7.0 GROUNDWATER RESOURCES

Introduction

Three groundwater study objectives were met during Phase 2 - they are listed below along with the primary deliverables:

Groundwater Study Objectives	Main Deliverable(s) and Authors
1. To develop a comprehensive State-of-the-Basin report to synthesize the current state of knowledge of groundwater in the Okanagan Basin and document sources of information on groundwater.	*Groundwater and Hydrogeological Conditions in the Okanagan Basin of British Columbia – a State-of-the-Basin report.* **Appendix D**
2. To develop as thorough a series of conceptual models of the groundwater systems throughout the Okanagan Basin as is possible with existing information.	*Groundwater Study Objectives 2 and 3: Phase 2 Okanagan Water Supply and Demand Project – Final Report* **Appendix E**
3. To represent Okanagan groundwater systems in the format required by a water balance model of the basin.	Completed 1996-2006 monthly water balances for 79 unconsolidated aquifers. **Appendix K**

This summary focusses on the conceptual groundwater flow model developed in Appendix E. That model was based primarily on the information identified in Appendix D.

The methodology developed for the water balance modelling used a spreadsheet tool custom-designed for this Project (Groundwater Balance Analysis Tool - GWBAT). The water balance (GWBAT) model is based on upland areas recharging valley-bottom aquifers. The concept underlying the model is that a significant portion of the recharge in the upland areas of the Basin reports to a shallow bedrock flow system and that this flow, along with infiltration of some streamflow along the edges of the Okanagan Valley is conveyed to the Valley bottom unconsolidated aquifers.

Two upland groundwater flow systems exist within the conceptual model: i) a shallow upland flow system consisting of relatively thin and localized surface deposits overlying weathered upper bedrock formations; and ii) flow through deeper-seated bedrock fractures. The model assumes that upland recharge mainly supplies the shallow upland aquifer zone, not the deeper zone. Groundwater within this system stays within the boundaries of the overlying surface catchment area, and is recharged, stored and discharged to lower-lying unconsolidated aquifers and streams on a timeframe of years to decades. The model assumes that groundwater flow patterns are determined by local surface topography.

Upland recharge to fracture-flow systems in deep-seated bedrock is thought to be small as a percentage of total groundwater recharge, but occurs across a broad area and over a very long timeframe (hundreds to thousands of years). The deep-seated system may hold large amounts of water in storage, but due to the physical constraints of deep-seated fracture flow much of this water remains in storage and moves through the system on a timeframe that far exceeds the weekly/monthly time steps of the water balance analysis. It is possible that higher-permeability geological structures such as faults and fracture zones may exist in the deep-seated bedrock flow system, but the basin-wide scale of this study does not provide sufficient resolution to identify and quantify such features.

Recharge from bedrock to the lower-lying unconsolidated aquifers is assumed to be constant, whereas recharge from stream losses to unconsolidated aquifers is seasonally variable and proportional to surface water runoff, with the majority occurring immediately following snowmelt-generated peak streamflows in spring. In general, annual water level fluctuations in representative observation wells in valley-bottom unconsolidated aquifers are relatively small, ranging from less than 1 m to about 2 m. Larger water level fluctuations may be observed near pumping wells and in upland areas.

A total of 79 distinct unconsolidated aquifers were identified (Attachment 2), located primarily in the valley bottom. Characteristics of these aquifers are described in Section 5.0 and Appendix III of the main groundwater report (Appendix E).

Three areas of the Basin contain connected aquifer systems of regional importance (Section 7.3 of Appendix E):

- North Okanagan: Coldstream-Vernon and Spallumcheen unconsolidated aquifers;
- Central Okanagan: Greater Kelowna aquifers; and
- South Okanagan: Vaseux Lake to Osoyoos Lake aquifers.

Detailed analysis was applied to each aquifer, and the resulting models are applicable to a Basin-scale estimation of groundwater balance. Different results can be expected from other studies conducted at the local, sub-basin or catchment scale. The information from the Phase 2 work provides a useful starting point for gathering the quantitative groundwater and hydrologic/hydrogeologic information that would be needed for a local-scale study.

Monthly water balances were computed for the 79 unconsolidated aquifers delineated in this study. The spreadsheet-based water balance tool (GWBAT) allows for the determination of water balances for individual aquifers based on an approximate analytical solution, rather than a complex numerical solution. The tool used data from several sources that form part of the Phase 2 work, including gridded climate data, regional surface water runoff data, calculated bedrock recharge values, predicted groundwater use, and predicted irrigation return flow. In addition, the groundwater study team developed estimates of stream loss, recharge, physical aquifer properties, and water table evaporation for selected aquifers.

The estimated mean annual flow (total discharge to the valley-bottom rivers/lakes) in all 79 unconsolidated aquifers for the 11-year period 1996-2006 is 943,000 ML/yr. The year 2003 had the lowest annual flow (928,000 ML), while the highest annual flow was 956,000 ML in 1997 and 2000. The difference between the largest and smallest estimated annual flow is only 28,000 ML.

The mean annual groundwater discharge into Okanagan Lake is estimated to be 296,000 ML (40 percent of mean annual (total) inflow to the Lake, as reported in the Surface Water Hydrology report (Appendix G)), with Aquifer 234 (Summerland) contributing approximately 25 percent of this amount. Based on the water balance results, it can be inferred that 92 percent of the mean annual groundwater flow to the Lake occurs through the unconsolidated systems (many of which receive recharge from the shallow bedrock flow system), with many of these systems surrounded by large catchments. By comparison, the 11-year mean annual groundwater discharge to Okanagan Lake, calculated in Appendix G is only 41,300 ML. This is only 5.7 percent of the mean annual lake inflow (compared with 40% as calculated in the groundwater study). That these two independent methods give such different results is a reflection of the quantity and quality of the available groundwater data; and different approaches to accounting for groundwater-surface water interaction (e.g. aquifers can contribute baseflow to streams and streams can act as sources of recharge to groundwater – different accounting methods will account for these source/sink terms differently and could result in some of the groundwater being accounted for as surface water and vice versa). The actual volume of groundwater discharge reporting to Okanagan Lake, on a long-term annual basis likely lies between the two estimates and should be refined on a smaller scale (i.e. within specific sub-basins) once better groundwater data, streamflow data and baseflow separation analysis are available to support more detailed groundwater-surface water accounting.

Figure 7.1 provides a summary assessment of groundwater aquifer recharge in the Okanagan Basin. It should be emphasized that the red areas (areas of minimal recharge) may contain significant volumes of groundwater stored in bedrock aquifers. However, natural recharge to such aquifers appears to be very low, and more detailed study is warranted in these areas before significant groundwater development occurs. Most of the bedrock aquifers surrounding the mainstem lakes are denoted red on Figure 7.1 and are recharge-limited. Further development of groundwater resources in these recharge limited areas may not prove sustainable.

Recommended investigations to improve understanding of groundwater resources (Section 9, Appendix E) include:

- Surface water-groundwater interaction assessments - collecting and mapping streamflow data in creeks crossing alluvial fans and monitoring water levels in aquifers near the creeks to identify and quantify areas where streams may be losing or gaining with respect to groundwater;
- Adding more provincial groundwater observation wells in aquifers currently not monitored;
- Conducting studies to confirm the conceptual model of groundwater flow in bedrock areas; and
- Refining evapotranspiration values as this affects upland aquifer recharge, which has a large influence on Valley-bottom groundwater balances.

Ultimately, (as more data become available) it may be possible to use more sophisticated modelling approaches than those used in this basin-scale analysis to develop or refine aquifer water balance estimates.

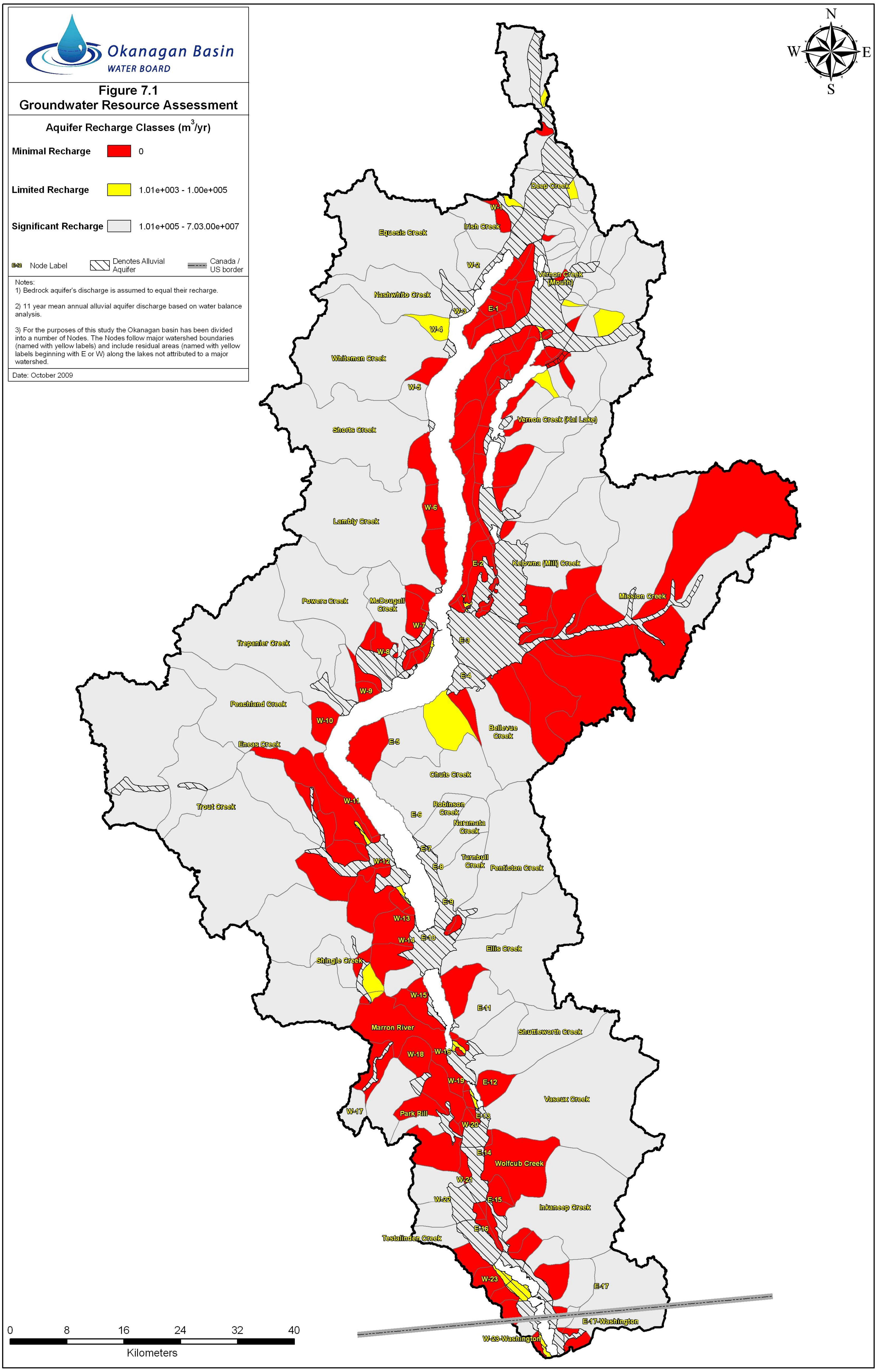

Figure 7.1 Groundwater resource assessment.