET can be determined through several approaches and should be organized by elevation band(s). Relatively little information is available at higher elevations, with the exception of data presented by Cohen et al. (2004) based on the UBC Watershed Model. Estimates should be compared with Okanagan Basin Agreement study estimates and information available from Agriculture and Agri-Food Canada and BC Ministry of Agriculture, Food and Fisheries. Since preparation of the draft Phase 1 report, preliminary discussions have occurred between the study team and University of British Columbia - Okanagan researchers regarding the potential to undertake a detailed evapotranspiration study in selected Okanagan sub-basins. Thus there may be an opportunity to confirm ET estimates based on recent focussed research. However, the potential scope and cost of these studies has not been addressed in this final report.

Generally, G is not independently determined, but is the residual in equation 1. Estimates of WD can be estimated based on water use analyses (both supply- and demand-side analyses) and RF would be based on estimated sewer and storm water discharge, surface runoff, and sub-surface return flows. Estimates of Q_{out} can be developed independently based on natural or natural streamflow records, and various modelling approaches.

The general water balance for a mainstem lake is represented by the following equation:

$$Q_{in\ (tribs)} + Q_{in\ (resid)} + P + G_{in} - E - WD + RF - Q_{out(lake)} = \Delta S \qquad \text{..... [eq. 2]}$$

where,

$Q_{in\ (tribs)}$ = net inflow from tributaries;

$Q_{in\ (resid)}$ = net inflow from residual areas;

P = direct precipitation (onto lake);

G_{in} = net groundwater inflow;

E = evaporation loss;

WD = withdrawals;

RF = return flow (accounting for any recycled water use);

$Q_{out(lake)}$ = flow out of lake; and

ΔS = Change in storage.

$Q_{in\ (tribs)}$ and $Q_{in\ (resid)}$ is based on the sum of Q_{out} from the areas contributing flow to the lake. P is based on valley-bottom precipitation data. G_{in} is based on the sum of groundwater inflows estimated from the contributing areas. Estimates of E can be developed based on information from the Okanagan Basin Study, as well more recent and sophisticated research presented by Trivett (1984). WD and RF can be estimated as outlined above. $Q_{out(lake)}$ and ΔS are based on available hydrometric records.

The general water balance for the mainstem Okanagan River locations is represented by the following equation, which includes components already discussed above:

$$Q_{river} = Q_{out(lake)} + Q_{in\ (tribs)} + Q_{in\ (resid)} + G_{in} - WD + RF \qquad \text{..... [eq. 3]}$$

where,

Q_{river} = flow in river at point-of-interest;

$Q_{out(lake)}$ = flow out of lake;

$Q_{in(tribs)}$ = net inflow from tributaries between upstream lake and point-of-interest;

$Q_{in(resid)}$ = net inflow from residual areas between upstream lake and point-of-interest;

G_{in} = net groundwater inflow between upstream lake and point-of-interest;

WD = withdrawals between upstream lake and point-of-interest;

RF = return flow between upstream lake and point-of-interest; and

P and E are assumed to be negligible along the river and are not included in Equation 3.

The primary objective of the technical analyses in Phase 2 is to determine the best estimates of the above-noted components of the water balances for the tributaries, lakes and mainstem river locations. In order to accomplish this, the suite of technical analyses has been organized by water use analysis (Section 6.5), surface water supply analysis (Section 6.6), and groundwater analysis (Section 6.7). The software requirements for organizing the many complex calculations that will be required during model calibration and running are outlined in Section 6.4. Model calibration procedures are summarized in Section 6.8.

6.4 SOFTWARE CONSIDERATIONS

6.4.1 Introduction

The Phase 2 water supply and demand analysis involves a large number of locations and scenarios (see Table 7.1). The Okanagan Water Model will therefore be highly dimensional in nature - it will require a large volume of data for locations and scenarios, and it will have many site and context-specific requirements. This necessitates an iterative modelling approach that is best suited to a database programming environment. Desktop model diagramming tools, such as STELLA, are not well suited to this scale of application. Diagramming tools are well suited to the initial exploration of a few scenarios that can be configured with a relatively small amount of data. They can also be used by domain experts to explore different model logic and provide insight to the inner workings of a particular model, as well as for educational purposes in the hands of an instructor. However, they are incapable of handling large volumes of data and scenarios, as each scenario variable must be configured and executed in a manual fashion. With a programming/iterative technology that uses a relational database, it is possible to execute and store the results for millions of scenarios automatically and more rapidly explore highly dimensional results. This covers a wider range of scenarios and promotes more efficient sensitivity analysis. This is also valuable if the model logic is under development as after preliminary explorations and modest changes to the core models, one can then easily re-run the range of scenarios at a click of a button.

Given the large number of sites, variables and scenarios, an infrastructure to manage the large volume of data and to automate the analysis will be necessary. This not only involves fundamental bookkeeping of the required information, but also supports core needs such as model calibration, linking the output at points-of-interest in a downstream direction, running scenarios and providing ready access to key output in a useable format. To achieve this and significantly reduce the likelihood of errors we recommend the design, construction and population of a **relational database** to organize, store and retrieve the fundamental information that will be used throughout the Okanagan Water Model analysis. Furthermore, this database will support an **engine** that will automate the application of the water balance equations on this information.

In addition to the effort required to calibrate the model, there are potentially millions of future scenarios that are to be evaluated. This makes it impractical to manually generate monthly site specific model results - were such an approach taken it would likely be subject to high rates of errors, and come in a format (e.g., thousands of isolated Excel or other kinds of files) that could not be readily filtered or used effectively. Thus, we also recommend design and construction of a simple **reporting service** as part of the tool. This element would be responsible for producing the essential summary outputs required for model calibration, and assist in ranking and making critical comparisons amongst results of future scenarios. It is anticipated that the format and method of generation of outputs should be designed for efficient and rapid communication in consultation settings to more effectively communicate findings and engage stakeholders and interactively address their questions. As with other specifics, such as the precise technology platforms chosen, the desired output formats would be defined during a **user needs assessment**.

In summary, there are four recommended steps in developing a framework to automate the Okanagan supply and demand analysis:

1. A **user needs assessment** to quantify current technical and user requirements (i.e. model calibration and evaluation of future scenarios), as well as to look forward to potential future LWBC information system needs;

2. Development of a relational **database** to standardize site specific datasets gathered from the analytical steps described later in Section 6.0, as well as to house scenario configuration and water balance model results;

3. An **engine** to automate the millions of calculations that will be necessary to quantify monthly water supply and use information for the many points-of-interest for current conditions, and for use in both hindcasting and forecasting modes; and

4. A **reporting service** to automate querying of the database to compare and rank specific results in simplified graphical and tabular formats (determined during user needs assessment).

The role of these elements is illustrated in Figure 6.1.

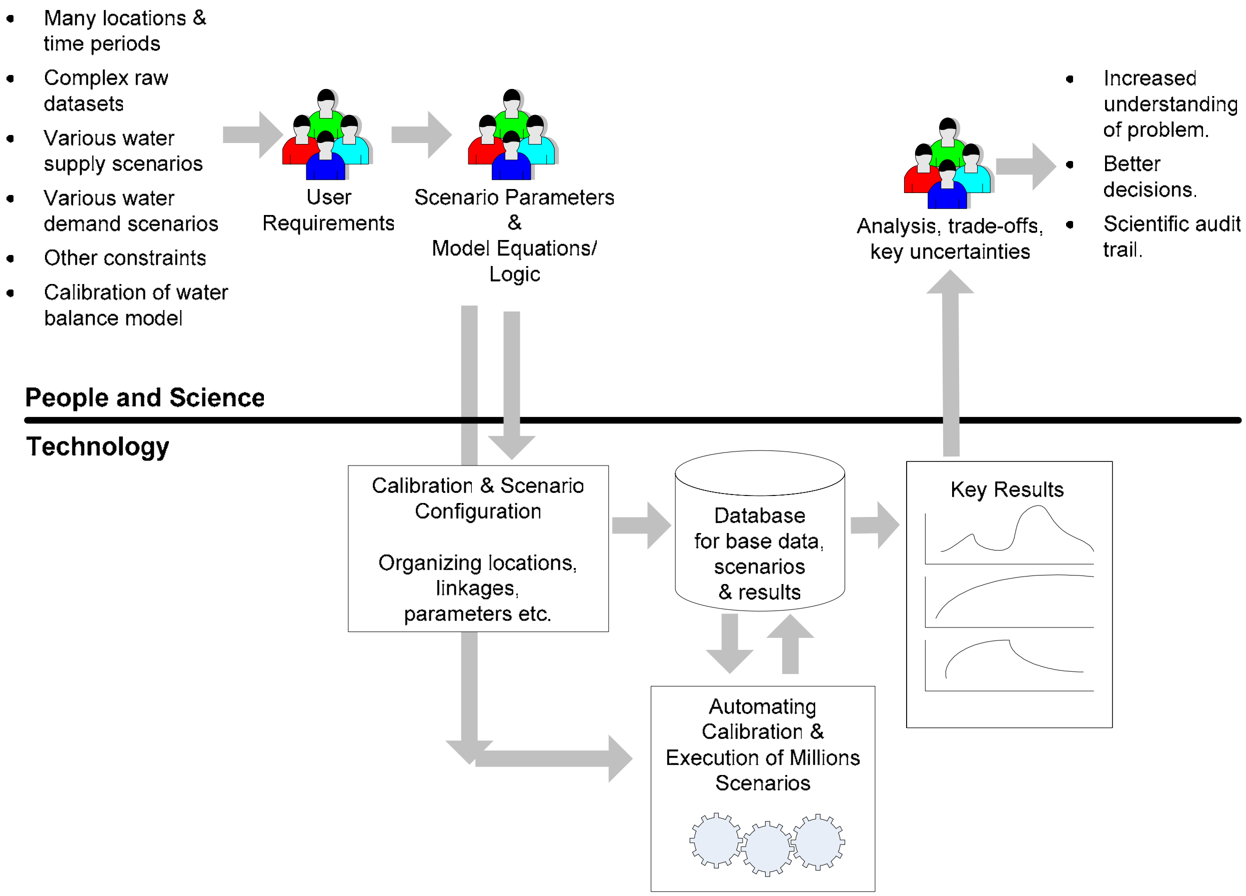

Figure 6.1 "20,000 foot" view of relationship between project planning, science and technology for the evaluation of current and future water supply and demand.

6.4.2 Understand User Needs

As with any initiative involving modeling/software, a user needs assessment is the critical first step to enable the consultants to fully understand technical requirements associated with data organization, model calibration, the complexity of scenarios the tool must process and the types of output that would be most helpful. It will also be used to define the end user expectations for how the tool would (and would not) be most effectively employed both in the study and perhaps later on. The aim is to identify, design and develop the best computer tool for running the model in Phase 2 and to make repeating aspects of the study easier in the future. This requirements-focused approach is also an opportunity to review ways in which existing databases and other tools might be leveraged to support the Phase 2 analysis.

To achieve these ends, a candidate list of technical and user questions would be developed relating to how the model would be expected to answer various technical and end user needs. Example technical questions might include:

- What are the values of each component of the relevant water balance equations for each point-of-interest?
- How much water is licensed upstream of a point-of-interest?
- How much water is actually used upstream of this point?
- Factoring in ecological constraints (e.g., in-stream flows for fish), how much water remains unused by month for this point in dry, average and wet water years?

Possible questions to be addressed through the scenario running process include:

- When will demand outstrip supply?
- What is the effect of a 30% reduction in domestic use?

- What are the overall cumulative implications of historical through present day water allocation decisions, taking into account additional licences presently on the table or expected in year *y*?

Possible user-focused questions to be addressed include:

- Who needs to run the analysis?
- Who needs to get output from the study?
- To what kinds of output do these people need to gain ready access? What would be the best ways to illustrate answers to the questions above? What would you want to see?
- How often should the analysis be repeated?
- What other use cases are there for a system like this inside or outside of LWBC's business?
- What other kinds of tools/databases might the water balance model link with?

In general, the user needs assessment would focus on supporting the workflow used by the engineers and scientists completing the supply and demand analysis. There is also an opportunity to think ahead, and begin to define the requirements of a full-scale information system that might be pursued by LWBC in a future phase. For these reasons a user needs assessment meeting is recommended under the recommended and enhanced work programs. Specifically, we recommend seeking answers to an expanded set of questions above from LWBC, the Steering Committee, and possibly the Working Group and other interested parties early in the model development process. Under the minimum work program, an abbreviated version of the user needs assessment is recommended by conference call. While user needs will still be considered under the minimum work program, software programming will be significantly streamlined to meet only the immediate technical requirements of the study.

Although it is understood that there is at present no intention to commit to any work beyond the Phase 2 study outlined here, the automated model used for calibration and running of multiple future scenarios could easily be designed upfront to be modified in future to help LWBC make future water allocation decisions. We therefore see a potential advantage to LWBC to consider during the user needs assessment the possibility that the automated model might be useful beyond the conclusion of the Phase 2 study – for the testing of possible future licence applications or water use alternatives against a series of rules and constraints (which are not yet developed). This process could be accomplished at a later date by:

1. Addition of rules and constraints to the underlying database and scenario engine;
2. Addition of a comparison routine whereby scenario outputs are evaluated against constraints; and
3. Extending the reporting service to generate further types of comparisons.

Possible future questions that could be asked (and evaluated with an appropriately designed model) include:

- Is it sensible to license additional water at this point, considering local and downstream demands and constraints?
- Would there be enough water for the proposed development at this point, considering local and downstream needs?
- In light of anticipated climate driven changes in water supply and present day water demand, are we licensing water at a sustainable rate relative to expected population growth and related future demands? What assumptions are we making on the existence and origins of future supplies?
- Are our decisions robust to uncertainties in key supply and demand factors? Have we struck the appropriate balance of risks?

Finally, such a model could be useful to others as well as to LWBC – an attribute that was suggested by participants in the March 8 workshop. This could be achieved through design and construction of web-enabled user interfaces. Hence, for the "enhanced" program outlined below, we have suggested the development of web-enabled user interfaces.

6.4.3 Guiding Principles

There are several principles that should be considered in developing the design for the automated model:

1. **Phase containment and early prototyping.** Software development components of the study will be structured around a phased project life-cycle and built around a quality control framework. The project life-cycle will include deliverables that are reviewed between each step and act as quality control checkpoints. With the correct level of planning and execution of quality control measures, any shortfall in quality can be captured and mitigated before negative repercussions affect the project budget and schedule.

   Furthermore**,** it is crucial that a first prototype of the system be up and running as quickly as possible – in this way users (e.g., water balance model analysts, LWBC staff) can provide feedback, and thus influence its focus and direction before development has proceeded to the point where making changes is more difficult. By developing and testing early prototypes, the time and resources required getting a final prototype up and running can be reduced.

2. **Avoid duplication of data and systems.** The Phase 1 consultants are aware of existing potentially relevant systems (e.g., WLIS, OKFWM, UBC Watershed Model, STELLA, CommunityViz, WaterBucket.ca). To the extent possible, Phase 2 work should learn from and if possible leverage the relevant design highlights of these systems. In the case of data, it makes sense for data required by multiple systems to be stored in only one place. This ensures that the data are up-to-date, ensures there is one definitive source for all data, and reduces time and effort associated with unnecessary duplication of existing storage. However, based on the data review in Phase I it is not likely that significant saving in storage can be achieved in this project.

3. **Database for model engine designed to support future decision support tools.** The user needs assessment should consider the longer-term vision for LWBC's decision support system requirements to avoid closing off or limiting future opportunities. This can dramatically improve the overall return on investment associated with the prototype database used with scenario automation. Further, this "looking ahead" approach will likely suggest use of current, enterprise database platforms (e.g., SQL Server or Oracle) able to handle large data volumes over time, multiple users, geospatial data needs, modern internet connectivity features and more robust security and backup features.

4. **Well architected, object-oriented design.** The system architecture should follow a *n*-tier design that separates the database (first tier) from water balance model logic (middle tier) and any user interface (third tier) components (e.g., user reports). It should also use object-oriented design (OOD) within each of these components. The fundamental physical objects and processes in the water balance model would be defined by classes that can be inherited and extended, then instantiated to take on specific parameter values and behaviours (i.e., different scenarios) and rapidly passed *en-masse* into the fundamental algorithms needed to produce the desired outputs. This type of programming model will greatly assist in efficiently automating millions of supply and demand scenarios.

5. **Output reports that are readable using widely held applications.** To simplify communication and dissemination of results and reduce costs, the reporting tool used to manage queries against the relational database should produce reports that are readable in common software applications such as Microsoft Excel. This typically reduces development costs associated with the alternative of tedious manual generation of output or programming/customizing third party reporting products.

6. **Web/Internet-based interface.** As many people include the use of the Internet as an everyday part of their business roles, working with web browsers has wide familiarity. Hence, from a user perspective, web-based interfaces are easy to use

and require minimal training. On the software development side, the benefits of web-based solutions are even more significant. Web-enabled software is far easier to update and support than distributed client applications because ultimately, only one computer - the web server - needs to be maintained. If in the long-term a broad user group is a possibility, then use of a web-based interface is highly recommended. Under the enhanced program of Phase 2, the user interface should be made readily adaptable to possible future use by a wider range of users than LWBC (e.g., it should be web-based), even if such a future use is not contemplated at this time.

6.4.4 Recommended Software Development Work Plan

This section outlines the specific software development tasks to develop a robust database, a linking model, and a scenario driver in a user-friendly format under the recommended work program of the Phase 2 study. Differences between the recommended, minimum, and enhanced programs are discussed at the end of this section. We have integrated the development of the water balance model and its scenarios with the most essential software development components as best as possible, to improve efficiency of the science-based elements, and to improve the quality and relevance of the final deliverables.

Task 1: User needs assessment and design

Recommended specific steps are as follows:

- User needs assessment (meeting) and user design recommendations;
- Identify / confirm system scope;
- Define functional requirements;
- Review of technical data and analysis steps to be used in Phase 2;
- Define design and technology requirements (e.g., choice of technology platforms);

- Review existing systems and infrastructure (to avoid reinventing already well-designed wheels);
- Define alternative design options;
- Compare and evaluate design options; and
- Prepare final architectural design.

Task 2: Build initial prototype

Following completion of the user needs assessment, development of the system to automate water balance computations would begin with database design and population. The next step would be to build the "engine" needed to automate the application of the water balance model equations for hundreds of calibration runs and millions of potential future scenarios. The third step would then be construction or incorporation of an appropriate query engine (reporting service or tool) to produce the desired summary reports (several of which will have been described during Task 1). While the decision is open, we have found that Microsoft Excel works particularly well for resource management and engineering audiences.

Task 3: Test initial prototype

The initial prototype tool should be tested and presented to LWBC and/or the Working Group at the second scheduled meeting to ensure that the core technical infrastructure and science specific to Phase 2 objectives are being met according to expectations. A focus of the meeting will be to identify critical missing features and refine the types of output reports that were suggested during the user needs assessment.

Task 4: Configure model for calibration runs

The prototype system database would be populated and configured to run the model for calibration purposes. A minimum reporting standard would be defined and implemented to describe the appropriate raw format in which results of water balance calculations should be stored in the system database.

Task 5: System testing and revisions

Based upon suggestions provided by LWBC staff during Task 3 as well as from internal tests by the project scientists and engineers, the system will be revised, as required, in order for it to efficiently and accurately complete the calibrations.

Task 6: Configure model for future scenario runs, test and revise

The refined model would be configured to run the range of scenarios identified during the scenario identification process described in Section 7.0. As with calibration, a prototype build of the scenario management aspects of the automation engine would be followed by one or more rounds of testing and revision (as required).

Task 7: Scenario analysis and results compilation

The system would apply the Okanagan Water Model and generate results for all scenarios configured during Task 6. The reporting service (query engine) would then be run to generate the critical comparisons defined in Task 1.

Task 8: Draft technical documentation

Based on standards defined during Task 1, draft documentation describing the three major parts of the application (its installation, use and maintenance) would be produced. Deliverables of the automated Okanagan Water Model development work should include:

- System scope and functional requirements;
- Architectural design specifications and technology requirements (implementation plan);
- Technology proof-of-concept prototype and assessment;
- Operational version of system for water balance model calibration and scenario analysis, as well as summary reporting; and
- Draft system documentation.

Task 9: Training of LWBC staff in use of the model

Following completion of the Phase 2 project, the consultants should train LWBC staff in the strengths, limitations, and use of the Okanagan Water Model.

Minimum Work Program

Under the minimum work program, software development tasks will be streamlined to provide only the basic software required to calibrate and run the Okanagan Water Model by the consultants. While the minimum program does not eliminate any of the above-noted tasks, each will be substantially reduced in scope. For example, an abbreviated user needs assessment would be conducted by conference call. While no incorporation of future LWBC or other user-needs beyond Phase 2 is planned, the user needs assessment remains useful in model development for Phase 2. Also, testing and calibration of the model will be completed to a reasonable standard, and scenario runs would be limited to a few chosen by the study team and LWBC. This would result in a limited sensitivity analysis and limited ability to compare parameters.

Enhanced Work Program

Under the enhanced work program, all software development tasks under the recommended program would be conducted, and additional efforts would be made to ensure a significantly more robust, flexible, and user-friendly model than under the recommended work program. Here, effort would shift to enhancing user-interface aspects of the tool, internet accessibility and multi-user capabilities. Additional scenarios to account for additional possible futures would also be run than under the recommended program (e.g., additional economic forecasts, additional water demand scenarios, additional effort to characterize price elasticity).

6.5 WATER USE ANALYSIS

6.5.1 General Recommended Approach

Section 6.5 outlines the recommended strategy for the water use analysis under the recommended work program. Differences for the minimum and enhanced work programs are outlined in Section 6.5.5.

In order to develop a clear understanding of current water use in the Okanagan Basin, the analysis of water use should be broken down according to source, water purveyor, location, and land-use sector (Table 6.2). Two main approaches should be used to estimate water use in the Okanagan Basin under current conditions. The first is a supply-side approach, where water use is partitioned and estimated by source and purveyor. The second approach is a demand-side estimate, which involves estimating water use based on land-use and population information. The use of both methods improves the confidence of the final estimates since an iterative procedure is followed whereby the results of the two approaches are compared and underlying assumptions are refined until the two approaches are reconciled. The reconciled estimates then form the basis for the best estimate of actual water use under average conditions. These estimates should then be compared with licensed quantities (for surface water and the mainstem lakes and river) in order to identify current allocation issues. Actual water use estimates also provide a basis for naturalizing streamflow records under the water supply analysis.

Table 6.2 Overall breakdown of water use analysis.

Source	Purveyor	Location	Land-use sector
Surface water (streams)	Large water suppliers	Regional District	Residential
Mainstem lakes	Small water suppliers	Municipalities, electoral areas, First Nation Reserves	Commercial / Industrial / Institutional
Groundwater	Individual water licensees	Neighbourhood, communities	Agriculture
			Golf courses

In addition to estimates of average water use in the basin, estimates of water use during dry years is also critical and should be developed based on comparison with representative dry years (e.g., 2003) and/or using scaling factors based on available literature. This information will be developed where the available data supports it, and as necessary extrapolated to areas with weaker information.

6.5.2 Water Licences

Water licence information has been compiled by LWBC for the Okanagan Basin using the Water Licence Information System (WLIS). This information is the basis for determining total licensed quantities by water use category for areas above the main tributaries (that enter the mainstem lakes and Okanagan River), the mainstem lakes, and Okanagan River at three (3) existing WSC hydrometric stations. Since obtaining the WLIS data, additional points-of-interest have been identified, so that additional queries will be required in Phase 2. In addition, in Phase 2 it will be necessary to ascribe licence data to each of the areas-of-interest (Table 6.1) by analyzing current maps and identifying all licensed points-of-diversion. This task, to be completed using GIS, will also ensure that all licences in the Basin are properly accounted for[5]. As a check, water licences and points-of-diversion should be cross-referenced with information from major purveyors, and should be confirmed with information from a pilot project now in progress by the Ministry of Water, Land and Air Protection to collect information on drinking water systems in the Okanagan.

The compilation of water licence information facilitates the comparison between licensed and actual water use, which is known to be significant in parts of the Basin.

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[5] The point-of-diversion map base should be cross-referenced with the WLIS output in order to identify potential licences not represented in the WLIS output. According to McKee (2004), WLIS data generally does not include licences for springs located off the main drainage network.

6.5.3 Water Use by Source and Purveyor

The analysis of actual water use from surface and groundwater sources should be organized by area upstream of each point-of-interest (outlined in Table 6.1). Within each area-of-interest, actual water use estimates should be obtained from several data sources. The principal sources are large and small water utilities that have been identified in Phase 1 as having reasonably complete records of water use. The information obtained by questionnaire from the water utilities in Phase 1 should be supported by additional information in order to add confidence in the data. In many cases, raw data is available directly from the utilities or have been summarized in various water planning and engineering reports. Efforts should be focussed on the 20 largest water utilities; however, some slightly reduced effort should be made to establish reasonable estimates from the remaining smaller utilities. To ensure the most efficient collection of information, we recommend water supply engineers with direct local experience with the major utilities perform much of this task.

Estimates of water use by those other than the utilities with reasonable records should be based on representative proportions of licensed quantities and/or demand-side estimates. One challenge will be to accurately ascribe water use by a utility covering a large geographic area to specific surface water sources. In addition, it is important to understand where water is distributed to in order to identify and estimate the locations and quantities of return flow (e.g., effluent discharge to lakes). GIS should be utilized during this stage.

Since some portion of the volume of water used offstream is routed back to the basin (either downstream of the point-of-diversion on the same stream or downstream to a lake), estimates should be developed to account for return flow. As an initial basis the return flows presented in Okanagan Basin Agreement reports may be used, but these should be reviewed to ensure they remain valid. Efforts should be made to establish the volumes of effluent and other surface and sub-surface return flows from each area-of-interest based on information collected from individual water utilities.

6.5.4 Water Use Based on Land Use

In order to develop demand-side estimates of water use, land-use should be categorized by residential (indoor and outdoor use); commercial/industrial; agricultural; and golf courses. Distribution system losses should also be accounted for. Within each of these categories the best estimates of water use should be developed for each area (i.e., watershed) in the basin.

Residential Water Use

Estimates of residential demand for water are available from several water utilities in the basin and the latest summary of this information is provided by KWL (1990). These should be cross-referenced with current population estimates of the areas served (based on BC Stats and official community plans) in order to establish the current per capita rate of water use in each of the 79 specified areas of the basin. In order to provide a detailed breakdown of the current population so that the population serviced by each utility and water source can be determined, an experience planner should be involved. This team member would compile population estimates from all relevant sources (e.g., municipalities, First Nations, school districts, health authorities) and organize it so that populations dependant upon each source and water utility can be estimated. Residential water use estimates should also be confirmed with previous estimates of per capita water use in the basin to ensure all values are reasonable and justified.

Commercial, Industrial, and Institutional Water Use

Commercial and industrial water use estimates should be obtained from selected water utilities that maintain these records. Where these records are unavailable, commercial and industrial use should be estimated using employment figures in various sectors of the Okanagan and factors developed to convert commercial and industrial use to equivalent single family dwellings (e.g., Urban Systems, 2002). A selected number of major commercial, industrial, and institutional users should be contacted for water use information in order to add additional confidence to the estimates.

Agricultural Water Use

The agriculture sector is the dominant water user in the Basin, and thus deserves the most effort to understand and document. Considerable progress has been made in developing estimates of crop water use in the Okanagan by the staff at Agriculture and Agri-Food Canada. Current and future (assuming climate change) annual water demand estimates throughout the Okanagan have been completed and are organized by water purveyor and crop type. Additional, but possibly dated information, is available from KWL (1990). Efforts in Phase 2 should be focused on updating this information to reflect current conditions and to ascribe the current estimates of water use by source (i.e., watershed). These estimates should be independently verified with agricultural water use estimates provided directly by the larger water utilities as well as a select number of orchards, vineyards, and farms in the Basin. Agricultural land reserve maps and Ministry of Agriculture, Food and Fisheries agricultural profiles should be obtained as well.

Within the Okanagan, there has been a slow decline of agricultural water use due to advances in irrigation technologies and application techniques, conversion to crops with lower water requirements, and cessation of irrigation on agricultural land (e.g., removal of fruit trees with no replacement) due largely to economic reasons. That last factor may be particularly significant and should be investigated in Phase 2. The key point would be to identify agricultural areas that are not currently irrigated but that potentially could be in the future. This should be done by analyzing the land-grading system (which outlines where water is used) employed by several water utilities. The difference between the volume of water actually used and the volume committed[6] by utilities to various users is a major concern of some utilities. From LWBCs allocation viewpoint, it remains important to know the scope for expansion above existing licences (i.e., the difference between the licensed quantity and the available supply).

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[6] Water committed to users by utilities refers to the volume of water that would be used if all current users used their allocated amount.

Golf Courses

Golf course water use is significant and thus warrants its own category in the water use assessment. In order to develop estimates of golf course water use, information should be obtained from a selection of the managers of major golf courses, most of which are metered. This information should be supplemented with estimates based on total irrigated golf course areas in the Okanagan and representative irrigation rates. Areas of irrigated golf courses should be confirmed using a combination of map and aerial photography, along with information from individual golf courses.

Water Reuse

Reuse of wastewater in Vernon and to a lesser extent in Penticton is substantial and must be accounted for as a means of meeting agricultural and golf course water demands.

Distribution System Losses

Distribution system losses are often difficult to quantify and may range from 5-10% (EarthTech, 2003). All available estimates from water utilities should be used in assigning or estimating these losses across the basin.

Total Water Use (best estimate)

The best estimates of water use should be based on reconciling the two methods noted above by adjusting underlying assumptions. All estimates should be summarized by source, purveyor, location and land-use sector. An important point is that average water use is often reported without any indication of the variability. Efforts should be made to summarize water use under dry as well as average conditions.

6.5.5 Optional Work Programs

Sections 6.5.1 through 6.5.4 outline the recommended program for the water use analysis. Below are the key points that differentiate the minimum and enhanced work programs from the recommended work program.

Minimum Work Program

While the minimum work program would follow a similar supply-based and demand-based water use assessment framework, Phase 2 would involve no additional effort to obtain new information in areas where information is still deemed to be weak. Reliance would be placed on what has already been assembled in Phase 1. No effort would be made to assemble additional information from water utilities, and no effort would be made to obtain updated agricultural information tailored to the study. While this minimum work program would still result in reasonable estimates, the precision of, and confidence in, the model will be significantly reduced. Our evaluation of the Phase 1 information we have assembled to date indicates that it is not advisable to reduce the water use analysis to the minimum program.

Enhanced Work Program

An enhanced work program would follow the same framework as the recommended program; however the level of effort in compiling principal water use data would be substantially increased. In particular we would obtain and incorporate information from the large number of smaller utilities, and add effort to the task of obtaining accurate information on the population serviced by each utility and source. The explicit inclusion of the most up-to-date information from all smaller water utilities identified in Phase 1 (and possibly others) will improve model accuracy and precision over that expected from the recommended program in areas served by small water utilities. This will increase overall confidence in the study results.

6.6 SURFACE WATER SUPPLY ANALYSIS

Section 6.6 proposes a strategy for the surface water supply analysis under the recommended work program. Section 6.6.3 outlines the differences between the recommended and enhanced and minimum work programs.

In order to meet project objectives, the surface water analysis should utilize the best available information and models that are currently available to estimate various natural flow characteristics. Only after these flow characteristics are known is it possible to accurately develop the Okanagan Water Model and identify the effects of water use on surface water sources.

The overall analysis should be divided into analyses of 1) tributary water supply and 2) mainstem water supply in Okanagan Lake and Okanagan River.

6.6.1 Background

A major objective of the surface water analysis is to provide confident estimates of natural flow in each of the major tributaries and residual areas entering the mainstem lakes and Okanagan River (Table 6.1). Although 179 hydrometric stations have been established in the Okanagan (150 measuring streamflow and 29 measuring lake levels) only 18 stream gauges and 6 lake level gauges remain active. Furthermore, none of the tributaries has a continuous record of unregulated flows at its mouth over the period 1971 to 2000 (this period is chosen based on the general availability of data and to be consistent with climate normals reported by Environment Canada). Since the existing hydrometric records cannot be directly used to identify natural streamflow characteristics, a combination of methods is required. These methods are outlined below.

6.6.2 Recommended Work Plan Framework

Tributary Water Supply

Since water is stored and diverted for human use in the majority of watersheds in the Okanagan Basin, estimates of the natural flow regime require some method of indirect estimation. The study framework in Phase 2 involves adopting the methods used by NHC (2001) where a combination of procedures or sources was used and the best estimate was adopted based on the quality of the data and professional judgment. These methods include:

- Naturalization of streamflow records near stream mouths;
- Utilizing sub-regional relations prepared by Obedkoff (1998 and 2000); and

- Independently checking the results using regression equations prepared by Levtak (1980a and 1980b) and several previous stream-specific reports and studies.

Naturalization of gauging records involves obtaining and adjusting measurements of regulated flows by accounting for the effects of storage and withdrawal. These flows are therefore estimated, not measured, and are referred to as "*naturalized"* to avoid confusion with measured "*natural*" flows from non-regulated streams. Streams where this method has been previously applied by NHC (2001) include:

- Peachland Creek;
- Trepanier Creek;
- Shorts Creek;
- Whiteman Creek;
- Equesis Creek;
- Bellevue Creek;
- Deep Creek; and
- Kelowna (Mill) Creek.

Unlike NHC (2001), we propose to naturalize the streamflow records using estimates of actual water use rather than licensed water use. This is a key difference since actual use and licensed use are generally not equivalent. In addition, we recommend that all estimates be standardized to the normal period of 1971-2000.

In cases where there is a large storage volume, inter-basin diversions, or a lack of streamflow records, regional hydrologic analyses are generally better suited for estimating natural flows. In a similar manner as NHC (2001), we recommend utilizing the framework used to develop sub-regional relations in Obedkoff (1998 and 2000). A key task will be to update these relations to the 1971-2000 normal period with available streamflow data. The revised relations should be used to estimate streamflows from watersheds that are ungauged or prove difficult to naturalize and to confirm estimates from other methods (e.g., naturalization).

To provide additional confidence and ensure that the results from the naturalization of gauging records and sub-regional relations are reasonable, we recommend comparing the results with available tributary streamflow estimates (at the mouths of all major Okanagan tributaries) based on the UBC Watershed Model. Cohen and Neale (2003) and Cohen et al. (2004) have used this model to estimate current and future streamflows in 21 tributaries in the Basin. An independent check of the model output by the study team suggested some bias in the model, which although it may not have been significant for climate change analyses, appears significant for this study. Discussions between the study team and UBC modellers suggest that significant improvements in the model are possible with a reasonable level of effort (Alila, pers. comm., 2005). Therefore, we recommend that the study team sub-contract the UBC modellers to re-calibrate the UBC model and re-run the model for all locations and current and future scenarios presented in Cohen et al. (2004). Once this is done, the UBC Watershed Model results would provide a reasonably sound check for natural streamflow estimates under the current conditions. Additionally, this re-run of the model would provide a solid basis for evaluating the effects of climate change on tributary streamflows and for modelling the effects of land use changes (e.g., fire and beetle-kill) on water supply.

As another check, all relevant information from reports (e.g., Hydrology Section studies) identified in Phase 1 (many of which were received late and not reviewed) should be extracted and cross-referenced with the estimates determined by the study team to ensure reasonable and consistent estimates are used in the Okanagan Water Model.

Mainstem Water Supply

In order to determine the mainstem Okanagan River/Lake water supply, options are available to utilize a combination of the tributary inflow estimates (noted above) with a updated run of the model prepared by Obedkoff (1994), which accounts for inflows to Okanagan Lake (and Okanagan River downstream), water use, and dam management guidelines. The results of the updated model would be revised estimates of water supply in Okanagan Lake and Okanagan River at selected points-of-interest under average, and wet or dry scenarios that would be identified during the defining of realistic future scenarios in Phase 2. These estimates would then provide a semi-independent check of the Okanagan Water Model parameters.

A key aspect of the mainstem water supply is evaporation from the lake surfaces. With the effects of climate change, changes in lake evaporation may be extreme (Cohen and Neale, 2003). While detailed process-based methods are available for estimating radiation from open water, these methods required detailed meteorological inputs that are not generally available throughout the Basin. Therefore, a simpler radiation based method is recommended (e.g., Priestley-Taylor equation). Much of this information has already been compiled (for current and future conditions) by Cohen et al. (2004) and is available. This information should be evaluated against the results of Trivet (1984) and the earlier estimates presented in Okanagan Basin Agreement studies.

Land-use Effects

Efforts in Phase 2 should also be made to compile existing timber harvesting information (e.g., ECAs) in the Basin. Based on this information and the research literature on the relationship between harvesting and water balance (e.g., Upper Penticton Creek), an assessment of the current effects of forestry of the timing and quantity of streamflow can be made for each point-of-interest. In addition, the potential effects of fire and beetle-kill should be assessed. Efforts should also be made to identify any references to the potential current effects of tourism, mining or recreation on water supplies (references that were not identified in Phase 1)

6.6.3 Optional Work Programs

Section 6.6.2 outlines the recommended program for the water supply analysis that involves a reasonable level of effort and would result in reasonably accurate and precise estimates of water supply that reflect optimal use of the best available data and science.

Below are the key points that differentiate the minimum and enhanced work programs from the recommended work program.

Minimum Work Program

The minimum program would rely on information that has already been assembled in Phase 1. No additional effort would be made to obtain any new information in areas where information is still deemed to be weak. Specifically, the minimum program would not involve updating available regional relations [e.g., Obedkoff (1998)] and would involve a general reduction in effort to confirm estimates based on independent methods (e.g., stream specific studies by the Hydrology Section). The minimum program would also not involve a re-examination and running of the UBC Watershed Model; but would instead adopt the results presented by Cohen et al. (2004), which are the best currently available despite concerns about the adequacy of the calibrations of the model identified by the study team. In addition, the minimum program would not involve the use of an updated version of Obedkoff's (1994) model to provide a check on the results developed by the Okanagan Water Model. Although estimates of water supply could still be developed for use in the Okanagan Water Model, their accuracy and precision would not be the best available, and this reduced program is not recommended.

Enhanced Work Program

An enhanced work program would follow the same general framework as the recommended program; with additional levels of effort placed in cross-referencing and incorporating the information available in the large number of stream-specific investigations with the independent methods to be used by the study team. This increase in effort will result in a reduction in overall uncertainty in water supply estimates.

6.7 GROUNDWATER ANALYSIS

6.7.1 Overview of Recommended Approach

The primary objective of the groundwater analysis is to develop estimates of the groundwater component of the Okanagan Water Model. This will provide a basis to characterize the role of groundwater in defining the long-term sustainable yield in the Okanagan Basin. Groundwater is a significant component of the water balance of the Okanagan Basin. The two most significant aspects are:

- Aquifers that provide a significant yield are a developable water supply resource. These aquifers underlie a small portion of the overall surface area; and
- Groundwater discharging to surface water is particularly important in dry periods. This discharge is provided by groundwater in storage, available both from the mapped aquifers and from the remainder of the watershed.

A tiered approach based on level of effort, available data, and the need for focused study, designed to estimate the maximum sustainable groundwater yield and present-day groundwater demand in the Okanagan Basin is proposed in this section. The approach makes use of GAOB results anticipated to be available in time to be incorporated, supplemented by additional work where the GAOB will not be able to contribute.

As discussed in Section 4.2, very little data or analyses which integrate available groundwater data on a watershed, aquifer, or Basin-wide basis are available. Although significant site-specific data and analyses have been completed, no regional synthesis of groundwater knowledge has been performed. Therefore, to provide an initial basis for aquifer and groundwater analysis, we recommend that water balance models developed for each point-of-interest (Table 6.1) be refined and calibrated using a tiered approach. Generalized aquifer, hydrogeologic and water well production data should be used to identify the overall component of groundwater supply and demand for each watershed. Where available, more refined and accurate estimates of groundwater components should be developed (under the enhanced program) by improving the initial water balance models with site-specific geologic, stratigraphic, aquifer and groundwater production data.

By integrating initial groundwater estimates from water balances with focused aquifer analyses, reasonable estimates of long-term groundwater supply and use can be generated for areas with substantial groundwater data; and less accurate but still usable estimates of groundwater supply and use can be made for areas with limited aquifer data. Groundwater information for each watershed, tributary, aquifer and point-of-interest should then be totalled to provide an overall estimate of sustainable groundwater supply and current use for the entire Okanagan Basin.

6.7.2 Use of Timely Results from the GAOB

Several GAOB projects are presently underway that are scheduled for completion in 2005 or 2006, and therefore could contribute to the overall success of the Phase 2 study. Current GAOB project data and results should be incorporated into the Phase 2 groundwater study as they become available. Brief descriptions, the current status of these GAOB projects, and their potential contributions to the Phase 2 study are provided in Table 6.3.

Table 6.3 GAOB Projects that could contribute to Phase 2.

Project / Task	Brief Description	Status	Potential Contribution to LWBC Phase 2 Study
Update MWLAP WELL database	1400 well records in Victoria are in various stages of processing, including well locating	Pilot project in progress, with assistance from local organizations and well drillers	The updated well database will provide a more accurate resource from which to identify and characterize aquifers, and for developing estimates of potential aquifer yield and groundwater demand
Collect and Cross-Reference Drinking Water Systems Information in Okanagan Basin	Project components include accurately georeferencing points of extraction (including elevation) and drinking water system facilities for both surface and groundwater supplies, collecting information on volumes of extraction, correlating wells with aquifers and collecting other relevant information of drinking water supplies	In progress. Pilot study which included assessment of approximately 60 systems out of 274 systems is largely complete.	Will support more accurate assessments of surface and groundwater demand by providing detailed locations and rates of surface and groundwater extraction
Collect and compile groundwater related Okanagan Basin data including well records and data reports	All types of groundwater data will be obtained including reports, aquifer test data, well records, also will include reviewing applicable contaminated site data	Entire Okanagan Basin scheduled to be completed by the end of March or April, 2005.	Collecting and compiling widely scattered groundwater data will assist LWBC by greatly reducing the amount of effort needed to obtain this information
Collect and analyze existing hydrogeologic data	Analyze pumping test data collected as part of the groundwater record and data collection task to determine hydraulic properties and boundary conditions	In progress	These analysis will provide additional hydrogeologic parameter data of known and good quality for completing aquifer analyses where the wells are located

Table 6.3 cont'd.

Project / Task	Brief Description	Status	Potential Contribution to LWBC Phase 2 Study
Compile and digitize existing surficial and bedrock maps in the Okanagan Basin	Prepare digital maps of surface and bedrock geology for use in aquifer mapping	Maps for the north Okanagan are completed; maps for south are in progress. May be completed by 2006	These maps will provide substantial data to support of LWBC Phase 2 aquifer boundary delineation and analysis
Assess groundwater resources in the Spallumcheen area	Little groundwater data is available for this area, and groundwater is heavily used in this area; Aquifer is classified as 1A – Heavily Developed and Highly Vulnerable	In progress	This analysis will provide specific aquifer characteristics and groundwater pumping data that will directly support North Okanagan and local watershed water balance estimates
Aquifer classification mapping in the Kelowna mapsheet area	Develop aquifer maps and classifications for the west side of Okanagan Lake	Presently underway for Westbank; will be completed in 2005	This analysis will provide specific aquifer characteristics and groundwater pumping data that will directly support Central Okanagan and local watershed water balance estimates
Obtain and analyze hydrogeologic data from Provincial Observation Wells	Complete slug tests in 14 observation wells in the Okanagan Basin. Estimate hydraulic conductivity values for each aquifer. Compare water level data with climate / precipitation data to evaluate water level response to climate variations	Field work complete. Data analysis in progress	These analysis will provide additional hydrogeologic parameter data of known and good quality for completing aquifer analyses where the wells are located
Computer modeling of climate change and hydrologic conditions in south Okanagan area	Model response of water level data from Provincial observation wells and climate data, and develop detailed recharge and groundwater model for the Oliver-Osoyoos area	In progress	Data from this study will provide more accurate input into watershed water balance calculations
Southern Okanagan valley dissolved oxygen and nitrate study	Develop greater understanding of groundwater recharge rates, flow paths and flow rates, overall groundwater chemistry, and geochemical controls on Nitrate in the southern Okanagan Valley	Wells sampled and analyzed, short report due Spring 2005	Data from this study will provide increased knowledge of surface-groundwater interactions and support more accurate water balance estimates for the area

Each of these projects will address significant data gaps in our understanding of groundwater in the Basin, and will also address significant gaps in our management of Basin groundwater data. For example, by updating the MWLAP WELLS database, more accurate aquifer mapping and water production estimates can be made. Digitized maps of bedrock and surficial geology will facilitate more efficient delineation of aquifer boundary maps, as well as greater understanding of groundwater recharge and discharge areas. By addressing these data gaps, the GAOB projects summarized above will assist LWBC with developing more accurate estimates of groundwater availability and demand locally and basin-wide. To the extent that each of these projects is completed within 2005 and 2006, the results will be obtained and utilized for the benefit of the Phase 2 study.

6.7.3 Recommended Methods

As discussed in Section 6.1, estimates of local and Basin-wide surface and groundwater supply should be completed by using water balance modeling for watershed tributaries, points of interest, and the entire Basin. Depending upon available data and funding, three levels of effort – minimum, recommended, and enhanced – are proposed to achieve increasingly accurate estimates of groundwater use and projected groundwater sustainable yields. The levels of effort incorporate the following work:

- **Minimum Program** – The minimum groundwater program should use available groundwater data to develop and refine the basic water balance model input parameters for each contributing area above points-of-interests identified in Section 6.2. The focus should be on estimating the pumping rates, the groundwater storage volumes, the relationship between volume in storage and recharge and discharge rates, and the rate that groundwater bypasses the point of interest;
- **Recommended Program** – The recommended program builds on work performed for the minimum program and is designed to provide generalized aquifer characteristics and groundwater supply and demand parameters for water

balance models for all watersheds, tributaries, and points-of-interest within the Okanagan Basin; and

- **Enhanced Program** – The enhanced program is intended to further refine, calibrate and supplement the broad initial water balance models in selected areas with site-specific aquifer and groundwater data analysis and interpretations.

The minimum program should provide basic water balance input parameters related to groundwater for each contributing area. However, its limited value with respect to aquifer characteristics and groundwater supply estimates makes it difficult to recommend. The recommended work program should be designed to identify and incorporate additional and refined model input data and thereby improve the accuracy of the estimates of available groundwater supply. The enhanced program would further refine the groundwater information. These programs are described below.

Minimum Program – Basic Groundwater Model Input Development

The minimum groundwater program is designed to utilize readily available groundwater data and interpretations to develop basic groundwater components for the water balance models of each tributary and point-of-interest. These basic components include estimates of recharge and discharge, of the volume of groundwater held in storage, the amount of groundwater withdrawn by pumping, the rate of groundwater passing under the point of interest. The initial water balance models generated for each tributary and point-of-interest should provide very generalized estimates of groundwater availability, production for individual watersheds and areas, and contribution to stream flow above points-of-interest. No estimates of sustainable yield will be developed in the Minimum program.

Recommended Program – Develop Aquifer and Watershed Hydrogeologic Data Sets

The minimum program will only provide the most basic groundwater data for use in the overall water balance models. The recommended groundwater assessment program builds and improves on the minimum program work by completing aquifer analyses for each watershed using readily available information. The hydrogeologic data sets should then be used to significantly refine the initial water balance models and resulting estimates of groundwater availability and sustainable yield for each watershed.

An initial conceptualization of the hydrogeology of each watershed should be developed with the following tasks:

- Collect, compile, and develop summary tables of published geologic, hydrogeologic, groundwater production, and well data for each watershed, residual area and aquifer;
- Use MWLAP aquifer maps, supported by current and GAOB digital surficial and bedrock mapping data as available, to establish and clarify known aquifer boundaries, and to estimate boundaries and thicknesses of alluvial basins where presently uncertain or unknown;
- Use well depth and stratigraphic data from the existing NTS and WELL database, as compiled and updated by GAOB, to estimate aquifer thickness information and to develop maps of generalized aquifer lithologies;
- Use groundwater test data obtained from current GAOB projects as well as NTS reports to develop estimates of average aquifer parameters including hydraulic conductivity, groundwater extraction rates and production horizons or depths, well specific capacities, and other hydrogeologic parameters for each aquifer or watershed;
- Develop generalized geologic cross-sections illustrating the hydrogeology of each aquifer or watershed;
- Use reported groundwater elevations to develop generalized potentiometric surface maps and maps of generalized groundwater flow for each aquifer or watershed;
- Estimate groundwater production from known sources including water purveyors, and data from the GAOB drinking water assessment and cross-referencing project;

- Develop an expected relationship between groundwater volumes in regional areas and aquifers with expected groundwater discharge rates for use in water balance model; and
- Develop more detailed estimates of sustainable groundwater yield for each watershed using the refined water balance models.

After initial water balance models are developed for each watershed and the Basin, detailed aquifer and hydrogeologic information completed by performing the Recommended work will result in significantly more refined and accurate model input parameters, and supply and demand groundwater data for tributary and point-of-interest models. The watershed and point-of-interest models based on the Recommended Program will provide rough but sound estimates of groundwater availability and use, and rough estimates of sustainable groundwater yield for each watershed and the Okanagan Basin as a whole.

Enhanced Program – Watershed and Aquifer –Specific Analyses

The level of effort proposed for the recommended program will provide rough initial estimates of groundwater availability and use for each watershed and the Basin, but will not provide groundwater supply data for specific areas-of-interest and will only include, where sufficient data exist, cursory assessment of groundwater availability in Basin areas presently identified as residual. In addition, the recommended program will not provide sufficient data or analyses to develop more than very rough estimates of sustainable maximum yield, as these estimates are based on aquifer and land use-specific parameters. Finally, the Recommended Program will provide only a rough estimate of the expected variation of groundwater discharge to stream baseflows from groundwater as a function of groundwater storage volumes. To achieve additional understanding of groundwater in specific areas of interest, it will be necessary to conduct additional detailed assessments to improve our estimates of groundwater use and availability, current and potential impacts to surface water flow, and maximum sustainable yield.

These detailed analyses will build upon the recommended work program. Significant groundwater data, analyses and interpretations are available for several areas within the Basin. Where detailed hydrogeologic and groundwater production knowledge exists, more accurate estimates of sustainable groundwater availability can be provided.

The MWLAP aquifer classification database lists 11 aquifers in the Okanagan Basin which have been classified as highly developed with a high resource demand, and another 16 have been classified as moderately developed with a moderate resource demand. (MWLAP, 2005). MWLAP's aquifer development classification is based on two basic criteria:

1) Comparing the amount of groundwater withdrawn from the aquifer to the aquifer's inferred ability to supply groundwater for use; and
2) Evaluating the groundwater demand from the aquifer, which is based on the reported number, capacity, and distribution of wells in the aquifer.

These aquifers constitute those where better knowledge of groundwater supply and demand are needed. Specific aquifers or watersheds should be selected for additional study using the following parameters:

- Current known groundwater demand on the watershed or aquifer;
- Potential demand growth on watershed or aquifer;
- Available aquifer data and or hydrogeologic test or performance information; and
- The importance of groundwater discharge in establishing potential safe yield from an aquifer.

The enhanced analyses of aquifer and hydrogeologic parameters in selected aquifers should include the following tasks:

- Collect, compile, analyze, and summarize additional site-specific watershed parameter, aquifer, hydrogeologic, and groundwater production data for each selected area;

- Develop detailed stratigraphies for selected aquifers and watersheds, and identify the lateral boundaries and thicknesses of water-bearing and non-water bearing stratigraphic units within selected aquifers;
- Establish the hydrogeologic and water production characteristics of mapped residual areas;
- Refine our understanding of groundwater demand by acquiring additional groundwater production demand data from private sources;
- Improve the estimate of direct discharge from groundwater streams and mainstem lakes;
- Develop maps illustrating approximate areas and quantities of groundwater recharge for each watershed based on soil type, refined precipitation data, detailed land use information, irrigation recharge and other criteria;
- Develop maps of current groundwater demand for each aquifer or watershed; and
- Recommend additional aquifer and groundwater data collection requirements, including drilling, aquifer testing, geophysical assessments, and streamflow measurements to further improve our understanding of aquifer and watershed parameters and thereby improve model results.

After the model parameters have been refined using the improved and focused data, additional time should be spent fitting the model results to observed data. Sensitivity analyses should be performed on selected inputs or model parameters to observe changes in model response to changed inputs. Sensitivity analyses should also be beneficial in determining the direction of future data collection activities. Data for which the model is relatively sensitive will require future characterization.

The enhanced groundwater assessment program will result in more accurate and precise water balance model input data, such as improved aquifer storage data, improved estimates of groundwater withdrawal rates and volumes, improved definitions of boundary conditions, and improved knowledge of surface-groundwater interactions for specified areas. Utilizing this improved model input data will thus provide more accurate estimates of sustainable groundwater supply and demand for selected aquifers, watersheds and the Basin.

Groundwater Model Calibration

All water balance models should be calibrated to maximize the correlation between model input parameters to predicted model results. Through the process of model calibration the values of the different hydrogeologic conditions are varied to minimize disparity between the model simulations and field data.

Model calibration will result in more accurate estimates of sustainable groundwater supply for each watershed. Where limited or no aquifer or hydrogeologic data are available, aquifer and groundwater production parameters may be "transferred" from known watershed areas to less known watershed areas to increase the model accuracy. Alternatively, estimates of groundwater availability in areas with less model validation data will be accepted as less accurate, and recommendations will be made to obtain the required data to improve the model results. The model inputs can also be modified to investigate how changes in input parameters, such as land use or climate changes, result in changes in groundwater and surface water dynamics. Potential environmental impacts may include the redistribution of recharge and discharge areas, reduced groundwater discharge to streams, or changes in groundwater recharge rates.

The minimum level of effort will be calibrated using simple correlations between various model output parameters and measured watershed, aquifer, streamflow and well production data. Where available data exist, each model output should be calibrated against actual field data. For example, measured stream baseflow should be assumed to originate solely from groundwater. The watershed model input parameters should be adjusted so that, at minimum, predicted groundwater discharge matches the measured stream baseflow. If groundwater production from wells can be adequately characterized in a watershed, the predicted groundwater discharge should be adjusted to match the sum of stream base flow and well production. Model estimates of aquifer storage should be calibrated against actual estimates of storage based on field assessments of aquifer thickness and porosity.

The recommended and the enhanced programs should be calibrated by adjusting model input parameters to identify and minimize the disparities between measurable watershed, hydrogeologic and aquifer data including

- Predicted and actual potentiometric surface elevations on a watershed and aquifer basis;
- Predicted and actual groundwater flow directions;
- Predicted and actual well drawdown;
- Vertical and horizontal variations in aquifer characteristics;
- Vertical aquifer boundaries including aquitards and aquicludes;
- Predicted and actual groundwater storage including vertical and horizontal variability; and
- Predicted and actual groundwater discharge at specific locations.

Using site-specific aquifer data to refine and calibrate the sub-basin groundwater models will result in well-supported estimates of sustainable groundwater availability where groundwater data exist, and will provide rough estimates of groundwater availability where limited or no groundwater data are available.

Groundwater Demand Estimation

Insufficient data are presently available to accurately measure current groundwater production from all wells in the Basin. Present-day groundwater demand should be estimated by totalling known groundwater production from each watershed and residual area, estimating the undocumented quantity of groundwater production for each watershed and residual area, and summing these values into an estimate of total groundwater demand for the entire Basin. This analysis should be primarily based on groundwater production data obtained from water suppliers and irrigation districts as discussed in Section 4.2 and from the GAOB Drinking Water Assessment and Cross-

Referencing project presently underway (Table 5.3). However, in areas where limited groundwater data are available, the number of wells and approximate groundwater withdrawals will be estimated.

Increased knowledge of present and future groundwater supply and demand will greatly assist LWBC with future development of local and basin-wide water resource management policies, and will also assist local water managers with resource development, protection, and management.

Phase 2 Limitations

The currently available groundwater data will support reasonably accurate estimates of groundwater supply and actual demand for some but not all areas in the Basin. The Phase 2 study findings will be used to develop recommendations for acquisition of specific watershed or aquifer-specific data to improve groundwater knowledge. These recommendations may include focused aquifer drilling and aquifer testing, surface-groundwater interaction studies on selected streams, basin analyses using geophysical methods as performed for the 1974 Okanagan Basin study, or other watershed and aquifer evaluations.

6.8 CALIBRATION AND VERIFICATION OF THE OKANAGAN WATER MODEL

This section summarizes the steps outlined in the above sections to develop accurate and reliable calibrations of the water balance model, and to verify the specification of model parameters. The general process of model calibration will involve adjusting the values of the model parameters in the water balance equations outlined in Section 6.3 to minimize differences between model estimates and actual or independently estimated data. The process of verification involves checking the calibrated model by evaluating output against independently estimated or measured values in areas for which the model has not been calibrated. Model calibration and verification will be done using accepted methods that have been outlined in several reference sources, including Haan et. al. (1982).

Specific recommended calibration procedures have been outlined in the above sections, and some key examples are listed here:

- To obtain the best estimate of precipitation, all relevant precipitation records and models should be utilized and compared (e.g., Environment Canada climate stations, B.C. Ministry of Water, Land and Air Protection snow survey data, Okanagan Basin study climate information);
- To obtain the best estimate of water use, supply-based (i.e., by source and purveyor) and demand-based (by land-use) estimates should be developed and reconciled for each point-of-interest throughout the Basin;
- To obtain the best estimate of water supply, streamflow estimates should be based on a combination of several methods depending on data availability. These methods include use of natural streamflow records, naturalized streamflow estimates, regionally-based estimates, and updated UBC Watershed Model output;
- To calibrate the model for tributaries, model output should be reconciled with available streamflow records (where available) - including Water Survey of Canada records and recent records maintained by the Ministry of Water, Land and Air Protection (Penticton);
- Estimated inputs (from tributaries and residual areas) to Okanagan Lake should be matched with the lake level and outflow records that date from 1922 to permit calibration of the tributary water balance models;
- Matching estimates of the tributary flows downstream of Penticton with the output of the tributary flow model contained within the Okanagan Fish-Water Management Tools Model will allow a check of the tributary flow estimates;
- To obtain the best estimate of evapotranspiration, several methods including the Priestly-Taylor method should be used and compared with independently reported estimates, and with values produced by the UBC watershed model;
- The watershed model input parameters should be adjusted so that, at a minimum, predicted groundwater discharge matches the measured stream baseflow;
- To calibrate model estimates of groundwater storage, available groundwater elevation data from wells should be correlated with predicted changes in storage, and should be

calibrated against actual estimates of storage based on field assessments of aquifer thickness and porosity;

- To calibrate model estimates of total watershed discharge, predicted discharge values should be adjusted to match the sum of stream base flow and groundwater production; and
- To calibrate the model for the mainstem, model output should be verified with output based on Obedkoff's (1994) mainstem model.

In summary, model parameters will be estimated using several different methods (where adequate data exist to support this effort) and calibrated by comparing the results with measured or independently estimated data. Model calibration will result in accurate estimates of sustainable surface and groundwater supply for areas above each point-of-interest and for the Okanagan Basin lakes and mainstem.

Model verification will include testing the model by comparing its predictions in residual areas or tributary basins where no independent data exists against estimates derived by other reliable methods. For example, model-generated estimates of streamflow for tributaries where no actual streamflow data exists to assist in calibration will be compared with estimates generated by other means (such as regional relations or the UBC watershed model).

7.0 FUTURE SCENARIOS

7.1 SCENARIO IDENTIFICATION PROCESS

For both supply and demand, a range of possible future scenarios should be developed and analyzed. Under the recommended and enhanced work programs, these scenarios should be developed according to the following process:

- Consultant identifies a preliminary suite of possible future scenarios;
- LWBC, the Steering Committee, and the Working Group refine the suite of realistic future scenarios;
- The suite of possible scenarios is reviewed with stakeholders, and further refined to an agreed set (the set is anticipated to be larger under the enhanced work program and smaller under the minimum program);
- Each future scenario is analyzed using the automated Okanagan Water Model. The results of each scenario should be identified at each point of interest (as for the current case), and for each of 3 future times (mid-2020s, mid-2050s, and mid-2080s).

The scenario identification process under the minimum program is identical to that suggested for the recommended and enhanced work programs, except that the suite of possible scenarios is reviewed and refined only in consultation with LWBC (i.e., no meeting of the Working Group or Steering Committee is planned). With the exception of this difference, the future scenario modelling under the three work program differs only in the number of scenarios run (with the minimum, recommended, and enhanced programs having increasing numbers).

7.2 ALTERNATIVE FUTURE SCENARIOS

7.2.1 Future Water Supply Scenarios

In future, the Okanagan water supply will be affected by natural within and between-year variations in climate, natural cycles including the roughly 25-year Pacific Decadal Oscillation (PDO) cycle, and the roughly five year El Nino/Southern Oscillation Index

(ENSO) cycle. In addition, it is now clear that the climate has been systematically changing over the recent past, and current global circulation models indicate that these recent trends will continue to affect climate and water supply. All of these sources of variation should be considered in defining a range of realistic future water supply scenarios.

The output of UBC Watershed Model runs conducted by the UBC Faculty of Forestry for each of 21 tributaries in the Okanagan (i.e. 6 outputs, based on 3 models and 2 CO_2 scenarios each) should be the basis for assessing future changes. These runs would be based on the work outlined in Cohen et al. (2004) but include the revised calibrations outlined in Section 6.6.2 to improve overall model performance. The relative differences in natural streamflows identified for each tributary under the effects of climate change should be used in conjunction with the best estimates of current natural streamflows to produce natural streamflow estimates for the mid-2020s, mid-2050s, and mid-2080s (6 outputs). This will identify a reasonable range of possible future water supplies at each point-of-interest in the study (e.g., each tributary mouth and specific locations along the mainstem river and lakes).

If the rate of timber harvesting is expected to significantly change throughout the Basin, it would also be recommended that the estimated future levels of harvesting also be assessed and incorporated into the UBC Watershed Model as additional scenario runs (under the enhanced program only). In addition, it would be recommended that two (a high and low) fire and/or beetle-kill scenarios be assessed (under the enhanced program only).

7.2.2 Future Water Demand Scenarios

There is an infinite range of possible future water demand at each of the identified points-of-interest in the Okanagan. Future demand depends on a set of factors including the following:

- Land use;

- Population;
- Climate; and
- National, provincial, and local economies.

Land Use

Land use change will affect the distribution of water demand across the basin. The principal land uses to consider include residential and agricultural.

The future form of residential development (i.e., whether it will consist of single-family detached dwellings with significant outdoor irrigation requirements or whether it will include increasing densification of urban areas) will factor into future projections of domestic water use. Land use information on current and projected future use from all municipalities and regional districts should therefore be obtained. This may be in the form of current OCPs or other planning documents that should be obtained by the study team.

Future water demand is affected by changes in future agricultural land use. These changes may include changes in areas of crops harvested, crop types, irrigation technology and efficiencies, irrigation scheduling and market forces (e.g., production costs including cost of water and prices for agricultural products). Information on the likely changes in this sector will require a review of current irrigation practices as outlined in KWL (1990) and Cohen et al. (2004), and should be supplemented with direct communication with water utilities and representatives of the agricultural sector (e.g., B.C. Tree Fruit Association).

The tourism sector (part or the commercial sector) is also a major land use in the Okanagan Basin, particularly in the summer, and future projections in this sector should also be evaluated in developing realistic scenarios. Potential major water use activities includes recreational activities, such as golf.

Population

An effort should be made to develop future population projections throughout the Okanagan at the community/neighbourhood level in order to facilitate the evaluation of existing and future water demand within the areas-of-interest identified in Table 6.1. Current BC Stats 20-year projections and other projections provided in OCPs of municipalities and regional districts (typically developed without explicit consideration of water availability) should also be assessed and levels of uncertainty explicitly stated in order to provide a realistic range in population growth estimates. These projections should also be extended to provide a basis for supply/demand scenario runs for the 2050s and 2080s by considering the factors that govern future population changes (e.g., quality of life, cost and availability of water).

The range of future population estimates will provide the basis for projecting residential and commercial/industrial water demand. Well-established models for relating residential to commercial/industrial water use should be calibrated and utilized in Phase 2.

Climate Change

The effect of climate change on water demand will vary depending on land use. Under the recommended and enhanced programs, updated information on agricultural land use and crop water demand (for the 1971-2000 standard period) organized by the points-of-interest of this study would be developed and provided by Denise Neilsen of Agriculture and Agri-Food Canada. Under the minimum program, research data for the 1961-1990 period identified in Cohen et al. (2004) would be utilized and rough estimates would be necessary to ascribe water use estimates organized by water purveyor to the areas above each point-of-interest in this study.

In addition, to account for climate change effects, the outdoor portion of residential water use should be scaled based on similar or representative agricultural demand increases. The indoor portion may be assumed to remain unchanged due to climate change.

Commercial and industrial uses may be assumed to remain unchanged due to climate change unless some significant outdoor portions of their total water use is identified.

National, provincial and local economies

Economic changes may influence overall land use changes and population growth in the Basin. Therefore a thorough analysis by an experienced land use economist is recommended in developing the range of realistic scenarios.

7.3 RUNNING FUTURE SCENARIOS

Future scenarios will be examined at each of the points-of-interest (Table 6.1). However, given that each of the factors affecting the components of the water balance has a range of likely possibilities, it is anticipated there will be a relatively large suite of future scenarios identified for each point-of-interest (Table 7.1). After confirming which scenarios to run (through the steps outlined in Section 7.1), the automated Okanagan Water Model should be used to facilitate the forecasting of water supply and demand under each future scenario. This should enable the study team to forecast surface water and groundwater supplies and demands for each point-of-interest for the selected future time periods (mid-2020s, mid-2050s, and mid-2080s) and will allow for relatively rapid generation and evaluation of multiple scenarios as well as assessing the sensitivity of the water supply and demand to each of the identified factors or input parameters (e.g., future precipitation, evapotranspiration, groundwater recharge, population, or changes in land use or groundwater production rates).

In summary the suite of model runs (based on scenarios) will provide a basis to:

- Determine the relationships between the parameters of the Okanagan Water Model;
- Assess the sensitivity of each parameter;
- Determine the relative importance of the parameters;
- Illustrate graphically the importance of each parameters;

- Determine the amount of water available for allocation for a range of alternative futures.
- Educate stakeholders and the public; and
- Initiate a process to agree on which scenarios and constraints to adopt for future allocations decisions.

Table 7.1 Some factors that should be considered in defining future scenarios.

Major factors to consider in defining future scenarios	**Likely number of realistic possibilities**	**Example**
Points-of-interest	79	Tributary mouths, residual areas, mainstem lakes and river
Periods-of-interest	3	2020s, 2050s, 2080s
Water supply		
Future climatic conditions affecting supply	7	3 models, each with 2 assumed CO_2 emission scenarios, plus an average of all available models
Future changes in timber harvesting or forest land base	5 +/-	Maintain, reduce or increase level of harvesting; high and low fire and or beetle-kill scenarios
Water demand		
Future form of residential development	3 +/-	Urban sprawl, intermediate, densification
Future crop types	3 +/-	Conversion to vineyards
Future irrigation application efficiency	2 +/-	Spray vs. drip irrigation, irrigation scheduling
Future irrigable land	Several	Full irrigation of ALR, full irrigation on First Nations land
Future economy (affecting agriculture, population growth, economic activity)	Several	
Future commercial development (including tourism)	Several	
Future population	3 +/-	For each period-of-interest, an expected, upper and lower population estimate
Price	Several	Variations in demand based on price elasticity
Adoption of residential water conservation measures	4 +/-	Four levels based on expected savings due to for example metering and pricing; regulations; education; incentive programs
Future implications of climate change on demand	Several	Depends on form of future agricultural and residential use
Fish flows	3 +/-	Minimum flows recognizing Federal Fisheries Act, optimum flows

8.0 CONSULTATION PROGRAM

In addition to technical meetings between the study team (four scheduled meetings under the recommended and enhanced programs, and two meetings under the minimum program), a comprehensive consultation program will be developed and implemented during Phase 2 of the study. The consultation program will satisfy the need to receive input on technical issues and achieve other “non-technical” objectives, such as communication, information sharing, raising awareness, and identifying future steps and future user needs. However, the list of objectives has not yet been fully developed, so this report does not attempt to describe the program. It will be designed early in Phase 2 to meet multiple objectives. Stakeholders and Okanagan First Nations will be identified and invited to participate.

The cost estimate for the consultation program under all three work program (presented in Section 13.0) assumes that two meetings between stakeholders and First Nations will be held during Phase 2. Under the recommended and enhanced work programs, we recommend the addition of a parallel consultation program with a broader audience. We have assumed that this parallel program would consist of three meetings under the recommended program and six meetings under the enhanced program. No parallel consultation program (in addition to the two stakeholder meetings outlined above) is recommended under the minimum work program.

Under the recommended and enhanced work programs an Advisory Panel of experienced local consultants that can provide advice and review during the study should be established. This panel would not be established under the minimum program.

9.0 ANALYSIS AND DEVELOPMENT OF RECOMMENDATIONS

Following the evaluation of the current surface and groundwater supply and the development and assessment of a suite of possible future scenarios, the study team should analyze and synthesize the results. This synthesis should include the following:

- Summarizing and discussing the output of the Okanagan Water Model graphically and in tables;
- Identifying the relationships between the parameters of the Okanagan Water Model;
- Identifying the sensitivity of each parameter;
- Identifying the relative importance of the parameters;
- Identifying the amount of water available for allocation on a tributary-specific basis for a range of alternative futures; and
- Suggesting limits to surface water, groundwater and lake extractions given only the technical input.

Recommendations should be developed that outline the following:

- How the information from Phase 2 can be used;
- What could be the next steps (e.g., agreeing on scenarios, agreeing on constraints that must be met in future allocation decisions in the Basin); and
- If there are any enhancements that could provide tangible benefits (e.g., developing methods to evaluate supply and demand at locations upstream of tributary mouths or within currently defined residual areas).

10.0 DELIVERABLES

To meet the needs of LWBC and other stakeholders, the deliverables from Phase 2 will include a final report and supporting mapping in the following formats:

- Hardcopy;
- Digital copy on CD suitable for printing or press (e.g., Adobe Acrobat – high resolution);
- Digital copy suitable for posting on the web (e.g., Adobe Acrobat – low resolution); and
- An updated version of the information database developed in Phase 1 that includes at least 70 new entries for documents received too late in Phase 1 (under all work programs), and new documents identified in Phase 2 (under the recommended and enhanced work programs only).

In addition to the full technical report, an executive summary for policy makers should be produced under all three work programs. Under the enhanced work program, a summary brochure for the general public should also be produced. The summary brochure should be designed for ease of use and present the overall findings in a clear and simple format (possibly organized as in the Okanagan Basin Study (1974) where key questions and answers regarding the Basin supply and demand are provided). We suggest that hardcopies of the study deliverables be provided to public libraries and other interested stakeholders and digital copies be made available through LWBC or other web sites (e.g., Waterbucket.ca).

Near the completion of Phase 2 the study team should also provide training and guidance to LWBC staff in the use of the Okanagan Water Model under all work programs.

11.0 SCHEDULE

Given the urgency for updated information for water management purposes and the level of effort required, we recommend that Phase 2 span a period from June 1, 2005 to November 30, 2006. An outline of the recommended workflow, as summarized in Section 5.5, is outlined in Figure 11.1.

		2005							2006										
Task No.	**Description**	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	The consultant reviews the Phase 1 report, confirms the approach, and develops a detailed work plan and cost estimate.	■																	
2	The Technical Working Group reviews the detailed work plan and cost estimate and provides feedback to the consultant.	■																	
3	The consultant reviews and evaluates all relevant information either not received or received late in Phase 1.	■	■																
4	A user-needs assessment conducted with LWBC, the Working Group, and Steering Committee		■																
5	The consultant develops an overall Okanagan Water Model including programming, database, and scenario driver.		■	■	■	■													
6	a) Water use/demand analyses are conducted by the consultant.		■	■	■	■	■	■	■	■	■	■	■						
	b) Surface water supply analyses are conducted by the consultant.		■	■	■	■	■	■	■	■	■	■	■						
	c) Groundwater analyses are conducted by the consultant.		■	■	■	■	■	■	■	■	■	■	■						
7	The assessment of current water use and supply is reviewed with the Working Group.												■						
8	The consultant develops a suite of scenarios for future water use and supply analysis.												■	■					
9	The future scenarios are reviewed with the Working Group.													■					
10	Meeting with stakeholders is held review current conditions and propose approach to forecasting future conditions.													■					
11	The consultant conducts the technical analyses using the adopted suite of realistic scenarios.													■	■	■			
12	The consultant synthesizes the analyses and develops recommendations.													■	■	■			
13	The consultant prepares and submits the draft report for review by the Working Group.													■	■	■	■		
14	A meeting is held with the consultant and the Working Group.																■		
15	The consultant refines the draft report as necessary.																■	■	
16	A meeting with the Steering Committee (and other stakeholders) is held to review the overall study findings.																	■	
17	The consultant provides training of LWBC staff in use of the model																	■	■
18	The consultant refines the draft report as necessary and prepares the final report and deliverables for submission.																	■	■

Figure 11.1 Gant chart outlining the recommended schedule for Phase 2.

12.0 SUMMARY OF THE WORK PROGRAMS

The overall strategy for Phase 2 has been outlined in Section 5.0, and a strategy to develop an Okanagan Water Model (incorporating a database/linking model and scenario driver) for evaluating current and possible future water supply and demand is provided in Sections 6.0 and 7.0. Discussion of a proposed consultation program is outlined in Section 8.0, and a description of the type of conclusions and recommendations that should be provided at the completion of Phase 2 is outlined in Section 9.0.

A recommended work program has been identified in the above-noted sections, which is considered the optimum level of effort required to meet the objectives of Phase 2 and have reasonable confidence in the results. A minimum program has also been identified, which minimally meets Phase 2 objectives with reduced accuracy and precision, but in some areas (e.g., groundwater analysis) the level of confidence is significantly reduced. An enhanced program presents elements that increase confidence or add additional value where it is justified. In order to simplify comparison between the optional work programs, the highlights of each are outlined below.

12.1 RECOMMENDED PROGRAM

The highlights of the recommended program include the following:

Okanagan Water Model

- Developing a robust database, linking model, and scenario driver in a user-friendly format.

Water use analysis

- Obtaining additional information from water utilities to add significantly to the confidence we now have in the water use data;
- Confirming water use data, by focussing efforts on obtained information from the largest 20 utilities; however, some effort to establish reasonable estimates from the remaining smaller utilities would also be made;

- Collecting independent water use information from selected users from various land-use sectors (e.g., golf courses, commercial users, institutions); and
- Collecting detailed up-to-date information from Agriculture Canada, MAFF, and grape growers in support of present and future agricultural water use information.

Surface water supply analysis

- Reviewing and assessing water supply information received late in Phase 1;
- Updating Obedkoff's (1998) regional relations to add confidence to regional estimation procedures needed for the study;
- Improving the calibrations of the UBC watershed model in order to provide a sound basis for evaluating current natural streamflows, and forecasting future conditions;
- Using a revised version of Obedkoff's (1994) mainstem model as an independent check of the Okanagan Water Model parameters;
- Assessing land-use effects (e.g., timber harvesting) on water supply; and
- Using the UBC watershed model to run future land use change scenarios, including fire and beetle kill effects on water yield.

Groundwater analysis

- Developing initial understanding (where none presently exists) of the hydrogeology in the Basin;
- Developing generalized hydrogeologic data sets for individual aquifers and watersheds;
- Developing generalized aquifer maps, lithologies, and parameters for each watershed;
- Developing generalized potentiometric surface maps and maps of generalized groundwater flow for each aquifer or watershed;
- Estimating groundwater production from known sources; and
- Developing refined estimates of groundwater availability and initial rough estimates of sustainable yield.

Consultation Program

- Four (4) technical meetings among the study team are planned;
- Two (2) consultation meetings are planned with stakeholders and First Nations;
- Three (3) additional consultation meetings are planned with a broader audience; and
- An Advisory Panel of experienced local consultants would be established to provide advice and review during the study.

Deliverables

- Phase 1 database updated with information obtained late in Phase 1 and new information obtained in Phase 2;
- Training of LWBC staff in use of the Okanagan Water Model;
- Hardcopy and digital versions (suitable for web publication) of the final Phase 2 report; and
- Executive summary of project.

Bottom Line Results

- Phase 2 objectives achieved with reasonable accuracy and precision, leading to confidence in the results.

12.2 MINIMUM PROGRAM

The minimum program includes the following:

Okanagan Water Model

- Developing a database, linking model and scenario driver. However, only a basic scenario driver would be developed. A user interface suitable for the study team only would be developed and no incorporation of future LWBC or other user-needs beyond Phase 2 would be done; and

- Scenario runs would be limited to a few chosen by study team and LWBC. This would result in a limited sensitivity analysis and limited ability to compare parameters.

Water use analysis

- No additional effort would be made to obtain any new information in any of the areas where information is still deemed to be weak. Reliance would be placed on what has already been assembled in Phase 1.

Surface water supply analysis

- No additional effort would be made to obtain any new information in any of the areas where information is still deemed to be weak. Reliance would be placed on what has already been assembled in Phase 1;
- No effort would be made to update Obedkoff's (1998) regional relations. The existing relations would be used (with less confidence) where regional estimation procedures are required;
- No recalibrating of UBC Watershed Model (even though there are weaknesses in the existing calibration); and
- No effort would be made to revise or use Obedkoff's (1994) mainstem model as an independent check of the Okanagan Water Model parameters.

Groundwater analysis

- Developing basic watershed model input parameters only – groundwater storage, groundwater production, and stream baseflow estimates;
- No aquifer or watershed specific analyses;
- No estimates of sustainable groundwater yield;
- No assessment of potential impacts of increased groundwater demand; and
- Developing only generalized estimates of groundwater availability.

Consultation Program

- Two (2) technical meetings among the study team are planned;
- Two (2) consultation meetings are planned with stakeholders and First Nations; and
- An Advisory Panel of experienced local consultants would not be established.

Deliverables

- Phase 1 database updated with information obtained late in Phase 1, but no new information would be obtained in Phase 2;
- Training of LWBC staff in use of the Okanagan Water Model;
- Hardcopy and digital versions (suitable for web publication) of the final Phase 2 report; and
- Executive summary of project.

Bottom Line Results

- Phase 2 objectives would only minimally be met. The minimum program would result in inaccuracies and larger residual uncertainty in the results, resulting in reduced confidence in results compared with the recommended program.

12.3 ENHANCED PROGRAM

The enhanced program includes the following:

Okanagan Water Model

- Developing a significantly more robust database, linking model, and scenario driver in a user-friendly format that is flexible to accommodate future identified user needs. Considerable additional development and testing would be needed;
- Additional calibration of each component of the water balance model would be completed to add confidence in the calibrations; and

- Additional scenario runs to account for additional possible futures would be conducted (e.g., additional economic forecasts, additional possible demand reduction scenarios).

Water use analysis

- Obtaining additional information from all water utilities that provided information in Phase 1 to add significantly to the confidence we now have in the water use data;
- Confirming water use data, by placing major effort on obtaining and confirming information from all of the utilities (including smaller utilities) identified in Phase 1;
- Collecting independent water use information from a considerable number of selected users from various land-use sectors (e.g., golf courses, commercial users, institutions); and
- Collecting detailed up-to-date information from Agriculture Canada, MAFF, and grape growers in support of present and future agricultural water use information.

Surface water supply analysis

- Reviewing, assessing and incorporating water supply information received late in Phase 1 into the water supply analysis. The principal enhancement over the recommended program will involve additional effort in this task to extract as much relevant information as possible;
- Updating Obedkoff's (1998) regional relations to add confidence to regional estimation procedures needed for the study; and
- Improving the calibrations of the UBC watershed model in order to provide a sound basis for evaluating current natural streamflows, and forecasting future conditions;
- Using a revised version of Obedkoff's (1994) mainstem model as an independent check of the Okanagan Water Model parameters; and

- Using the UBC watershed model to run future land use change scenarios, including fire and beetle kill effects on water yield.

Groundwater analysis

- Includes recommended program plus additional groundwater work to provide more accurate estimates of groundwater production and sustained availability for selected areas;
- Identifying and selecting watersheds and / or aquifers for detailed study;
- Completing detailed hydrogeologic analyses of selected watersheds and aquifers; and
- Developing maps of current groundwater demand for each aquifer or watershed;

Consultation Program

- Four (4) technical meetings among the study team are planned;
- Two (2) consultation meetings are planned with stakeholders and First Nations;
- Six (6) additional consultation meetings are planned with a broader audience; and
- An Advisory Panel of experienced local consultants would be established to provide advice and review during the study.

Deliverables

- Phase 1 database updated with information obtained late in Phase 1, and new information obtained in Phase 2;
- Training of LWBC staff in use of the Okanagan Water Model;
- Hardcopy and digital versions (suitable for web publication) of the final Phase 2 report;
- Executive summary of project; and
- Summary brochure designed for public dissemination.

Bottom Line Results

- Phase 2 objectives would be achieved with high confidence in the results, robust easy to use tools that accommodate future user-needs, and tools to educate the public.

13.0 ESTIMATED COSTS

The estimated costs to complete the recommended, minimum and enhanced work programs of Phase 2 are outlined in Tables 13.2 through 13.4, respectively. The estimates are considered to have a precision of about +/-20%. Each table has a breakdown of the task, level of effort and costs associated with each study team member. Project expenses have been assumed at 10% of total fees, and a 20% contingency has been identified. Table 13.1 summarizes this information, and distributes the costs approximately into fiscal year 2005 and fiscal year 2006.

The estimated cost of the recommended program is $1,096,865 (not including any contingency or GST). The estimated cost of the minimum program is $599,830, and the estimated cost of the enhanced program outlined herein is $1,444,080.

The figures presented in this final Phase 1 report match those presented in the draft report. However, since preparation of the draft Phase 1 report, we have received additional information that could be used to refine these numbers, but because the potential refinements would lie within about 5% of the estimated total, we have chosen not to do this. It is recommended that before Phase 2 begins, a detailed budget discussion takes place with the consultants, with the goal of developing a detailed Phase 2 budget that will form the basis of a contract for Phase 2.

Table 13.1 Summary of estimated costs for the supply/demand analysis

Program	**Item**	**Estimated cost ($)**	**Estimated costs distributed approximately by fiscal year ($)**	
			Fiscal Year 2005	**Fiscal Year 2006**
Recommended	Fees	997,150	648,150	349,000
	Disbursements	99,715	64,815	34,900
	Total	1,096,865	712,960	383,905
	Total, including 20% contingency	1,316,238	855,555	460,683
Minimum	Fees	545,300	354,445	190,855
	Disbursements	54,530	35,445	19,085
	Total	599,830	389,890	209,940
	Total, including 20% contingency	719,796	467,867	251,929
Enhanced	Fees	1,312,800	853,320	459,480
	Disbursements	131,280	85,332	45,948
	Total	1,444,080	938,652	505,428
	Total, including 20% contingency	1,732,896	1,126,382	606,514

Notes:
Disbursements are estimated at 10% of fees
GST is not included

Table 13.2 Summary of estimated costs for the Phase 2 Recommended Program.

			Develop Water Balance Model		Water Use Analysis		Surface Water Analysis		Groundwater Analysis		Future Scenarios		Meetings and Consultation		Reporting		Total	
Labour	unit	cost/unit	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost
Core Group																		
Project Manager & Senior Technical Leader	day	$ 1,100	17	$ 18,700	16	$ 17,600	18	$ 19,800	6	$ 6,600	19	$ 20,900	18	$ 19,800	15	$ 16,500	109	$119,900
Senior Technical Advisors (3)	day	$ 1,100	10	$ 11,000	15	$ 16,500	7	$ 7,700	4	$ 4,400	2	$ 2,200	6	$ 6,600	6	$ 6,600	50	$55,000
Surface Water Supply/Demand Leader	day	$ 800	36	$ 28,800	27	$ 21,600	33	$ 26,400	6	$ 4,800	19	$ 15,200	15	$ 12,000	27	$ 21,600	163	$130,400
Groundwater Supply/Demand Leader	day	$ 900	14	$ 12,600	13	$ 11,700	0	$ -	31	$ 27,900	6	$ 5,400	15	$ 13,500	9	$ 8,100	88	$79,200
Hydrologists	day	$ 600	20	$ 12,000	66	$ 39,600	113	$ 67,800	0	$ -	61	$ 36,600	0	$ -	40	$ 24,000	300	$180,000
Groundwater hydrologists	day	$ 600	25	$ 15,000	0	$ -	0	$ -	48	$ 28,800	0	$ -	0	$ -	23	$ 13,800	96	$57,600
Technical Architech	day	$ 800	34	$ 27,200	0	$ -	0	$ -	0	$ -	2	$ 1,600	6	$ 4,800	5	$ 4,000	47	$37,600
Computer programmer	day	$ 500	83	$ 41,500	0	$ -	0	$ -	0	$ -	5	$ 2,500	0	$ -	8	$ 4,000	96	$48,000
Technical support	day	$ 500	19	$ 9,500	18	$ 9,000	12	$ 6,000	20	$ 10,000	14	$ 7,000	9	$ 4,500	34	$ 17,000	126	$63,000
Mapping	day	$ 600	10	$ 6,000	25	$ 15,000	12	$ 7,200	11	$ 6,600	10	$ 6,000	9	$ 5,400	22	$ 13,200	99	$59,400
Specialty Role Players																		
Consultation facilitator	day	$ 750	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	18	$ 13,500	2	$ 1,500	20	$15,000
Consultation assistant	day	$ 500	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	9	$ 4,500	2	$ 1,000	11	$5,500
Economist	day	$ 1,000	0	$ -	0	$ -	0	$ -	0	$ -	5	$ 5,000	1	$ 1,000	1	$ 1,000	7	$7,000
Senior Water Supply Engineers (4)	day	$ 1,100	0	$ -	15	$ 16,500	0	$ -	0	$ -	2	$ 2,200	0	$ -	4	$ 4,400	21	$23,100
Junior water supply engineers (4)	day	$ 600	0	$ -	50	$ 30,000	0	$ -	0	$ -	0	$ -	0	$ -	10	$ 6,000	60	$36,000
Ag Canada leader	day	$ 750	0	$ -	15	$ 11,250	0	$ -	0	$ -	0	$ -	0	$ -	2	$ 1,500	17	$12,750
Ag Canada staff	day	$ 400	0	$ -	30	$ 12,000	0	$ -	0	$ -	0	$ -	0	$ -	5	$ 2,000	35	$14,000
UBC Watershed model leader	day	$ 750	0	$ -	0	$ -	12	$ 9,000	0	$ -	0	$ -	0	$ -	0	$ -	12	$9,000
UBC Watershed model staff	day	$ 400	0	$ -	0	$ -	45	$ 18,000	0	$ -	0	$ -	0	$ -	0	$ -	45	$18,000
Planner	day	$ 800	0	$ -	10	$ 8,000	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	10	$8,000
Advisors																		
Project Advisors (4)	day	$ 1,100	3	$ 3,300	2	$ 2,200	5	$ 5,500	1	$ 1,100	2	$ 2,200	0	$ -	4	$ 4,400	17	$18,700
Total labour			**271**	**$ 185,600**	**302**	**$ 210,950**	**257**	**$ 167,400**	**127**	**$ 90,200**	**147**	**$ 106,800**	**106**	**$ 85,600**	**219**	**$ 150,600**		**$ 997,150**
Sub-total				**$185,600**		**$210,950**		**$167,400**		**$90,200**		**$106,800**		**$85,600**		**$150,600**		**$997,150**
Disbursements (10% of total labour)																		**$99,715**
Sub-total																		**$1,096,865**
Contingency (20%)																		**$219,373**
GRAND TOTAL																		**$1,316,238**

Table 13.3 Summary of estimated costs for the Phase 2 Minimum Program.

			Develop Water Balance Model		Water Use Analysis		Surface Water Analysis		Groundwater Analysis		Future Scenarios		Meetings and Consultation		Reporting		Total	
Labour	unit	cost/unit	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost
Core Group																		
Project Manager & Senior Technical Leader	day	$ 1,100	13	$ 14,300	14	$ 15,400	15	$ 16,500	3	$ 3,300	14	$ 15,400	8	$ 8,800	12	$ 13,200	79	$86,900
Senior Technical Advisors (3)	day	$ 1,100	10	$ 11,000	10	$ 11,000	6	$ 6,600	1	$ 1,100	2	$ 2,200	4	$ 4,400	4	$ 4,400	37	$40,700
Surface Water Supply/Demand Leader	day	$ 800	36	$ 28,800	20	$ 16,000	21	$ 16,800	0	$ -	17	$ 13,600	8	$ 6,400	16	$ 12,800	118	$94,400
Groundwater Supply/Demand Leader	day	$ 900	4	$ 3,600	3	$ 2,700	0	$ -	15	$ 13,500	6	$ 5,400	8	$ 7,200	8	$ 7,200	44	$39,600
Hydrologists	day	$ 600	23	$ 13,800	53	$ 31,800	52	$ 31,200	0	$ -	43	$ 25,800	0	$ -	21	$ 12,600	192	$115,200
Groundwater hydrologists	day	$ 600	0	$ -	0	$ -	0	$ -	21	$ 12,600	0	$ -	0	$ -	2	$ 1,200	23	$13,800
Technical Architech	day	$ 800	13	$ 10,400	0	$ -	0	$ -	0	$ -	2	$ 1,600	4	$ 3,200	11	$ 8,800	30	$24,000
Computer programmer	day	$ 500	40	$ 20,000	0	$ -	0	$ -	0	$ -	4	$ 2,000	0	$ -	18	$ 9,000	62	$31,000
Technical support	day	$ 500	11	$ 5,500	8	$ 4,000	7	$ 3,500	3	$ 1,500	13	$ 6,500	4	$ 2,000	23	$ 11,500	69	$34,500
Mapping	day	$ 600	8	$ 4,800	24	$ 14,400	10	$ 6,000	8	$ 4,800	8	$ 4,800	4	$ 2,400	15	$ 9,000	77	$46,200
Specialty Role Players																		
Consultation facilitator	day	$ 750	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	8	$ 6,000	0	$ -	8	$6,000
Consultation assistant	day	$ 500	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	4	$ 2,000	0	$ -	4	$2,000
Economist	day	$ 1,000	0	$ -	0	$ -	0	$ -	0	$ -	5	$ 5,000	1	$ 1,000	1	$ 1,000	7	$7,000
Senior Water Supply Engineers (4)	day	$ 1,100	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$0
Junior water supply engineers (4)	day	$ 600	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$0
Ag Canada leader	day	$ 750	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$0
Ag Canada staff	day	$ 400	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$0
UBC Watershed model leader	day	$ 750	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -		$ -	0	$ -	0	$0
UBC Watershed model staff	day	$ 400	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -		$ -	0	$ -	0	$0
Planner	day	$ 800	0	$ -	5	$ 4,000	0	$ -	0	$ -	0	$ -		$ -	0	$ -	5	$4,000
Advisors																		
Project Advisors (4)	day	$ 1,100	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$0
Total labour			**158**	**$ 112,200**	**137**	**$ 99,300**	**111**	**$ 80,600**	**51**	**$ 36,800**	**114**	**$ 82,300**	**53**	**$ 43,400**	**131**	**$ 90,700**		**$ 545,300**
Sub-total				**$112,200**		**$99,300**		**$80,600**		**$36,800**		**$82,300**		**$43,400**		**$90,700**		**$545,300**
Disbursements (10% of total labour)																		**$54,530**
Sub-total																		**$599,830**
Contingency (20%)																		**$119,966**
GRAND TOTAL																		**$719,796**

Table 13.4 Summary of estimated costs for the Phase 2 Enhanced Program.

			Develop Water Balance Model		Water Use Analysis		Surface Water Analysis		Groundwater Analysis		Future Scenarios		Meetings and Consultation		Reporting		Total	
Labour	unit	cost/unit	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost	units	cost
Core Group																		
Project Manager & Senior Technical Leader	day	$ 1,100	22	$ 24,200	18	$ 19,800	20	$ 22,000	12	$ 13,200	21	$ 23,100	25	$ 34,100	19	$ 20,900	137	$157,300
Senior Technical Advisors (3)	day	$ 1,100	35	$ 38,500	15	$ 16,500	7	$ 7,700	11	$ 12,100	2	$ 2,200	6	$ 6,600	17	$ 18,700	93	$102,300
Surface Water Supply/Demand Leader	day	$ 800	40	$ 32,000	29	$ 23,200	39	$ 31,200	10	$ 8,000	19	$ 15,200	18	$ 16,800	31	$ 24,800	186	$151,200
Groundwater Supply/Demand Leader	day	$ 900	25	$ 22,500	9	$ 8,100	0	$ -	34	$ 30,600	6	$ 5,400	18	$ 18,900	11	$ 9,900	103	$95,400
Hydrologists	day	$ 600	20	$ 12,000	82	$ 49,200	125	$ 75,000	0	$ -	61	$ 36,600	0	$ -	56	$ 33,600	344	$206,400
Groundwater hydrologists	day	$ 600	38	$ 22,800	10	$ 6,000	0	$ -	99	$ 59,400	0	$ -	0	$ -	25	$ 15,000	172	$103,200
Technical Architech	day	$ 800	38	$ 30,400	0	$ -	0	$ -	0	$ -	4	$ 3,200	6	$ 4,800	5	$ 4,000	53	$42,400
Computer programmer	day	$ 500	124	$ 62,000	0	$ -	0	$ -	0	$ -	10	$ 5,000	0	$ -	10	$ 5,000	144	$72,000
Technical support	day	$ 500	21	$ 10,500	18	$ 9,000	14	$ 7,000	24	$ 12,000	26	$ 13,000	12	$ 6,000	42	$ 21,000	157	$78,500
Mapping	day	$ 600	14	$ 8,400	32	$ 19,200	12	$ 7,200	20	$ 12,000	10	$ 6,000	12	$ 7,200	29	$ 17,400	129	$77,400
Specialty Role Players																		
Consultation facilitator	day	$ 750	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	24	$ 22,500	7	$ 5,250	31	$27,750
Consultation assistant	day	$ 500	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	12	$ 6,000	6	$ 3,000	18	$9,000
Economist	day	$ 1,000	0	$ -	0	$ -	0	$ -	0	$ -	5	$ 5,000	1	$ 1,000	1	$ 1,000	7	$7,000
Senior Water Supply Engineers (4)	day	$ 1,100	0	$ -	23	$ 25,300	0	$ -	0	$ -	2	$ 2,200	0	$ -	4	$ 4,400	29	$31,900
Junior water supply engineers (4)	day	$ 600	0	$ -	90	$ 54,000	0	$ -	0	$ -	0	$ -	0	$ -	10	$ 6,000	100	$60,000
Ag Canada leader	day	$ 750	0	$ -	15	$ 11,250	0	$ -	0	$ -	0	$ -	0	$ -	2	$ 1,500	17	$12,750
Ag Canada staff	day	$ 400	0	$ -	30	$ 12,000	0	$ -	0	$ -	0	$ -	0	$ -	5	$ 2,000	35	$14,000
UBC Watershed model leader	day	$ 750		$ -	0	$ -	12	$ 9,000	0	$ -	0	$ -	0	$ -	0	$ -	12	$9,000
UBC Watershed model staff	day	$ 400		$ -	0	$ -	45	$ 18,000	0	$ -	0	$ -	0	$ -	0	$ -	45	$18,000
Planner	day	$ 800			15	$ 12,000	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	15	$12,000
Advisors																		
Project Advisors (4)	day	$ 1,100	4	$ 4,400	2	$ 2,200	5	$ 5,500	2	$ 2,200	2	$ 2,200	0	$ -	8	$ 8,800	23	$25,300
Total labour			**381**	**$ 267,700**	**388**	**$ 267,750**	**279**	**$ 182,600**	**212**	**$ 149,500**	**168**	**$ 119,100**	**134**	**$ 123,900**	**288**	**$ 202,250**		**$ 1,312,800**
Sub-total				**$267,700**		**$267,750**		**$182,600**		**$149,500**		**$119,100**		**$123,900**		**$202,250**		**$1,312,800**
Disbursements (10% of total labour)																		**$131,280**
Sub-total																		**$1,444,080**
Contingency (20%)																		**$288,816**
GRAND TOTAL																		**$1,732,896**

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Appendix B

STAKEHOLDER WORKSHOP RESULTS

WORKSHOP DOCUMENTATION
OKANAGAN BASIN WATER SUPPLY AND DEMAND STUDY

On March 8th, 2005, more than 30 water professionals and elected officials met in Kelowna to provide input to the Okanagan Basin Water Supply and Demand Study. Participants were grouped according to expertise, with each of the four groups completing two worksheets: one focused on Phase 1 (information identification and review, gap analysis, and the supply and demand analysis study design), the other on Phase 2 (the supply and demand analysis).

The technical and temporal/boundaries of the study set the scope and supply/demand analysis to be conducted in Phase 2:

Present	Future
Surface water supply	Surface water supply
Surface water demand/use	Surface water demand/use
Groundwater supply	Groundwater supply
Groundwater demand/use	Groundwater demand/use

Prioritized findings and recommendations are as follows:

Worksheet #1

Question #1: With reference to the above table, is there other information relevant to Phase 2 that we have not identified?

Group 1	• FN current and future water needs (future development plans, e.g. golf courses, vineyards) • Current land-use status (e.g. ALR, Class 9) • Irrigation groundwater use (and surface H20) • Effects of land use change and timing on surface and groundwater quantities • Account for licence use • Instream flow needs • Drought management plans • How to account for present and future demand • Smaller irrigation districts' current use and demand • Sewage return flows (efficiency in use) • Irrigation return flows (efficiency in use)
Group 2	• Emphasize obtaining demand and supply data that presently exists (more effort into collecting existing data) • More accurately define evapotranspiration losses • Groundwater/surface water interactions poorly defined • Capture reservoir management data
Group 3	• Amount of data collected on land use changes (e.g. agricultural land use decreasing in some areas)

	• OCPs…do we have them all? Are they current? Some areas don't have OCPs • Grape growers have detailed maps of grapes grown • Water districts—assessments for Grade "A", Grade "C" etc. (Lands allowed rights vs. if they're using them) • Basin wide—Agricultural use on a parcel-by-parcel basis (e.g. crop type, soil type, irrigation application method) • ALR land currently irrigated—future potential with climate change? (MAFF agricultural profiles) • Agricultural profiles for communities (e.g. do they have all the census data? • Federal issues, are all users interests included (e.g. First Nations)
Group 4	• First Nations rights/concerns • Difference between supply allocated and supply now used (large percentage not yet used) • Water use information from smaller, loosely management utilities (need information from the rest of the 52 purveyors) • Agricultural lands (in ALR) no yet irrigated. Check using tax records (class 9) for parcel information • Water loss in systems • Reclaimed water use • Define areas for future residential or agricultural use and develop a theoretical model that would apply across the basin • More groundwater information

Question #2: Are there any significant data gaps that we have not already identified?

Group 2	• Groundwater/surface water interactions • Lack of available evaporation data • First Nations water rights and title • Reservoir operation for instream flow vs. water supply • Recycled water use • Improved water conservation influences on demand and supply
Group 3	• Gap…understanding of what is licensed vs. what is actually utilized • On many sources…return flow (e.g. stream recharge going back to creeks) • Groundwater data gap…reserves present to buffer surface low flows • How significant is groundwater contribution or potential groundwater contribution • Fish flow requirements…detailed requirements on stream-by-stream basis to maintain fish flow • Other hydrometric data…sites that are not part of the usual network of data • Licensing differential between tributaries (e.g. some fully licensed,

	some have spare capacity [in isolation]) • How does demand in one are affect supply in other areas downstream • Leakage in distribution systems • Reclaimed water use…current vs. potential
Group 4	• Groundwater interaction five or ten years after well is built • Fish flow data…NW Hydraulics data • Basin meteorology in upper elevations is lacking • Existing irrigation practices correlated to soil conditions and what crop demands are • Get outstanding water purveyor information • Significant gaps re: supply…Have all drainage basins been assessed for hydrology and maximum storage? • First Nation water records and potential treaty obligations • Search historical water records/archives

Question #3: Have we underrated some sources of information and overrated others in terms of potential usefulness to Phase 2?

Group 3	• Census data…tie interrelation to water use • Water licenses typically don't match up well (not accurate) • Ratings…dependant on accuracy of data…must look beyond data and where it comes from • Population growth projections should be tied back to lifestyles • Densification vs. urban sprawl…could be even more significant with global warming • Lake evaporation losses
Group 4	• Overrated: Ag Canada's demand findings…it is not sufficiently detailed and is based on a lot of assumptions • Overrated: detailed water demand information • Underrated: water supply information • Underrated: fish flow data

Worksheet #2

Question #1: Considering your own interests and needs related to water supply and demand information, is the Phase 2 scope as outlined herein appropriate? If not, what additions to or deletions from the proposed scope would you suggest?

Group 1	• Need to get information tool to decision makers (Phase 3)
Group 2	• Fisheries Act requires flows for fish
Group 3	• Modelling tool needs LWBC allocation, but also useful for others…links to federal National Land and Water Inventory…need a model that is sustainable, not a one-time output

	• Capture existing and future initiatives that can feed data into the model and fill in gaps…have components that can be plugged in, not a model that needs those beforehand
Group 4	• Difficult to isolate quantity from quality • Aquatic ecosystem information shouldn't be ignored…need in-stream flow requirements (regulatory) and naturalized flow (decision making) • Daily models, rather than monthly, may be required to estimate peak demands

Question#2: Does the general approach to the Phase 2 water supply and demand analysis, as presented, make sense? If not, what alternative approach(es) should be considered?

Group 1	• Pre-set scenarios may not be best approach…could this be area-specific…let users define scenarios
Group 2	• Groundwater recharge to mainstream, how much? • Groundwater discharge areas in tributaries • Consider sub-basin approach to extrapolation • Ensure points select4ed are appropriate to LWBC decision requirements
Group 3	• Define maximum sustainable withdrawals…need consensus on sustainability • Lacking fisheries expertise on working group • Needs greater First Nations participation on working group • Local government planning expertise on working group • Lacking instream flow requirements in the water balance model equation • Need water resources legal expert, not just water law
Group 4	• One addition…include T° for low flow biology and water chemistry • Extreme events… 1 in 50 year etc. may change with climate change influence

Question #3: Are the proposed Phase 2 objectives achievable? If not, which specific objectives are not achievable, and why not? What alternative and/or additional objective(s) would be more appropriate?

Group 1	• Groundwater requirements need extended time frame and/or more resources • Alternative tools are needed to communicate the science to the public and decision makers
Group 2	• Recommending an approach for future allocation decisions will be difficult (Phase 3?)
Group 3	• Sensitivity analysis…if we make certain assumptions, then how accurate are the results? How do we decide on which assumptions? Which have the greatest impact on outcomes?
Group 4	• Is definitive allocation achievable? May only be able to determine

	recommendations • Need to provide clear information to stakeholders about benefits associated with water conservation

Question #4: Does Phase 2 have the appropriate level of effort given the defined scope and objectives? If not, where should additional/less effort by applied and why?

Group 1	• Alternate funding sources will be required • Legal constraints shouldn't affect implementation of project
Group 2	• More involvement with user groups to ease transition to Phase 3
Group 3	• Low level of effort on economic side…greater focus on completing technical study
Group 4	• Geographical scope needs to be expanded to include Kalamalka and Wood Lakes • McDougall, Inkameep, Naswhito Creeks will also be important for future allocations

Questions #5: The proposed Phase 2 methodology includes technical and consultation components. Is the proposed methodology reasonable? If not, how would you improve it?

Group 1	• Consultation should occur earlier in project
Group 2	• Consultation with key stakeholders for water management prior to finalizing Phase 2 • Legal consultation requirements with First Nations
Group 3	• Consultation with agriculture sector might help capture water use info which might be helpful early in Phase 2 • Consultation with local governments, First Nations, industry, etc. may be useful at scenario stage • Educational component even more important…need representative e presenting at Water Supply Association of B.C. and other association meetings (e.g. First Nations ONA) • For broader communications strategy plug into waterbucket.ca and other relevant websites
Group 4	• Need to take into account existing laws/regulations • Notably, *Fisheries Act* is not considered

Question #6: In what formats should the final report be available?

Group 1	• Paper report • CD • Website • Digital mapping products • Decision-making tools for local governments to use

	• Executive Summary • Questions (scenarios) and decisions (results)
Group 3	• Paper report, CD, website • Final report should be linked on water portal (e.g. waterbucket.ca) • Local libraries should receive copies
Group 4	• Technical report (paper, digital, CD, website) • Summaries of technical info/findings for specific audiences (e.g. Executive Summary for policy makers)

Question #7: Other than a report, are there other products related too an updated supply and demand analysis that would be useful to you?

Group 3	• Evaluation indicator • Public reporting of the results • Generic modeling tool • Database needs to be compatible with DWIMP database • Next steps and recommendations separated from the final report, possibly communicated on websites • Visual graphic of supply and demand over time for educational tools
Group 4	• Central repository for information (e.g. UBCO) • Provide standard reporting formats for water supply/demand information from purveyors

Question #8: What barriers could prevent the Phase 2 report from getting the exposure it deserves? How could these barriers be removed?

Group 1	• Consultation if not done at an early states could impact results • General public and decision makers' lack of understanding • Present to OMMA • Present to First Nations Tribal Council
Group 3	• Needs a hook to grab media • Needs a hook to grab decision-makers' attention (the tool and graphic indicator may be the hook) • Clear plan for how results will be used • Communications needed with each of the regional districts and municipalities • If Phase 2 consultations are not done properly, this will be a barrier
Group 4	• Credibility gap may occur because not all interests, stakeholders, regulatory agencies represented • Phase 2 Steering Committee composition

Additional Comments:

Group 1	• Crop trade off and impacts on water-use supply variability • Base flow (instream flows) need to be identified • First Nation interests must be incorporated
Group 2	• STELLA decision support tool should be evaluated (S. Cohen) Stacy Langsdale

Appendix C

SUMMARY OF ANNUAL LICENSED QUANTITIES IN THE OKANAGAN BY SOURCE AND PURPOSE

ANNUAL SUMMARY BY LICENCE PURPOSE All values in cubic metres		MAIN VALLEY LAKES AND OKANAGAN RIVER:					MAJOR TRIBUTARIES:																		RESDUAL AREA:
	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	All Okanagan Basin (in B.C.)	Okanagan Lake	Skaha Lake	Vaseux Lake	Osoyoos Lake	Okanagan River	Vernon Creek	Deep Creek	Equesis Creek	Whiteman Creek	Shorts Creek	Lambly Creek	Kelowna Creek	Mission Creek	Bellevue Creek	Powers Creek	Trepanier Creek	Peachland Creek	Trout Creek	Penticton Creek	Ellis Creek	Shingle Creek	Shuttleworth Creek	Vaseux Creek	Sum of all residual areas
Waterworks Local Authority	135,050,677	73,327,765	1,507,465	0	497,787	414,823	21,297,143	147,677	0	0	746,681	6,928,231	518,528	6,835,297	0	2,434,260	1,733,490	4,729,596	1,391,418	6,670,346	5,727,039	0	0	0	143,131
Waterworks (Other than a local authority)	28,427,416	28,053,246	8,296	0	0	0	349,281	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16,593
Domestic	1,460,226	673,080	62,223	4,978	17,427	5,808	150,465	16,095	14,104	10,785	6,637	7,467	16,593	69,690	906	4,148	57,246	5,808	20,160	1,659	830	77,987	830	4,978	230,324
Incidental - Domestic	21,571	0	0	0	0	0	21,571	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Processing	649,612	597,344	0	0	33,186	0	18,252	0	0	0	0	0	0	0	0	0	830	0	0	0	0	0	0	0	0
Cooling	20,455,727	20,447,431	0	0	0	0	0	0	0	0	0	8,296	0	0	0	0	0	0	0	0	0	0	0	0	0
Enterprise	899,557	651,760	15,282	0	79,646	4,978	146,231	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,659
Ponds	9,868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,868
Watering	2,667,346	1,103,751	0	1,480	233,129	0	85,419	284,763	0	0	424,320	0	4,317	87,084	0	0	826	0	0	44,406	0	0	0	0	397,850
Camps	14,934	1,659	0	0	0	0	8,296	0	0	0	0	0	0	0	0	0	4,978	0	0	0	0	0	0	0	0
Dust control	17,886	12,335	0	0	0	0	0	0	0	0	0	5,551	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire protection	214,321	214,321	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frost Protection	55,088	0	0	0	27,754	3,700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23,634
Institutions	830	830	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Public Facilities	4,564	2,075	0	0	0	0	0	0	0	0	0	0	0	2,489	0	0	0	0	0	0	0	0	0	0	0
Stockwatering	141,869	1,659	0	0	0	2,489	44,801	3,650	3,319	0	1,659	1,659	16,593	830	0	0	1,244	498	23,230	3,319	3,319	10,785	0	830	21,986
Swimming Pool	8,296	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,296
Water Delivery	28,208	28,208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish Hatchery	17,860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17,860	0	0	0	0	0	0
Amusement Park	29,867	0	0	0	29,867	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential Lawn / Garden Watering	83,199	42,099	0	555	23,991	0	1,998	0	0	0	0	0	0	4,934	0	0	0	0	0	0	0	0	0	0	9,621
Irrigation Local Authority	235,323,157	6,590,926	2,466,978	390,399	74,420,092	4,210,515	18,487,410	169,728	0	0	0	7,807,985	13,688,027	56,529,814	0	6,679,306	1,613,145	3,014,647	18,863,747	5,415,017	2,559,490	0	0	0	12,415,930
Irrigation	82,349,607	7,726,347	1,619,608	0	9,702,834	14,389,636	6,821,984	2,711,172	4,149,457	801,151	363,201	221,411	2,370,920	3,510,226	1,233	274,057	637,553	348,461	552,270	159,650	0	5,690,516	822,157	1,043,643	18,432,119
Land Improvement	315,992,956	1,363,597	0	0	0	0	5,358,029	31,261,339	0	0	308,372	0	7,401	2,870,206	893,005	0	0	0	0	0	0	0	0	0	273,931,007
Power - Residential	6,251,034	0	0	0	0	0	0	0	6,251,034	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power - Commercial	8,930,049	0	0	0	0	0	0	0	8,930,049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Storage (non-power)	164,336,444	0	0	0	0	0	36,072,152	814,411	2,645,834	0	740,093	17,447,702	9,982,626	39,784,954	1,345	5,956,210	762,370	9,164,823	17,108,492	14,192,524	1,440,715	2,770,823	774,631	98,679	4,578,057
Conservation - Stored Water	3,174,816	0	0	0	0	160,354	2,793,853	0	0	0	0	0	0	308	123,349	0	0	0	0	0	0	0	0	0	96,952
Conservation - Use of Water	21,401,156	0	0	0	0	0	0	0	49,115	0	0	0	8,763,754	1,467,929	895,452	2,679,015	0	3,080,867	0	0	0	0	0	0	4,465,025
Conservation - Construct Works	13,372,807	0	0	0	0	724,037	4,584,335	0	0	0	9,956	0	0	910,440	0	0	0	7,144,039	0	0	0	0	0	0	0
ANNUAL SUMMARY BY CATEGORY	All Okanagan Basin (in B.C.)	Okanagan Lake	Skaha Lake	Vaseux Lake	Osoyoos Lake	Okanagan River	Vernon Creek	Deep Creek	Equesis Creek	Whiteman Creek	Shorts Creek	Lambly Creek	Kelowna Creek	Mission Creek	Bellevue Creek	Powers Creek	Trepanier Creek	Peachland Creek	Trout Creek	Penticton Creek	Ellis Creek	Shingle Creek	Shuttleworth Creek	Vaseux Creek	Sum of all residual areas
Offstream use (not returned at point-of-diversion)	752,670,687	119,027,406	5,679,853	397,412	85,065,713	19,031,948	47,432,851	3,333,086	4,166,880	811,936	1,542,498	14,972,305	281,837,437	67,040,365	2,139	9,391,771	4,049,312	8,099,009	20,850,825	12,294,396	8,290,677	5,779,288	822,987	1,049,450	31,701,142
Offstream use (returned at point-of-diversion)	351,657,495	21,811,027	0	0	0	0	5,358,029	31,261,339	15,181,084	0	308,372	8,296	7,401	2,870,206	893,005	0	0	0	17,860	0	0	0	0	0	273,940,875
Conservation	34,773,964	0	0	0	0	724,037	4,584,335	0	49,115	0	9,956	0	8,763,754	2,378,369	895,452	2,679,015	0	10,224,906	0	0	0	0	0	0	4,465,025
Storage (non-power & conservation)	167,511,260	0	0	0	0	160,354	38,866,005	814,411	2,645,834	0	740,093	17,447,702	9,982,626	39,785,263	124,693	5,956,210	762,370	9,164,823	17,108,492	14,192,524	1,440,715	2,770,823	774,631	98,679	4,675,010