



International Osoyoos Lake Board of Control

2021 Annual Report to the International Joint Commission



Cover photo:

Aerial photograph taken at 11:15 am PST on November 17, 2021. Muddy water from the Similkameen River that flowed upstream into the Okanogan River and Osoyoos Lake in contrasts with clear water in Osoyoos Lake.

(credit: Mary Davisson, Fisheries Biologist, Confederated Tribes of the Colville Reservation, at the outlet of Osoyoos Lake to the Okanogan River north of Oroville, Washington).

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EXECUTIVE SUMMARY

This report documents the activities of the International Osoyoos Lake Board of Control (IOLBC or Board), hydrologic and climatic conditions of the Okanagan/Okanogan and Similkameen basins, and compliance of the Applicant to the International Joint Commission (IJC or Commission) Orders of Approval for Osoyoos Lake during 2021. The Board, comprised of ten members with equal representation from Canada and the U.S., was established on September 12, 1946 by the IJC to carry out the provisions of the Commission's Order of Approval. In 2021, the Board operated under the authority of the Commission's Supplementary Order dated January 29, 2013.

To fulfill its mandate, the Board's efforts are focused on water-level management issues related to the operation of Zosel Dam, located on the Okanagan (Canadian spelling)/Okanogan (U.S. spelling) River about 1.6 mi (2.6 km) downstream from the outlet of Osoyoos Lake, a water body that straddles the international boundary between Canada and the United States. Zosel Dam is owned by Washington State, which is referred to as the Applicant in the IJC Orders and this annual report. The dam is operated by the Oroville-Tonasket Irrigation District under authority of the Washington State Department of Ecology (WADOE).

During 2021, the Board held quarterly teleconferences, hosted virtual annual Board and Public meetings, and briefed IJC Commissioners during the virtual spring and fall semi-annual meeting to fulfill its mandate from the IJC to oversee the IJC Orders for Osoyoos Lake. The Board also oversaw several special projects including 1) the development of a hydrologic model of current and future conditions of the Similkameen River Basin to understand and plan for the effects of climate change within the Similkameen River Basin and potential impacts on the IJC Orders for Osoyoos Lake and 2) a bathymetric survey of Osoyoos Lake and parts of the Okanogan and Similkameen Rivers. The Board also developed proposals to fund the integration of the Similkameen River model with an existing hydrologic model of the Okanagan/Okanogan Basin to assess and plan for the effects of projected climatic changes within the Okanogan River Basin on the IJC Orders of Osoyoos Lake. A second proposal was developed by the Board to assess the history and environmental conditions contributing to the formation of ice jams on Osoyoos Lake. Finally, the Board oversaw the planning of the Osoyoos Lake Science Forum, which has been rescheduled for fall 2022 in Osoyoos, BC.

Hydroclimatic conditions were near-normal through the early to mid-winter period. After February however, drier than normal conditions prevailed throughout the basin until the fall, with above-normal temperatures occurring from June through August and with extremely high temperatures during the late-June heat dome event. Snowpack in the Similkameen and Okanagan/Okanogan basins were near normal for most of the winter but decreased below normal in response to drier conditions during the late winter and spring. Only one of the three drought criteria for the IJC Orders for Osoyoos Lake, Condition 8bii, was met (Okanogan Lake

level was below 1,122.6 ft) so a drought was not declared for purposes of the Orders in 2021. Although no significant peaks occurred during the spring freshet on the Similkameen River, cumulative runoff exceeded the 1,000,000 acre-feet drought criterion. Net inflow to Okanogan Lake became negative about a month earlier than usual due to warm temperatures but cumulative net inflow during June and July (195,000 acre-feet) defined by the drought criterion within the IJC Orders for Osoyoos Lake was exceeded. During 2021, Osoyoos Lake level was within the rule curve and no peak from the spring freshet was present and no backwater conditions from the Similkameen River occurred during the spring freshet. Finally, discharge capacity of the Okanogan River (2,500 cfs) when Osoyoos Lake level is 913 feet and no backwater occurs was not able to be demonstrated in 2021.

In mid-November, landfall of a Category 5 atmospheric river resulted in flooding within the Similkameen River basin and a peak discharge measured at the USGS Similkameen River at Nighthawk gage of 26,900 cubic feet per second (cfs) (762 cubic meters per second (cms)) on November 16th. High Similkameen River discharge coupled with relatively low Osoyoos Lake elevation during this event resulted in a reversal of flow of the Okanogan River on November 16, a historically unprecedented event during the fall; all previously recorded occurrences of flow reversal occurred during the spring freshet.

LIST OF ACRONYMS

IJC	International Joint Commission
IOLBC	International Osoyoos Lake Board of Control
IWI	International Watersheds Initiative
OBWB	Okanagan Basin Water Board
USGS	U.S. Geological Survey
ECCC	Environment and Climate Change Canada
USACE	U.S. Army Corps of Engineers
WADOE	Washington State Department of Ecology
BCFLNRORD	BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development
OTID	Oroville-Tonasket Irrigation District

LOCATION OF OSOYOOS LAKE

Osoyoos Lake is a 10-mile (16-km) long by 1-mile (1.6-km) wide lake that spans the international boundary between Canada and the United States in southcentral British Columbia and northcentral Washington state (Figure 1). The Okanogan River flows into Osoyoos Lake north of Osoyoos, BC, and is largely regulated by Okanogan Lake Dam operations. During normal hydrologic conditions, outflow from Osoyoos Lake into the Okanogan River is controlled by the operation of Zosel Dam about 1.6 mi (2.6 km) downstream from the outlet of Osoyoos Lake. During periods of high runoff, the Similkameen River may cause backwater of the Okanogan River at which point the stage of the Similkameen River controls outflow from Osoyoos Lake. The Similkameen River's watershed is mostly within Canada, but two of its headwaters tributaries, the Pasayten and Ashnola rivers, originate in the United States.

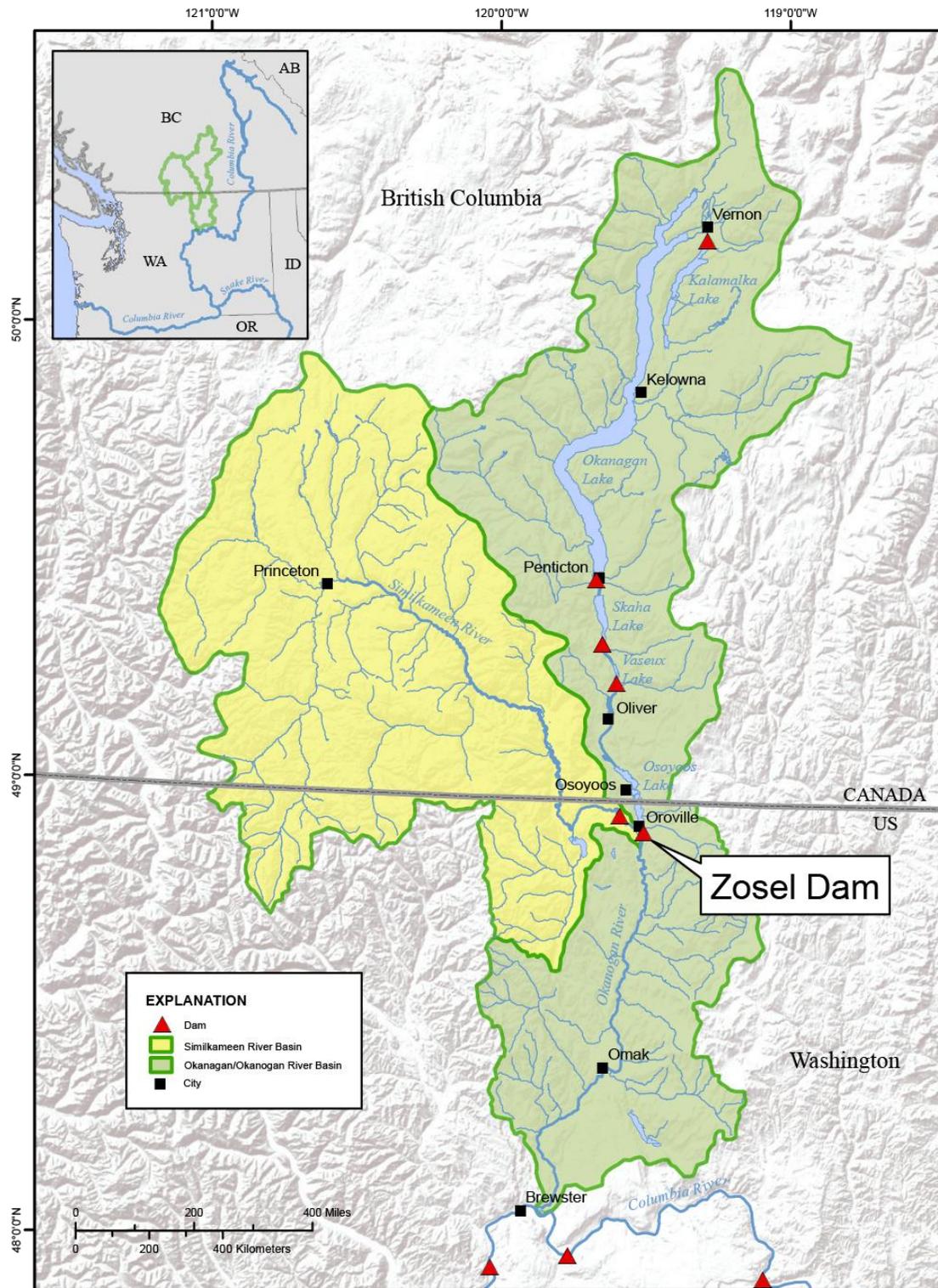


Figure 1 - Location of Zosel Dam, and the Okanagan/Okanogan and Similkameen watersheds.

ORDERS OF APPROVAL

Throughout any given year, Osoyoos Lake levels may fluctuate in accordance with criteria specified in the IJC's Supplementary Order of Approval dated January 29, 2013. These criteria are summarized within the rule curve presented in Figure 2.

The gray area in Figure 2 shows the allowable range of normal operating elevations: an upper range of 911.5 ft (277.8 m) on January 1; 911.5 ft (277.8 m) on March 1; 912 ft (278.0 m) on May 1; 912 ft (278.0 m) on September 15; 911.5 ft (277.8 m) on November 1 and 911.5 ft (277.8 m) on December 31; and to the extent possible the elevation of Osoyoos Lake does not fall below the NGVD 1929 elevation of 909.0 ft (277.0 m) on January 1; 909.0 ft (277.0 m) on March 31; 910.0 ft (277.4 m) on April 1; 911 ft (277.7 m) on June 1; 911 ft (277.7 m) on September 15; 910.0 ft (277.4 m) on October 31; 909.0 ft (277.0 m) on November 1 and 909.0 ft (277.0 m) on December 31. Elevation limits are linearly interpolated between dates.

The area between the red dashed lines in Figure 2 shows the lake elevations authorized by the IJC from April 1 to October 31 if drought criterion 8(a) and either 8(b i) or 8(b ii) in table 1 are declared in effect by the Board, or such as in 2019, when a Condition 10 variance is approved. During such conditions, the elevation of Osoyoos Lake may be raised to 912.5 ft (278.1 m) from April 1 to September 15, after which the lake level shall be decreased to reach an elevation of 911.5 ft (277.8 m) by November 1. To the extent possible, during the April 1 to October 31 period, the elevation of Osoyoos Lake should not fall below 910.0 ft (277.4 m) on April 1; 910.5 ft (277.5 m) on June 1; 910.5 ft (277.5 m) on September 15; and 910.0 ft (277.4 m) on October 31. Between dates, elevation limits are linearly interpolated. Condition 9 of the 1982 Order recognizes that backwater from high flow in the Similkameen River and (or) excessive flow in the Okanagan River may cause Osoyoos Lake levels to rise above the authorized range.

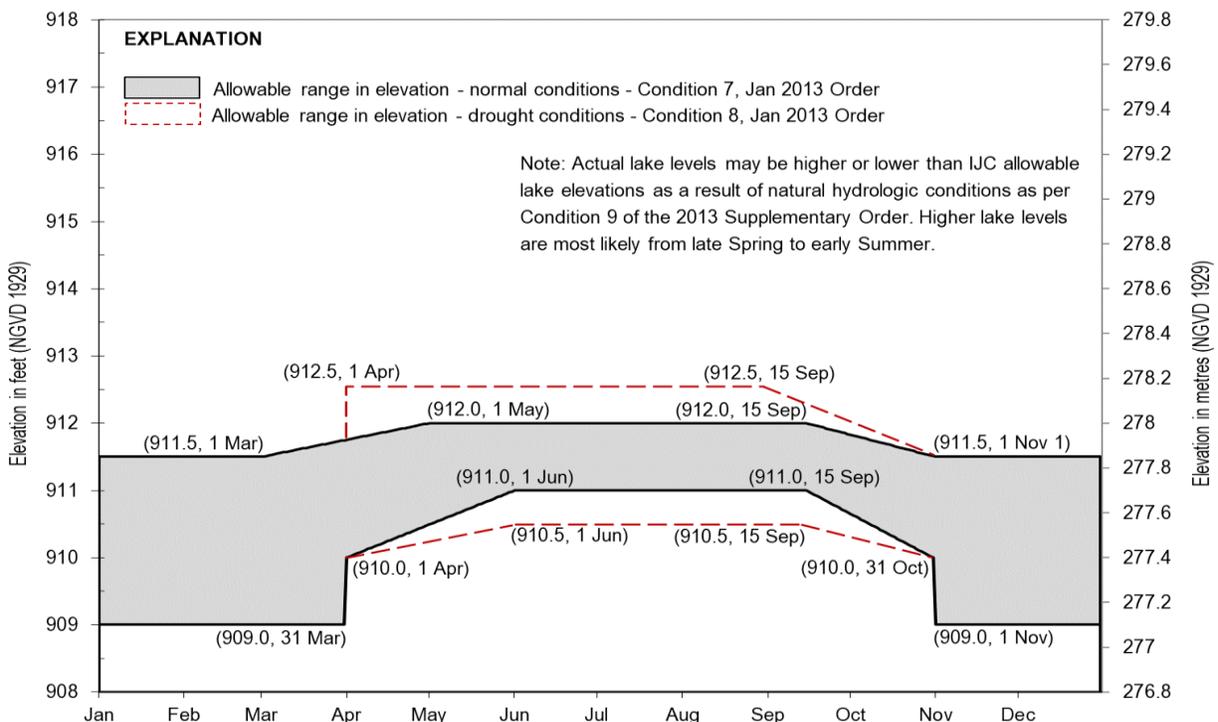


Figure 2 - 2013 Osoyoos Lake Supplementary Order of Approval rule curve.

BOARD MEMBERSHIP

In 2021, the number of Board members remained the same at a total of ten members with equal representation from Canada and the U.S. There were no changes in the Board’s membership in 2021.

	<i>Canadian Section</i>		<i>U.S. Section</i>
	<u>Dave Hutchinson</u> (Chair) Environment & Climate Change Canada National Hydrological Services		<u>Cindi Barton</u> (Chair) U.S. Geological Survey Washington Water Science Center
	<u>Ted White</u> (Member) B.C. Ministry of Forests, Lands, Natural Resource Operations & Rural Development		<u>Col. Alexander Bullock</u> (Member) U.S. Army Corps of Engineers Seattle District
	<u>Anna Warwick Sears</u> (Member) Okanagan Basin Water Board		<u>John Arterburn</u> (Member) Confederate Tribes of the Colville Reservation
	<u>Sue McKortoff</u> (Member) Mayor of Osoyoos		<u>Kris Kauffman</u> (Member) Water Resource Engineer
	<u>Brian Symonds</u> (Member) B.C. Ministry of Forests, Lands, Natural Resource Operations & Rural Development (retired)		<u>Arnie Marchand</u> (Member) Private Citizen
	<u>Martin Suchy</u> (Secretary) Environment & Climate Change Canada National Hydrological Services		<u>Andrew Gendaszek</u> (Secretary) U.S. Geological Survey Washington Water Science Center

BOARD ACTIVITIES IN 2021

Board Quarterly Calls

The Board continued holding quarterly conference calls in March, June, September, and December (as initiated in 2015). Agenda items included discussion of current hydrologic conditions, tracking work plan and special projects progress, and preparing for upcoming meetings. Summaries of these calls are posted on the Board’s public website (<https://ijc.org/en/olbc/library/minutes>).

Annual Board Meeting

The Annual Board Meeting was held Thursday October 14, 2021 from 12:30 to 3:30 pm PDT. Due to the COVID-19 pandemic, the meeting was held virtually using the Microsoft Teams platform. Dave Hutchinson (Board Chair, Canadian Section) opened the meeting with welcoming remarks and introductions of the Board members, IJC Commissioners, and guests who were in attendance. The review of the IOLBC Work Plan was deferred to the December quarterly call.

The 2021 hydrologic conditions and compliance with the IJC Orders of Approval for Osoyoos Lake were reviewed. Trevor Hutton (Washington State Department of Ecology) updated the Board about Washington State Department of Ecology’s operation of Zosel Dam in 2021.

Ecology and OTID were able to follow their operational plan and maintain compliance with the rule curve defined by the IJC Orders of Approval. Shaun Reimer (British Columbia – Forest, Lands, Natural Resources Operations and Rural Development) provided an overview of the Okanagan Lake Regulation system (OLRS) operations in 2021.

Next, presentations were given on the Board’s special projects. Anna Warwick Sears (Board Member, Canadian Section) presented an update about Lake Osoyoos bathymetry. Andy Gendaszek (Board Secretary, U.S. Section) presented a summary of the second phase of the Okanagan/Similkameen model integration. John Arterburn (Board Member, U.S. Section) presented an update about a proposal idea for consideration by the IJC-IWI program concerning the formation of ice jams at the southern end of Osoyoos Lake. Anna Warwick Sears updated the Board about planning for the Osoyoos Lake Water Science Forum.

Annual Public Meeting

The public meeting of the Board was held Tuesday October 14, 2021. Due to the COVID-19 pandemic the meeting was held virtually using the GoToWebinar platform. Dave Hutchinson provided some opening remarks and presented an overview of the IJC, IOLBC, and the IJC Orders of Approval for Osoyoos Lake. Ted White (Board Member, Canadian Section) presented a review of hydrologic conditions of Osoyoos Lake, the Okanagan/Okanogan River, and the Similkameen River during 2021.

Next, updates were given on the Board’s special projects. Martin Suchy (Board Secretary, Canadian Section) provided an overview of the recently completed Similkameen hydrologic modeling. Anna Warwick Sears presented an update of recent bathymetric mapping collected within the Canadian part of the Okanagan basin commissioned by OBWB. Andy Gendaszek presented an update of the second phase of the hydrologic modeling within the Similkameen and Okanagan River basins. Anna Warwick Sears provided an update about the fourth Osoyoos Lake Water Science Forum.

The Board subsequently responded to comments and questions from the public. All questions and the Board responses are summarized in the minutes of the public meeting, which are posted to the Board’s website.

Board Field Tour

Due to the COVID-19 pandemic, the annual Board and public meetings were held virtually in 2021 and no field trip took place. The Board previously planned to travel along the Similkameen River from its mouth at Oroville to the headwaters in Canada. This field trip will be considered for the next in-person annual Board meeting.

Board Appearances at IJC Semi-Annual Meetings

The Board virtually presented a progress report during the spring semi-annual IJC appearance on April 22 in Washington DC. The U.S. section chair Cindi Barton presented on behalf of the Board, and the meeting was attended by Canadian chair Dave Hutchinson along with numerous board members from both sections. Both secretaries were also in attendance.

The fall Ottawa meeting was held on October 20 and attended virtually by the Canadian and U.S. section Co-chairs Dave Hutchinson and Cindi Barton, respectively, along with Board Members from both sections and was supported by both Board Secretaries. The Board presented current activities and projects, along with providing an update on communications strategies and challenges.

Public Communications

The Board posted five news releases on its website to inform the public and news media about Board activities and hydrologic conditions within the Okanagan/Okanogan and Similkameen Basins that affect Osoyoos Lake levels and the IJC Orders for Osoyoos Lake. The first news release on April 23 indicated that the spring freshet had begun, and that river flows and lake levels were increasing. A second news release on July 6 informed the public that the Osoyoos Lake level reached the summer target elevation of 911.70 feet in late May, then crested to 911.82 feet (277.923 m) on June 15, below the maximum allowable International Joint Commission (IJC) Order of Approval rule curve of 912.0 feet. A third news release on August 23 informed the public of the International Osoyoos Lake Board of Control Virtual Public Meeting on October 14. The next news release on November 18 informed the public of the record high Similkameen River flows that caused Okanogan River to reverse direction at Zosel Dam. The final news release on December 24 indicated that the targeted winter operational lake elevation of between 909.45 to 909.55 feet was reached for Osoyoos Lake.

Special Projects

The Board submitted two IJC-IWI proposals in 2021. These included a proposal in summer 2021 to measure the bathymetry of Osoyoos Lake and a proposal submitted in fall 2021 to investigate the history and environmental factors contributing to the formation of ice jams at the outlet of Osoyoos Lake to the Okanogan River. The proposal to measure Osoyoos Lake was funded in August 2021 and in September 2021 a contractor completed an airborne LiDAR bathymetric and shoreline survey of the U.S. portion of Osoyoos Lake, the Okanogan River main stem from the Osoyoos Lake outlet to the confluence with the Similkameen River, the Similkameen River up to Enloe Dam, and the cross-channel between the Okanogan and the Similkameen Rivers. This survey will be joined to a Public Safety Canada funded near-shore bathymetry project from Osoyoos Lake to Kalamalka Lake near Vernon and final deliverables from this project are expected by March 2022. These data will be used during the integration of the Similkameen and Okanogan hydrologic models to be funded by a proposal to the IJC-IWI program to analyze future climate change scenarios on the hydrologic conditions of the Osoyoos Lake, the Similkameen River, and the Okanagan/Okanogan Rivers. The proposal to investigate ice-jam history on Osoyoos Lake was conditionally approved for funding and the Board Secretaries are developing a scope of work for this project.

The first phase of the project to develop a hydrologic model of the Similkameen River Basin to assess the impact of projected climate change on the IJC Orders of Approval for Osoyoos Lake was funded by the IJC-IWI in 2020 and was completed by the contractor, Northwest Hydraulic Consultants (NHC), in spring 2021. The second phase of this project currently under consideration for funding will integrate the hydrologic model of the Similkameen Basin developed during the first phase of the project with previously developed hydrologic and hydraulic models of the Okanagan/Okanogan basin funded by the OBWB. This second phase will complete the assessment of the impact of projected climate change on the IJC Orders of Approval for Osoyoos Lake. The IJC-IWI selected the second phase of this project for funding

by the U.S. Section of the IJC in spring 2021 following the completion of the Similkameen basin model. The Board Secretaries are working with the IJC to implement the second phase of the project.

In fall 2020, the IJC-IWI selected the Osoyoos Lake Science Forum for funding by the U.S. Section. Due to the ongoing COVID-19 pandemic, the Forum has been delayed to fall 2022 and will be held in Osoyoos, BC. The Forum's steering committee has engaged indigenous facilitators from the Okanagan Nation Alliance to facilitate the Forum, solicited contributions to the technical program, and secured funding from public and private sponsors in the U.S. and Canada.

The IJC-IWI funded High-Water Monument was installed in spring 2019 in Osoyoos, BC and the U.S. monument was to be installed in spring 2020 in Veterans Memorial Park but was not yet installed because of COVID-related travel restrictions. The U.S. monument is scheduled to be installed in spring 2022.

2021 HYDROLOGIC CONDITIONS

Snowpack and Precipitation

Snowpack in the Similkameen basin, as measured at Blackwall Peak (elevation 1,940 m (6,365 ft)), was near normal through the winter, but started to decrease below normal by late-May and June. Snowpack at Blackwall Peak reached zero by mid-June, consistent with the historical mean. In the Okanagan basin, as measured at Mission Creek (elevation 1,780 m/5,840 ft), above-normal snowpack persisted through the winter and spring until rates of melting increased in May and June. The snowpack at Mission Creek in the Okanagan reached zero at the beginning of June. Record high temperatures during the late June heat dome event resulted in minimal increases in runoff because most of the snowpack had melted prior to the heat-dome event (Figure 3). No concerns about drought existed in the winter and early spring because of normal to above-normal snowpacks, but drought became an increasing concern by May and June as snowpack decreased below normal.

Snow Water Indices for both the Similkameen and Okanagan Basins exceeded 100% of normal for the entire season up until June, when the Okanagan melted earlier than normal (Figure 4).

In fall 2020, ECCC and NOAA issued a seasonal outlook for La Nina conditions, which typically result in wetter conditions on the coast and colder conditions inland with Osoyoos Lake at the boundary between the two. Although early winter precipitation for the Similkameen and Okanagan basins was near normal precipitation, below normal precipitation began in February and persisted through the spring and summer with typical June rainfall absent in 2021 (Figure 5). Except for a below-normal period of cold weather in February, temperature was near normal during the winter and spring. In late June, a record-breaking heat dome developed across the western U.S. and Canada and above normal temperatures persisted through July and August.

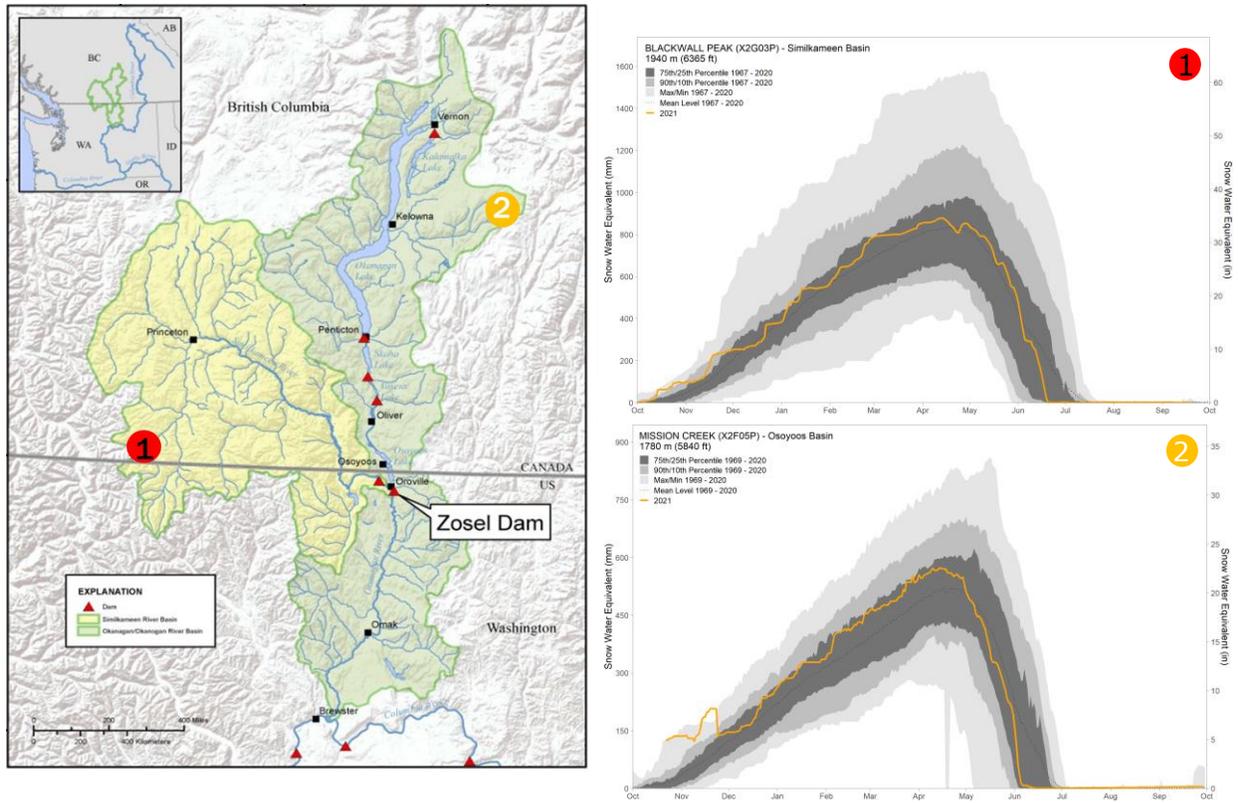


Figure 3 – Mountain snowpack conditions for water year 2020-2021. Historical Maximum, 75th/25th Percentile, Daily Mean, Minimum, and 2020/2021 data. 1) Blackwell Peak (1967-2020) Similkameen River Basin, 2) Mission Creek (1969-2020) Okanagan/Okanogon River Basins. (BC River Forecast Center, 2021).

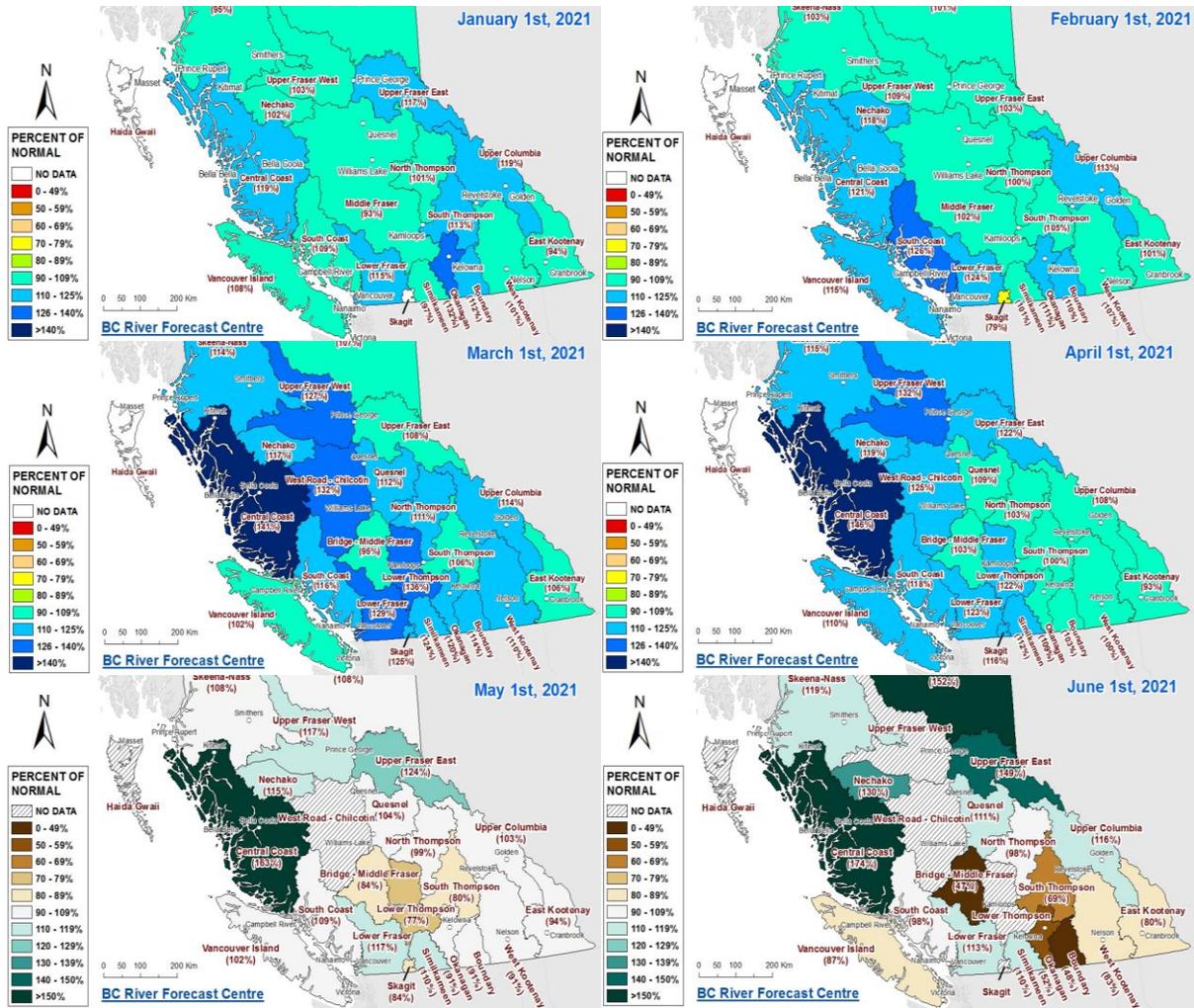


Figure 4 - Monthly Basin Snow Water Index, indicating conditions as a percent of normal. For the period January to June 2021 (Province of British Columbia, River Forecast Centre, 2021).

Note: the Snow Basin Map was updated in May to a more color-accessible scheme

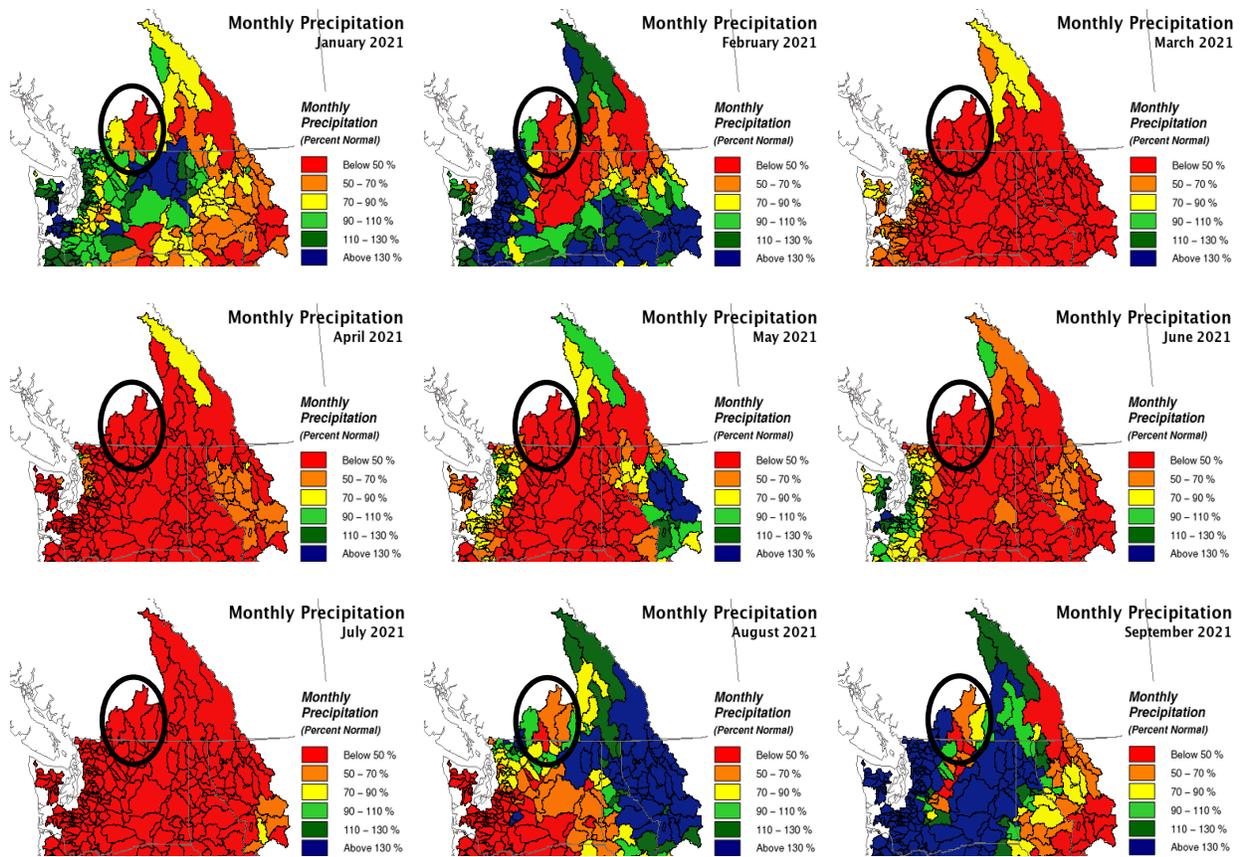


Figure 5 - Monthly Precipitation in the Columbia River Basin. The black oval represents the Okanagan/Okanogan and Similkameen River Basins. January to September 2021.

NOAA, https://www.nwrhc.noaa.gov/water_supply/wy_summary/wy_summary.php?date=10/01/2019&tab=1

Drought Criteria

Condition 8 of the Commission's Supplementary Orders of Approval dated January 29, 2013, provides three criteria for declaring a year of drought (Table 1). In a year when the Board has declared a drought, Osoyoos Lake level may be managed under the drought rule curve specified within Condition 8 that allows a wider range from April through October as compared to non-drought years (Figure 2). In early spring 2021, the forecasted hydrologic conditions did not meet any of the three drought criteria within the IJC Order. However, drought concerns within the Okanagan and Similkameen basin increased throughout the summer as a result of lower-than-expected inflow to Okanagan Lake and runoff within the Similkameen basin. Although Okanagan Lake levels were forecasted in April and May to exceed the IJC Order drought threshold of 1,122.6 feet (Condition 8bii), peak Okanagan Lake level on June 18 was actually 1,125.25 feet and this part of the drought criteria was met. A drought was not declared, since Condition 8a was not met for the Similkameen, and the Applicant operated the dam under the normal Condition 7 conditions. No request from the Applicant for a Condition 10 variance was received. Graphs demonstrating the hydrologic conditions with drought condition 8a and condition 8b for 2021 are shown in Figure 6 and Figure 7, respectively.

Table 1 – Summary of drought criteria and forecast and actual values in 2021. The Board declares a drought if condition 8(a) and either condition 8(b i) or 8(b ii) are met (af, ac-ft; acre-foot; ft, feet)

Criteria for declaring a drought	Numerical criteria	2021 Value forecasted in (a) Early April (b) Early May	Actual 2021 value (c)	Drought criterion met?
Condition 8(a): Volume of flow in the Similkameen River at Nighthawk, WA, for the period April through July as calculated or forecasted by U.S. authorities is less than 1 million ac-ft	< 1,000,000 ac-ft	(a) 1,363,000 ac-ft (b) 1,507,000 ac-ft	(c) 1,322,360 ac-ft	(a) No (b) No (c) No
Condition 8(b i): Net inflow to Okanagan Lake for the period April through July as calculated or forecasted by Canadian authorities is less than 195,000 ac-ft	< 195,000 af	(a) 415,900 ac-ft (b) 256,000 ac-ft	(c) 244,000 ac-ft	(a) No (b) No (c) No
Condition 8(b ii): Level of Okanagan Lake in June or July is less than or is forecasted by Canadian authorities to be less than 1,122.6 ft (Canadian Geodetic Survey Datum)	< 1,122.6 ft	(a) 1,123.06 ft (b) 1,122.70 ft	(c) 1122.25 ft (peak June 18)	(a) No (b) No (c) Yes

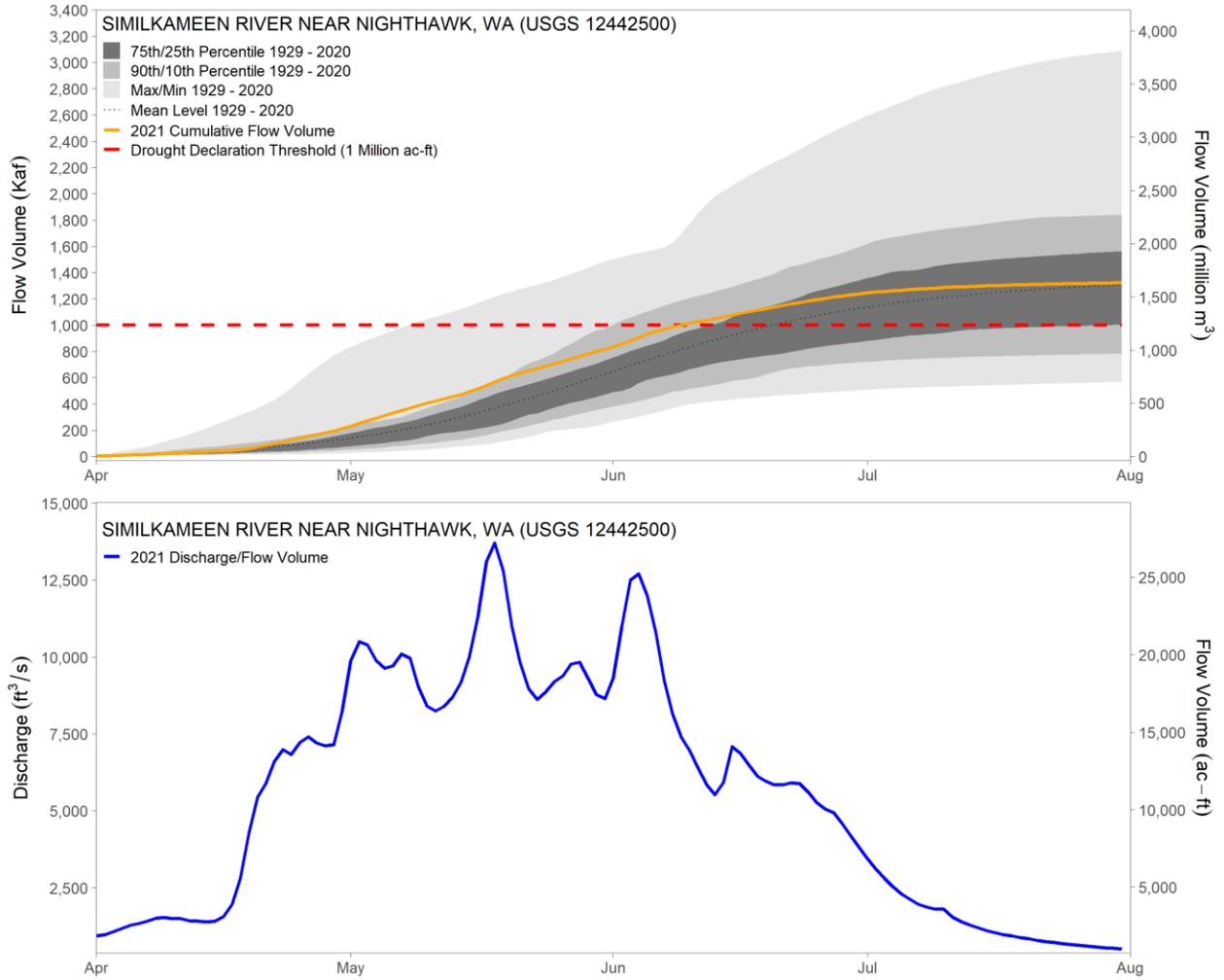


Figure 6 – Top: Similkameen River Cumulative Flow Volume for the period of April to July 2021 and Condition 8a Drought Criteria – 1 Million ac-ft. Bottom: Similkameen River near Nighthawk (USGS station 12442500) discharge, and Daily Flow Volume.

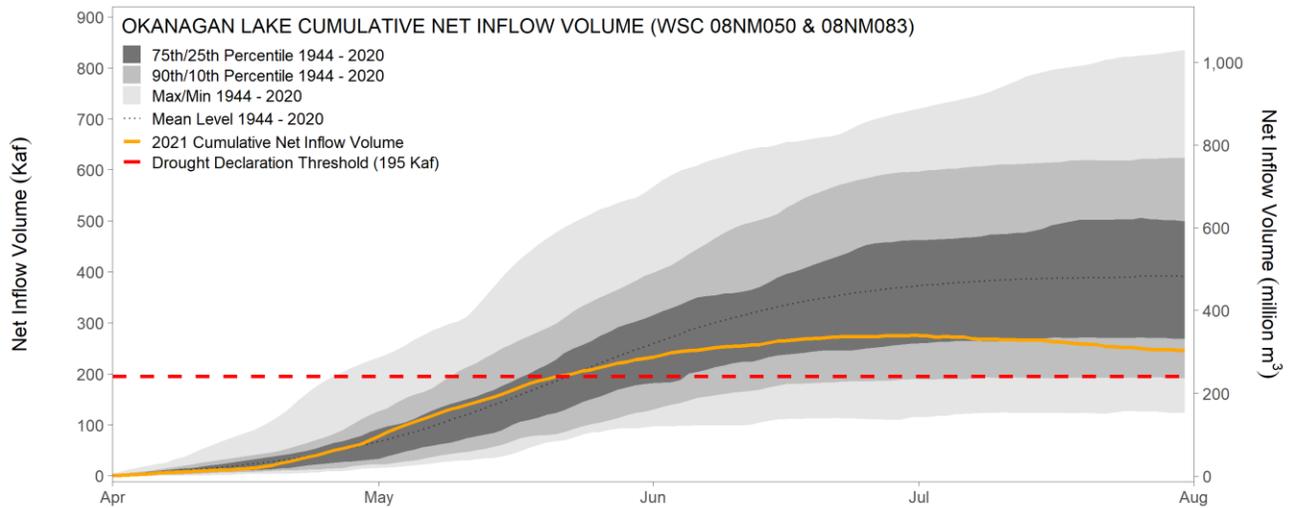


Figure 7 – Top: Okanagan Lake Cumulative Net Inflow Volume for the period of April to July 2021 and Condition 8bi Drought Criteria – 195 Kaf.

Okanagan Lake Inflow, Okanagan Lake Level, and Okanagan River Discharge

The Condition 8 drought criteria based on Okanagan net inflow and lake level were forecast to be exceeded in early April through early May. Actual Okanagan Lake net inflow, which was greatest in May, was lower than earlier forecasts and reached 244,000 acre-foot (300 million m³). This was still above the drought criteria. Okanagan Lake net inflow peak was about four weeks earlier than normal and net losses began earlier this year as well because of dry conditions starting in July; in a normal year net losses do not begin until August (Figure 8). The 2021 peak Okanagan Lake level did not meet the operational target of 1,123.6 feet (342.48 m) (Figure 9). The discharge of Okanagan River at Penticton and Oliver is shown in Figure 10 and Figure 11, respectively.

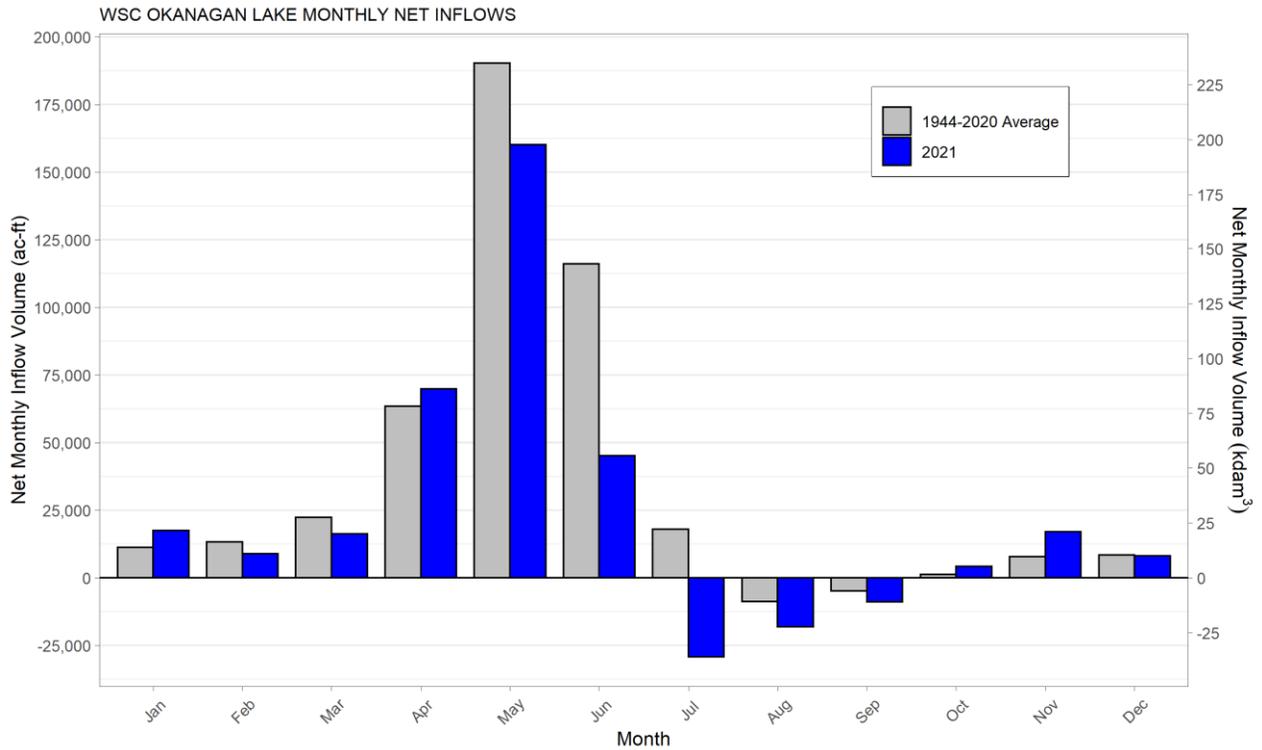


Figure 8 - Historical monthly mean (1921-2020), and 2021 monthly net inflow to Okanagan Lake.

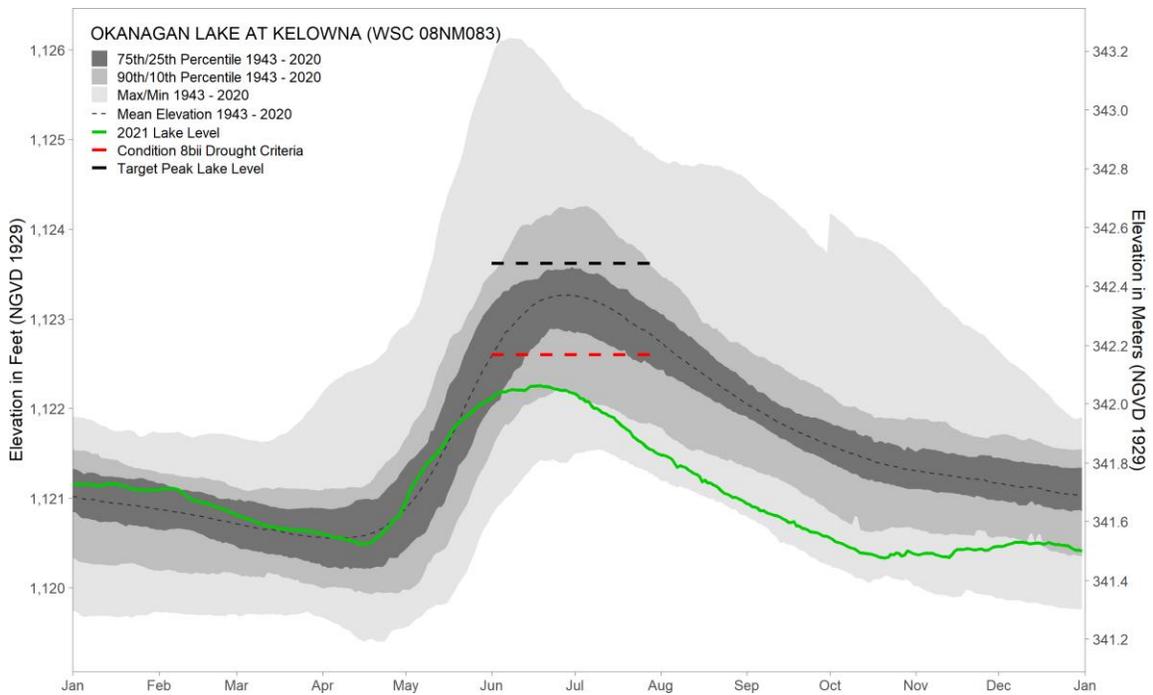


Figure 9 - Okanagan Lake at Kelowna (WSC station 08NM083), BC. Historical (1944-2020): Maximum, 90th/10th and 75th/25th Percentiles, Daily Mean, Minimum, 2021 water-surface elevation (Environment and Climate Change Canada, 2022), and Condition 8bii Drought Criteria – 1,122.6 ft (IJC Order of Approval).

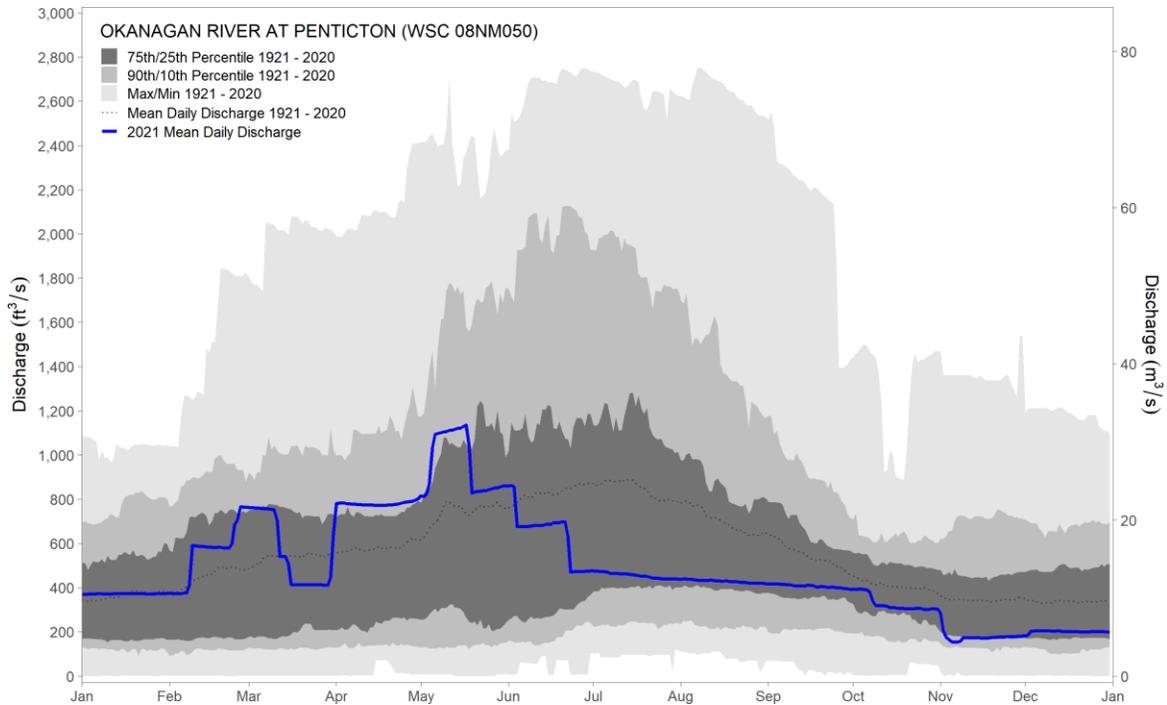


Figure 10 - Okanagan River at Penticton (WSC station 08NM050), British Columbia. Historical (1921-2020): Maximum, 90th/10th and 75th/25th Percentiles, Daily Mean, Minimum, and 2021 streamflow discharge (Environment and Climate Change Canada, 2022).

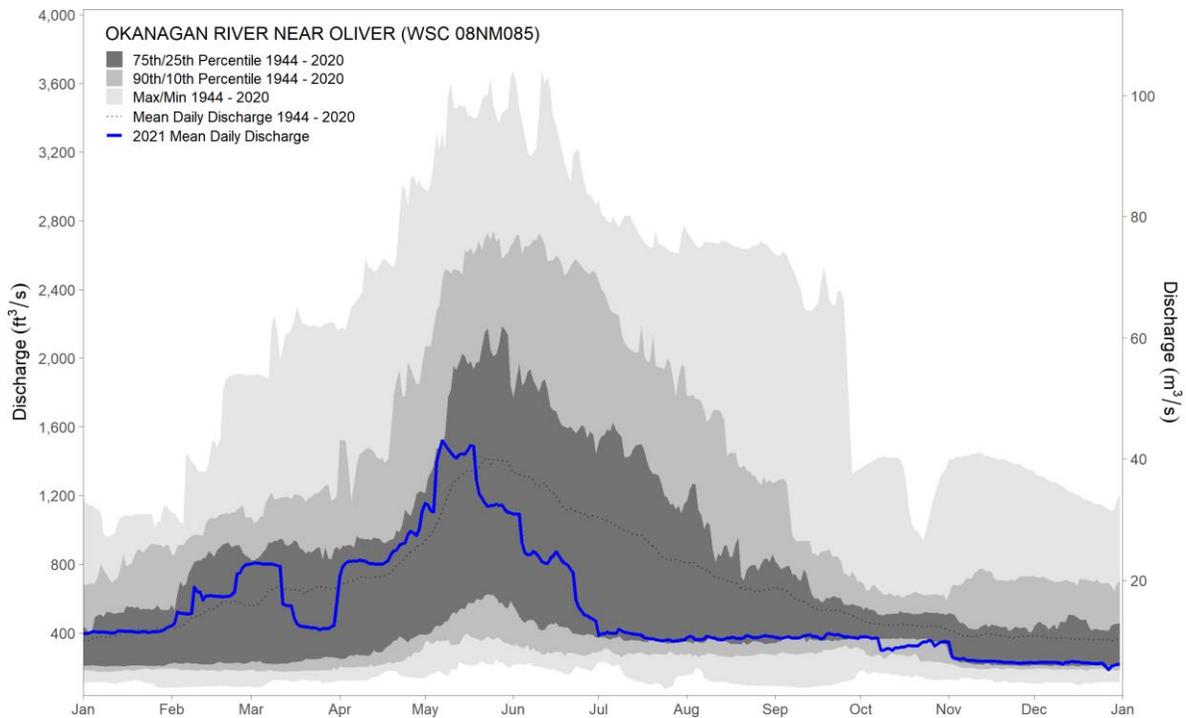


Figure 11 - Okanagan River near Oliver (WSC station 08NM085), British Columbia. Historical (1944-2020): Maximum, 90th/10th and 75th/25th Percentiles, Daily Mean, Minimum, and 2021 streamflow discharge (Environment and Climate Change Canada, 2022).

Similkameen River Discharge and Okanogan River Discharge

Drought criteria 8a regarding the Similkameen River was not met in 2021. Cumulative April - July flow volume for the Similkameen River was 1,322,360 acre-foot as measured at the USGS streamflow gaging station at Nighthawk, which was lower than the early April and early May forecasts (Table 1) but still above the 1 million acre-foot threshold.

On November 15th, discharge of the Similkameen River began to increase rapidly. This was due in part to the landfall of a Category 5 atmospheric river causing heavy, sustained rainfall and rising temperatures resulting in additional runoff from snowmelt. Discharge peaked at the USGS Similkameen River at Nighthawk gage at 26,900 cubic feet per second (cfs) (762 cubic meters per second (cms)) at 3:00 pm on November 16th. The previous historical maximum for the month of November during the 92-year record at this gage was 14,400 cfs (420 cms) on November 30th, 1995. The all-time historical maximum discharge of the Similkameen River at Nighthawk was 31,200 cfs (883 cms) on May 10th 2018 during the spring freshet. Other key maximum and minimum values can be found in the Appendix. The 2021 discharge of the Similkameen is shown in Figure 12.

The record high autumn discharge of the Similkameen River coupled with low Osoyoos Lake levels and minimal inflow of the Okanogan River into Osoyoos Lake, created a reversal of flow in the Okanogan River downstream of Osoyoos Lake. In the late evening on November 15th, the flow of the Okanogan River at Oroville reversed direction. At approximately 2:00 pm PST on November 16th, the river level downstream of Zosel Dam crested the dam's spillway and began flowing up the channel towards Osoyoos Lake (Figure 13). The reversed flow is depicted by the negative flow values. Additional information on the event is provided below in the Backwater Conditions section.

Mean daily discharge of the Okanogan at Oroville (downstream from Zosel Dam) ranged from a minimum of -330 cfs (-9.3 cms) on November 16 to 1,550 cfs (43.9 cms) on May 9. The minimum discharge recorded on November 16 resulted from the reversal of flow. Other key maximum and minimum values are reported in the Appendix.

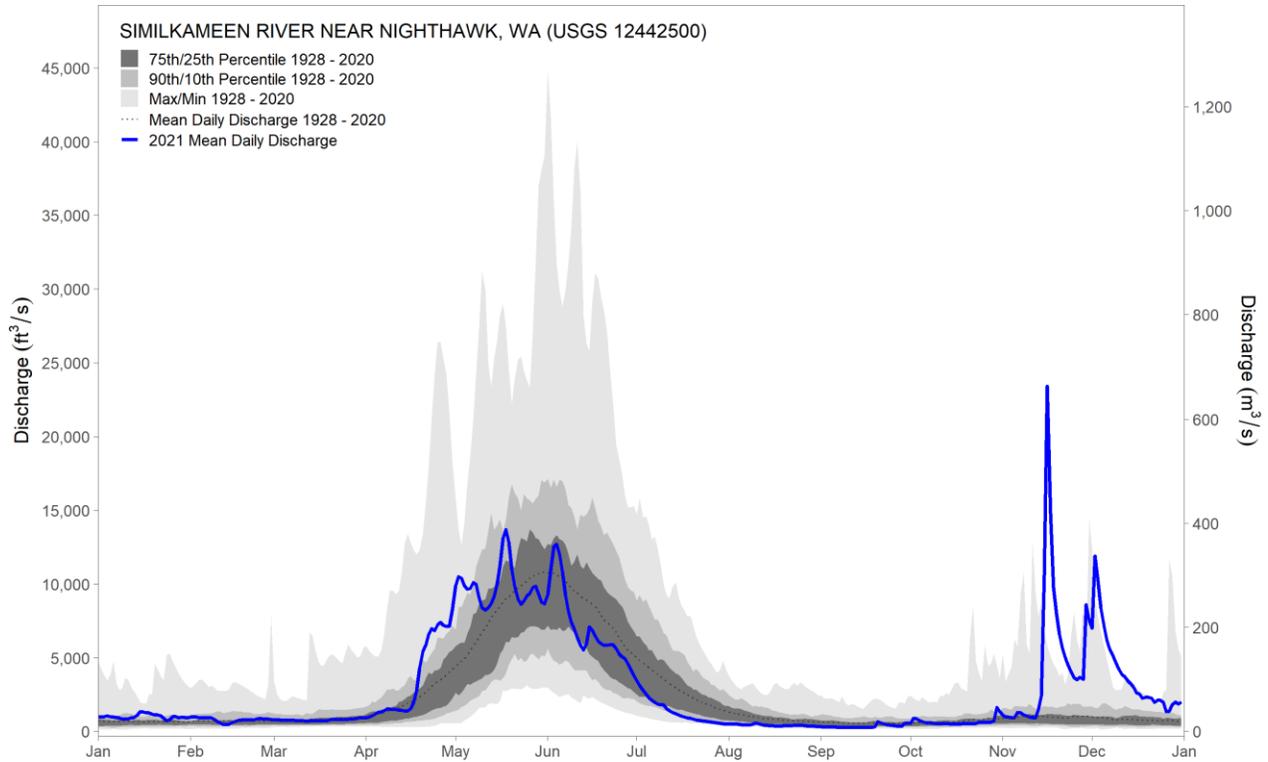


Figure 12 - Similkameen River at Nighthawk (USGS 1244250), Washington. Historical (1929-2020): Maximum, 90th/10th and 75th/25th Percentiles, Daily Mean, Minimum, and 2021 mean daily discharge (US Geological Survey, 2021).

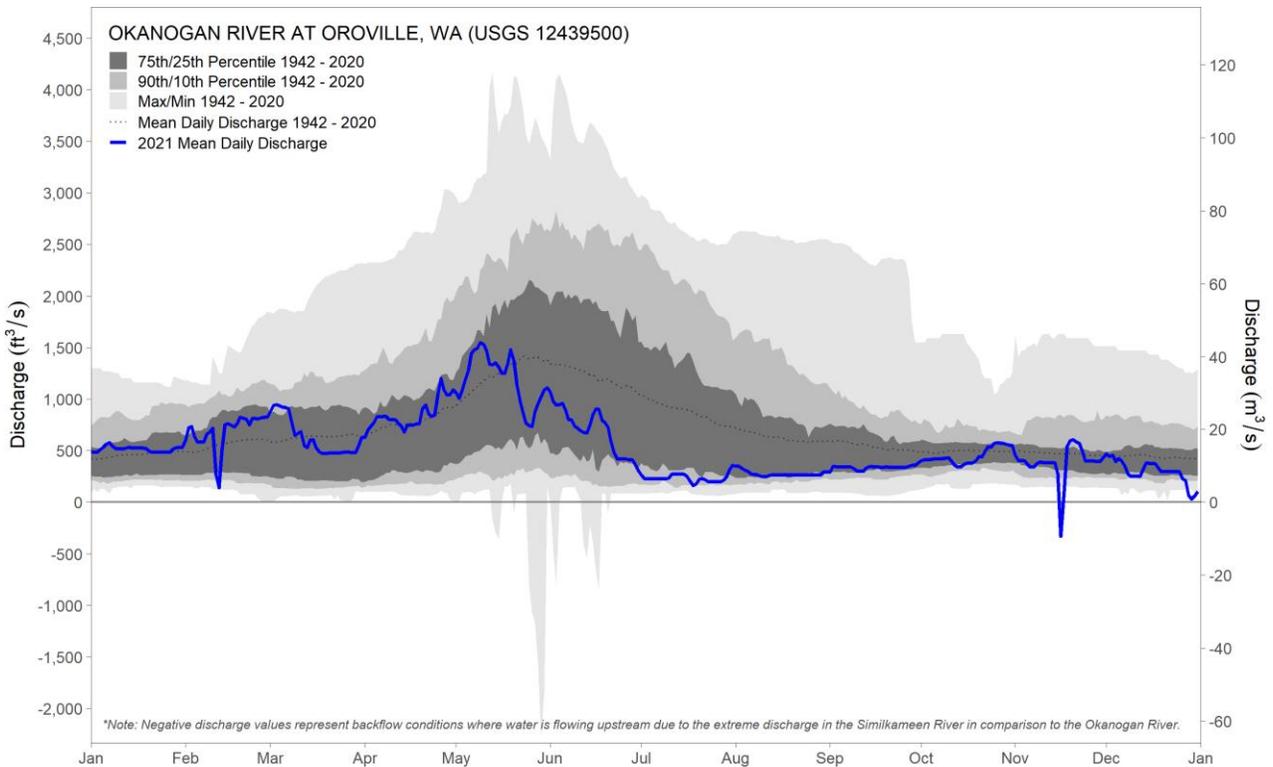


Figure 13 - Okanogan River at Oroville (USGS station 12439500), Washington. Historical (1943-2019): Maximum, 90th/10th and 75th/25th Percentiles, Daily Mean, Minimum, and 2021 mean daily discharge (US Geological Survey, 2021).

2021 OSOYOOS LAKE LEVEL AND ORDER COMPLIANCE

Throughout any given year, Osoyoos Lake levels may fluctuate in accordance with criteria specified in the IJC’s Supplementary Order of Approval dated January 29, 2013. Lake levels are influenced naturally by discharge in the Okanagan/Okanogan and Similkameen Rivers and by the operation of Zosel Dam. Mean daily lake levels measured at the USGS Station no. 12439000 (Osoyoos Lake at Oroville) are plotted in green for 2021 (Figure 14).

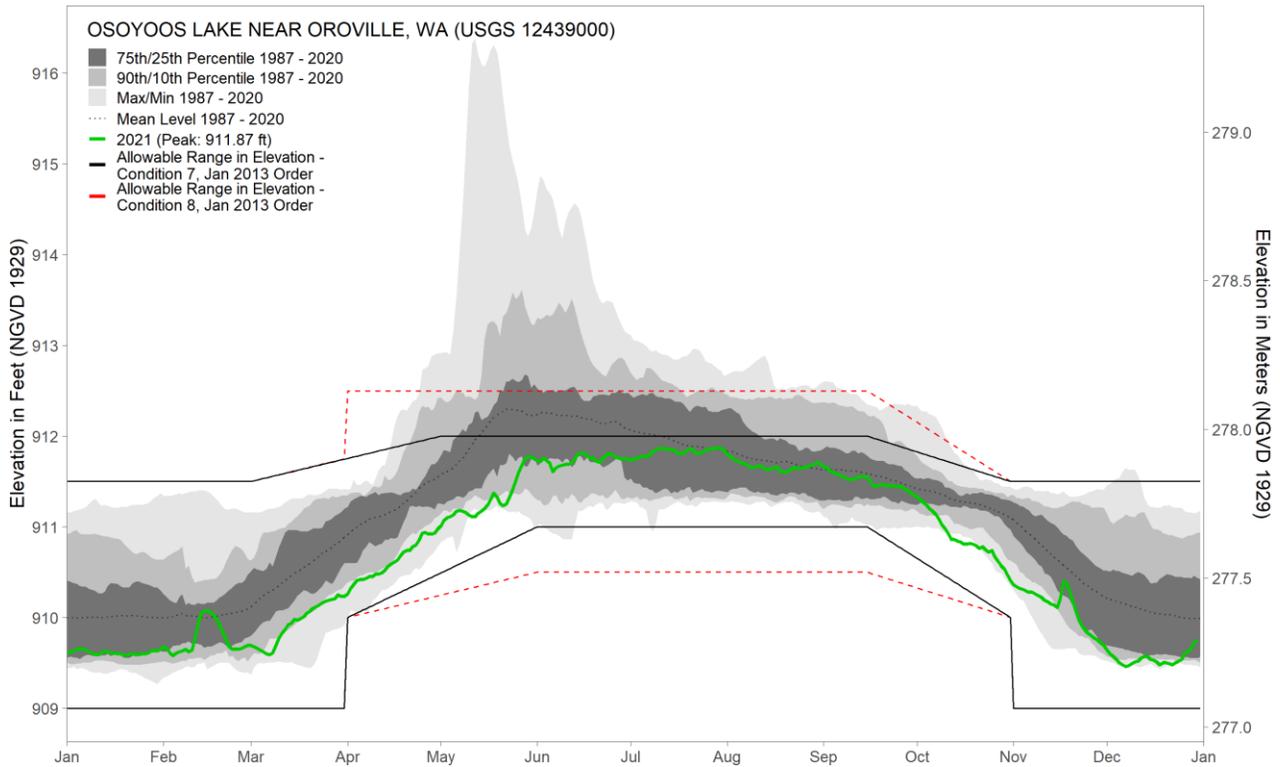


Figure 14 - Allowable Osoyoos Lake elevations per IJC Supplemental Order of Approval dated January 29, 2013, Historical (1987-1919): Maximum, 75th/25th and 90th/10th Percentiles, Daily Mean, Minimum, and 2021 daily mean lake elevations recorded at USGS station 12439000.

Osoyoos Lake levels were maintained within the standard Condition 7 rule curve with a peak lake level of 911.87 feet in late July. Key maximum and minimum values are reported in the Appendix.

An abrupt increase in lake stage in late February, which occurred entirely within the rule curve, occurred as a result of decreased capacity at the outlet of Osoyoos Lake due to an ice jam that formed during a period of cold weather. The Board monitored the development of the ice jam and Osoyoos Lake stage during the ice-jam event until the jam thawed in late February, ice no longer impacted outflow from Osoyoos Lake, and lake levels lowered.

The second noteworthy increase in the Osoyoos Lake stage occurred mid-November, due to significant increases to the Similkameen discharge during the consecutive atmospheric river events. The lake stage also remained within the allowable range of the rule curve during this event.

Backwater Conditions

Inflows into Osoyoos Lake from the Okanogan River, combined with high flows in the Similkameen River (at the confluence with Okanogan River) during freshet may result in a stop or reversal of flow across Zosel Dam due to a hydraulic dam that limits outflow from Osoyoos Lake under certain conditions. In 2021, elevated discharge of the Similkameen River (above 10,000 cfs, Figure 15 – light blue line) did not contribute to reduced discharge of the Okanogan River at the outlet of Osoyoos Lake during the spring freshet (Figure 15 – dark blue line). The figure illustrates that there were no spring backwater conditions in 2021. However, as previously indicated, record setting backwater conditions and a reversal of flow did occur in the autumn as a result of the storm event (Figure 16).

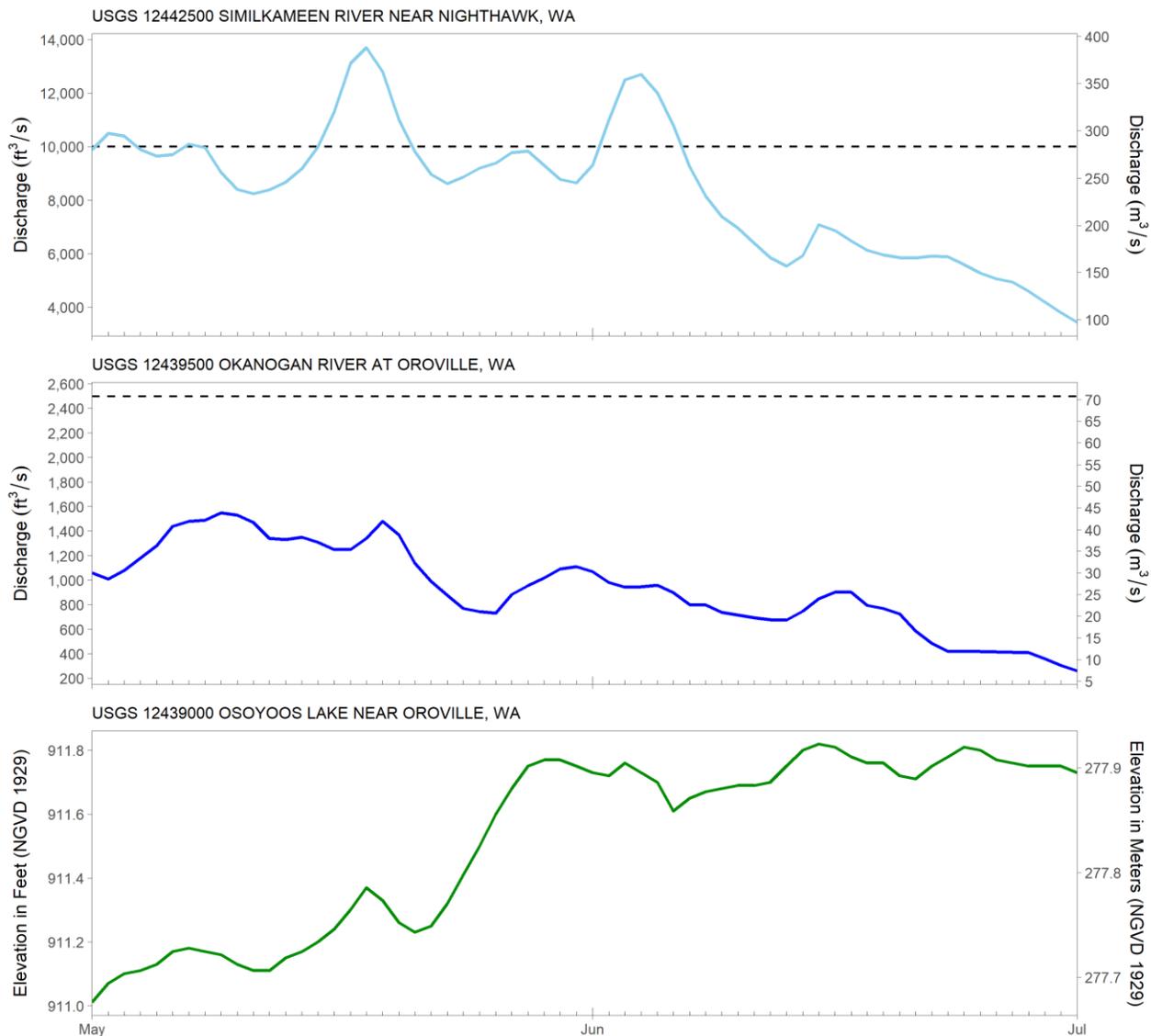


Figure 15 – Similkameen River spring 2021 backwater conditions. As Similkameen discharge increases (particularly when above 10,000 cfs), Okanogan River at Oroville (between Zosel Dam and Similkameen/Okanogan River confluence) discharge begins to decrease. If Osoyoos lake inflows continue, Osoyoos Lake levels rise quickly.

The Category 5 atmospheric river made landfall in southwestern British Columbia and northwestern Washington State on November 14, 2021 bringing two days of intense precipitation to the region. The Similkameen River basin (and specifically the Tulameen River sub-basin) responded rapidly to the increased runoff from precipitation and snowmelt, resulting in record high flows, which coupled with low Osoyoos Lake levels and minimal inflows, triggered a flow reversal of the Okanogan River downstream of Osoyoos Lake. The river level downstream of Zosel Dam then crested the dam’s spillway and began flowing up the channel, an event which had previously only been observed during the spring freshet (Figure 16). On November 17 the muddy floodwaters of the Similkameen River reached Osoyoos Lake.

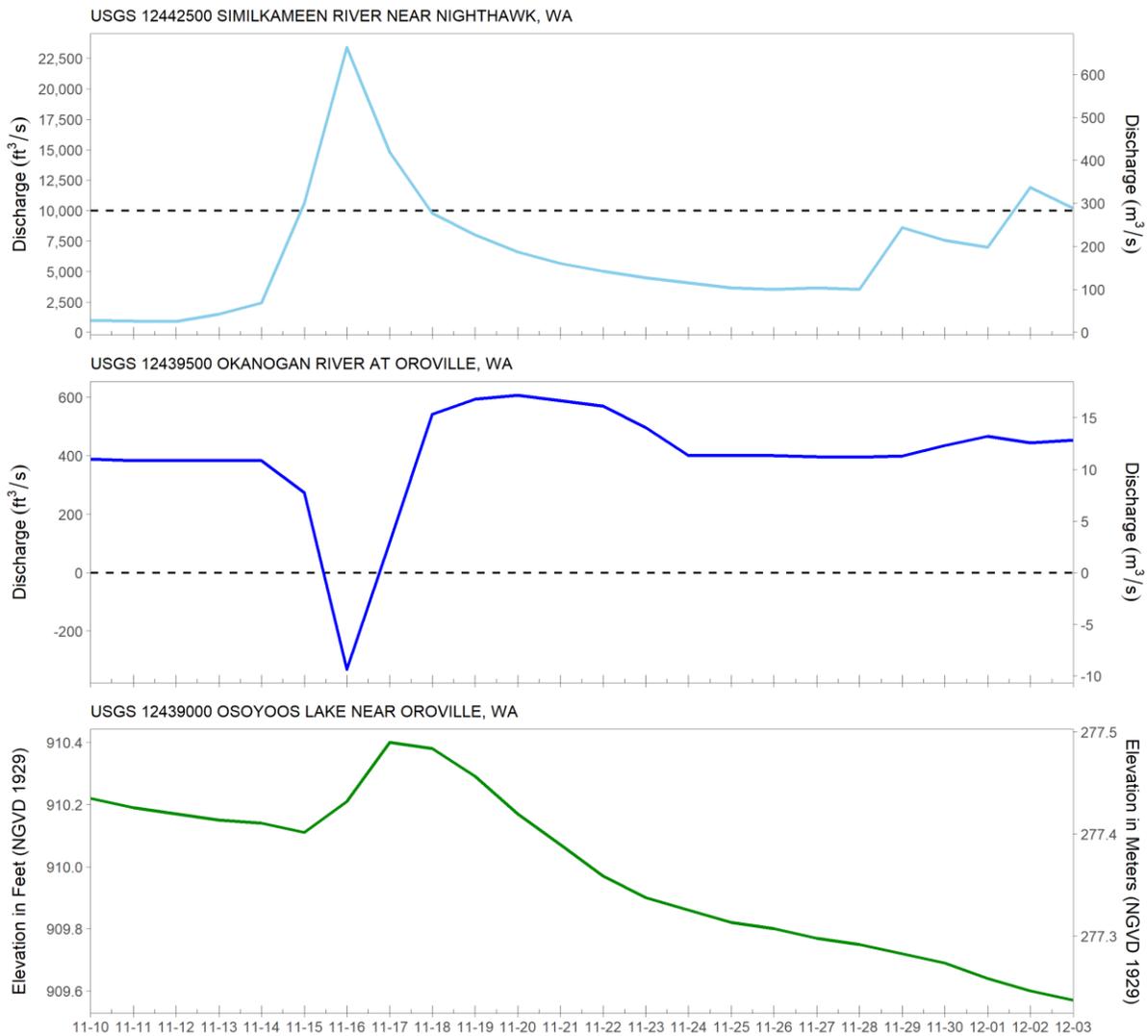


Figure 16 – Similkameen River autumn 2021 backwater conditions. As Similkameen discharge increases (light blue line), Okanogan River at Oroville discharge begins to decrease (blue line), and eventually becomes negative (representing a reversal of flow). Osoyoos Lake levels then rise quickly as seen by the green line.

Okanogan River Flow Capacity

Conditions 3 and 4 of the IJC Order of 1982 specify that the flow capacity of the Okanogan River channel between the outlet of Osoyoos Lake up to and including Zosel Dam be at least 2,500 cfs (70.8 cms) when the elevation of Osoyoos Lake is 913.0 ft (278.3 m) and there is no appreciable backwater effect from the Similkameen River. Discharge of the Okanogan River as measured at the USGS gage at Oroville downstream of Zosel Dam (USGS station 12439500) did not surpass 2,500 cfs in the spring. The maximum daily mean discharge measured at this location was 1,550 cfs (43.9 cms) on May 9, while Osoyoos Lake elevations did not surpass 913.0 feet in the spring. As a result, there was no requirement to assess the discharge capacity of the Okanogan River in 2021. This is illustrated in Figure 17.

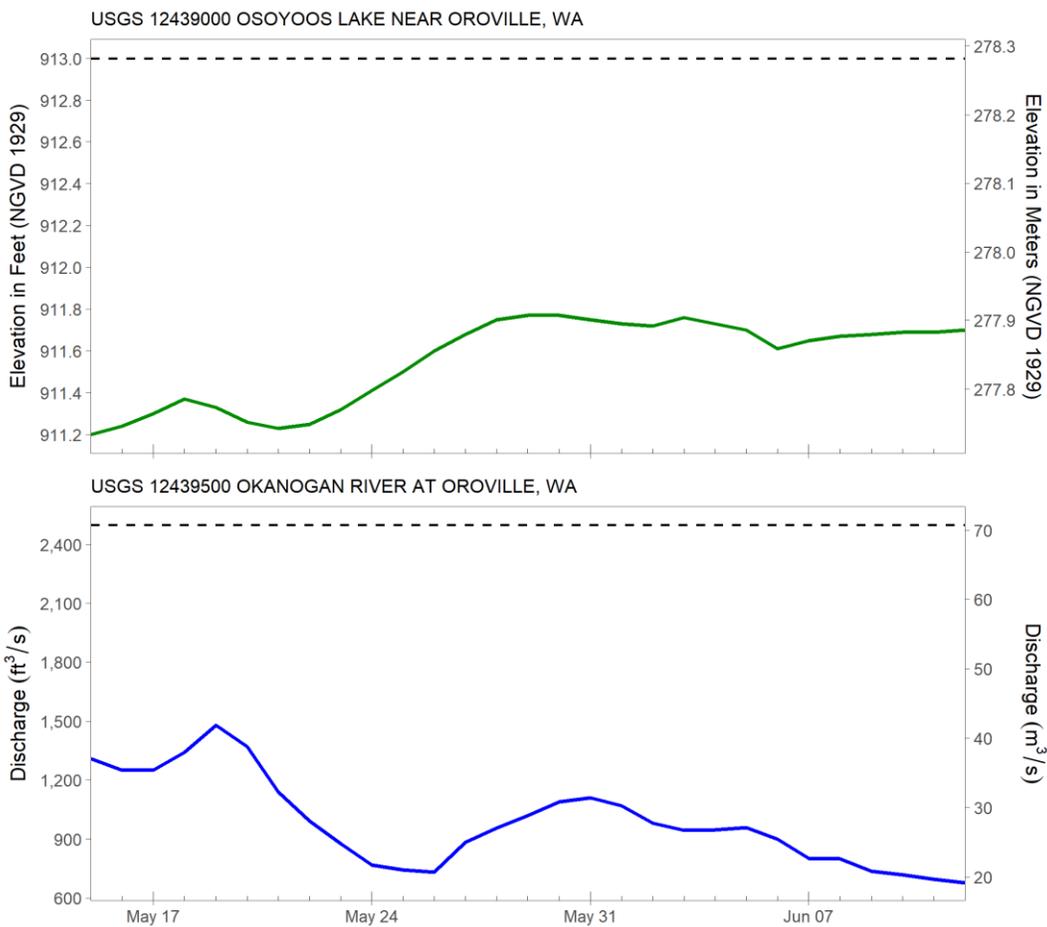


Figure 17 – Okanogan River flow capacity demonstration for the period May 15 to June 12, 2021. Top, mean daily Osoyoos Lake elevations recorded at USGS station 12439000, along with 913 ft. threshold. Bottom, mean daily discharge recorded at Okanogan River at Oroville (USGS station 12439500) and 2,500 cfs threshold.

APPENDIX: OSOYOOS LAKE LEVELS, INFLOWS, AND OUTFLOWS IN 2021

A. International gaging stations in operation throughout the year:

(1) For Stage Records

Osoyoos Lake near Oroville, Washington
 Okanogan River at Oroville, Washington (auxiliary gage)

(2) For Discharge Records

Okanagan River near Oliver, British Columbia
 Okanogan River at Oroville, Washington (base gage)
 Similkameen River near Nighthawk, Washington

B. Compliance with the lake levels specified in the Orders of Approval is measured at the station "Osoyoos Lake near Oroville," where elevations are expressed in terms of the U.S. National Geodetic Vertical Datum of 1929 (NGVD 1929).

C. Osoyoos Lake near Oroville (USGS station no. 12439000)

Maximum instantaneous elevation	911.89 ft. (277.94 m) – Jul 10 21:30–22:00, Jul 11 0:00, 1:00–1:15, 4:00, Jul 20 6:15–6:30, 8:00, & 8:30–8:45
Minimum instantaneous elevation	909.44 ft. (277.20 m) – Dec 7 12:30, Dec 8 0:45, 1:15 & 2:00
Maximum daily mean elevation	911.87 ft. (277.94 m) – Jul 11, 29, & 30
Minimum daily mean elevation	909.46 ft. (277.20 m) – Dec 7
Lake elevation at maximum daily mean discharge for Okanogan River at Oroville	911.16 ft. (277.72 m) – May 9

D. Okanogan River at Oroville (USGS station no. 12439500)

Maximum instantaneous discharge	1,610 cfs (45.6 cms) – May 19 6:30–6:45 & May 20 8:00
Minimum instantaneous discharge	-398 cfs (-11.3 cms) – Nov 16 19:00–20:00
Maximum daily mean discharge	1,550 cfs (43.9 cms) – May 9
Minimum daily mean discharge	-330 cfs (-9.3 cms) – Nov 16
Annual mean discharge	545 cfs (15.4 cms)

The annual mean discharge was 78 percent of the 78-year (1943–2020) average of 695 cfs (19.7 cms).

E. Similkameen River near Nighthawk (USGS station no. 12442500)

Maximum instantaneous discharge	26,900 cfs (761.7 cms) – Nov 16 14:15 & 14:45–15:00
Minimum instantaneous discharge	258 cfs (7.3 cms) – Sep 10 11:00–23:30, Sep 11 14:15–14:45, Sep 11 19:00–Sep 12 16:45 & Sep 15 11:15–11:45
Maximum daily mean discharge	23,400 cfs (662.6 cms) – Nov 16
Minimum daily mean discharge	260 cfs (7.4 cms) – Sep 10 & Sep 12
Annual mean discharge	2,870 cfs (81.3 cms)

The annual mean discharge was 124 percent of the 92-year (1929–2020) average of 2,317 cfs (65.6 cms).

F. Okanagan River at Oliver (ECCC station no. 08NM085)

Maximum instantaneous discharge	1,561 cfs (44.2 cms) – May 7 5:45 & 6:25
Minimum instantaneous discharge	173 cfs (4.9 cms) – Dec 27 5:35–7:20
Maximum daily mean discharge	1,529 cfs (43.3 cms) – May 8
Minimum daily mean discharge	187 cfs (5.3 cms) – Dec 28
Annual mean discharge	537 cfs (15.2 cms)