Study 7 (Part 1): Demonstration of Factors that Govern Osoyoos Lake Levels During High Water Periods

SUMMIT
ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

International Joint Commission

March 2010

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Mr. Tom McAuley
International Joint Commission
234 Laurier Avenue West, 22nd Floor
Ottawa, Ontario, K1B 6K6

Via email: McAuley@ottawa.ijc.org

Re: STUDY 7 (PART 1): DEMONSTRATION OF FACTORS THAT GOVERN OSOYOOS LAKE LEVELS DURING HIGH WATER PERIODS – FINAL REPORT

Dear Mr. McAuley:

Summit Environmental Consultants Inc. (Summit) is pleased to provide a final report summarizing our assessment of the factors responsible for high water levels on Osoyoos Lake and the ability of Zozel Dam to mitigate high water levels on the lake. The report concludes that Zozel Dam cannot be operated to achieve a reduction in the high lake levels reached when Okanagan River inflow is high and the Similkameen River provides backwater. However, there is some potential to delay the onset of high water conditions for a few days, thereby reducing the period of time during which the lake is above 912.5 feet elevation.

If you have any further questions please call or email.

Yours truly,

Summit Environmental Consultants Inc.

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
B. T. GUY

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Senior Geoscientist

EXECUTIVE SUMMARY

Introduction

The operation of Zozel Dam at the outlet of Osoyoos Lake is governed by the International Osoyoos Lake Board of Control (IOLBC), under "Orders of Approval" prescribed by the International Joint Commission (IJC). These "Orders" specify that the lake must be maintained within certain ranges of elevations in winter (November 1 – March 31) and summer (April 1 – October 31) (the elevations are given with respect to the United States Coast and Geodetic Survey Datum (USCGS)). The Dam has a limited ability to manage high inflows, particularly when downstream backwater conditions exist, and the lake frequently exceeds the upper limit of the acceptable range in the summer period. The "Orders" will be renewed in 2013. The IJC has initiated this study to review the operation of Zozel Dam in order to help determine whether the Dam can be operated any differently to mitigate high water conditions, and to determine whether any changes to the Orders are required prior to 2013.

Summit Environmental Consultants Inc. and Sequoia Mediation were retained by the IJC to complete Study 7. Study 7 was divided into Part One: an investigation of the factors controlling Osoyoos Lake level, and Part Two: development of an outreach program to communicate the results of Part One to local stakeholders. Part One was completed by Summit Environmental Consultants Inc., and Part Two was completed by Sequoia Mediation. The overall objectives of Part One of Study 7 are to:

1. Review the circumstances and factors responsible for Osoyoos Lake levels exceeding 911.5 feet (277.8 m) USCGS between 1988 and 2008;
2. Review the capabilities of Zosel Dam to regulate water levels, and demonstrate how water levels (especially high levels) would compare in the absence of the dam;
3. Provide an assessment of how Zosel Dam could have been operated differently between 1988 and 2008 to control high water levels on Osoyoos Lake, and how much difference this would have made in terms of the magnitude and duration of the high water levels;
4. Provide a review of the effects on lake levels and Okanogan River flows of operating Zosel Dam with the principal goal of minimizing lake levels that have a negative impact on stakeholders and property owners; and
5. Provide recommendations on how to optimize the storage potential in Osoyoos Lake in the future in order to minimize high water events, while accounting for other stakeholders and the aquatic environment.

This report covers Part One of Study 7; Part Two is reported separately by Sequoia Mediation.

Background

Osoyoos Lake is located in the southern Okanagan Valley and straddles the border between British Columbia and Washington State. Approximately two-thirds of Osoyoos Lake lies in British Columbia, while one-third is located in Washington State. The Okanagan River flows into Osoyoos Lake at the north end of the lake (Figure 2.1) and represents the largest inflow of water to the lake. Additional inflows to Osoyoos Lake are provided primarily by groundwater, precipitation, and tributary streams (e.g. Inkaneep Creek, Ninemile Creek). The outlet of Osoyoos Lake is located at the southern end of the lake. The river flowing out of the lake is referred to as the Okanogan River (Figure 2.1). Aside from Okanogan River outflows, Osoyoos Lake loses water to evaporation, groundwater, and water extractions for human use. Zosel Dam, which regulates the lake levels, is located approximately 2.5 miles (4 km) downstream from the Osoyoos Lake outlet.

The operation of Zosel Dam varies annually based on summer (April 1 to October 31) and winter (November 1 to March 31) operating ranges (Condition 7, Table 2.1). For the winter range, Zosel Dam is operated to maintain Osoyoos Lake water levels between 909.0 ft (276.1 m) and 911.5 ft (277.8 m) USCGS. However, for the summer range, the identification of "normal" and "drought" conditions, as defined through the Orders of Approval, is required before the operational range of Osoyoos Lake water levels is specified. During summer, Zosel Dam is operated to maintain Osoyoos Lake water levels between 911.0 ft (277.7 m) and 911.5 ft (277.8 m) USCGS under normal conditions and between 910.5 ft (277.5 m) and 913.0 ft (278.3 m) USCGS under drought conditions. The higher operating range during drought conditions is intended to provide additional storage and flexibility in meeting water demands from Osoyoos Lake and downstream.

High water levels within the Similkameen River can restrict the flow within the Okanogan River and outflow of Osoyoos Lake. As a result, the Orders of Approval (Condition 9) state that during appreciable backwater conditions, Zosel Dam shall be operated as to maintain Osoyoos Lake water levels as near as possible to the elevations prescribed in Conditions 7 and 8 (Table 2.1) (IJC 1982).

This backwater makes lake level management extremely difficult, especially since it is a natural phenomenon that would occur whether or not Zosel Dam was present (IJC 2000). Additionally, backwater conditions generally occur during the spring freshet when the Okanagan River inflows are large; therefore, management options are limited. In an attempt to reduce Osoyoos Lake levels during high flows in the Similkameen River, the Okanagan River is managed so as to reduce inflows into Osoyoos Lake. However, if high Similkameen River flows occur for an extended period, the management options for the Okanagan River are very limited.

The IOLBC indicated that the public voices concerns when Osoyoos Lake levels rise above 912.5 ft (278.2 m) USCGS. Additionally, the public has continued to question the IOLBC about ways to prevent Osoyoos Lake water levels from rising above the target maximum levels (Sequoia Mediation 2010). Consequently, during drought conditions the WSDOE and B.C. Ministry of Environment (MOE) typically make an informal agreement to keep maximum water levels at or below 912.5 ft (278.2 m) USCGS to limit high water levels.

Osoyoos Lake Water Levels, 1988-2008

A review of the historic water levels indicates that from 1988 to 2008, Osoyoos Lake has been above its operating range in ten of those years (for variable lengths of time). The highest water levels occurred in 1990, 1991, 1996, and 1997, when peak water levels were above 913.0 ft (278.3 m) USCGS, under normal operating conditions. During these peak years, actual inflows into Okanagan Lake and flows within the Similkameen River were some of the highest on record (Table 2.2). From 1988 to 2008, Osoyoos Lake has only exceeded its operating range under normal conditions.

Under normal operating conditions (in the summer period) Osoyoos Lake water levels have exceeded the top end of the operating range [911.5 ft (277.8 m) USCGS] approximately 21% of the time over the period of record. Additionally, Osoyoos Lake has exceeded 912.5 ft (278.2 m) USCGS approximately 7% of the time, while it has exceeded 913.0 ft (278.3 m) USCGS approximately 4% of the time.

Osoyoos Lake Storage Capacity

Osoyoos Lake has a total storage volume of approximately 24,400 acre-feet (30,100 dam^3) over the entire range of Osoyoos Lake's specified operating range (909.0 ft (277.1 m) to 913.0 ft (278.3 m) USCGS). One acre-foot is a volume of water covering an area of an acre to a depth of one foot, and one dam^3 is a volume measuring 10 m by 10 m by 10 m, and is equivalent to one ML (one million litres). However, during normal and drought operating conditions in the summer period, the total volume of storage is only approximately 3,200 acre-feet (4,000 dam^3), and 15,300 acre-feet (18,900 dam^3), respectively.

Under high water conditions, outflows are often restricted by backwater caused by the Similkameen River. As a result, with the small storage capacity under normal conditions, high inflows, and restricted outflows, lake levels will rise, which has frequently been observed in Osoyoos Lake.

However, under drought conditions, the available storage capacity of the lake is almost five times greater than it is under normal conditions. Accordingly, the lake is able to store more water within the specified operating range. Therefore, even under backwater conditions when outflows are restricted, there is generally enough storage capacity within the lake to allow for the management of water levels, as evidenced by the fact that water levels have not been observed outside the drought condition operating range from 1988-2008 (Table 2.2).

Osoyoos Lake Water Balance

The water balance of Osoyoos Lake was reviewed to investigate the management options for Zosel Dam, particularly those options to reduce high water levels during normal conditions. In particular, the water balance investigation focused on the years where the water levels were above 912.5 ft (278.2 m) USCGS. Although the upper limit of the normal operating range is 911.5 ft (277.8 m) USCGS, the assessment at 912.5 ft (278.2 m) USCGS allowed for the highest inflow years to be assessed, which have caused the greatest concern regarding the shoreline environment and structures.

A water balance spreadsheet model was developed to investigate the management of Zosel Dam. The model was constructed on a daily time step. The role of Zosel Dam and its operation and management strategy were assessed by allowing the model to manipulate streamflow at the USGS station on the Okanogan River (Station No. 12439500), located just downstream of Zozel Dam.

The water balance spreadsheet model was developed using Microsoft Excel. It requires the following: 1) inputs from inflows into Osoyoos Lake by the Okanagan River (Q_{in}), 2) outflows out of Osoyoos Lake (and through Zosel Dam) (Q_{out}), 3) change in Osoyoos Lake volume ($\Delta S_{Osoyoos\ Lake}$), and 4) water withdrawals by the Oroville – Tonasket Irrigation District (OTID) (WD_{OTID}). Modeling constraints included the maximum and minimum flow releases during open flow and backwater conditions, which followed those outlined by WSDOE (1990), while a multiple regression equation was developed for maximum flow releases during backwater conditions using Okanogan River discharges, Similkameen River discharges, and Osoyoos Lake water levels.

The water balance investigation focused on years where the water levels were above 912.5 ft (278.2 m) USCGS (i.e. 1990, 1991, 1996, 1997, and 1999). Scenarios were selected to identify what would have happened to the Osoyoos Lake water level if the dam had operated differently during each of these years. The scenarios used for this investigation were the modeling of the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 911.0 ft (277.7 m) (Scenario 1); 911.25 ft (277.75 m) (Scenario 2); and 909.25 ft (277.14 m) (Scenario 3) USCGS prior to and during spring freshet.

The results indicated that by maximizing the storage potential of Osoyoos Lake prior to spring freshet, some additional storage could be obtained to keep water levels within the specified ranges for a few more days in spring; however, the peak water levels could not be reduced. This was largely a result of backwater conditions within the Okanogan River channel restricting outflow from Zosel Dam. As a result, alternate management of Zosel Dam during the years in question would still have resulted in the high water levels observed.

Recommendations

The only other feasible way to control Osoyoos Lake levels in normal years is to manage storage upstream on the Okanagan River, or to develop new storage on the Similkameen River. If additional water level control is desired, these two options should be evaluated further.

Additionally, Summit recommends that the IJC continue the practice of maintaining the water level at or below 912.5 ft (278.2 m) USCGS during drought conditions, which will limit the amount of shoreline impacts.

Lastly, under normal conditions, and with a low risk of future drought conditions, operators should maintain water levels near the lower limit of the specified operating range (911.0 ft (277.7 m) USCGS) prior to and throughout the spring freshet. This will minimize the period of time for which the lake is at risk of exceeding its target operating range in the summer period. However, if there is a risk that a drought will subsequently be declared, operators should balance the desire to maintain an acceptable lake level for a longer period against the risk that sufficient storage might not be available in a subsequent drought condition. In this case, a higher level within the 911.0 to 911.5 foot operating range should be targeted.

ACKNOWLEDGEMENTS

Part One of the study (this report) was completed by Summit Environmental Consultants Inc., with the assistance of Polar Geoscience Ltd. Part Two (under separate cover) was completed by Sequoia Mediation. The study team for Part One would like to thank the members of the Osoyoos Lake Board of Control, staff of the International Joint Commission, Oroville – Tonasket Irrigation District, and Washington State Department of Ecology who provided information and guidance throughout this investigation.

We would also like to thank the Okanagan Basin Water Board, which provided Osoyoos Lake bathymetry data and water balance information compiled during Phase 2 of the Okanagan Water Supply and Demand Project.

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Zozel Dam is situated on the Okanogan River downstream of the outlet of Osoyoos Lake. Most of the time the dam controls the level of Osoyoos Lake, however under some conditions the dam is unable to prevent the level of the lake from rising beyond its usual range. This study focuses on the operation of the dam, and on whether it could be managed any differently to prevent or reduce the impacts of the exceedances of the usual operating range of lake levels.

Osoyoos Lake is operated under "Orders of Approval" prescribed by the International Joint Commission (IJC) to maintain certain lake levels, which allows for a normal summer period (April 1 – October 31) water elevation range of between 911.0 and 911.5 feet (277.7 and 278.8 m) USCGS. When drought conditions are considered to have occurred, this level is allowed to be increased to 913.0 feet (278.3 m) USCGS within the summer period, through regulation of the outflow through Zosel Dam. However, natural flows during the spring and early summer may result in water levels exceeding the normal upper limit of 911.5 feet (278.8 m) USCGS.

In 2013, the Orders terminate and at that time the IJC will need to know whether to renew or modify them (Glenfir Resources 2006). As a result, Glenfir Resources was commissioned by the IJC to explore issues associated with the present Orders and to recommend studies accordingly. This investigation represents Study 7 recommended by Glenfir Resources (2006). Study 7 is split into two parts: Part 1 includes an independent review of the ability of Zosel Dam to be used for high water control; while Part 2 is the development of an outreach program designed to increase public awareness of the factors that control water levels in Osoyoos Lake during high water events (as outlined in Part 1).

This report covers Part 1 of Study 7; Part 2 was completed by Sequoia Mediation (2010), and has been submitted under separate cover.

1.2 PROJECT OBJECTIVES

The objectives of this study were outlined in the proposal "*Plan of Study for Renewal of the International Joint Commission's Osoyoos Lake Orders – Studies 7 & 8*" submitted by Summit Environmental Consultants (Summit) to the IJC on May 6, 2009:

- Provide a review of the circumstances and factors responsible for Osoyoos Lake levels exceeding 911.5 feet (277.8 m) USCGS between 1988 and 2008;

- Provide a review of the capabilities of Zosel Dam to regulate water levels, and demonstrate how water levels (especially high levels) would compare in the absence of the dam;
- Provide an assessment of how Zosel Dam could have been operated differently between 1988 and 2008 to control high water levels on Osoyoos Lake, and how much difference this would have made in terms of the magnitude and duration of the high water levels;
- Provide a review of the effects on lake levels and Okanogan River flows of operating Zosel Dam with the principal goal of minimizing lake levels that have a negative impact on stakeholders and property owners; and
- Provide recommendations on how to optimize the storage potential in Osoyoos Lake in the future in order to minimize high water events, while accounting for other stakeholders and the aquatic environment.

1.3 STUDY METHODS

The review and assessment included the following tasks:

- Project initiation meeting (June 25, 2009) in Oroville, WA with members of the IJC (including members from Environment Canada, United States Geological Survey (USGS), State of Washington Department of Ecology (WSDOE), and the Oroville -Tonasket Irrigation District) to obtain background information and review the scope of work;
- A field tour between Osoyoos Lake and the Similkameen River on June 25, 2009, with a specific focus on the outlet of Osoyoos Lake, Zosel Dam, and the confluence between the Okanogan and Similkameen Rivers;
- Review of relevant geologic and topographic information relevant to the identified area of study;
- Review, compilation, and summarizing of relevant hydrologic information to Osoyoos Lake including USGS streamflow records, Water Survey of Canada (WSC) streamflow records, water use records (actual and modeled), precipitation (modeled), evaporation (modeled), groundwater inflow estimates, lake storage capacity estimates, and naturalized inflow estimates;
- Development and calibration of a detailed spreadsheet model based on the water balance of Osoyoos Lake to assess flood events since 1988;
- Analysis and reporting of select scenarios run through the spreadsheet model to identify the results of hypothetical changes to Zosel Dam operation; and
- Preparation of this report.

2.0 OSOYOOS LAKE

2.1 GENERAL CHARACTERISTICS

Osoyoos Lake lies within the rain shadow of the Okanagan sub-range, which leads to the lowest annual precipitation in Canada. Total precipitation at Osoyoos (Environment Canada Climate Station: Osoyoos West; No. 1125865; Elevation 297.3 m (975.4 ft); 1971 – 2000 normals) averages 12.5 inches (317.6 mm), of which 1.95 inches (49.6 mm) (water equivalent) falls as snow (between the months of October and March). Mean daily temperatures at Osoyoos range from a high of 71.1 °F (21.7 °C) in July to a low of 28.2 °F (-2.1 °C) in January.

Osoyoos Lake is located in the southern Okanagan Valley and straddles the border between British Columbia and Washington State, east of the Cascade Mountains (Okanagan sub-range) (Figure 2.1). Approximately two-thirds of Osoyoos Lake lies in British Columbia, while one-third is located in Washington State. Osoyoos Lake covers approximately 5,729 acres (23.2 km^2) and can store up to 14,323 acre-feet (17,700 dam^3) of water (Glenfir Resources 2006).

Osoyoos Lake is located at the southern end of the Canadian portion of the Okanagan River watershed. The Okanagan River is a tributary of the Columbia River. In the United States, the river is named Okanogan River. The Okanagan 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. There are six biogeoclimatic zones in the Okanagan Basin upstream of Osoyoos Lake: Ponderosa Pine (PPxh1), Interior Douglas-fir (IDFxh1), Montane Spruce (MSdm2), Englemann Spruce-Subalpine Fir (ESSFxc1), Interior Cedar Hemlock (ICFmk1), and Bunchgrass (BGxh1). The drainage area of the Okanagan River at Osoyoos Lake is approximately 7,550 km^2 (1,866,000 acres).

The Okanagan River flows into Osoyoos Lake at the north end of the lake (Figure 2.1) and is the largest inflow of water to the lake. Additional inflows to Osoyoos Lake are provided by groundwater, precipitation, and tributary streams (e.g. Inkaneep Creek, and Ninemile Creek). The outlet of Osoyoos Lake is located at the southern end of the lake. Aside from Okanogan River outflows, Osoyoos Lake loses water to evaporation, groundwater, and water extractions for human use.

Zosel Dam, which regulates the lake levels, is located approximately 2.5 miles (4 km) downstream of Osoyoos Lake outlet. The operation of Zosel Dam is governed by Orders of Approval from the IJC, which are monitored by the International Osoyoos Lake Board of Control (IOLBC), and implemented by the WSDOE.

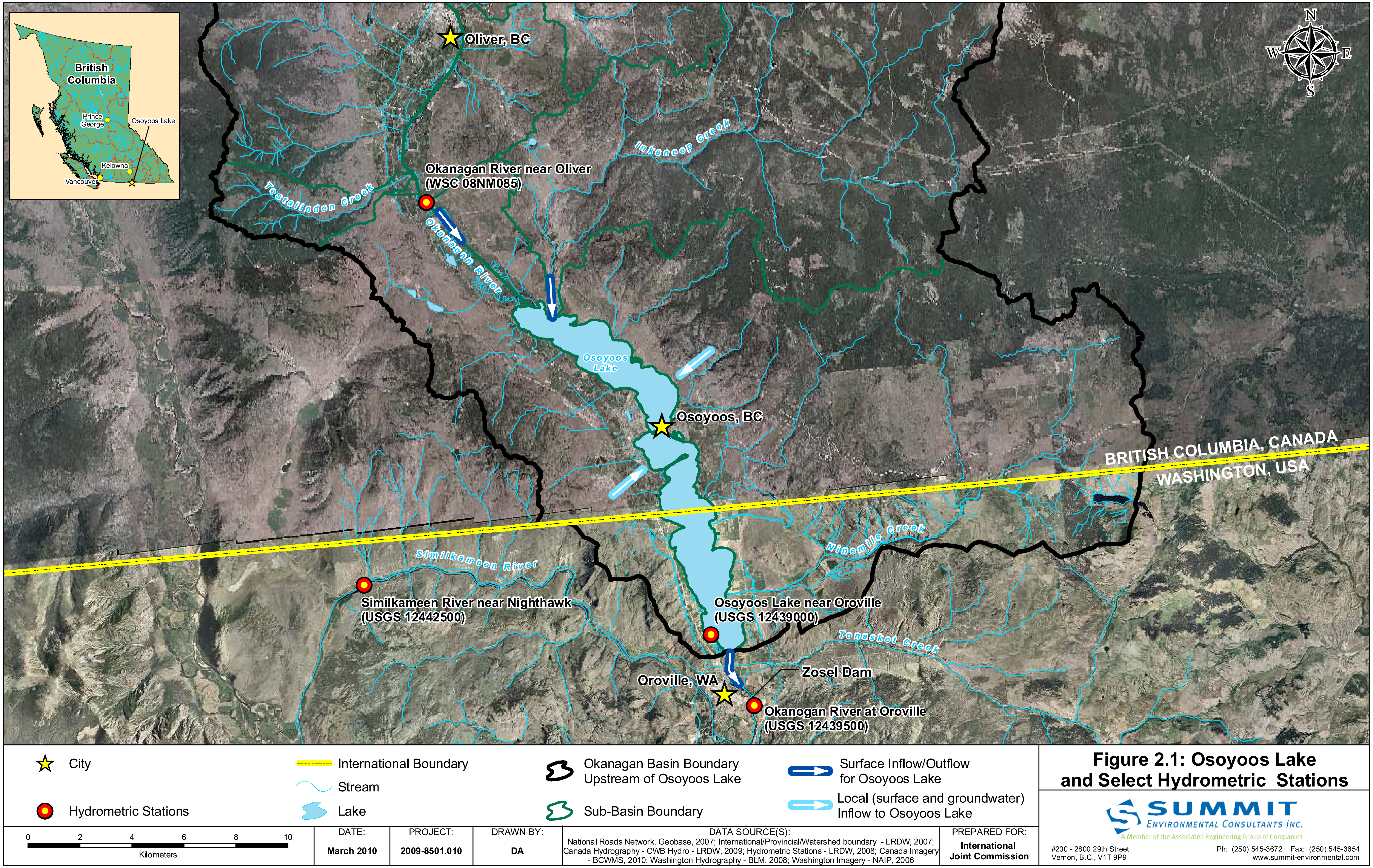


Figure 2.1: Osoyoos Lake and Select Hydrometric Stations

2.2 GENERAL HYDROLOGY REVIEW

According to Obedkoff (2003), the Okanagan Basin is located in the Southern Thompson Plateau and Fraser Plateau Hydrologic Zones (#24 and #15). Snowmelt between April and June is the primary source of runoff in the Okanagan Basin (and Osoyoos Lake). In addition, high intensity thunderstorms and late fall rainstorms are common, recharging soil moisture and producing short-duration peak flows. Low flows generally occur from the end of November to March, and in the hot summer months, with the lowest flows commonly occurring in January or February. Osoyoos Lake water levels follow the Okanagan Basin runoff regime; however, they are also governed by the Okanagan River Regulation System (ORRS), in which flows are partially controlled via dams on Okanagan, Skaha, and Vaseux Lakes and by the operation of Zosel Dam.

Additionally, the Similkameen River joins the Okanogan River just below Zosel Dam. Because the peak flow of the Similkameen can be up to 10 times greater than that of the Okanogan River and because the land at the confluence is relatively flat, high water levels in the Similkameen River actually slow or block the flow out of the Okanogan River and Osoyoos Lake. With extreme high water in the Similkameen River (greater than 10,000 ft^3/s (283 m^3/s))[1], flow in the Okanogan River may reverse and flow upstream into Osoyoos Lake, although this reversal is a rare occurrence (last seen in 1976). A more common scenario is for flows into Osoyoos Lake to exceed its outflow capacity. When either of these conditions occur, Osoyoos Lake water levels rise. A more detailed description of the role the Similkameen River plays on Osoyoos Lake water levels is provided in Section 2.3.3 of this report.

Osoyoos Lake water levels and Okanogan River discharges are also influenced by water extractions from Osoyoos Lake and the Okanogan River, by the Town of Osoyoos and the OTID. The Town of Osoyoos extracts water directly from Osoyoos Lake for domestic and irrigation purposes; with an average annual extraction of approximately 9,000 acre-feet (11,100 dam^3). The OTID extracts water from the Okanogan River between Osoyoos Lake outlet and Zosel Dam; with an average annual extraction of approximately 12,900 acre-feet (16,000 dam^3) between April and October.

The WSC operates a hydrometric station on the Okanagan River near Oliver (WSC Station No. 08NM085); while the USGS operates hydrometric stations on Osoyoos Lake at Oroville (USGS

[1] Measured at “Similkameen River near Nighthawk, WA” (USGS Station No. 12442500) (Figure 2.1).

Station No. 12439000) and the Okanogan River at Oroville (USGS Station No. 12439500) (Figure 2.1). The records for the hydrometric station on Osoyoos Lake extend from 1965-2009 (Figure 2.2)[2].

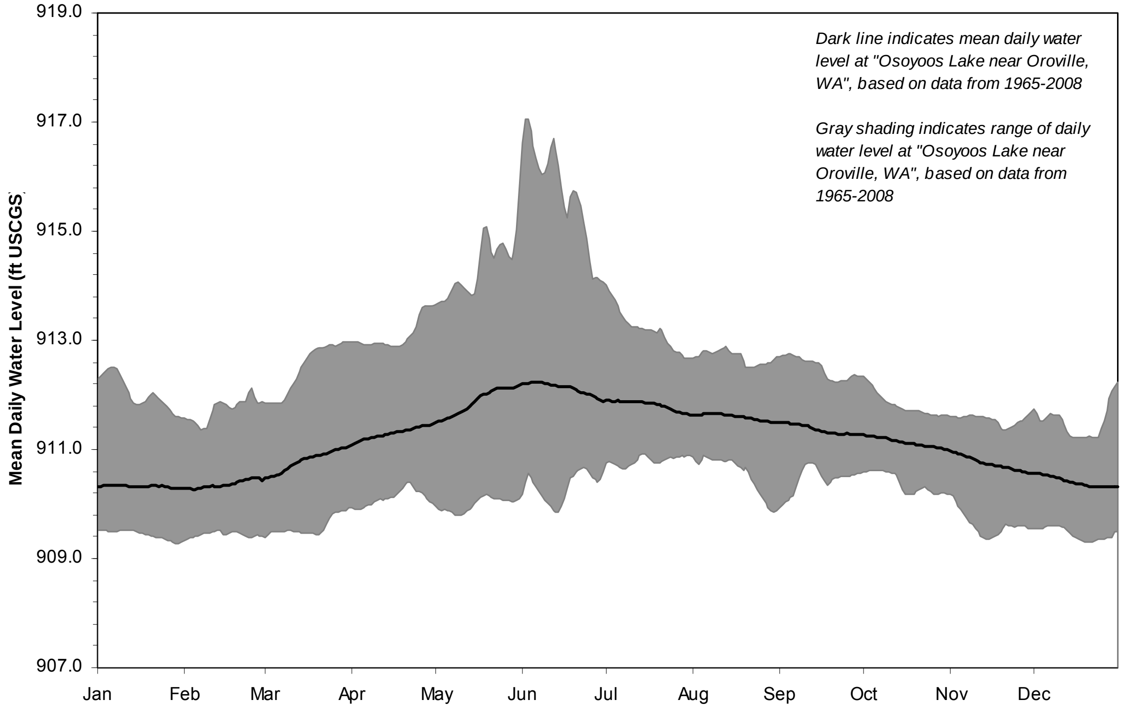


Figure 2.2 Mean daily water level of Osoyoos Lake near Oroville, WA (USGS Station No. 12439000), 1965-2008.

2.3 OSOYOOS LAKE WATER LEVEL MANAGEMENT

This study focuses on the regulation of Osoyoos Lake via Zosel Dam. The regulation of the Okanagan River upstream of Osoyoos Lake (via other dams) is not considered further in this study. The timing and magnitude of the Okanagan River inflows to Osoyoos Lake is largely controlled by the B.C. Ministry of Environment (MOE) to meet domestic and irrigation requirements, fisheries needs, and acceptable water levels for recreation, navigation, and tourism. As a result, the Okanagan River impacts Osoyoos Lake water levels, but very few additional management opportunities (upstream of Osoyoos Lake) are available to be used in association with the operation of Zosel Dam to control water levels in Osoyoos Lake. According to Glenfir Resources (2006), the operational plan for

[2] Water levels recorded by the hydrometric station “Osoyoos Lake at Oroville” (USGS Station No. 12439000) are reported using the United States Coast and Geodetic Survey Datum (USCGS).

Okanagan Lake (and subsequently the Okanagan River) reduces flood peaks to Osoyoos Lake, but prolongs the period of high water.

2.3.1 Zosel Dam – Structure

Osoyoos Lake water levels are managed through Zosel Dam. Zosel Dam was initially constructed in 1927 as a millpond dam to provide logs to Zosel Mill. As a result of complaints of high lake levels, the IJC held hearings to investigate the hydraulics of the outlet of Osoyoos Lake. Subsequently, the IJC released an Order in 1946 for an increase in the capacity of the dam to pass 2,500 ft^3/s (70.8 m^3/s) at a millpond elevation of 911.0 ft (277.7 m) USCGS (IJC 2001).

In 1982, due to the deterioration of Zosel Dam, the IJC issued an Order of Approval for the reconstruction of the dam. As outlined in the Orders (IJC 1982) and Supplementary Orders (IJC 1985), Zosel Dam was to be relocated to its current location, downstream of Tonasket Creek (Figure 2.1). The reconstructed Zosel Dam was completed in 1987 and included a control structure, manual controls, and overflow weir (Figure 2.3).

Figure 2.3 Aerial view of Zosel Dam indicating the control structure and overflow weir.

The overflow weir is 198 ft (60.4 m) long and has a concrete top elevation of 913.0 ft (278.3 m) USCGS (WSDOE 1990). The control structure is 171 ft (52.1 m) long and consists of four spillways (each with a gate), two fishways, and other associated infrastructure (eg. a control room, a stoplog storage vault, a dewatering pump vault, a gear actuator gallery, and an emergency generator room) (WSDOE 1990). The spillways are 25 ft (7.6 m) wide and have an upstream floor elevation of 906.0 ft (276.1 m) USCGS and a downstream floor elevation of 901.0 ft (274.6 m) USCGS; the spillways are designed to pass 2,500 ft^3/s (70.8 m^3/s) at an Osoyoos Lake elevation of 913.0 ft (278.3 m) USCGS (WSDOE 1990). The gates are each 25 ft (7.6 m) wide, 7.5 ft (2.3 m) tall, and can travel 13.5 ft (4.1 m) from fully open to closed; the fishways are located on either side of the spillway section and are 8 ft (2.4 m) wide, 73 ft (22.3 m) long, and each are designed to pass 45 ft^3/s (1.27 m^3/s) (WSDOE 1990).

The Supplementary Orders (IJC 1985) indicate that all necessary measures are required to ensure that the flow capacity of the Okanogan River, upstream and downstream from Zosel Dam is maintained. The WSDOE currently monitors the channel capacity of the Okanogan River, which is outlined within Study 8 (Summit 2010).

Zosel Dam is owned by the WSDOE and operated under contract by the OTID.

2.3.2 Zosel Dam – Operation

Osoyoos Lake water levels are managed by the closing and opening of the gates of Zosel Dam. The dam is operated following the procedures outlined within the Orders of Approval (IJC 1982) and WSDOE (1990) included in Table 2.1. The operation of Zosel Dam varies annually based on summer (April 1 to October 31) and winter (November 1 to March 31) operating ranges (Condition 7, Table 2.1).

For the winter range, Zosel Dam is operated to maintain Osoyoos Lake water levels between 909.0 ft (276.1 m) and 911.5 ft (277.8 m) USCGS. However, for the summer range, the identification of normal and drought conditions, as defined through the Orders of Approval, is required before the operational range of Osoyoos Lake water levels is specified.

Table 2.1 Zosel Dam operational procedures.

Criteria	Zosel Dam Operation	Reference
Condition 7	*"Upon completion of construction the Applicant, in consultation with the Board of Control appointed under Condition 14, shall operate the works so as to maintain the levels of Osoyoos Lake between elevation 911.0 and 911.5 feet (277.7 and 277.8 m) USCGS to the extent possible from 1 April to 31 October each year except under drought conditions in the Okanogan Valley (in Canada Okanagan Valley), as defined in Condition 8 and also during the appreciable backwater conditions and excessive inflows described in Condition 9. Furthermore, the Applicant shall operate the works so as to maintain the levels of Osoyoos Lake between elevation 909.0 and 911.5 feet (277.1 and 277.8 m) USCGS from 1 November to 31 March each year."*	Order of Approval (IJC 1982; 1985)
Condition 8	*"During a year of drought as determined by the Board of Control in accordance with the criteria set forth below, the levels of Osoyoos Lake may be raised to 913.0 feet (278.3 m) USCGS and may be drawn down to 910.5 feet (277.5 m) USCGS during the period 1 April to 31 October. The criteria are:* *(a) the volume of flow in the Similkameen River at Nighthawk, Washington for the period April through July as calculated or forecasted by United States authorities is less than 1.0 million acre-feet or* *(b) the net inflow to Okanagan Lake for the period April through July as calculated or forecasted by Canadian authorities is less than 195,000 acre-feet or* *(c) the level of Okanagan Lake fails to or is forecasted by Canadian authorities to fail to reach during June or July elevation 1122.8 feet (342.2 m) Canadian Geodetic Survey Datum.* *Drought year operations shall be terminated when in the opinion of the Board of Control none of the three criteria defining a drought year exist. The level of Osoyoos Lake shall then be maintained in accordance with Condition 7."*	Order of Approval (IJC 1982; 1985)
Condition 9	*"During appreciable backwater conditions caused by flows in the Similkameen River, particularly during the freshet period, and during abnormal excessive flows in the Okanagan River, the works shall be operated so as to maintain the level of Osoyoos Lake as near as possible to the elevations prescribed in Conditions 7 and 8 herein. In such an event every effort shall be made to lower the level of Osoyoos Lake in the shortest practicable time"*	Order of Approval (IJC 1982; 1985)

Table 2.1 Cont'd.

Operational Requirement	Zosel Dam Operation	Reference
Condition 9 – WSDOE	*"The structure shall be operated to maintain the level of Osoyoos Lake within the prescribed elevations. When appreciable backwater conditions cause the Osoyoos Lake level to exceed 911.5 feet USCGS, all four gates shall be lifted clear of the water and remain open until the lake level returns to 911.5 feet (277.8 m) USCGS. Historical runoff patterns of the upper Okanogan River basin and the Similkameen River basin are similar and backwater occurs only during the spring freshet (May – June) when high flows are present in both rivers."*	Zosel Dam Operating Procedures Plan (WSDOE 1990)
Fisheries	*"The operation of Zosel Dam includes the passage of migrating fish. To the extent possible, the following fish consideration should be met when discharging water from Zosel Dam:* *1. Discharge 80% of the October average flow during the period between 1 October and 15 April in order to maintain egg/fry survival of Chinook salmon. Chinook spawning, incubation, and emergence occurs between mid-October and mid-April.* *2. Discharge 80% of the March average flow during the period between March and 15 June in order to maintain egg/fry survival of steelhead salmon. Steelhead spawning, incubation, and emergence occurs between mid-March and mid-June.* *3. Stream flows should remain at or above 300 ft^3/s (8.50 m^3/s) for full utilization of winter rearing habitats during the months of October to March.* *4. Juvenile sockeye salmon outmigration from the Osoyoos Lake nursery area extends from 20 April through 10 June. During this period, sufficient flow at the surface is needed to successfully pass fish through Zosel Dam and subsequently allow them to move downstream out of the Okanagan River. In the absence of any means to provide downstream fish migration at Zosel Dam, the stoplogs are used to form a waterfall to help the sockeye and steelhead pass through the dam. A few stoplogs are placed in the spillway and the gate is opened, allowing water to spill over the stoplogs.* *5. A stream flow of 200 ft^3/s (5.66 m^3/s) from 15 June to 1 August should be maintained if possible, for the protection of resident fisheries.*	Zosel Dam Operating Procedures Plan (WSDOE 1990)

The identification of normal or drought conditions is based on three separate criteria outlined by Condition 8 of the Orders (Table 2.1). These criteria are based on: 1) forecast inflows to the Similkameen River, 2) forecast inflows to Okanagan Lake, and 3) Okanagan Lake levels. For the Similkameen River, water supply forecasts are produced by the National Weather Service, Northwest River Forecast Center, while for Okanagan Lake, water supply and lake level forecasts are produced by the River Forecast Center of the B.C. MOE.

Beginning April 1st the IOLBC reviews each forecast; if any forecast is below the criteria as outlined in Condition 8 (Table 2.1), a drought is declared. Drought declaration is generally based on the April 1st forecast; however, forecasts are updated every two weeks and the declaration is re-assessed until July 31st. A drought declaration can be rescinded on the basis of subsequent forecasts, although once a drought has been rescinded, the IOLBC will not re-instate a drought declaration.

Accordingly, during the summer operating range, Zosel Dam is operated to maintain Osoyoos Lake water levels between 911.0 ft (277.7 m) and 911.5 ft (277.8 m) USCGS under normal conditions and between 910.5 ft (277.5 m) and 913.0 ft (278.3 m)[3] USCGS under drought conditions. Annual Osoyoos Lake operating ranges are presented graphically in Figure 2.4.

[3] The WSDOE and MOE agree on trans-border Osoyoos Lake water levels every year and have recently developed an informal agreement for a maximum Osoyoos Lake water level of 912.5 ft (278.1 m) USCGS during drought conditions, which is consistent with the Orders.

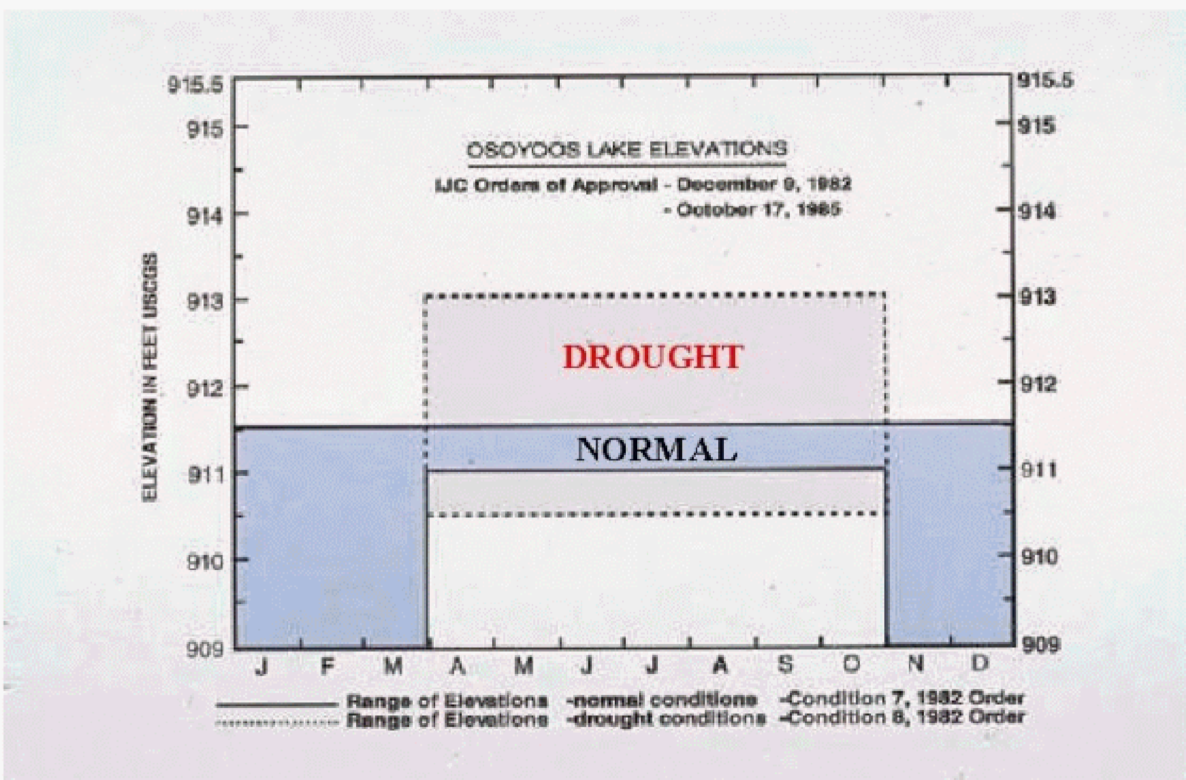


Figure 2.4 Osoyoos Lake winter and summer operating ranges as specified within the IJC's Orders of Approval (adapted from IJC (2000)).

2.3.3 Backwater

The IJC (2000) indicates that because the land surrounding the confluence of the Similkameen and Okanogan Rivers is relatively flat (Figure 2.5), high water levels within the Similkameen River can restrict the flow within the Okanogan River and out of Osoyoos Lake. This restriction has been estimated to occur when the discharge of the Similkameen River exceeds 10,000 ft^3/s (283 m^3/s) (as measured at Similkameen River near Nighthawk; USGS Station No. 12442500). As a result of this restriction, backwater occurs within the Okanogan River, and if the backwater reduces the outflows from Osoyoos Lake to less than the inflows, the level of Osoyoos Lake will rise. Under extreme high flows in the Similkameen River, a flow reversal of the Okanogan River at Zosel Dam has been observed, but this is rare (the last documented occurrence was 1976) (IJC 2000). Backwater events generally occur during the spring freshet in May and/or June.

During the field reconnaissance of the Similkameen and Okanogan River confluence, conducted during the project initiation meeting, the study team identified a point of flow restriction on the Okanogan River at high flows approximately 1.5 miles (2.5 km) downstream of Zosel Dam (Figure

2.5). At this location, a side channel from the Similkameen River flows into the Okanogan River. A discussion with a resident in the area supported these observations by indicating that a flow restriction does indeed occur at this point during high Similkameen River flows.

From an Osoyoos Lake management standpoint, this backwater process makes lake level management difficult, especially since a natural phenomenon is controlling the process (IJC 2000). Additionally, backwater conditions generally occur during the spring freshet when Okanagan River inflows are large. In an attempt to reduce Osoyoos Lake levels during high flows in the Similkameen River, the Okanagan River is managed so as to reduce inflows into Osoyoos Lake. However, if high Similkameen River flows occur for an extended period, the management options for the Okanagan River become very limited (IJC 2000).

As a result, the Orders of Approval (Condition 9) state that during appreciable backwater conditions Zosel Dam shall be operated to maintain Osoyoos Lake water levels as near as possible to the elevations prescribed in Conditions 7 and 8 (Table 2.1) (IJC 1982). However, if water levels rise above 911.5 ft (277.8 m) USCGS under backwater conditions, the WSDOE has directed that all four gates should be lifted clear of the water and remain that way until water levels return to 911.5 ft (277.8 m) USCGS (WSDOE 1990).

The USGS monitors backwater development within the Okanogan River channel downstream of Zosel Dam by using two complementary hydrometric stations: Okanogan River at Oroville, WA (Primary Gauge) (USGS Station No. 12439500) and Okanogan River at Oroville, WA (Auxiliary Gauge) (USGS Station No. 12439500) (Figure 2.5). Periods of backwater within the Okanogan River are noted by the USGS in their annual water data reports and included within the IOLBC's annual reports to the IJC. Backwater has been reported within the Okanogan River every year from 1988-2008.

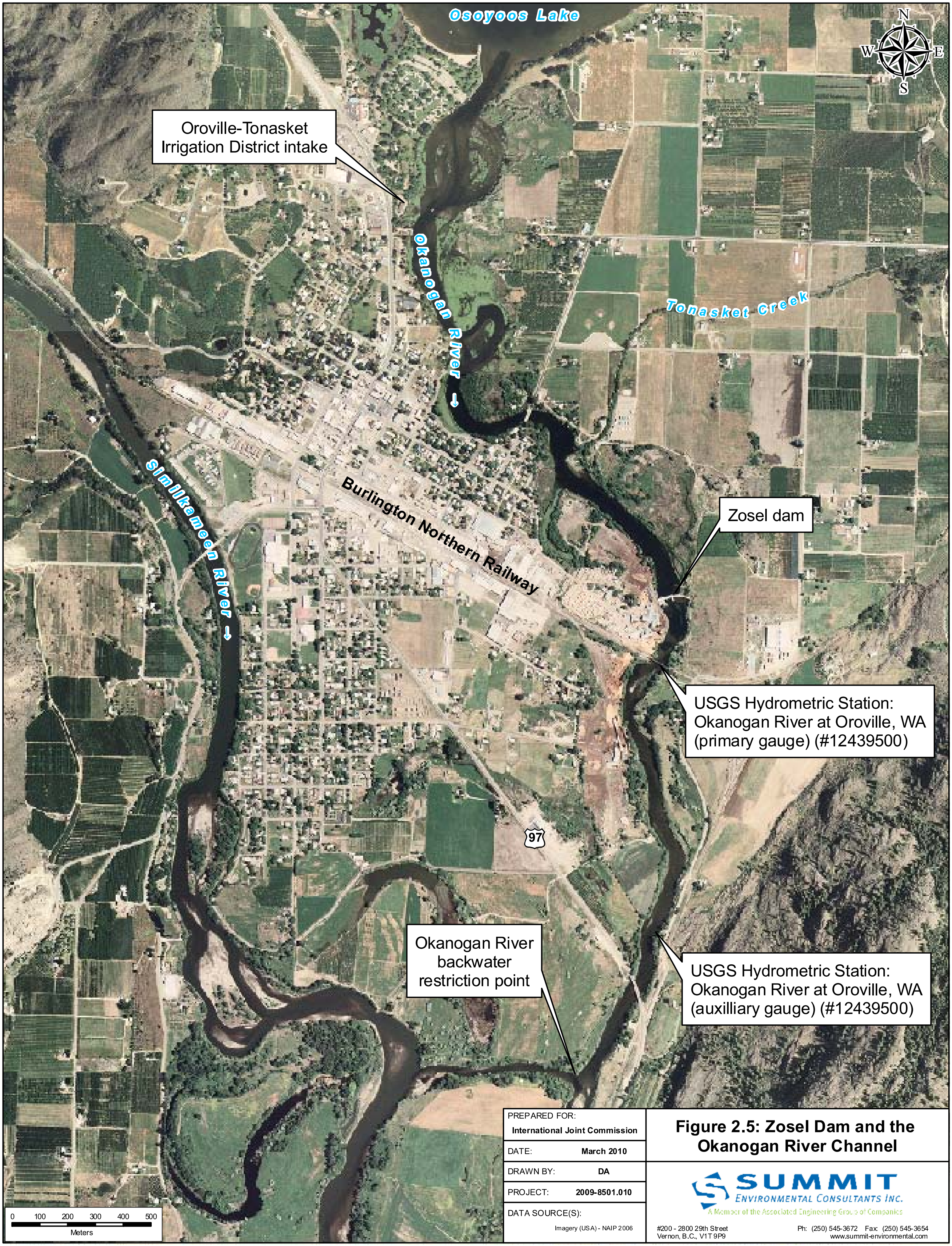


Figure 2.5: Zosel Dam and the Okanogan River Channel

2.4 OSOYOOS LAKE WATER LEVELS, 1988-2008

A summary of Osoyoos Lake water levels from 1988-2008 is provided in Table 2.2. A review of the water levels indicates that from 1988 to 2008, Osoyoos Lake has been outside of its operating range in ten of those years (for variable lengths of time). The highest water levels occurred in 1990, 1991, 1996, and 1997, when peak water levels were above 913.0 ft (278.3 m) USCGS, under normal operating conditions. During these peak years, actual inflows into Okanagan Lake and flows within the Similkameen River were some of the highest in the 21-year record examined for this study (Table 2.2). From 1988 to 2008, Osoyoos Lake has only exceeded its operating range under normal conditions.

The exceedance probability of water levels in Osoyoos Lake (for the summer period – April 1 to October 31) from 1988 to 2008 is presented in Figure 2.6. Under normal operating conditions, the Osoyoos Lake water level has exceeded the top end of the operating range (911.5 ft (277.8 m) USCGS) approximately 21% of the time over the period of record. Additionally, Osoyoos Lake has exceeded 912.5 ft (278.2 m) USCGS approximately 7% of the time, while it exceeded 913.0 ft (278.3 m) USCGS approximately 4% of the time. The influence of summer period drought condition operations can also be seen on Figure 2.6.

Table 2.2 Osoyoos Lake water level summary statistics, 1988-2008.

Year	Max Daily WL (ft USCGS)	Min Daily WL (ft USCGS)	Mean Daily WL (ft USCGS)	# Days[1] >911.5 ft	# Days[1] >912.5 ft	# Days[1] >913.0 ft	Drought Criteria[2]			Condition
							Similkameen River Volume (acre-feet)	Okanagan Lake Inflows (acre-feet)	Okanagan Lake Level (ft GSC)	
1988	912.64	909.43	911.15	112	10	0	933,296	192,700	1122.32	Drought
1989	911.53	911.03	911.31	6	0	0	1,060,974	296,700	1123.54	Normal
1990	913.81	910.46	911.48	86	39	20	1,565,775	536,000	1124.90	Normal
1991	914.66	909.74	911.25	52	25	11	2,299,868	479,100	1123.42	Normal
1992	912.96	909.40	911.25	104	59	0	735,541	123,600	1121.87	Drought
1993	912.49	909.66	911.39	181	0	0	938.989	458,300	1123.56	Drought
1994	912.44	909.68	911.25	155	0	0	885,375	302,600	1123.39	Drought
1995	911.97	910.14	911.15	28	0	0	1,305,004	368.400	1123.17	Normal
1996	914.04	910.12	911.25	69	29	14	1,661,380	654,000	1124.07	Normal
1997	915.09	909.60	911.48	157	64	45	1,946,984	863,100	1124.81	Normal
1998	912.80	909.56	911.18	83	14	0	1,230,960	391,000	1123.47	Drought / Rescinded
1999	912.53	909.64	910.98	54	1	0	1,706,980	560,700	1123.39	Normal
2000	911.45	909.37	910.71	0	0	0	1,070,039	431,200	1123.41	Normal
2001	912.52	909.50	911.42	174	8	0	566,825	192,300	1122.72	Drought
2002	912.50	909.49	910.77	23	0	0	1,546,158	417,900	1123.70	Normal
2003	912.92	909.27	911.13	174	24	0	781,500	137,600	1122.46	Drought
2004	912.73	909.47	910.98	92	40	0	1,143,082	269,000	1122.80	Drought / Rescinded
2005	912.50	909.53	911.21	183	0	0	622,230	328,900	1123.87	Drought
2006	912.35	909.46	910.90	41	0	0	1,065,038	452,800	1123.89	Normal
2007	911.47	909.81	910.96	0	0	0	1,372,000	260,237	1123.01	Normal
2008	912.48	909.50	910.87	10	0	0	1,221,200	306,380	1123.74	Normal

Note:

1. Coloured boxes represent periods when the water level of Osoyoos Lake is outside the operating ranges specified in the Orders of Approval (IJC 1982).
2. The values reported for the drought criteria are actual values, not forecasted. In order for the IOLBC to make a drought declaration (Section 2.3.2), at least one of the following criteria must be met:
   a. The volume of flow in the Similkameen River at Nighthawk, WA, for the period April through July as calculated or forecasted by United States authorities is less than 1.0 million acre-feet; or
   b. The net inflow to Okanagan Lake for the period April through July as calculated or forecasted by Canadian authorities is less than 195,000 acre-feet; or
   c. The level of Okanagan Lake fails to or is forecasted by Canadian authorities to fail to reach during June or July an elevation of 1122.80 ft Canadian Geodetic Survey Datum (GSC).

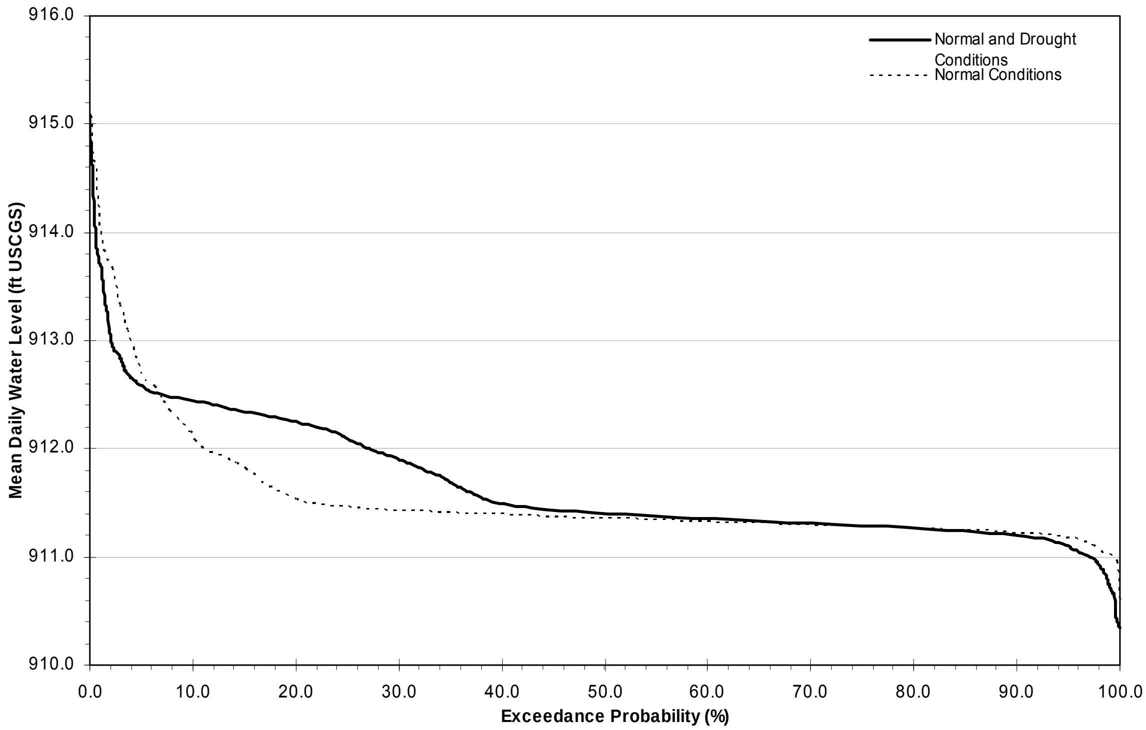


Figure 2.6 Osoyoos Lake water level exceedance probabilities for the summer operating period, both under normal conditions, and for normal and drought conditions combined (1988-2008 data).

2.5 PUBLIC CONCERNS

A review of public comments related to Osoyoos Lake level management and the operation of Zosel Dam was completed by Sequoia Mediation (2010). A summary of public comments is provided in Table 2.3; all comments are from IOLBC board meeting minutes, 1998-2007.

Table 2.3 Summary of public comments related to Osoyoos Lake levels (adapted from Sequoia Mediation (2010)).

Key themes or issues raised	Total times recorded
Development regulations and encroaching lake levels	4
Property damage and erosion	2
Irrigation & agriculture: timing of drought declaration and change in water levels	4
Compensation for loss of land	3
Sewage leakage during spring freshet	1
Lake level management including timing of lake level adjustments	3
Effect of lake level on milfoil control	3
Climate change and potential for change in timing of freshet and amount of water flowing	3
Dams and reservoir installation and/or removal	3
Recreation requirements and hazards of higher lake levels	3
Drought declaration timing and notification	4
Fisheries seasonal requirements	2

For Osoyoos Lake, the IOLBC indicated that public concerns generally begin when lake levels rise above 912.5 ft (278.2 m) USCGS, as this is the upper limit before beaches are lost, campsites get wet, and basements get flooded (Kirk Johnstone, pers. comm., 2009). These concerns generally come from the Canadian side of Osoyoos Lake, as this side has the largest population of permanent and seasonal residents.

Additionally, the public continues to present questions to the IOLBC about ways to prevent Osoyoos Lake water levels from rising above the maximum levels specified (Sequoia Mediation 2010). These inquiries focus on the possibility of operating Zosel Dam or other dams upstream in such a way as to prevent lake levels from exceeding those specified in the Orders of Approval. With the placement of a man-made structure (i.e. Zosel Dam) on the Okanogan River, there are expectations by the public that the dam ought to be able to manage high water levels.

3.0 OSOYOOS LAKE STORAGE CAPACITY

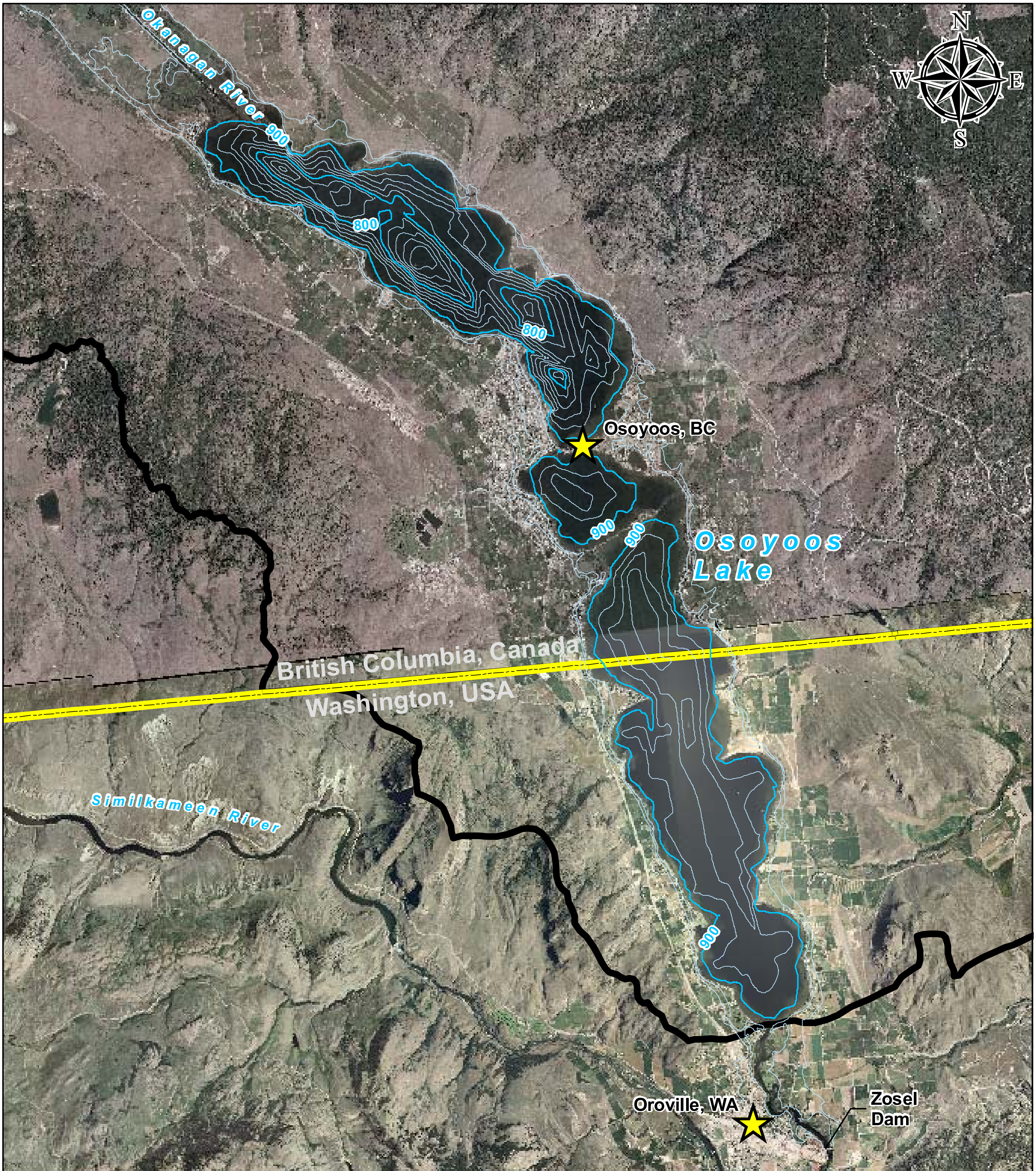
In order to begin to address the public's concerns about high water level management and the IJC's questions regarding the 2013 renewal of the Orders of Approval, an assessment of Osoyoos Lake's storage capacity was completed to provide an initial investigation into the operation of Zosel Dam as a management tool. In a subsequent section (Section 4.0), the storage capacity of Osoyoos Lake is a variable used within a water balance model.

3.1 BATHYMETRIC MAPPING

Original bathymetric mapping of Osoyoos Lake was completed by MOE (1971) and MOE (1981a); full Osoyoos Lake bathymetry is provided by MOE (1971), while MOE (1981a) only includes lake bathymetry from the north end of Osoyoos Lake to the international border.

Digitization of available hardcopy bathymetries of the Okanagan Basin's mainstem lakes was completed as part of the Okanagan Basin Water Board's (OBWB) Okanagan Basin Water Supply and Demand Project. The digital bathmetries were included in the development of a comprehensive, spatially-distributed deterministic hydrologic model of the Okanagan Basin using the MIKE SHE platform. This project combines a water demand model and the hydrology model into a water balance model that can be used to examine future scenarios driven by changing climate, population, land use, and other key factors.

For the present investigation, the study team received approval from the OBWB to use the digitized Osoyoos Lake bathymetry (Figure 3.1) and surface water, groundwater, and water supply and demand study results relevant to this investigation for analysis purposes (Anna Warwick Sears, pers. comm., 2009).



City	International Boundary
Okanagan Basin Boundary Upstream of Osoyoos Lake	20ft/100ft Contour Lines

0 0.5 1 1.5 2
Kilometers

DATA SOURCE(S):
Lake Bathymetry - SECL, 2008; International Boundary, Watershed Boundary - LRDW, 2007; Imagery (Canada) BCWMS, 2009; Imagery (USA) - NAIP 2006

PREPARED FOR:
International Joint Commission

Figure 3.1:
Osoyoos Lake Bathymetry

PROJECT: **2009-8501.010** DATE: **March 2010** DRAWN BY: **DA**

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3.2 OPERATING RANGE STORAGE CAPACITY

A deliverable from the lake bathymetry digitization work completed for the OBWB was the development of storage capacity rating curves for each of the mainstem lakes in the Okanagan Basin. MOE (1981b) had previously produced a storage capacity curve for Osoyoos Lake; however, the storage curve did not include the lake volume south of the international border. Therefore, the storage capacity rating curve developed by the OBWB for Osoyoos Lake is used to address storage capacity in this investigation; the rating curve is presented in Figure 3.2.

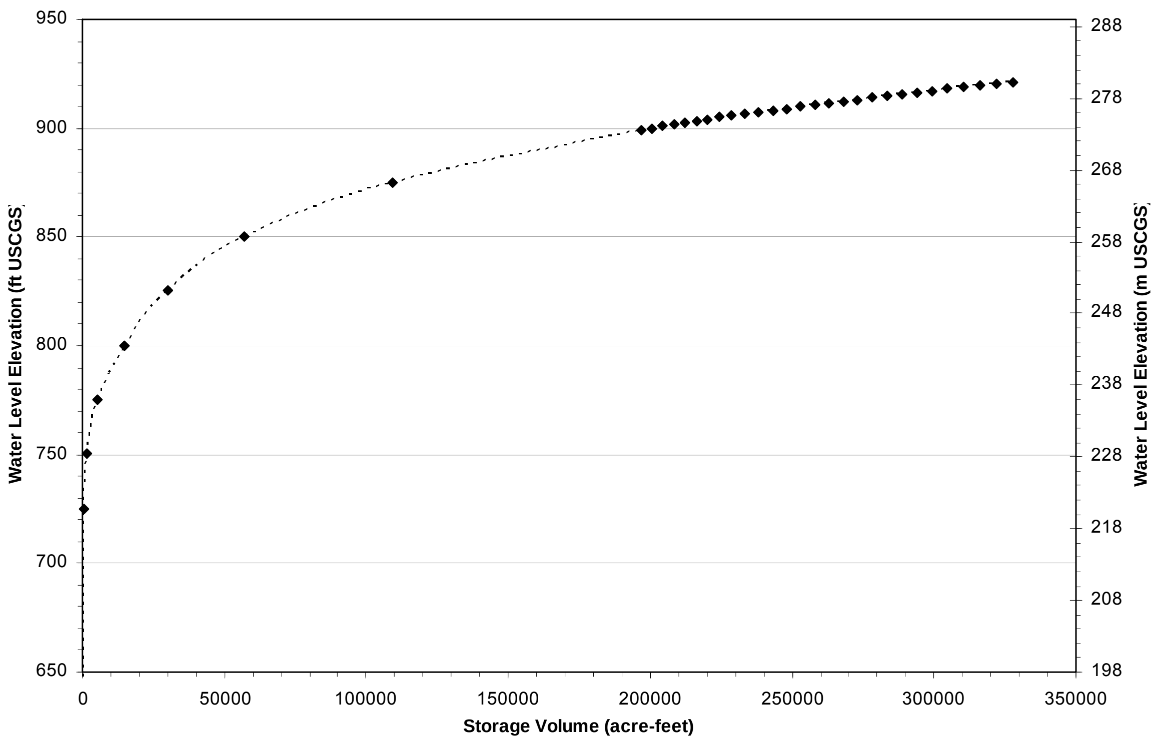

Figure 3.2 Osoyoos Lake storage volume capacity rating curve.

The rating curve indicates that under the specified operating water level range outlined within the Orders of Approval, Osoyoos Lake's volume ranges from approximately 247,700 acre-feet (305,500 dam^3) at an elevation of 909.0 ft (277.1 m) USCGS to approximately 272,100 acre-feet (335,600 dam^3) at an elevation of 913.0 ft (278.3 m) USCGS (Table 3.1). This results in a total volume of approximately 24,400 acre-feet (30,100 dam^3) of storage over the entire range of Osoyoos Lake's specified operating range. However, during normal operating conditions in the summer period (911.0 ft (277.7 m) to 911.5 ft (277.8 m) USCGS), the total volume of storage is only 3,200 acre-feet (4,000 dam^3). During drought conditions (910.5 ft (277.5 m) to 913.0 ft (278.3 m) USCGS) the storage volume is 15,300 acre-feet (18,900 dam^3).

Table 3.1 Osoyoos Lake storage volumes across the IJC's specified operating range.

Osoyoos Lake Elevation (ft USCGS)	Lake Volume (acre-feet)	Lake Volume (dam^3)
909.0	247,700	305,500
910.5	256,800	316,700
911.0	259,800	320,400
911.5	263,000	324,400
913.0	272,100	335,600

The amount of controllable lake storage is small, particularly under normal conditions, when a single day of inflow often approaches or exceeds the 3,200 acre-feet (4,000 dam^3) within the allowable 0.5 ft (0.15 m) range.

3.3 Storage Capacity Review

Lake outflows are managed through the operation of Zosel Dam. However, under high water conditions, the outflows can be restricted by backwater effects caused by the Similkameen River. With a small controllable storage capacity, high inflows, and restricted outflows, water levels will rise, which has frequently been observed in Osoyoos Lake. Due to the significant inflow contribution from the Okanagan River (with daily inflow volumes in the spring and summer sometimes greater than the total lake storage capacity available under normal conditions (Figure 3.3)), if the lake outflows are restricted by the Similkameen River, the lake levels can increase rapidly with no other management options available once the Zosel Dam gates are completely open. As a result, water levels will rise above the specified operating range (as seen in 1989, 1990, 1991, 1995, 1996, 1997, 1999, 2002, 2006, 2008) (Table 2.2).

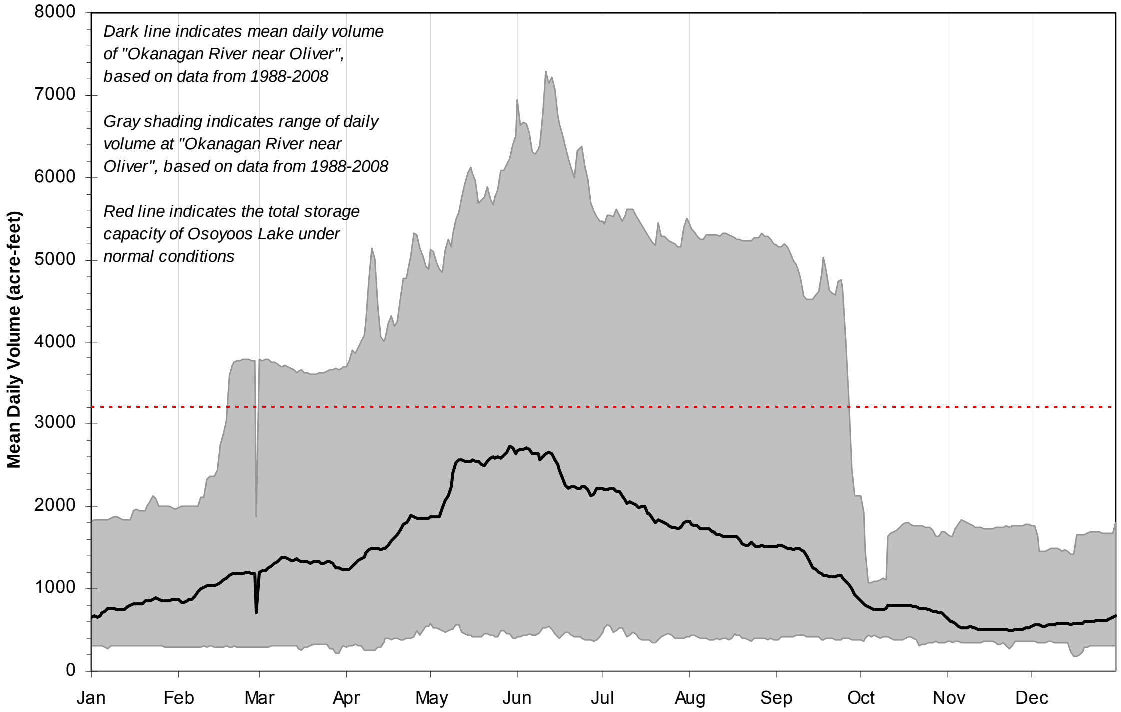

Figure 3.3 Mean daily volumes of Okanagan River near Oliver (WSC Station No. 08NM085), 1988-2008.

Under drought conditions, the available storage capacity of the lake is almost five times greater than it is under normal conditions. Accordingly, the lake is able to store more water within the specified operating range. Even under backwater conditions when outflows are restricted, there is generally enough storage capacity within the lake to allow for the management of water levels, as evidenced by no years with water levels outside the drought condition operating range from 1988-2008 (Table 2.2). As an example, in 1993, the operation of Zosel Dam was able to maintain water levels consistently below 912.5 ft (278.2 m) USCGS under high inflows (Figure 3.4).

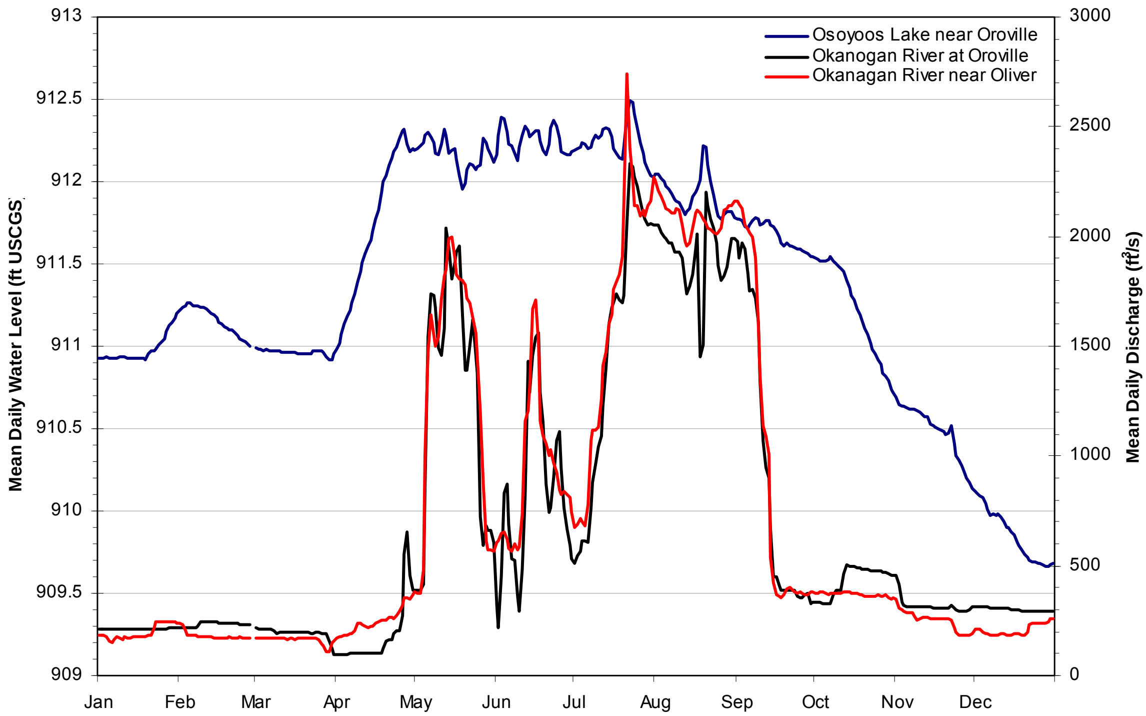

Figure 3.4 Osoyoos Lake water levels, Okanagan River inflows, and Okanogan River outflows in 1993 (a drought year).

4.0 OSOYOOS LAKE WATER BALANCE INVESTIGATION

To build upon the storage capacity review and the review of the 1988-2008 water levels, a water balance investigation of Osoyoos Lake was conducted to investigate the management of Zosel Dam to determine if other management strategies could have reduced high water magnitude, duration, and number of exceedances of the operating range during normal conditions. Scenarios were developed for the operation of Zosel Dam under normal conditions; no scenarios were included for drought conditions, as the review of Osoyoos Lake water levels (Section 2.4) indicated that Zosel Dam operations were able to manage water levels within the specified operating ranges. The water balance investigation focused on the years where the water levels were above 912.5 ft (278.2 m) USCGS (i.e. 1990, 1991, 1996, 1997, and 1999) (Table 2.2); since this was the level generally accepted by the IOLBC as the maximum level before the public begins to express concern. Although the upper limit of the normal operating range is 911.5 ft (277.8 m) USCGS, the assessment at 912.5

ft (278.2 m) USCGS allows the highest inflow years to be assessed, which have caused the greatest concern regarding the shoreline environment and structures. By assessing the years with the highest water levels, the results can be applied to all water levels.

4.1 General Water Balance

The general water balance for Osoyoos Lake can be represented by the following equation (each component expressed in units of volume):

$$\Delta S_{\text{Osoyoos Lake}} = P + Q_{in} + RF \pm GW - EVAP - WD - Q_{out} \qquad \text{Eq. 1.1}$$

where,

P = Precipitation;

Q_{in} = Surface runoff into Osoyoos Lake;

RF = Return Flow (accounting for any recycled use);

GW = Groundwater (groundwater recharge is negative and discharge is positive in Eq. 1.1);

EVAP = Lake Evaporation;

WD = Withdrawals (from all sources);

Q_{out} = Surface runoff out of Osoyoos Lake; and

$\Delta S_{\text{Osoyoos Lake}}$ = Change in lake storage (decrease in lake storage is negative and increase in lake storage is positive in Eq. 1.1).

As part of the OBWB's Okanagan Basin Water Supply and Demand Project, a significant amount of work was completed for water balance modeling of the entire Okanagan Basin using the MIKE SHE platform. The Okanagan Basin was divided into 81 points-of-interest, including tributary watersheds and residual areas (72 points in total), the mainstem lakes (5 points in total), and the Okanagan River (4 points in total). Water supply and demand estimates for the Okanagan Basin were generated by Dobson Engineering Ltd. (2008), groundwater flow estimates for aquifers within the Okanagan Basin were estimated by Golder Associates and Summit Environmental Consultants Ltd. (2009), naturalized inflow estimates for select streams within the Okanagan Basin were developed by Summit Environmental Consultants Ltd. (2009), and lake evaporation and precipitation estimates were provided by DHI Water and Environment (2009) (using data provided by Environment Canada and Agriculture and Agri-Foods Canada).

For the majority of the work completed for the OBWB, parameter estimates were provided as weekly totals or averages. However, OTID water extraction data was provided to Summit as total monthly volumes, while precipitation and lake evaporation data was provided as total daily values (RHF

Systems Ltd. 2009). Also, surface water inflow data by the Okanagan River, surface water outflow by the Okanogan River, and Osoyoos Lake water levels are available in a daily format from the WSC and USGS.

For this investigation, the water balance of Osoyoos Lake (Eq. 1.1) was simplified to (each component expressed in units of daily volume):

$$\Delta S_{Osoyoos\ Lake} = Q_{in} - (Q_{out} + WD_{OTID}) \pm \Delta WB \qquad \text{Eq. 1.2}$$

where,

Q_{in} = Surface runoff into Osoyoos Lake by the Okanagan River at the WSC gauge;

Q_{out} = Surface runoff out of Osoyoos Lake by the Okanogan River at the USGS gauge;

WD_{OTID} = Water extraction by the Oroville-Tonasket Irrigation District;

$\Delta S_{Osoyoos\ Lake}$ = Change in lake storage (decrease in lake storage is negative and increase in lake storage is positive in Eq. 1.2); and

ΔWB = Net change in the remaining water balance terms (this is a coefficient used to balance the water balance equation).

For the water balance (Eq 1.2), Q_{in} is represented by the Okanagan River (WSC Station No. 08NM085), Q_{out} is represented by the Okanogan River (USGS Station No. 12439500), WD_{OTID} is represented by water withdrawal data provided by the OTID, and $\Delta S_{Osoyoos\ Lake}$ is represented by Osoyoos Lake water level data (USGS Station No. 12439000) converted to lake volume using the storage capacity curve (Section 3.1.2). Finally, the ΔWB coefficient represents the remaining water balance value between precipitation, lake evaporation, groundwater inflow and outflow, return flows, inflows other than the Okanagan River, and water withdrawals other than by the OTID, for each daily time step.

4.2 WATER BALANCE SPREADSHEET MODEL

In order to use the Osoyoos Lake water balance as a tool to investigate the management of Zosel Dam, a spreadsheet model was developed. The model was developed in the format of Eq. 1.2; descriptions of model development, input parameters, and modeling constraints are provided in the following sections.

4.2.1 Model Development

The water balance spreadsheet model was developed in Microsoft Excel to allow for ease of replication of model runs and for its ability to house large quantities of data. The model was constructed on a daily time step in the form of Eq. 1.2. The model was developed so that outflows below Zosel Dam (Okanogan River at Oroville, WA; USGS Hydrometric Station, No. 12439500) could be manipulated. By constructing the model in this format, the role of Zosel Dam and its operation and management strategy could be assessed, since the variable being manipulated is largely a direct result of the dam operation. A digital example of the model is provided in Attachment 1.

4.2.2 Input Parameters

Each model run requires input parameters, as outlined by Eq. 1.2; the following describes how each parameter was obtained and/or calculated.

4.2.2.1 Osoyoos Lake Inflows, Outflows, and Change in Storage

As noted previously, the inflows into Osoyoos Lake by the Okanagan River (Q_{in}) are assumed to be represented by the WSC hydrometric station (No. 08NM085) "Okanagan River near Oliver", while outflows out of Osoyoos Lake (and by Zosel Dam) (Q_{out}) are assumed to be represented by the USGS hydrometric station (No. 12439500) "Okanogan River at Oroville, WA". All data is provided by the WSC and USGS in daily format.

For the change in Osoyoos Lake volume ($\Delta S_{Osoyoos\ Lake}$), lake levels were converted to a volume using the storage capacity rating curve (Section 3.1.2). For water balance purposes, the daily volumes were converted to a change in storage by determining the difference between lake volumes on successive days over the modeling period for each year of investigation.

4.2.2.2 Oroville – Tonasket Irrigation District Water Withdrawals

The OTID provided Summit with total monthly water withdrawal volumes from Okanogan River from 1998-99, 2001-04, and 2006-08 (Table 3.2). The monthly volumes were reduced to daily volumes assuming the same amount of water withdrawal occurred during each day of the month.

Table 4.1 Water Withdrawals by the OTID from the Okanogan River, 1998-2008.

Year	Volume	Apr	May	June	Jul	Aug	Sept	Oct	Total
1998	acre-feet	639	1,626	2,026	3,321	3,305	2,580	395	13,892
	dam^3	788	2,006	2,499	4,096	4,076	3,182	487	17,136
1999	acre-feet	560	1,344	2,713	2,915	3,212	2,203	686	13,633
	dam^3	691	1,657	3,346	3,595	3,961	2,717	846	16,816
2001	acre-feet	506	1,933	1,913	2,608	2,883	2,736	385	12,964
	dam^3	624	2,384	2,360	3,217	3,556	3,375	475	15,990
2002	acre-feet	529	1,484	2,550	3,027	3,023	2,178	519	13,310
	dam^3	653	1,830	3,145	3,734	3,728	2,687	640	16,417
2003	acre-feet	400	1,353	2,655	3,266	3,017	2,280	831	13,802
	dam^3	493	1,669	3,275	4,029	3,721	2,812	1,025	17,024
2004	acre-feet	995	1,718	2,460	2,974	2,660	1,558	650	13,015
	dam^3	1,227	2,119	3,034	3,668	3,281	1,922	801	16,054
2006	acre-feet	267	1,561	1,708	2,889	2,767	1,686	658	11,538
	dam^3	329	1,925	2,107	3,564	3,413	2,080	811	14,231
2007	acre-feet	944	1,850	1,891	2,466	2,644	1,955	452	12,202
	dam^3	1,164	2,282	2,333	3.042	3,261	2,411	558	15,051
2008	acre-feet	792	1,508	2,020	2,770	2,690	1,922	428	12,130
	dam^3	977	1,860	2,492	3,417	3,318	2,371	528	14,962

Note:

1. Water withdrawal data for 2000 and 2005 was not available.

Since the water withdrawal data provided by the OTID does not encompass the entire period of investigation, total annual withdrawals for the years without information were estimated by using water withdrawal information provided by the Town of Osoyoos from 1991-2008 (Brianne Gabrieau, pers. comm., 2009). The years of overlapping records between the OTID and the Town of Osoyoos were identified and the ratio of the annual value to the average of the overlapping records was determined for the Town of Osoyoos. This ratio was assumed consistent between the Town of Osoyoos and the OTID and was used to estimate OTID annual water withdrawals. The annual water withdrawals were reduced to monthly values using the average OTID monthly distribution reported; these values were reduced to daily values assuming the same amount of water withdrawal occurred during each day of the month.

4.2.3 Modeling Constraints

The release of water from Zosel Dam is constrained by flow release volumes (maximum and minimums), as well as flow releases during backwater conditions. In order to accurately model the operation of Zosel Dam, operational constraints were included within the model framework. The following sections describe each constraint.

4.2.3.1 Maximum Flow Release with No Backwater

The maximum flow that can be released by Zosel Dam, at any water level, occurs when all four gates are completely open and above the water surface and no backwater is present within the Okanogan River channel. An open flow (or un-gated) rating curve is provided by WSDOE (1990), which includes a separate rating curve for water levels above 913.0 ft (278.3 m) USCGS, when water begins to spill over the overflow weir. Rating equations were not provided by WSDOE (1990); however, values from the hardcopy curves (WSDOE 1990) were transposed to create Figure 4.1, which allowed for the development of the rating equations. The open flow rating curve describes the maximum flow that can be released by Zosel Dam when no backwater is present in the Okanogan River channel downstream.

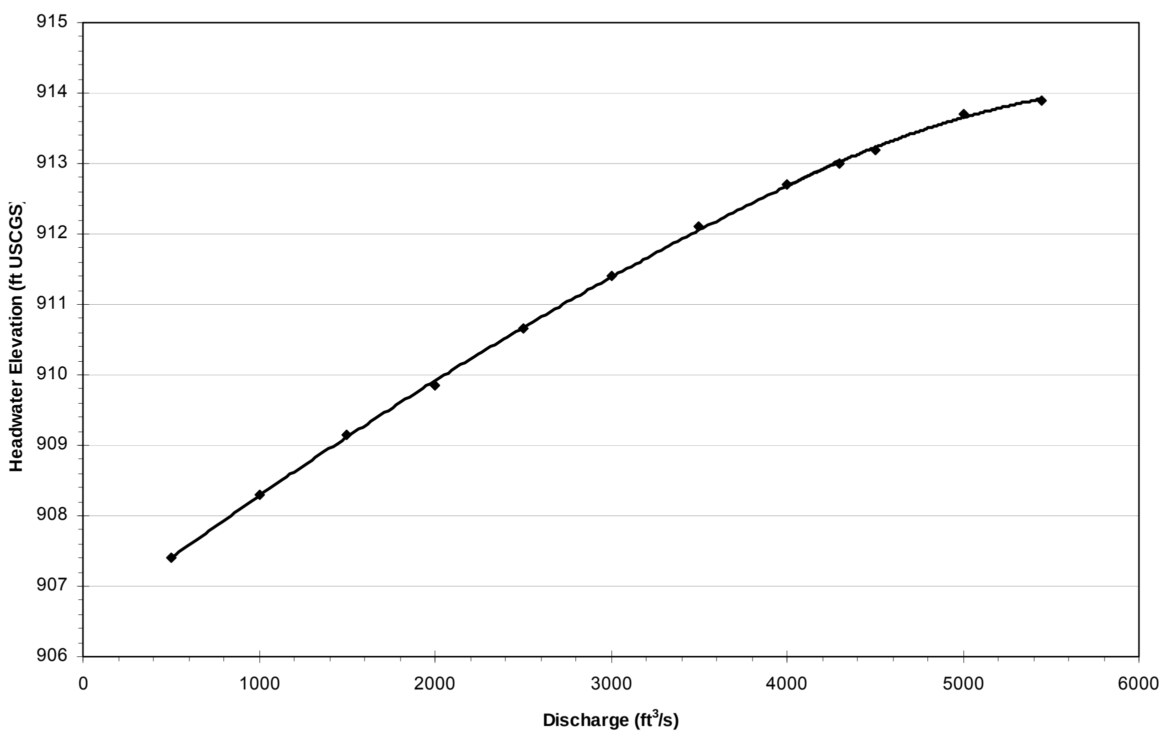

Figure 4.1 Zosel Dam open flow rating curve (from WSDOE (1990)).

4.2.3.2 Maximum Flow Release with Backwater

One of the biggest challenges to accurately model the operation of Zosel Dam is understanding the relationship between Osoyoos Lake, the Okanogan River, and the Similkameen River. As discussed earlier, during high water periods, the Similkameen River can cause backwater conditions within the Okanogan River channel due to the constriction of flows. As a result of the backwater conditions, outflows from Zosel Dam can be reduced, even when all the gates are completely open. This makes the open flow rating curve (Section 4.2.3.1) inaccurate for modeling under backwater conditions.

McNeil (1974) developed a method for predicting the outflow from Osoyoos Lake under Similkameen River backwater conditions requiring knowledge of the Similkameen River discharge and the level of Osoyoos Lake. This method was reasonably successful in simulating the extreme high water events that took place in 1948 and 1972; however, the curves produced by McNeil (1974) are out of date and are representative of conditions prior to the current location of Zosel Dam. As a result, the current relationship between Osoyoos Lake, the Okanogan River, and the Similkameen River was investigated for the period when backwater conditions were present within the Okanogan River and when Osoyoos Lake water levels were greater than 911.5 ft (277.8 m) USCGS. The water level elevation of 911.5 ft (277.8 m) USCGS was selected, as under backwater conditions during normal operation, the WSDOE (1990) indicates that the gates are to be lifted above the water level surface until the water level elevation returns to 911.5 ft (277.8 m) USCGS (Table 2.1).

In order to begin to understand the backwater relationship, all IJC annual reports were reviewed to identify periods of backwater within the Okanogan River under normal conditions. The relationship between the Okanogan River outflow from Zosel Dam and Osoyoos Lake water levels greater than 911.5 ft (277.8 m) USCGS, under backwater conditions is presented in Figure 4.2. The relationship between the Okanogan River outflow from Zosel Dam under backwater conditions and Similkameen River discharges is presented in Figure 4.3. Envelope curves are included in Figures 4.2 and 4.3; the variability below the curves is a result of backwater effects from the Similkameen River (Figure 4.2) and variable lake levels (Figure 4.3), as well Zosel Dam operation. In Figure 4.3, a step is present at Similkameen River discharges >10,000 ft^3/s (283 m^3/s); this is normally the discharge at which backwater has been suggested to occur within the Okanogan River (IJC 2000).

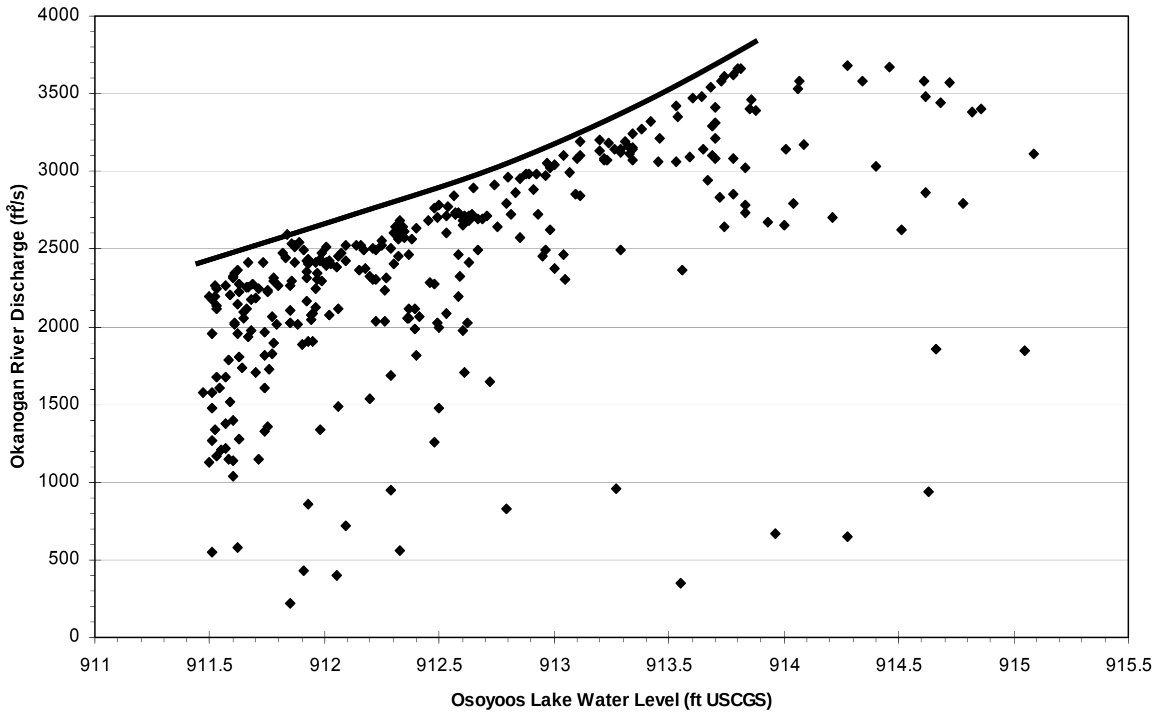

Figure 4.2 Okanogan River discharge and Osoyoos Lake water level (>911.5 ft (277.8 m) USCGS) relationship under backwater conditions and normal operations, 1988-2008.

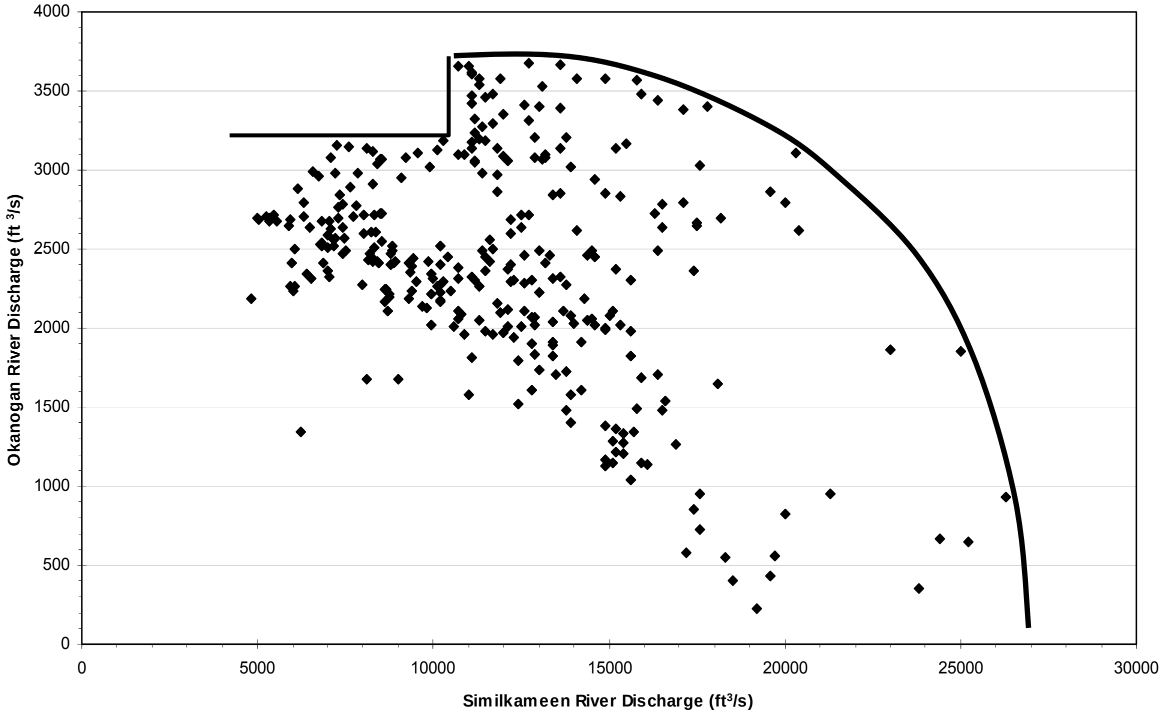

Figure 4.3 Okanogan River and Similkameen River discharge relationship under backwater conditions and normal operations, 1988-2008.

Due to the complexity of the backwater relationship within the Okanogan River, multiple regression was used to estimate Okanogan River outflows under backwater conditions (under normal operating conditions) based on Osoyoos Lake water levels and Similkameen River discharge. Using the data presented in Figures 4.2 and 4.3, the multiple regression equation for predicting Okanogan River discharges under backwater conditions is as follows:

$$Q_{Okanogan\ River} = 695.5(WL_{Osoyoos\ Lake}) - 0.14(Q_{Similkameen\ River}) - 630703.8 \qquad \text{Eq. 1.3}$$

where,

$Q_{Okanogan\ River}$ = Okanogan River discharge under backwater conditions (ft^3/s);

$WL_{Osoyoos\ Lake}$ = Osoyoos Lake water level (ft USCGS); and

$Q_{Similkameen\ River}$ = Similkameen River discharge (ft^3/s).

The coefficient of determination (R^2) between the observed and predicted Okanogan River discharges using Eq. 1.3 is 0.83 and the observed and predicted relationship is shown graphically in Figure 4.4.

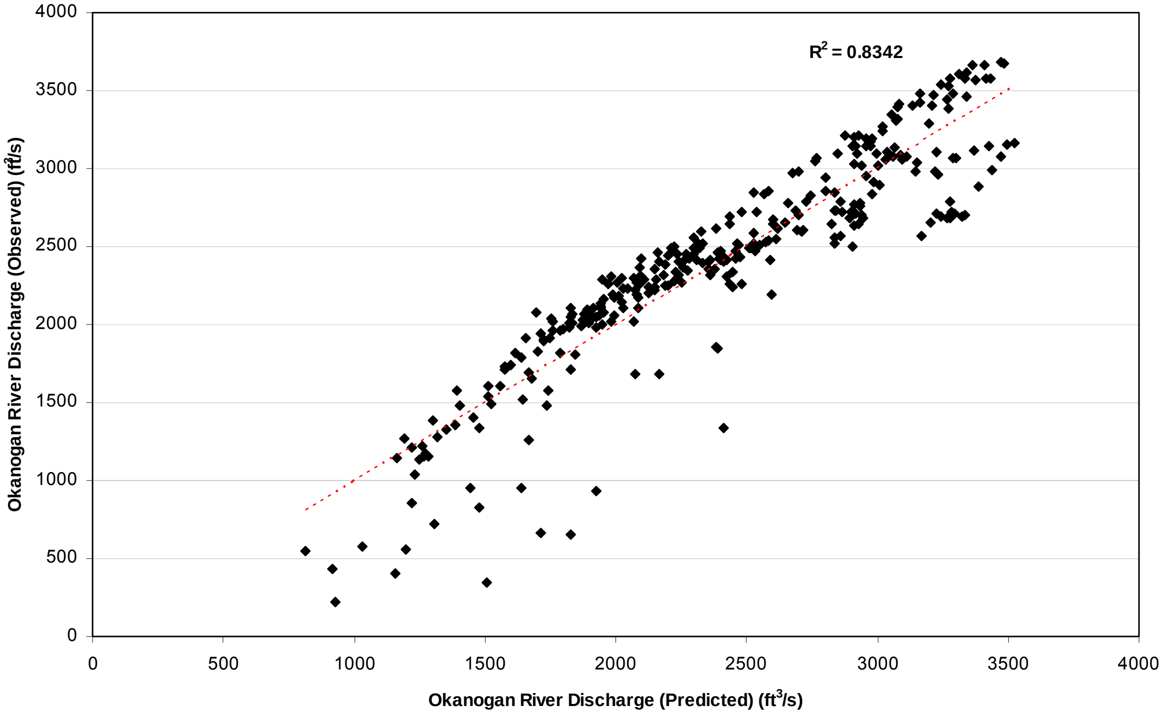

Figure 4.4 The relationship between observed and predicted (using multiple regression) Okanogan River discharges under backwater conditions.

The Okanogan River discharge estimated by Eq. 1.3 represents the maximum flow release from Zosel Dam under backwater conditions, when the gates are completely open. For Osoyoos Lake water levels below 911.5 ft (277.8 m) USCGS, Eq. 1.3 does not predict the operation of Zosel Dam if backwater is present within the Okanogan River channel. However, since Eq. 1.3 is used to estimate maximum flow releases when Zosel Dam gates are completely open, the assumption is made that for water levels below 911.5 ft (277.8 m) USCGS, Eq. 1.3 still estimates the maximum flow release if the gates were lifted clear of the water surface.

4.2.3.3 Minimum Flow Release

Minimum flow releases are based on fish flow requirements within the Okanogan River channel downstream of Zosel Dam; the fish flow requirements are outlined within Table 2.1. For modeling purposes, the minimum flow release of Zosel Dam is used to constrain the lower end of Zosel Dam's operation.

4.3 MODELING SCENARIOS

All input data was included within the spreadsheet model for each select year (1990, 1991, 1996, 1997, and 1999) and the model was calibrated to ensure proper function by comparing the model results to the actual water level records of Osoyoos Lake. Once calibrated, scenarios were selected to identify what would have happened to the Osoyoos Lake water levels if the dam had operated differently during each select year. The three scenarios used for this investigation are as follows:

1. Modeling the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 911.0 ft (277.7 m) USCGS prior to and during spring freshet;
2. Modeling the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 911.25 ft (277.75 m) USCGS prior to and during spring freshet; and
3. Modeling the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 909.25 ft (277.14 m) USCGS prior to and during spring freshet. The 909.25 ft (277.14 m) USCGS water level is the lowest recorded mean daily water level of Osoyoos Lake from 1988-2008; this water level represents an extreme modeling scenario.

These scenarios were developed to maximize the storage capacity of Osoyoos Lake prior to spring freshet. For each scenario, an assumption was made that on April 1st, the IOLBC declares normal or drought conditions for each individual year, thereby allowing for water to be released meeting the stated scenario.

4.4 MODELING RESULTS

The spreadsheet model was applied to the summer operating periods for 1990, 1991, 1996, 1997, and 1999. These years represented the highest water levels during spring freshet and included periods with water levels above 912.5 ft (278.1 m) USCGS. The results of each modeling scenario for each year under investigation are presented in Figures 4.5 and 4.6; the individual model runs for each year are provided digitally in Attachment 1. The details of each modeling run (for each year) are discussed below.

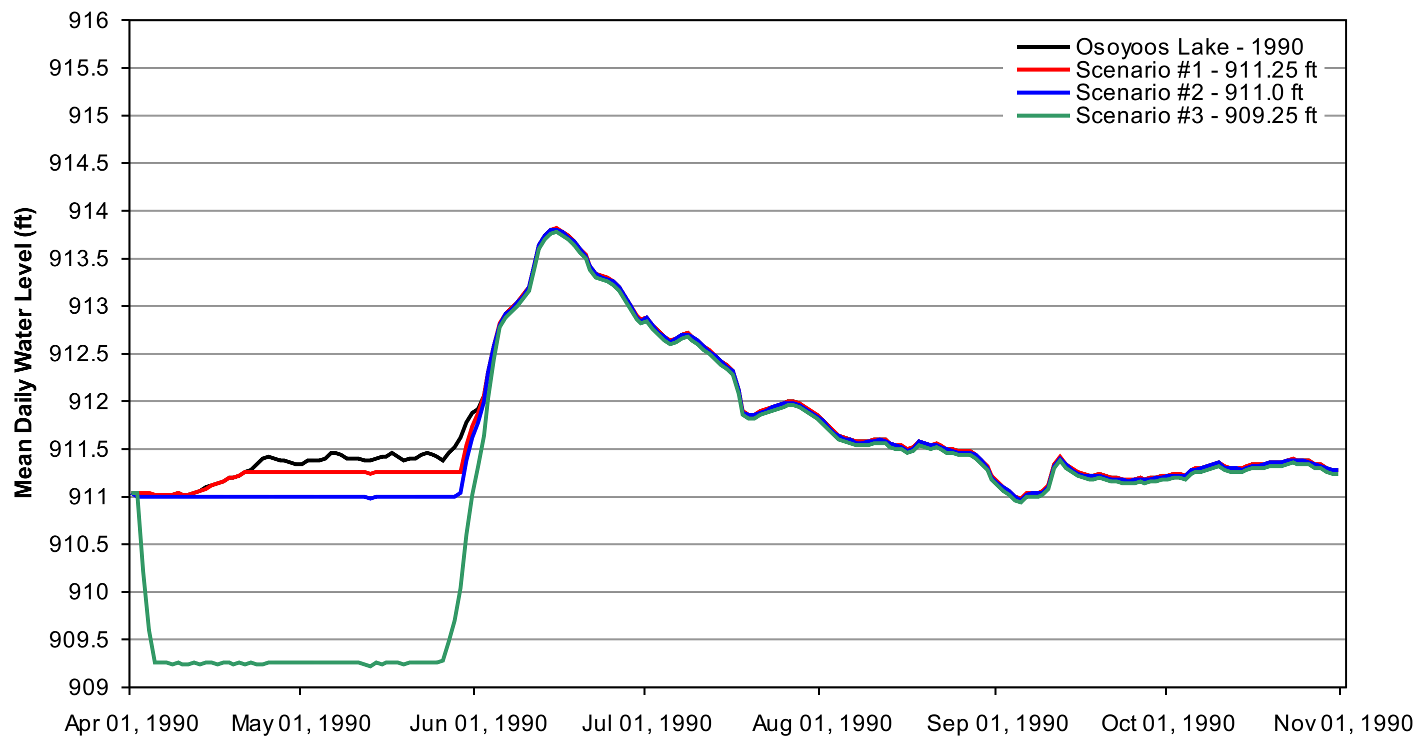

Figure 4.5(a): 1990 Osoyoos Lake water levels, including modeling scenarios 1, 2, and 3.

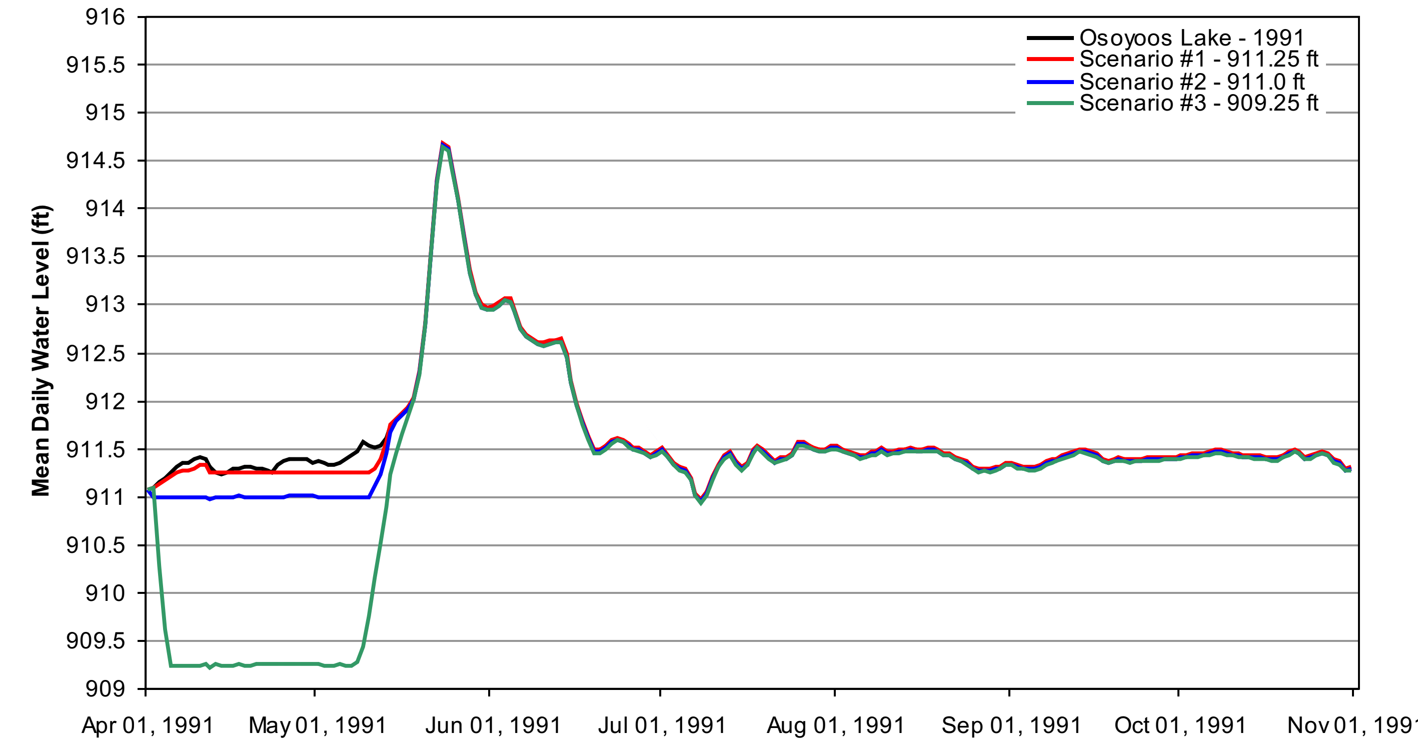

Figure 4.5(b): 1991 Osoyoos Lake water levels, including modeling scenarios 1, 2, and 3.

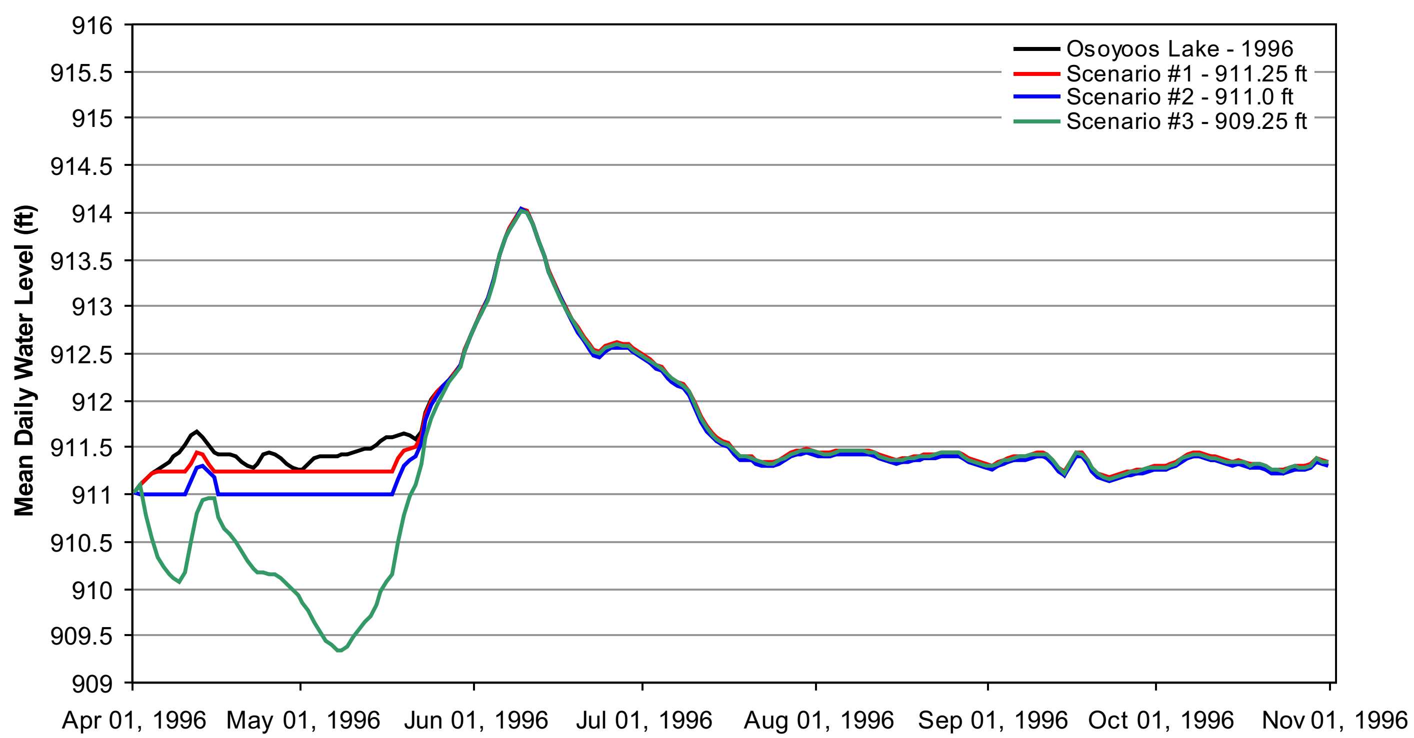

Figure 4.5(c): 1996 Osoyoos Lake water levels, including modeling scenarios 1, 2, and 3.

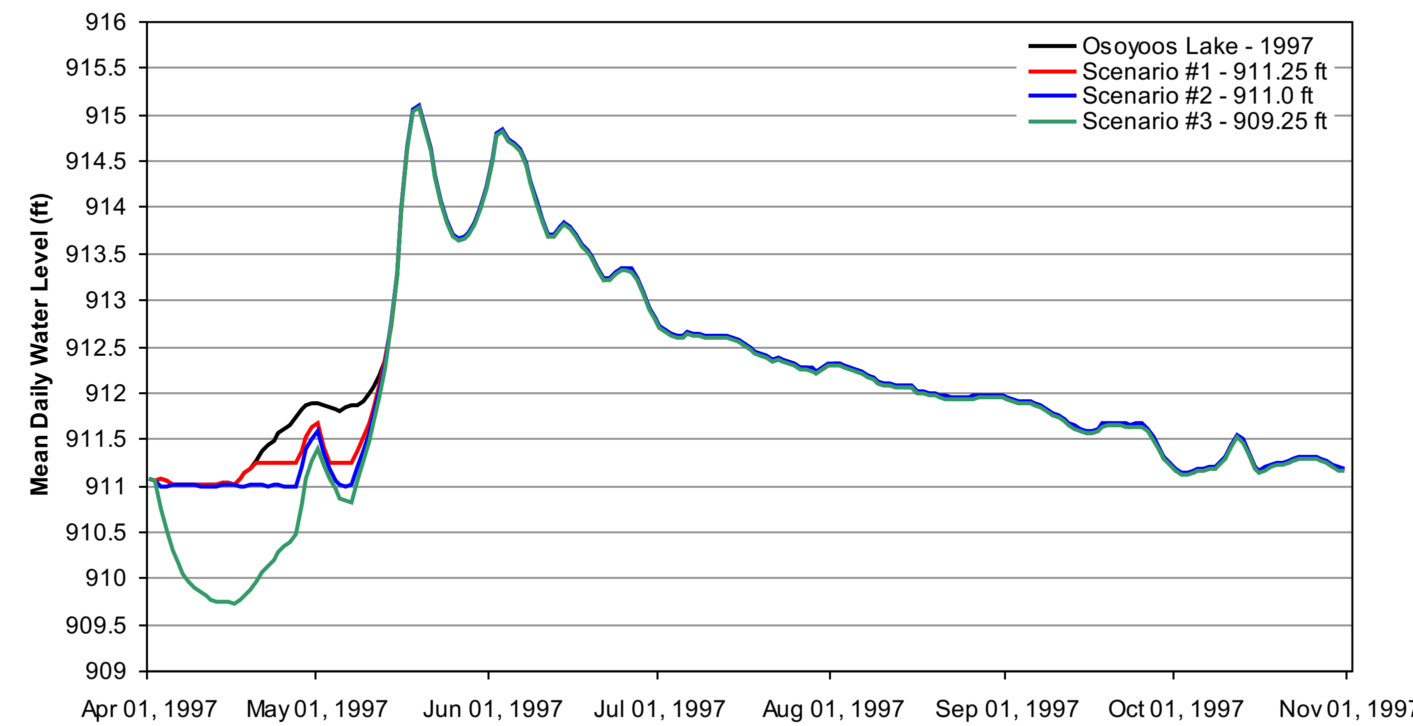

Figure 4.5(d): 1997 Osoyoos Lake water levels, including modeling scenarios 1, 2, and 3.

DATE: **March 2010**

DRAWN BY: **DL**

DATA SOURCE(S):

SUMMIT
ENVIRONMENTAL CONSULTANTS INC.
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PREPARED FOR: **International Joint Commission**

PROJECT: **Osoyoos Lake**

PROJECT NO.: **2009-8501.010**

DRAWNING NO. **1 of 1**

FILE: **Figure 4.4.cdr**

**FIGURE 4.5:
Modeling results of select scenarios for 1990, 1991, 1996, and 1997.**

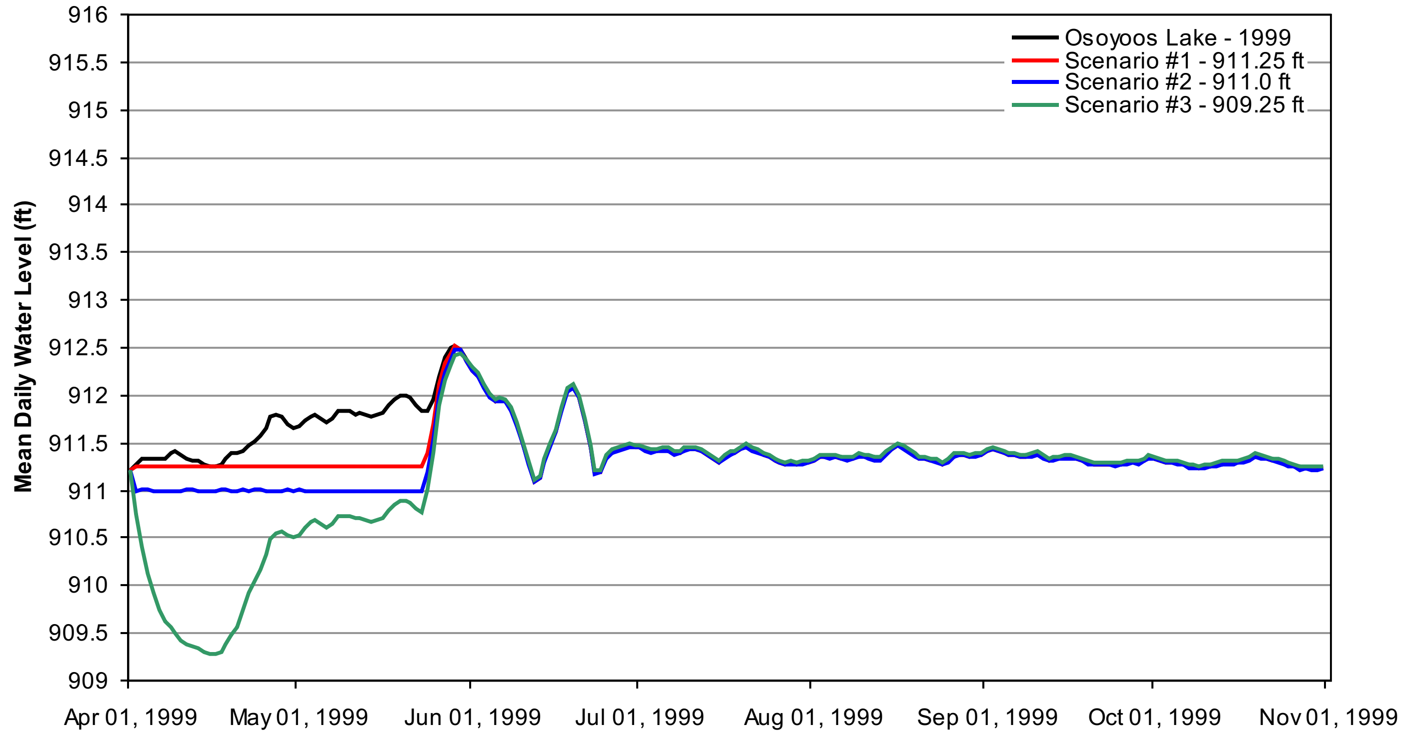

Figure 4.6(a): 1999 Osoyoos Lake water levels, including modeling scenarios 1, 2, and 3.

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DATA SOURCE(S):	

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PREPARED FOR: **International Joint Commission**

PROJECT: **Osoyoos Lake**

PROJECT NO.:	2009-8501.010
DRAWNING NO.	1 of 1
FILE:	Figure 4.5.cdr

FIGURE 4.6: Modeling results of select scenarios for 1999.

4.4.1 1990 High Water Modeling

The modeling results for 1990 are presented in Figure 4.5a. For each specific scenario, starting April 1st water was released from Zosel Dam (i.e. Okanogan River outflows), within modeling constraints, until the specific water level was achieved. Water was continually released, or held back at Zosel Dam in an attempt to maintain water levels and meet each specific scenario requirement. Once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all these scenarios, the modeled water levels ended up catching up to the actual water levels recorded in 1990. Once the modeled water levels caught up to the actual levels, the actual Zosel Dam releases were used for the rest of the modeling period[1].

Each scenario result indicated that peak water levels could not be reduced. However, the model suggested that by maintaining water levels at 909.25 ft (277.14 m) USCGS prior to the freshet, Osoyoos Lake water levels could have been held within the specific operating range an additional five days. Additionally, while maintaining water levels at 911.25 ft (277.75 m) and 911.0 ft (277.7 m) USCGS, Osoyoos Lake could have been held within the operating range an additional two and three days, respectively.

Zosel Dam gate operational notes were provided by the OTID to confirm gate operations prior to spring freshet; however, operational notes for 1990 were not available.

4.4.2 1991 High Water Modeling

The modeling results for 1991 are presented in Figure 4.5b; the modeling methodology for 1991 followed that described in Section 4.4.1. The results were similar to that in 1990; once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all scenarios in 1991, the modeled water levels caught up to the

[1] During the freshet, the goal of the management of Zosel Dam is to reduce water levels to within the normal operating range; therefore, the gates would be completely open. Once the modeled water levels caught up to the actual water levels, no more water could theoretically be released than was actually recorded. However, once the freshet passed and water levels fell to within the specified operating range, management of Zosel Dam was able to maintain the water levels within the range; therefore, no additional modeling was required.

actual 1991 recorded water levels. Similarly, once the modeled water levels caught up to the actual levels, the actual Zosel Dam releases were used for the rest of the modeling period.

Each scenario result indicated that peak water levels could not be reduced. However, the model suggested that by maintaining water levels at 909.25 ft (277.14 m) USCGS prior to the freshet, Osoyoos Lake water levels could have been held within the specific operating range an additional seven days. Additionally, while maintaining water levels at 911.25 ft (277.75 m) and 911.0 ft (277.7 m) USCGS, Osoyoos Lake could have been within the operating range an additional four and five days, respectively.

Zosel Dam gate operational notes indicated that all four gates were not completely open and above the water surface until May 10, 1991 (OTID 1991). This indicates that more water could have been released prior the spring freshet in 1991, which agrees with each model scenario.

4.4.3 1996 High Water Modeling

The modeling results for 1996 are presented in Figure 4.5c; the modeling methodology for 1996 followed that outlined for 1990 and 1991. The results were similar to the previous years; once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all scenarios in 1996, the modeled water levels ended up catching up to the actual 1996 recorded water levels. Similarly, once the modeled water levels caught up to the actual levels, the actual Zosel Dam releases were used for the rest of the modeling period.

Similar to the modeling of 1990 and 1991, the results indicated that peak water levels could not be reduced under any scenario; however, the model suggested that by maintaining water levels at 909.25 ft (277.14 m) USCGS prior to the freshet, Osoyoos Lake water levels could have been within the specific operating range an additional nine days. Additionally, by maintaining water levels at 911.25 ft (277.75 m) and 911.0 ft (277.7 m) USCGS, Osoyoos Lake could have been within the operating range an additional six and eight days, respectively.

Zosel Dam gate operational notes indicated that all four gates were not completely open and above the water surface until May 13, 1996 (OTID 1996). This indicates that more water could have been released prior to the spring freshet in 1996, which agrees with each model scenario.

4.4.4 1997 High Water Modeling

The modeling results for 1997 are presented in Figure 4.5d; the modeling methodology for 1997 followed that outlined for 1990, 1991, and 1996. The results were similar to the previous years; once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all scenarios in 1997, the modeled water levels ended up catching up to the actual 1997 recorded water levels. Similarly, once the modeled water levels caught up to the actual levels, the actual Zosel Dam releases were used for the rest of the modeling period.

Similar to the modeling of 1990, 1991, and 1996, the results indicated that peak water levels could not be reduced under any scenario; however, the model suggested that by maintaining water levels at 909.25 ft (277.14 m) USCGS prior to the freshet, Osoyoos Lake water levels could have been within the specific operating range an additional seventeen (17) days. Additionally, while maintaining water levels at 911.25 ft (277.75 m) and 911.0 ft (277.7 m) USCGS, Osoyoos Lake could have been within the operating range an additional twelve (12) and fourteen (14) days, respectively.

Zosel Dam gate operational notes do not indicate when all four gates were completely open and above the water surface; however, the operational notes indicate that on April 29, 1997 all four gate openings were six feet, while on May 16, 1997, the gate openings were eight feet (OTID 1997). The OTID indicated that the maximum opening of all gates is eight feet (Tom Davis, pers. comm., 2009). Without more information regarding the gate openings and the time at which they were above the water surface, the assumption is made that more water could have been released prior the spring freshet in 1997. Even if this assumption is incorrect, the overall result will not change, as both the actual and modeled peak water levels did not change. However, the number of days that the model suggests water levels could have been within the specific operating range would be incorrect.

4.4.5 1999 High Water Modeling

The modeling results for 1999 are presented in Figure 4.6a; the modeling methodology for 1999 followed that outlined for 1990, 1991, 1996, and 1997. The results were similar to the previous years; once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all scenarios in 1999, the modeled water levels ended up catching up to the actual 1999 recorded water levels. Similarly, once the modeled water levels caught up to the actual levels, the actual Zosel Dam releases were used for the rest of the modeling period.

Similar to the modeling of 1990, 1991, 1996, and 1997, the results indicated that peak water levels could not be reduced under any scenario; however, the model suggested that by maintaining water levels at 909.25 ft (277.14 m) USCGS prior to the freshet, Osoyoos Lake water levels could have been within the specific operating range an additional thirty-three (33) days. Additionally, while maintaining water levels at 911.25 ft (277.75 m) and 911.0 ft (277.7 m) USCGS, Osoyoos Lake could have been within the operating range an additional thirty-two (32) days, respectively.

Zosel Dam gate operational notes indicate that all four gates were completely open and above the water surface on May 16, 1999; however, the operational notes indicate that on April 23, 1999 all four gate openings were five feet, and again on April 29, 1999, the gate openings were five feet (OTID 1999). It is not known if the gates were above the water surface for the dates in April; therefore, without more information regarding the gate openings and the time at which they were above the water surface, the assumption is made that more water could have been released prior the spring freshet in 1999. As indicated previously (Section 4.4.5), even if this assumption is incorrect, the results still indicate that the peak water levels can not be reduced; however, the number of days that the model suggests water levels could have been within the specific operating range would be incorrect.

4.5 MODELING RESULTS SUMMARY

Based on the water balance modeling investigation, the results are summarized as follows:

1. Three scenarios were chosen to assess the operation of Zosel Dam; each scenario was selected in an attempt to maximize the storage capacity of Osoyoos Lake prior to spring freshet in normal years. The scenarios proposed the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 909.25 ft (277.14 m), 911.0 ft (277.7 m), and 911.25 ft (277.75 m) USCGS prior to and during spring freshet;
2. The water balance spreadsheet model was applied to the summer operating periods for 1990, 1991, 1996, 1997, and 1999 for each scenario, as these years produced the highest water levels during spring freshet, including periods with water levels above 912.5 ft (278.1 m) USCGS. Although the upper limit of the normal operating range is 911.5 ft (277.8 m) USCGS, the assessment at 912.5 ft (278.2 m) USCGS allowed for the highest inflow years to be assessed, which have caused the greatest concern regarding the shoreline environment and structures;

3. Using the water balance spreadsheet model for each specific scenario (and for each year investigated), starting April 1st water was released from Zosel Dam (i.e. Okanogan River outflows). Water was continually released, or held back at Zosel Dam in an attempt to maintain water levels and meet each specific scenario requirement. Once the freshet began, Zosel Dam releases became restricted both through backwater conditions present within the Okanogan River channel and because lower volumes of water are released by Zosel Dam at lower lake elevations. As a result, under all scenarios for all years, the modeled water levels ended up catching up to the actual recorded water levels during the peak water level periods; and
4. The results indicated that by maximizing the storage potential of Osoyoos Lake prior to spring freshet, some additional storage could be obtained to keep water levels within the specified ranges for a few more days; however, the peak water levels can not be reduced. This is largely a result of backwater conditions within the Okanogan River channel restricting outflow from Zosel Dam. Therefore, any alternate management strategies at Zosel Dam during the years in question would still have resulted in the high water levels observed.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

Based on the Osoyoos Lake water level review, storage capacity assessment, and the water balance investigation, we conclude the following:

1. In the past, lake levels have exceeded the specified range because under high inflow conditions, outflows from Zosel Dam are restricted by backwater caused by the Similkameen River, and because the specified acceptable range is very narrow (0.5 feet);
2. The review of the Osoyoos Lake water levels indicated that from 1988 to 2008, Osoyoos Lake has been outside of its operating range in ten of those years (for variable lengths of time). The highest water levels occurred in 1990, 1991, 1996, and 1997, when peak water levels were above 913.0 ft (278.3 m) USCGS, under normal operating conditions. During these peak years, actual inflows into Okanagan Lake and flows within the Similkameen River were some of the highest on record. From 1988 to 2008, Osoyoos Lake only exceeded its operating range under normal conditions (exceedances occurred 21% of the time under normal conditions); under drought conditions, the operation of Zosel Dam was capable of maintaining water levels within specified operating ranges;

3. The total storage capacity of Osoyoos Lake over the entire range of Osoyoos Lake's specified operating range is approximately 24,400 acre-feet (30,100 dam^3). However, during normal and drought operating conditions in the summer period, the total volume of storage is reduced to approximately 3,200 acre-feet (4,000 dam^3) and 15,300 acre-feet (18,900 dam^3), respectively;
4. A water balance investigation of Osoyoos Lake was conducted to investigate the management of Zosel Dam to determine if other management strategies could have reduced the high water levels during normal conditions. The water balance investigation focused on the years in which the water levels were above 912.5 ft (278.2 m) USCGS (i.e. 1990, 1991, 1996, 1997, and 1999); since this is the level generally accepted by the IOLBC as the maximum level before the public begins to express concern about high water levels;
5. A water balance spreadsheet model was developed to assess the role of Zosel Dam and its operation and management strategy. The model was developed on a daily time step so that outflows below Zosel Dam (Okanogan River at Oroville, WA; USGS Hydrometric Station, No. 12439500) could be manipulated, since this variable is a direct result of the dam operation;
6. Three scenarios were chosen to assess the operation of Zosel Dam; each was selected in an attempt to maximize the storage capacity of Osoyoos Lake prior to spring freshet. The scenarios proposed the adoption of lake level guidelines whereby once normal conditions have been declared by the IOLBC, water levels of Osoyoos Lake are to be kept as close as possible to 909.25 ft (277.14 m), 911.0 ft (277.7 m), and 911.25 ft (277.75 m) USCGS prior to and during spring freshet; and
7. The modeling results indicated that by maximizing the storage potential of Osoyoos Lake prior to spring freshet, some additional storage could be obtained to keep water levels within the specified ranges for a few more days each spring; however, the peak water levels could not be reduced. This is largely a result of backwater conditions within the Okanogan River channel restricting outflow from Zosel Dam. As a result, alternate management of Zosel Dam during the years in question would still have resulted in the high water levels observed.

5.2 RECOMMENDATIONS

Based on the Osoyoos Lake water level review, storage capacity assessment, and the water balance investigation, Summit recommends the following in an attempt to optimize the storage potential in Osoyoos Lake in the future in order to minimize high water events, while accounting for other stakeholders and the aquatic environment:

1. The IOLBC indicated that public concerns generally begin when lake levels rise above 912.5 ft (278.2 m) USCGS. Therefore, during drought conditions, the WSDOE and MOE should

continue the practice of establishing an informal agreement for a maximum Osoyoos Lake water level of 912.5 ft (278.1 m) USCGS.

2. Under normal conditions, and with a low risk of future drought conditions, operators should maintain water levels near the lower limit of the specified operating range (911.0 ft (277.7 m) USCGS) prior to and throughout the spring freshet. This will minimize the period of time for which the lake is at risk of exceeding its target operating range in the summer period. However, if there is a risk that a drought will subsequently be declared, operators should balance the desire to maintain an acceptable lake level for a longer period against the risk that sufficient storage might not be available in a subsequent drought condition. In this case, a higher level within the 911.0 to 911.5 foot USCGS operating range should be targeted.
3. Modeling indicated that the backwater effect caused by the Similkameen River largely dictates the outflow from Osoyoos Lake. As a result, additional management strategies other than the operation of Zosel Dam are required in order to reduce high water levels under normal conditions and high Similkameen River discharges. McNeil (1974) reported similar results and suggested that the only way to control high water levels in Osoyoos Lake would be by controlling the Similkameen River. As a result, an investigation into potential storage opportunities on the Similkameen River should be undertaken if it is considered desirable to reduce peak levels in normal years.
4. It is recommended that an additional study be conducted to investigate the potential for managing storage in Okanagan, Skaha, and Vaseux Lakes, to reduce high water levels in Osoyoos Lake.

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Attachment 1: Osoyoos Lake Spreadsheet Model