# ANNUAL REPORT

# OF THE

# COLUMBIA RIVER TREATY

# CANADIAN AND UNITED STATES ENTITIES

**FOR THE PERIOD**

**1 OCTOBER 2008 – 30 SEPTEMBER 2009**

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# EXECUTIVE SUMMARY

## General

The Canadian Treaty projects, Mica, Duncan and Arrow were operated during the 1 August 2008 – 30 September 2009 reporting period according to the 2008-09 and 2009-10 Detailed Operating Plans (DOPs), the 2003 Flood Control Operating Plan (FCOP), and several supplemental operating agreements described below. The Libby project was operated according to the Libby Coordination Agreement (LCA) dated February 2000, including the 21 January 2009 update to the Libby Operating Plan (LOP), and U.S. requirements for power and guidelines set forth in the U.S. Fish and Wildlife Service (USFWS) 2000 Biological Opinion and the U.S. National Marine Fisheries Service (NMFS) Biological opinions and Action Agency Plans, as approved by Court order. Canadian Entitlement power was delivered to Canada in accordance with the DOPs, the Entity Agreement on Aspects of the Delivery of the Canadian Entitlement dated 29 March 1999 and Entitlement related agreements described below.

## Entity Agreements

Agreements approved by the Entities during the period of this report include:

- Columbia River Treaty Entity Agreement on the Assured Operating Plan (AOP) and Determination of Downstream Power Benefits for the 2013-14 Operating Year, signed11 February 2009;
- Columbia River Treaty Entity Agreement on the DOP for Canadian Storage 1 August 2009 through 31 July 2010, signed 1 July 2009; and
- Columbia River Treaty Entity Agreement on the 2009 Summer Storage Agreement (Not Treaty) for 6 June 2009 through 4 September 2009, signed 29 June 2009.

## Columbia River Treaty Operating Committee Agreements

The Columbia River Treaty Operating Committee (CRTOC) completed five agreements during the reporting period:

- Agreement of the CRTOC on the Operation of Canadian Treaty and Libby Storage Reservoirs for the period 2 August 2008 through 31 December 2008 signed on 12 August 2008.
- CRTOC on the Provisional Storage for the period 1 September 2008 through 3 April 2009, signed 9 September 2008.
- CRTOC on Operation of Treaty Storage for Nonpower Uses for 15 December 2008 through 31 July 2009 signed on 20 November 2008.
- CRTOC Agreement for Flow Shaping for the period 10 January 2009 through 3 April 2009, signed 12 January 2009.
- CRTOC Agreement on Provisional Storage for the period 26 September 2009 through 3 April 2010, signed 28 September 2009.

In addition to the Operating Committee agreements listed here, the Bonneville Power Administration (BPA) and British Columbia Hydro and Power Authority (B.C. Hydro) developed a bilateral agreement entitled "2009 Summer Storage Agreement (Not Treaty) for the period 6 June 2009 through 4 September 2009," signed 10 June 2009.

## System Operation

Under the 2008-09 and 2009-10 DOPs, Canadian storage was operated according to criteria from the 2008-09 and 2009-10 AOPs. The 2008-09 AOP operating criteria is the same as the prior two AOP's, and the operating criteria during August and September 2009 from the 2009-10 AOP is similar to the 2008-09 AOP except for slightly higher critical rule curves.

Composite Treaty storage was very close to the Treaty Storage Regulation (TSR) composite storage except for small amounts of inadvertent draft or storage in all periods. Inadvertent draft or storage occurs routinely due to updated forecasts or differences between

forecast and actual inflows. Canadian storage began the operating year below the DOP levels (by 105 cubic hectometer ($hm^3$) or 85 thousand acre feet (kaf) determined in the TSR study primarily due to inadvertent draft. September through June show larger differences between TSR and Canadian storage because of supplemental operating agreements that were implemented and resulted in mutual benefits for both the US and Canada.

During August 2008, Canadian storage was operated to forecasted TSR levels, except for a small amount of draft at Arrow under the Libby Swap Agreement that was completed in December 2008. In accordance with a fall Supplemental Operating Agreement, Canadian stored 653 $hm^3$ (530 kaf) in September 2008, ending the month 571 $hm^3$ (463 kaf) above TSR levels. This also included a small amount of provisional return authorized by the Libby Coordination Agreement (LCA), and return of half of the Libby swap. October and November continued with an additional 899 $hm^3$ (729 kaf) of Canadian storage in accordance with the fall Supplemental Operating Agreement with maximum releases in February. The Canadian Entity exercised the option to provisionally draft Arrow the second time 306 $hm^3$ (248 kaf) in December. In accordance with two additional Supplemental Operating Agreements, Canadian storage filled to about 2750 $hm^3$ (2230 kaf) above the TSR in January 2009. Of this amount, 333 $hm^3$ (270 kaf) was stored at Arrow according to a January Storage Shaping because of runoff conditions and 1233 $hm^3$ (1000 kaf) was stored at Mica according to the Non-Power Uses Agreement. All of the fall storage was released by March and Arrow outflows remained at 680 $m^3/s$ (24 kcfs) or lower from April through June for fish protection, Canadian storage remained above the TSR through June, and returned to near TSR levels in July.

## Canadian Entitlement

During the reporting period, the U.S. Entity delivered the Canadian Entitlement to downstream power benefits from the operation of Mica, Duncan and Arrow reservoirs to the Canadian Entity, at existing points of interconnection on the Canada-U.S. border. The amount returned, not subtracting transmission losses and scheduling adjustments, was 464.9 average megawatts (aMW) at rates up to 1245 MW during 1 August 2008 through 31 July 2009, and 567.1 aMW at rates up to 1352 MW during 1 August 2009 through 30 September 2009.

During the course of the Operating Year, no curtailments of Canadian Entitlement occurred.

## Treaty Project Operation

At the beginning of the 2008-09 operating year, 1 August 2008, actual Canadian storage was at 17.6 $km^3$ (14.2 Maf) or 91.8 percent full. Canadian storage ended the operating year on 31 July 2009, at 15.7 $km^3$ (12.7 Maf) or 82.0 percent full.

The Mica (Kinbasket) reservoir reached a maximum elevation of 751.9 m (2,466.9 ft) on 15 September 2008, 2.47 m (8.1 ft) below full pool. The reservoir was drawn down during the fall and winter to meet electrical demands and to prepare for the spring runoff. It reached a minimum this year at 730.4 m (2396.2 ft) on May 9, 2009, a couple of weeks later than normal due to the delayed freshet. By comparison, in 2008, the minimum level was 718.14 m (2356.1 ft) on May 5. As is normal, reservoir releases were reduced in late May through early July in response to lower electrical demands and system constraints, and to achieve a high probability of refill on the reservoir. The reservoir reached a maximum elevation of 752.2 m (2467.7 ft), 2.2 m (7.3 ft) below full pool on 25 September 2009.

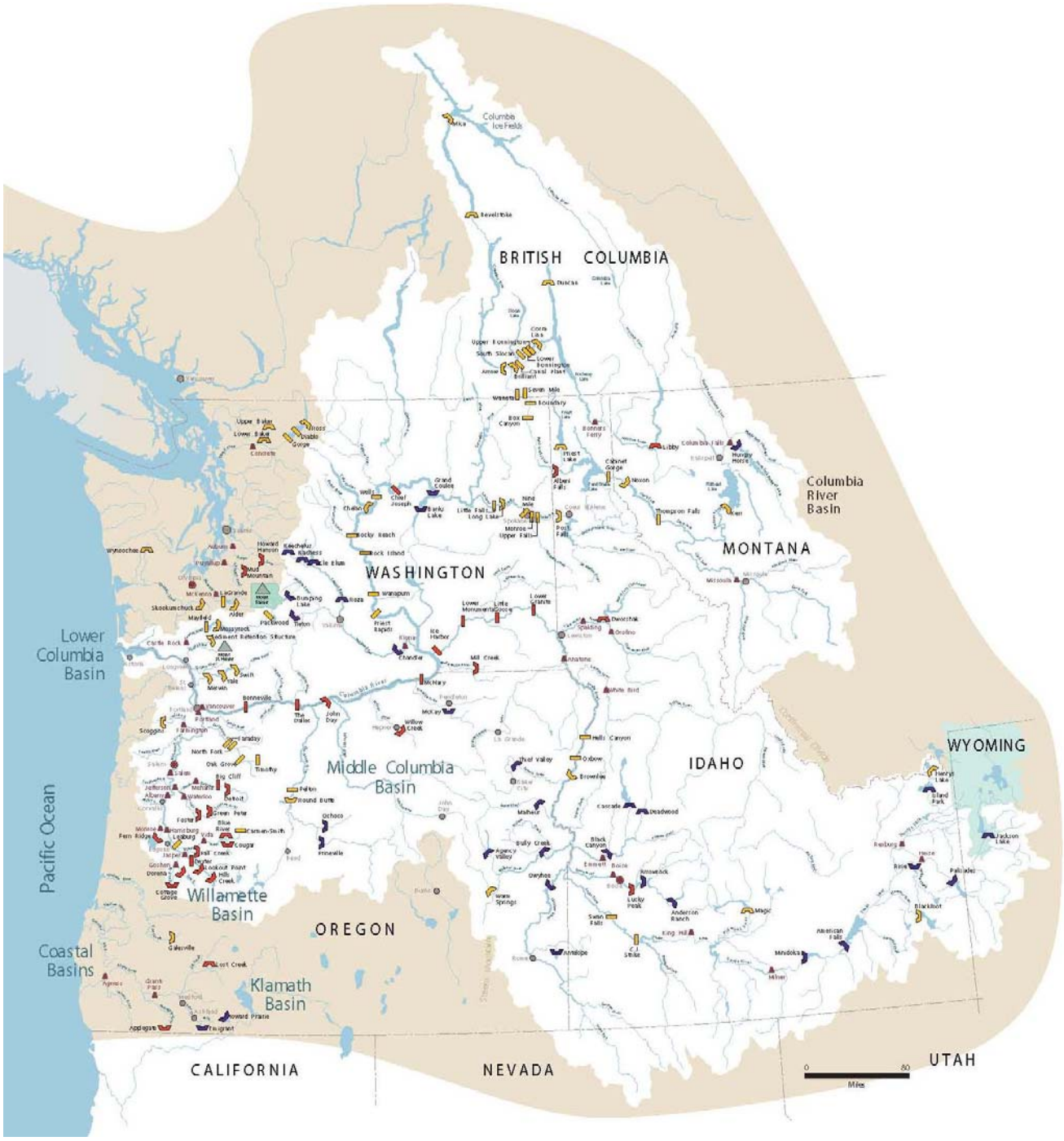
The Arrow reservoir reached a maximum elevation of 440.0 m (1,443.5 ft) on 5 July 2008, 0.15 m (0.5 ft) below full pool. Arrow reservoir drafted across fall and winter as is normal to meet Treaty firm loads. It reached a minimum level this year at 429.3 m (1408.6 ft) on March 30. By comparison, the Arrow Lakes Reservoir reached a minimum level of 430.76 m (1413.26 ft) on May 12, 2008. Influenced by relatively good starting conditions combined with the July 1990 Non-Treaty Storage Agreement (NTSA) and Treaty Flex operations, the reservoir refilled to its Treaty flood control level (maximum possible level) in May. The reservoir continued to refill across June through early July to reach a maximum elevation of 437.8 m (1435.6 ft) on June 30, 2.5 m (8.4 ft) below full.

Duncan reservoir refilled to 576.53 m (1,891.5 ft), 0.15 m (0.5 ft) below full pool on 11 August 2008. From September 2008 through April 2009, Duncan discharge was used to supplement inflow into Kootenay Lake and to provide spawning and incubation flows for fish. B.C. Hydro sought and received variance for February flood control to 552.5 m (1,812.5 ft). This was reached on 28 February 2009, and 551.0 m (1,807.7 ft) was reached on 13 March 2009. The reservoir drafted to a minimum elevation of 547.09 m (1,794.9 ft) on

23 April 2009. Reservoir discharge was reduced to a minimum of 3.0 $m^3/s$ (0.1 kcfs) on 25 May 2009 to initiate reservoir refill. The reservoir refilled to a maximum elevation of 575.86 m (1,889.3 ft), 0.82 m (2.7 ft) below full pool on 21 August 2009.

The Libby (Kookanusa) Reservoir began August 2008 at elevation 744.87 m (2,443.8 ft) and drafted through the fall and winter period. By 31 December, the reservoir was at elevation 734.84 m (2,410.9 ft) and operated during the winter to the VARQ storage reservation diagram. The reservoir drafted to its lowest elevation of 732.37 m (2,402.8 ft) on 9 April. During the refill period, Libby Dam operated in strict accordance to the VARQ operating procedures and provided 0.98 $km^3$ (0.8 Maf) of storage for sturgeon releases. The reservoir filled to its maximum elevation of 744.7 m (2,443.3 ft) on 25 August 2009, 4.8 m (15.7 ft) from full pool. The project drafted to elevation 744.63 m (2,443.0 ft) by 31 August.

# Columbia Basin Map



*2009 Report of the Columbia River Treaty Entities*

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# Acronyms and Abbreviations

AER.....Actual Energy Regulation

aMW…….. .....Average Megawatts

AOP…….....Assured Operating Plan

B.C. Hydro.....British Columbia Hydro and Power Authority

BiOp.....Biological Opinion

BG ….....Brigadier General

BPA.....Bonneville Power Administration

CEEA.....Canadian Entitlement Exchange Agreement

CEPA.....Canadian Entitlement Purchase Agreement

COL ……...Colonel

cfs.....Cubic feet per second

CRC.....Critical Rule Curve

CROHMS.....Columbia River Operational Hydromet Management System

CRT.....Columbia River Treaty

CRITFC.....Columbia River Inter-Tribal Fish Commission

CRTHC.....Columbia River Treaty Hydrometeorological Committee

CRTOC.....Columbia River Treaty Operating Committee

CSPE.....Columbia Storage Power Exchange

DDPB.....Determination of Downstream Power Benefits

DOP.....Detailed Operating Plan

DRL.....Duncan River below the Lardeau confluence

FCOP.....Flood Control Operating Plans

ft.....feet

$hm^3$.....Cubic hectometers

in.....inch

ICF.....Initial Controlled Flow

IJC.....International Joint Commission

JSS…….. January Storage Shaping

kaf .....Thousand acre feet

kcfs.....Thousand cubic feet per second

$km^3$ .....Cubic Kilometer (one million cubic meters)

ksfd.....Thousand second-foot-days (= kcfs x days)

LCA.....Libby Coordination Agreement

LOP .....Libby Operating Plan

m .....Meter

$m^3/s$ .....Cubic meters per second

Maf.....Million acre-feet

MW .....Megawatt

NMFS.....National Marine Fisheries Service

NOAA F.....NOAA Fisheries, formerly NMFS

NTSA .....Non-Treaty Storage Agreement

ORC .....Operating Rule Curve

OY.....Operating Year

PEB .....Permanent Engineering Board

PEBCOM .....PEB Engineering Committee

PNCA.....Pacific Northwest Coordination Agreement

PNW.....Pacific Northwest

POP ……Principles and Procedures

SOR.....System Operational Requests

TMT .....Technical Management Team

TSR .....Treaty Storage Regulation

U.S. .....United States

USACE .....U.S. Army Corps of Engineers

USFWS .....U.S. Fish and Wildlife Service

VARQ .....Variable discharge flood control

VRC .....Variable refill curves

WSF .....Water Supply Forecast

WUP.....Water Use Plan

WY .....Water Year

# I – INTRODUCTION

This annual Columbia River Treaty Entity Report is for the 2009 water year (WY), 1 October 2008 through 30 September 2009, with additional information on the operation of Mica, Arrow, Duncan, and Libby reservoirs during the reservoir system operating year, 1 August 2008 through 31 July 2009. The power and flood control effects downstream in Canada and the U.S. are described. This report is the 43rd of a series of annual reports covering the period since the ratification of the Columbia River Treaty (CRT) in September 1964.

Duncan, Arrow, and Mica reservoirs in Canada were constructed as required under the CRT, and Libby reservoir in the U.S. was constructed as provided for by the CRT. Treaty storage in Canada (Canadian storage) is operated for the purposes of flood control and increasing hydroelectric power generation in Canada and the U.S. In 1964, the Canadian and the U.S. governments each designated an Entity to formulate and carry out the operating arrangements necessary to implement the CRT. The Canadian Entity for these purposes is B.C. Hydro. The Canadian Entity for the limited purpose of making arrangements for disposal of all or portions of the Canadian Entitlement within the United States is the government of the Province of British Columbia. The U.S. Entity is the Administrator/Chief Executive Officer of Bonneville Power Administration (BPA) and the Division Engineer of the Northwestern Division, U.S. Army Corps of Engineers (USACE).

The following is a summary of key features of the CRT and related documents:

1. Canada was to provide 19.12 cubic kilometers (km3) (15.5 million acre feet (Maf)) of usable storage. This has been accomplished with 8.63 km3 (7.0 Maf) in Mica, 8.78 km3 (7.1 Maf) in Arrow, and 1.73 km3 (1.4 Maf) in Duncan.
2. For the purpose of computing downstream power benefits the U.S. base system hydroelectric facilities will be operated in a manner that makes the most effective use of the improved streamflow resulting from operation of the Canadian storage.
3. The U.S. and Canada are to share equally the downstream power benefits generated in the U.S. resulting from operation of the Canadian storage.

4. The U.S. paid Canada a lump sum of the $64.4 million (U.S.) for one half of the present worth of expected future flood control benefits in the U.S. to September 2024, resulting from operation of the Canadian storage.
5. The U.S. has the option of requesting the evacuation of additional flood control space above that specified in the CRT, for a payment of $1.875 million (U.S.) plus power losses for each of the first four requests for this "on-call" storage. No requests under this provision have been made to date.
6. The U.S. had the option (which it exercised) to construct Libby Dam with a reservoir that extends 67.6 kilometers (42 miles) into Canada and for which Canada agreed to make the land available.
7. Both Canada and the U.S. have the right to make diversions of water for consumptive uses. In addition, since September 1984, Canada has had the option of making, for power purposes, specific diversions of the Kootenay River into the headwaters of the Columbia River.
8. Differences arising under the Treaty which cannot be resolved by the two countries may be referred to either the International Joint Commission (IJC) or to arbitration by an appropriate tribunal.
9. The Treaty shall remain in force for at least 60 years from its date of ratification, 16 September 1964 (and otherwise indefinitely), after which either Government has the option to terminate most sections of the Treaty if a minimum of 10 years' advance notice has been given.
10. In the Canadian Entitlement and Purchase Agreement (CEPA) of 13 August 1964, Canada sold its entitlement to downstream power benefits (Canadian Entitlement) to the Columbia Storage Purchase Exchange (CSPE - a consortium of U.S. utilities) for 30 years beginning at Duncan on 1 April 1968, Arrow on 1 April 1969, and Mica on 1 April 1973. That sale has now expired and all Canadian Entitlement has reverted to British Columbia provincial ownership and is being either delivered to the Canada-U.S. border or sold directly in the United States.
11. Canada and the U.S. each appointed Entities to implement Treaty provisions and are to jointly appoint a joint Permanent Engineering Board (PEB) to review and report on operations under the CRT.

# II - TREATY ORGANIZATION

## Entities

There was one meeting of the CRT Entities (including the Canadian and U.S. Entities and Entity Coordinators) during the year on the morning of 24 February 2009 in Portland, Oregon.

The members of the two Entities at the end of the period of this report were:

| UNITED STATES ENTITY | CANADIAN ENTITY |
|---|---|
| Mr. Stephen J. Wright, Chairman<br>Administrator & Chief Executive Officer<br><br>Bonneville Power Administration<br>Department of Energy<br>Portland, Oregon | Mr. Robert G. Elton, Chair<br>President & Chief Executive Officer<br>British Columbia<br>Hydro and Power Authority<br>Vancouver, British Columbia |

Brigadier General William E. Rapp, Member
Division Engineer
Northwestern Division
U.S. Army Corps of Engineers
Portland, Oregon

The Entities have designated alternates to act on behalf of the primaries in their absence; appointed in the U.S. by a Memorandum of Agreement between Bonneville and Corps of Engineers, and in Canada by the B.C. Hydro Board of Directors. Mr. Wright's alternate is Bonneville Acting Deputy Administrator, Allen L. Burns; Mr. Elton's Deputy position is Chris K. O'Riley, Senior Vice President for Engineering, Aboriginal Relations & Generation; and BG William E. Rapp's alternate is COL Miroslav P. Kurka (Deputy Division Engineer).

The Entities have appointed Coordinators, Secretaries, and two joint standing committees to assist in CRT implementation activities that are described in subsequent paragraphs. The primary duties and responsibilities of the Entities as specified in the CRT and related documents are to:

1. Plan and exchange information relating to facilities used to obtain the benefits contemplated by the CRT;
2. Calculate and arrange for delivery of hydroelectric power to which Canada is entitled and the amounts payable to the U.S. for standby transmission services (the latter is no longer in effect);
3. Operate a hydrometeorological system;
4. Assist and cooperate with the PEB in the discharge of its functions;
5. Prepare and implement Flood Control Operating Plans (FCOPs) for the use of Canadian storage;
6. Prepare Assured Operating Plans (AOP) for Canadian storage and determine the resulting downstream power benefits that Canada is entitled to receive; and
7. Prepare and implement Detailed Operating Plans (DOPs) that may produce results more advantageous to both countries than those that would arise from operation under AOPs.

Additionally, the CRT provides that the two governments, by exchange of diplomatic notes, may empower or charge the Entities with any other matter coming within the scope of the CRT.

## Entity Coordinators & Secretaries

The Entities have appointed Coordinators from members of their respective staffs to help manage and coordinate CRT related work, and Secretaries to serve as information focal points on all CRT matters within their organizations. Those personnel are:

UNITED STATES ENTITY
COORDINATORS
Stephen R. Oliver
Vice President, Generation Supply
Bonneville Power Administration
Portland, Oregon

David J. Ponganis*
Director, Civil Works & Management
Northwestern Division
U.S. Army Corps of Engineers
Portland, Oregon

CANADIAN ENTITY
COORDINATOR
Renata Kurschner
Director
Generation Resource Management
B.C. Hydro
Burnaby, British Columbia

* David J. Ponganis temporarily replaced G. Witt Anderson as acting Coordination on 7 June 2009.

UNITED STATES ENTITY
SECRETARY
Dr. Anthony G. White
Regional Coordination
Power and Operations Planning
Bonneville Power Administration
Portland, Oregon

CANADIAN ENTITY
SECRETARY
Douglas A. Robinson
Generation Resource Management
B.C. Hydro
Burnaby, British Columbia

## Columbia River Treaty Operating Committee

The Columbia River Treaty Operating Committee (CRTOC) was established in September 1968 by the Entities, and is responsible for preparing and implementing operating plans as required by the CRT, making studies and otherwise assisting the Entities as needed. The CRTOC consists of eight members as follows:

UNITED STATES SECTION
Richard M. Pendergrass, BPA, Alt. Chair
James D. Barton, USACE, Alt. Chair
Steven B. Barton, USACE *
John M. Hyde, BPA

CANADIAN SECTION
Kelvin Ketchum, B.C. Hydro, Chair
Dr. Thomas K. Siu, B.C. Hydro
Gillian Kong, B.C. Hydro
Herbert Louie, B.C. Hydro

* Mr. Steven Barton was appointed to replace Ms. Cathy Hlebechuk on 6 July 2009.

The CRTOC met during the reporting period to exchange information, approve work plans, discuss issues, agree on operating plans, and brief the PEB and PEBCOM. There were six regular meetings held every other month alternating between Canada and the U.S., plus one meeting with the PEBCOM. During the period covered by this report, the CRTOC:

- Coordinated the operation of the CRT storage in accordance with the current hydroelectric operating plans and FCOP;
- Coordinated changes to procedures and reviewed scheduled delivery of the Canadian Entitlement according to the CRT and related agreements;

- Completed studies and documents for the 2013-14 AOP/Determination of Downstream Power Benefits (DDPB) and initiated studies for the 2014-15 AOP/DDPB;
- Completed the 1 August 2009 through 31 July 2010 DOP;
- Completed three supplemental operating agreements for Canadian storage;
- Implemented the Libby Coordination Agreement (LCA) including the 21 January 2009 update to the Libby Operating Plan (LOP) which involved scheduling of provisional draft, delivery of one average MW of power, and analysis and monitoring of Canadian power effects from Variable Q flood control operation at Libby;
- Briefed the PEBCOM on Entity activities, and completed the 2008 Entity Annual Report; and
- Continued studies and analysis for the 2014/Post-2024 CRT Review. A progress report was made to PEBCOM on 22 October 2008 and to PEB and PEBCOM on 24 February 2009. Presentations on the Treaty and 2014 were made to over a dozen Tribal, governmental, utility, and international groups. A 2014 web site was stood up. The U.S. Entity met with the U.S. Section of PEB on 1 June 2009, and a written update was provided to the PEB and PEBCOM on 2 June 2009. The process of preparing the Phase 1 Study Report, which will present results of the studies, was begun. The Entities continued to implement the Agreement on the Preparation of Joint Studies, agreed to on 4 July 2008.

These aspects of the CRTOC's work are described in following sections of this report, which have been prepared by the CRTOC with the assistance of others.

Pictured from left to right: Herbert Louie (B.C. Hydro, Member), Steve Oliver (BPA, Coordinator), Tom Siu (B.C. Hydro, Member), Dave Ponganis (USACE, Coordinator), John Hyde (BPA, Member), Rick Pendergrass (BPA, U.S. Alt. Chair), Stephanie Smith (B.C. Hydro, Canadian HydroMet Chair), Gillian Kong (B.C. Hydro, Member), Tony White (BPA, U.S. Entity Secretary), Doug Robinson (B.C. Hydro, Canadian Entity Secretary), Kelvin Ketchum (B.C. Hydro, Canadian Chair), James Barton (USACE, U.S. Alt. Chair), and Steve Barton (USACE, Member). In the background is Revelstoke Unit 5 under construction

## Columbia River Treaty Hydrometeorological Committee

The Hydrometeorological Committee was established in September 1968 by the Entities and is responsible for planning and monitoring the operation of data facilities in accordance with the Treaty and otherwise assisting the Entities as needed. The Committee consists of four members as follows:

| UNITED STATES SECTION | CANADIAN SECTION |
|---|---|
| David Bright*, BPA Co-Chair | Stephanie Smith, B.C. Hydro, Chair |
| Peter Brooks, USACE Co-Chair | Frank Weber**, B.C. Hydro, Member |

* David Bright replaced Brian Kuepper effective 3 August 2009.
** Frank Weber replaced Doug Smith as Canadian Member on 1 November 2008.

It was decided in 2008 for the CRTHC to meet regularly and semi-annually in WY2009. Meetings were held on 3 November 2008 and 10 June 2009, respectively at B.C. Hydro and Bonneville Power. WY2010 meetings are scheduled on 4 December in Canada, and six months later in the U.S. The 2008 Annual report was submitted on time, and the 2009 Annual Report will be completed prior to the February 2010 PEB Meeting with B.C. Hydro acting as lead. It was decided that from now on the committee will include forecast verification in annual report. David Bright, BPA replaced Brian Kuepper as the U.S. Co chair in August of 2009.

## Forecasting

The CRTHC prepared and submitted to CRTOC the objective procedure tool to forecast onset of Kootenay Lake spring Freshet. Kootenay Lake Board of Control/IJC is reviewing the proposal. The procedure will not replace human decision making. Walla Walla District is contemplating a modification to Dworshak volume forecast procedure to include mid-month adaptive management.

## Data Exchange

In accordance with Section 3.1.C(1) of the 2003 POP, the Entities participated in studies to update the estimated irrigation depletions in the historic streamflow record used for Assured Operating Plan studies. This effort, entitled the “2010 Modified Flows” formally began in August 2009 and is expected to be completed in years. Most of the work will be conducted by staff from the Northwestern Division of the U.S. Army Corps of Engineers, Bonneville Power Administration, and the Bureau of Reclamation. The contractors that produced the 2000 Modified Flows were hired to help train staff and their costs will be shared ($140K) by the PNCA Parties.

The Corps new Regional Water Control Data System (RWCDS) is on track for deployment in 2010. It will use agency standard hardware and software (CWMS 2.0). The RWCDS will be a tri-node system for redundancy and Continuity of Operations. All support

operations will be managed at the regional level, pooling resources from three Corps districts and the Columbia Basin Water Management Division. A Steering Committee (SC) has been established to oversee the RWCDS. The permanent Program Manager (Troy Fox) has been selected to lead implementation and manage the system as laid out by the SC.

### Stations

The Natural Resource Conservation Service in U.S. review of the SNOTEL network identified nine potential closures. The CRTHC and other water managers are reviewing the proposal. A status update will be made available in time for the 2010 PEB meeting. The CRTHC will prepare a draft proposal for review by CRTOC to recommend additional hydromet stations.

## Permanent Engineering Board

Provisions for the establishment of the Permanent Engineering Board (PEB) and its duties and responsibilities are included in the CRT and related documents. The members of the PEB at present are:

| UNITED STATES SECTION | CANADIAN SECTION |
|---|---|
| Stephen L. Stockton, Chair<br>Washington, D.C. | Tom Wallace, Chair<br>Ottawa, Ontario |
| Edward Sienkiewicz, Member<br>Newberg, Oregon | Tim Newton, Member<br>Vancouver, British Columbia |
| Dr. Robert A. Pietrowsky, Alternate<br>Washington, D.C. | Glen Davidson, Alternate<br>Victoria, British Columbia |
| George E. Bell, Alternate<br>Portland, Oregon | Ivan Harvie, Alternate<br>Calgary, Alberta |

The following serve as Secretaries to the Board:

| | |
|---|---|
| Jerry W. Webb, Secretary<br>Washington, D.C. | Darcy Blais, Secretary<br>Ottawa, Ontario |

* Mr. Glen Davidson replaced Mr. James Mattison on 4 June 2009.

Under the CRT, the PEB is to assemble records of flows of the Columbia River and the Kootenay River at the international boundary. The PEB is also to report to both governments if there is substantial deviation from the hydroelectric or flood control operating plans, and if appropriate, include recommendations for remedial action. Additionally, the PEB is to:

- Assist in reconciling differences that may arise between the Entities;
- Make periodic inspections and obtain reports as needed from the Entities to assure that CRT objectives are being met;
- Prepare an annual report to both governments and special reports when appropriate;
- Consult with the Entities in the establishment and operation of a hydrometeorological system; and
- Investigate and report on any other CRT related matters at the request of either government.

The Entities continued their cooperation with the PEB during the past year by providing copies of Entity agreements, operating plans, CRTOC agreements, updates to hydrometeorological documents, personnel appointments, pertinent correspondence, and the annual Entity report to the Board for their review. The annual joint meeting of the PEB and the Entities was held on 25 February 2009 in Portland, Oregon, where the Entities briefed the PEB on the preparation and implementation of operating plans, the delivery of the Canadian Entitlement, the 2014/2024 CRT Review, and other topics requested by the Board.

## PEB Engineering Committee

The PEB has established the PEBCOM to assist in carrying out its duties. The members of PEBCOM at the end of the period of this report were:

| UNITED STATES SECTION | CANADIAN SECTION |
|---|---|
| Jerry W. Webb, Chair<br>Washington, D.C. | Ivan Harvie, Interim Chair *<br>Victoria, British Columbia |
| Michael S. Cowan, Member<br>Lakewood, CO | Darcy Blais, Member<br>Ottawa, Ontario |

Kamau B. Sadiki, Member
Washington, D.C.

Ivan Harvie, Member
Calgary, Alberta

Patrick McGrane*, Member
Boise, ID

K.T. Shum, Member *
Victoria, British Columbia

* Mr. Patrick McGrane replaced D. James Fodrea on 27 February 2009; Mr. Roger McLaughlin retired in January of 2009, and was replaced on an interim basis by Mr. Harvie; K.T. Shum replaced Dr. Bala Balachandran on 21 November 2008.

The PEBCOM met with the CRTOC on 22 October 2008 in Portland, Oregon.

## International Joint Commission

The International Joint Commission (IJC) was created under the Boundary Waters Treaty of 1909, between Great Britain (on behalf of Canada) and the U.S. Its principal functions are rendering decisions on the use of boundary waters, investigating important problems arising along the common frontier not necessarily connected with waterways, and making recommendations on any question referred to it by either government. If the Entities or the PEB cannot resolve a dispute concerning the CRT, that dispute may be referred to the IJC for resolution.

The IJC has appointed local Boards of Control to insure compliance with IJC orders and to keep the IJC informed. There are three such boards west of the continental divide. These are the International Kootenay Lake Board of Control, International Columbia River Board of Control, and International Osoyoos Lake Board of Control. The Entities and IJC Boards conducted their CRT activities during the period of this report so that there was no known conflict with IJC orders or rules.

In fall of 2007, CRTOC approached the Kootenay Lake Board of Control on two issues:

1. Clarification/development of criteria for declaration of spring freshet on Kootenay Lake and
2. Influence of Kootenay Lake Order on operation of Duncan and Libby.

With respect to the spring freshet issue, a draft letter to the IJC on Kootenay Lake Declaration of the Freshet has been developed by the CRTHC. The draft will be forwarded to the Kootenay Lake Board of Control Secretaries as well as FortisBC for input/comments. With respect to the operation of upstream projects, the IJC staff gave their view in an e-mail

that the “Order of Approval is not directed to and does not affect the actions of the operators of the dams controlling inflows to Kootenay Lake" and said that the "The Commission concurs with this advice.” The Board of Control indicated that they are still evaluating the issue.

The U.S. Section Chair is Ms. Irene B. Brooks of Seattle, Washington. The Canadian Section Chair is The Right Honorable Herb Gray of Ottawa, Canada. Canadian members are Mr. Lyall D. Knott, Vancouver, B.C., and Mr. Pierre Trepanier, Montreal, Quebec. The U.S. members are Mr. Allen I. Olson, Edina, Minnesota and Dr. Samuel W. Speck of Ohio.

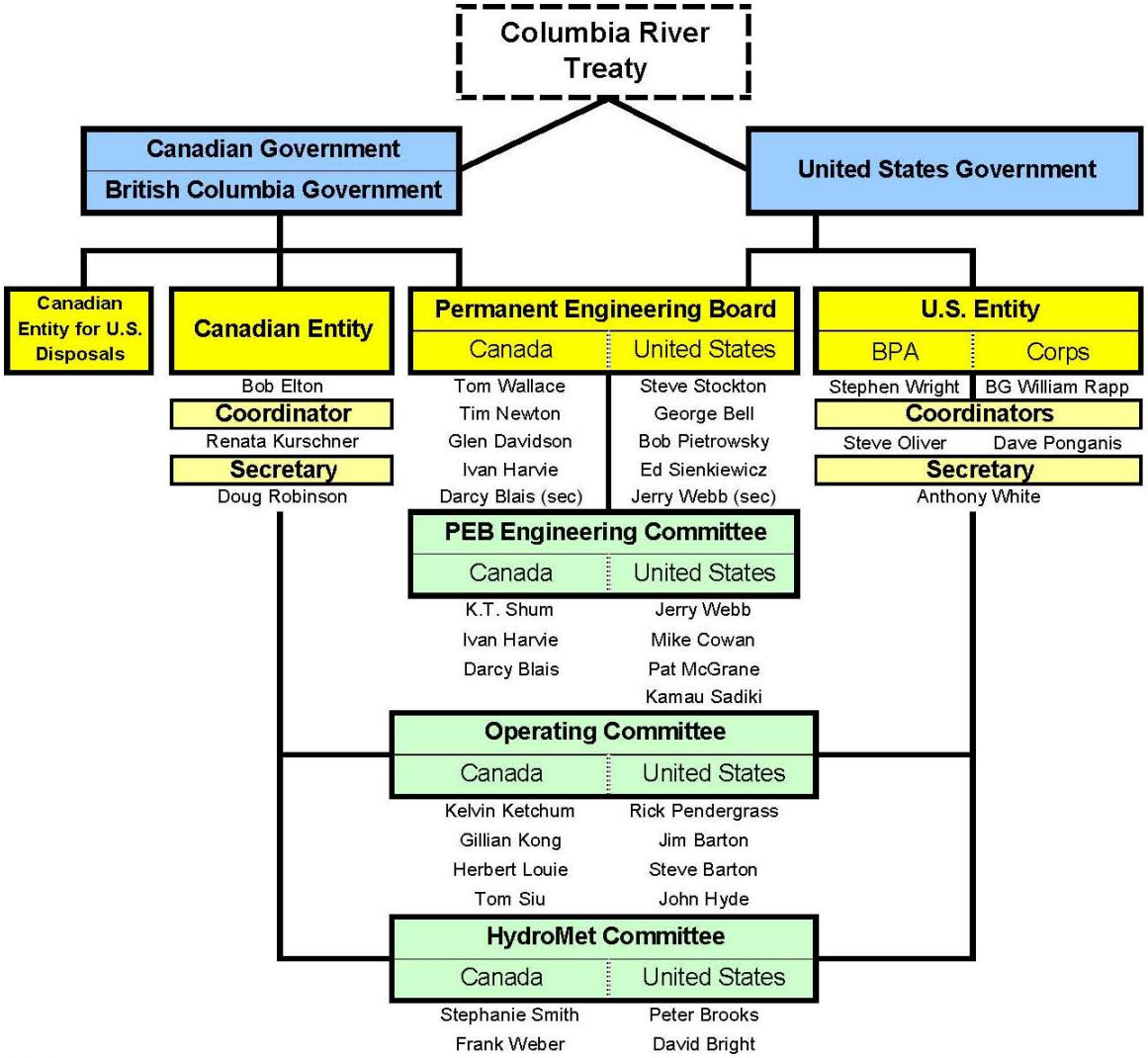
During the reporting period, members of the Operating Committee exchanged letters and met with the Kootenay Lake Board of Control on questions concerning potential constraints on the operation of Libby and Duncan when water levels in Kootenay Lake may exceed the reference elevations specified under the 1938 IJC Order. No conclusions were reached, and these discussions are expected to continue.

## Presentations

During the period covered by this report, CRT personnel made presentations about the history, structure, operations, challenges and communications associated with the CRT to visitors and inquirers from professional, environmental, academic and civic groups and individuals; new employees; Northwest Power Planning Council staff and foreign visitors from Brazil.

# Columbia River Treaty Organization

## Organization Chart for the Columbia River Treaty




Notes:
1) The Entities and the PEB are creations of the Treaty, and all report directly to their respective governments.
2) The Operating Committee and the HydroMet Committee report to the Entities; the PEBCOM reports to the PEB.
3) CRT XIV2(f): The Entities are tasked with "*assisting and cooperating with the PEB*".
4) CRT XV2(c): Similarly, the PEB is directed to *"assist in reconciling differences concerning technical or operational matters that may arise between the entities"*.

# III - OPERATING ARRANGEMENTS

## Power and Flood Control Operating Plans

The CRT requires that the reservoirs constructed in Canada be operated pursuant to flood control and hydroelectric operating plans developed hereunder. Annex A of the CRT:

1. Stipulates that the U.S. Entity will submit FCOPs.
2. States that the Canadian Entity will operate in accordance with flood control storage diagrams or any variation which the Entities agree will not reduce the desired aim of the flood control plan; and
3. Provides for the development of assured hydroelectric operating plans for Canadian storage for the sixth succeeding year of operation.

Article XIV.2.k of the CRT provides that a DOP be developed that may produce results more advantageous than the AOP. The Protocol to the CRT provides further detail and clarification of the principles and requirements of the CRT.

The "Principles and Procedures for the Preparation and Use of Hydroelectric Operating Plans for Canadian Treaty Storage", signed December 2003 (as amended), together with the "Columbia River Treaty Flood Control Operating Plan" dated May 2003 (as revised), establish and explain the general criteria used to develop the AOP and DOP and operate CRT storage during the period covered by this report.

The planning and operation of CRT Storage as discussed on the following pages are for the operating year, 1 August 2008 through 31 July 2009. The operation of Canadian storage was determined by the 2008-09 DOP and supplemental operating agreements. The DOP required a semi-monthly Treaty Storage Regulation (TSR) study to determine end-of-month storage obligations prior to any supplemental operating agreements. The TSR included all operating criteria from, and was based on, the Step I Joint Optimum Power Hydroregulation Study from the 2008-09 AOP, with agreed changes. Most of the hydrographs and reservoir charts in this report are for a 14-month period, August 2008 through September 2009.

## Assured Operating Plans

During the reporting period, the Entities completed the 2013-14 AOP. This AOP used the streamline procedures described in Appendix 6 of the 2003 POP and is based on the 2011-12 AOP/DDPB hydroregulation studies.

The 2013-14 AOP establishes Operating Rule Curves (ORCs), Critical Rule Curves (CRCs), Mica and Arrow Project Operating Criteria, and other operating criteria included in the Step I Joint Optimum Power Hydroregulation Study, to guide the operation of Canadian storage. The ORCs were derived from CRCs, Assured Refill Curves (ARC), Upper Rule Curves (Flood Control Rule Curves), Variable Refill Curves (VRC) and Operating Rule Curve Lower Limits (ORCLL), consistent with flood control requirements, as described in the 2003 POP. They provide guidelines for draft and refill under a wide range of water conditions. The Flood Control Rule Curves conform to the 2003 FCOP, and are used to define maximum reservoir levels for the operation of Canadian storage. The 2013-14 AOP uses the 5.03/4.44 $km^3$ (4.08/3.6 Maf) Mica/Arrow flood control allocation. The CRCs are used to apportion draft below the ORC when the TSR determines additional draft is needed to meet the Coordinated System firm energy load carrying capability. Because of the use of the streamline procedure, the 2013-14 AOP operating criteria is a direct carry-over from the 2011-12 AOP.

During the reporting period, the Entities initiated studies for the 2014-2015 AOP, which were not completed by the end of the reporting period.

## Determination of Downstream Power Benefits

For each operating year, the DDPB resulting from Canadian storage operation is made in conjunction with the AOP according to procedures defined in the CRT, Annexes, and Protocol and, except as noted in the AOP/DDPB documents, the 2003 Principles and Procedures agreement. For the 2013-14 DDPB, the Entities agreed to use the optional streamline procedures described in Appendix 6 of the 2003 POP. The 2013-14 DDPB results showed a 14.7 MW increase in the capacity benefit and a 1.0 aMW increase in the energy benefit compared to the previous year DDPB. This increase in the energy benefit from the prior year was mainly due to the change in thermal maintenance schedules. The total CRT downstream power benefits as a result of the operation of Canadian storage for the 2013-14

operating year were determined to be 1,011.0 aMW of annual usable energy and 2,671.0 MW of dependable capacity.

## Canadian Entitlement

For the period 1 August 2008 through 31 July 2009, the Canadian Entitlement amount, before losses, was 464.9 aMW of energy, scheduled at rates up to 1,245 MW, and from 1 August 2009 through 30 September 2009, the amount, before losses, was 567.1 aMW of energy, scheduled at rates up to 1,352 MW. The Canadian Entitlement obligation was determined by the 2008-09 and 2009-10 AOP/DDPB's.

During the course of the Operating Year, there were no curtailments of Canadian Entitlement deliveries for any reason.

## Detailed Operating Plans

During the period covered by this report, the CRTOC used the 1 August 2008 through 31 July 2009 "Detailed Operating Plan for Columbia River Treaty Storage," dated June 2008, and the 1 August 2009 through 31 July 2010 DOP, dated June 2009, to guide Canadian storage operations. These DOPs established criteria for determining the ORCs, proportional draft points, and include other operating criteria for use in actual operations. The 2008-09 and 2009-10 DOPs were based respectively on the 2008-09 AOP and 2009-10 AOP loads and resources, rule curves, and other operating criteria with agreed changes for both Canadian and U.S. projects. The 2008-09 and 2009-10 AOPs included a flood control allocation of 4.43 $km^3$ (3.6 Maf) in Arrow and 5.03 $km^3$ (4.08 Maf) in Mica. The 2008-09 DOP and 2009-10 DOP operating criteria were used to develop the Treaty Storage Regulation (TSR) studies. The changes from the AOP were mainly updates to hydro-independent data, the addition of a maximum January outflow limit at Arrow of 2265 $m^3/s$ (80 kcfs), incorporation of updated forecast errors and distribution factors, and updated Grand Coulee pumping estimates.

The TSR studies were updated twice monthly throughout the reporting period for current inflow forecasts, flood control curves and VRCs, and actual unregulated inflows for the previous month. The TSR and supplemental operating agreements, defined the end-of-month draft rights for Canadian storage. The VRCs and flood control requirements subsequent to 1 January 2009 were determined on the basis of seasonal volume runoff forecasts during

actual operation. The VRC calculations for Canadian reservoirs and Libby for the 2008-09 operating year are shown in Tables 2 through 5. The calculation in Table 5 for Libby's VRCs was used in the TSR study only and is not used in actual operations.

The CRTOC directed the regulation of the Canadian storage, on a weekly basis throughout the year, in accordance with the applicable DOPs, the Libby Coordination Agreement (LCA), and supplemental operating agreements.

## Libby Coordination Agreement

During the period covered by this report, the LCA procedures allowed the Canadian Entity to provisionally draft Arrow reservoir and exchange power with the U.S. Entity, and required delivery to the U.S. Entity of one (1) aMW, shaped flat, over the entire Operating Year. Provisional draft operations under the LCA are discussed in Section VI.

The most recent Libby Operating Plan (LOP) is dated 21 April 2006. However, a new one is being written to reflect the new NOAA Fisheries Biological Opinion dated 21 January 2009. It is expected to be completed by the end of the calendar year.

## Entity Agreements

During the period covered by this report, three joint U.S.-Canadian agreements were approved by the Entities:

| Date Signed by Entities | Description of Agreement |
|---|---|
| 11-Feb-2009 | Columbia River Treaty Entity Agreement on the Assured Operating Plan and Determination of Downstream Power Benefits for the 2013-14 Operating Year |
| 01-Jul-2009 | Columbia River Treaty Entity Agreement on the Detailed Operating Plan for Canadian Storage 1 August 2009 through 31 July 2010 |
| 29-Jun-2008 | Columbia River Treaty Entity Agreement on the [BPA-BCH] 2009 (Not Treaty) for 6 June 2009 through 4 September 2009. |

## Columbia River Treaty Operating Committee Agreements

During the period covered by this report, the CRTOC approved the following joint U.S.-Canadian storage agreements:

| Date Signed | Description | Authority |
|---|---|---|
| 12 Aug 2008 | Agreement of the CRTOC on the Operation of Canadian Treaty and Libby Storage Reservoirs for the Period 2 August 2008 through 31 December 2008. | Detailed Operating Plan 1 August 2008 through 31 July 2009, dated 19 June 2008. |
| 9 Sep 2008 | CRTOC Agreement on Provisional Storage for the Period 1 September 2008 through 3 April 2009 | Detailed Operating Plan 1 August 2008 through 31 July 2009, dated 19 June 2008. |
| 20 Nov 2008 | CRTOC Agreement on Operation of Treaty Storage for Nonpower Uses for 15 December 2008 through 31 July 2009 | Detailed Operating Plan 1 August 2008 through 31 July 2009, dated 19 June 2008. |
| 12 Jan 2009 | CRTOC Supplemental Operating Agreement on Flow Shaping between 10 January 09 and 3 April 09 – E-mail exchange | Detailed Operating Plan 1 August 2008 through 31 July 2009, dated 19 June 2008. |
| 28 Sep 2009 | CRTOC Agreement on Provisional Storage for the Period 26 September 2009 through 3 April 2010 | Detailed Operating Plan 1August 2009 through 31 July 2010, dated 1 July 2009 |

## Long Term Non-Treaty Storage Agreement

An Entity agreement dated 9 July 1990 approved the contract between B.C. Hydro and BPA relating to the initial filling of non-Treaty storage, coordinated use of non-Treaty storage, and Mica and Arrow refill enhancement. The CRTOC, in accordance with that agreement, monitored the storage operations made under this agreement throughout the operating year to insure that they did not adversely impact operation of CRT storage. The Entity agreement dated 28 June 2002, gave approval for B.C. Hydro and BPA to extend the expiration date of the contract by one year, from 30 June 2003 to 30 June 2004, which was done. Two mid-Columbia parties, Eugene Water and Electric Board and Tacoma Utilities, elected to extend their NTSA Agreement with BPA for the same one year period.

No further extension of the contract was completed, however, and as per contract terms, release rights under the Non-Treaty Storage Agreement (NTSA) terminated effective 30 June 2004. Beginning 1 September 2007, progress was made towards refilling the US account in FY2009. At the end of September 2009 the B.C. Hydro account remained at 88.4 percent of full, and the U.S. parties accounts stood at 88.3 percent of full. In the absence of a new agreement, the extended Provisions of the 1990 Agreement require that active Non-Treaty Storage Space in Mica be refilled prior to 30 June 2011.

# IV - WEATHER AND STREAMFLOW

## Weather

The Columbia Basin was generally warmer and drier than normal during the summer of 2008. After a full year of La Niña conditions in the equatorial Pacific, the region prepared for yet a second year of this signal. Typically, these cool, sea surface temperature-driven events bring higher than normal pressure into the Pacific Northwest, and this was the case for 2008.

High pressure, in July, kept the region dry, with only southwest Idaho receiving monsoonal rainfall, from thunderstorms. This placed them above normal for the month, in that category. The rainfall pattern over that part of the Basin contributed to record low temperatures for Stanley, Idaho, at -3.9 °C (25 °F), Burley with 5.6 °C (42 °F), and Idaho Falls at 4.4 °C (40 °F), all on the 12th. An average of the 31 weather stations, that register daily temperatures, yielded a regional departure of -0.67 °C (-1.2 °F), driven mainly by cooler night-time readings. Record daily rainfall was set at Stanley, Idaho, with 0.9 cm (0.36 inches) on the 22nd, and at Boise with 0.6 cm (0.22 inches) on the 23rd. July precipitation was 63 percent of normal at Columbia above Coulee, 25 percent of normal at the Snake River above Ice Harbor, and 46 percent of normal at Columbia above The Dalles. The high pressure from July carried over into August, strengthening to the point of setting up record heat by mid-month. Record high temperatures included: Portland 38.9 °C (102 °F), Medford 42.2 °C (108 °F), on the 14th, The Dalles, Oregon, 41.1 °C (106 °F), Moses Lake 39.4 °C (103 °F), Medford, 42.2 °C (108 °F) , on the 15th, and Vancouver, Washington, 38.3 °C (101 °F), Redmond, 41.1 °C (106 °F), and The Dalles, at 42.8 °C (109 °F). The 31 station regional temperature index departed 0.83 °C (+1.5 °F), driven by warmer daytime temperatures. Monsoonal moisture, too, continued into August, with several sites setting daily records: Porthill and Mullan Pass, Idaho, received 1.05” and 1.07” respectively on the 21st. Redmond, Oregon managed 0.78” three days earlier. August precipitation was 141 percent of normal at Columbia above Coulee, 75 percent of normal at the Snake River above Ice Harbor, and 117 percent of normal at Columbia above The Dalles.

High pressure again governed the weather in September, resulting in overall drier than normal conditions with episodes of autumnal heat. Record high temperatures occurred on the 11th, for Portland, with 32.8 °C (91 °F), for Tillamook at 30.0 °C (86 °F) on the 12th, at Boise

with 34.4 °C (94 °F) on the 19th, Pullman reaching 33.3 °C (92 °F) on the same day, and Quillayute recording 28.3 °C (83 °F) on the 29th. There were also a few low temperature records, including Rome, Oregon, with a low of 1.1 °C (34 °F), Porthill, Idaho, with -5.0 °C (23 °F), both on the 11th. Regionally, temperatures departed 0.3°C (+0.5 °F), and this was a nice balance between record high and low temperatures. With high pressure in control, precipitation was limited to near and north of the Canadian border. There were no daily record precipitation amounts. September precipitation was 77 percent of normal at Columbia above Coulee, 64 percent of normal at the Snake River above Ice Harbor, and 60 percent of normal at Columbia above The Dalles. Late in the month, a change in the weather pattern signaled a turn toward cooler conditions leading into October.

From the high pressure weather pattern of the summer and autumn, October transitioned to an early glimpse of winter, as a progressive set of weather systems moved through the Columbia Basin. There was one significant, and unseasonably cool, storm that brought early season snow to the region. This weather system helped many locations break daily low temperature records. Many of these were set on the 11th, including Bonners Ferry, Idaho, with -7.2 °C (19 °F), Priest River, Idaho at -6.7 °C (20 °F), Moses Lake, -3.3 °C (26 °F), Eugene with -2.2 °C (28 °F), Astoria at 0 °C (32 °F), Bellingham with -3.3 °C (26 °F), Olympia at -2.2 °C (28 °F), Pendleton recorded -3.9 °C (25 °F), Meacham -9.4 °C (15 °F), Sea-Tac 2.8 °C (37 °F), and Walla Walla with 0.6 °C (33 °F). The very next day, Pendleton, Meacham and Walla Walla set additional record lows with -4.4 °C (24 °F), -9.4 °C (15 °F), and -1.7 °C (29 °F), respectively. The Basin temperature profile, from the 31-station index, could not have been closer to normal, at 0 °C (-0.1 °F), as milder British Columbia temperatures offset those in the U.S. part of the Basin. Precipitation-wise, Pocatello broke a daily snowfall record of 8.1 cm (3.2 inches) on the 12th. October precipitation was 82 percent of normal for Columbia above Coulee, 76 percent of normal at the Snake River at Ice Harbor, and 78 percent of normal at Columbia above The Dalles.

The progression of weather systems adjusted toward the close of month, so that by November, the onus of the precipitation fell across Washington through central Idaho, leaving both the Canadian, and remaining U.S. districts, drier than normal. With the heavy rainfall across Washington, then, numerous rivers in western Washington exceeded flood stage during an early month precipitation event. This was a mild airflow, and regional

temperatures were warmer than normal, especially closest to the Continental Divide. Precipitation was 91 percent of normal at Columbia above Coulee, 111 percent of normal at the Snake River at Ice Harbor, and 103 percent of normal at Columbia above The Dalles. The weather pattern again adjusted by late November into early December, and transitioned into what many experts believed to be a "classic La Niña" for the Pacific Northwest and western Canada.

Even though December started with fairly benign weather, and averaged drier than normal, the look of La Niña brought a strong low pressure area into the region. This stormy, and increasingly cold, regime held through Christmas. The month had numerous record cold temperatures along with record valley snowfall amounts. At the end of the month, a few warm fronts added more, much-needed, precipitation to the region. This helped to melt most valley snow. Of the many low temperature records (since those were the main driver to the snowfall) set in December, these are the highlights: On the 14$^{th}$, -23.9 °C (-11 °F) at Hungry Horse, Montana, and -23.3 °C (-10 °F) at Polson, Montana. On the 15$^{th}$, it was -29.4 °C (-21 °F) at Anaconda, Montana, and -5.0 °C (23 °F) at Seattle. In Oregon, on the 16$^{th}$, Rome dropped to -21.1 °C (-6 °F), Bend, -20.0 °C (-4 °F), Condon, -20.6 °C (-5 °F), Hermiston, -23.3 °C (-10 °F), Pendleton, -22.2 °C (-8 °F), and Redmond, -24.4 °C (-12 °F). On the 17$^{th}$, Condon again was very cold with -20.6 °C (-5 °F), Eugene fell to -12.2 °C (10 °F), and Madras was at -17.8 °C (0 °F). Later, on the 20$^{th}$, Winthrop, Washington fell to -29.4 °C (-21 °F) and Spokane reached -27.8 °C (-18 °F). The month ended up colder than normal, as the Columbia Basin registered temperatures -1.1 °C (-2 °F). The record snow fall amounts included 43.2 cm (17 inches) at the Spokane International Airport on the 17$^{th}$, while Coeur d'Alene recorded 63.5 cm (25 inches). On the 18$^{th}$, Spokane reported another record daily amount of 27.4 cm (10.8 inches). More records came later in the month, including 11.9 cm (4.7 inches) of snow at Boise, on the 22$^{nd}$, 5.6 cm (2.2 inches) at Lewiston, Idaho, 8.6 cm (3.4 inches) at Missoula, 7.6 cm (3 inches) at Pendleton, 5.1 cm (2 inches) at Kennewick, Washington, and 17.8 cm (7 inches) at Madras, Oregon, also on the 22$^{nd}$. With snowfall, and late month warm frontal valley rainfall, the contribution resulted in precipitation averaging 103 percent of normal at Columbia above Coulee, 138 percent of normal at the Snake above Ice Harbor, and 108 percent of normal at Columbia above The Dalles. So, 2008 closed on a very wintry note, with the heavy snowfall of December following the rainfall and flooding of

November. As La Niña conditions continued, 2009 opened with nearly textbook, La Niña style.

January opened up with two strong storm systems bringing heavy precipitation and a turn from colder, to warmer than normal, temperatures to the region for the first two weeks of the New Year. First, temperatures responded, recoiling from the chill of December, such that January saw a few record high temperatures: On the 11th, The Dalles set a record of 12.8 °C (55 °F), on the 12th; The Dalles did it again, with 16.7 °C (62 °F). Record highs occurred at Meacham, Oregon, with 11.1 °C (52 °F) on the 13th, Redmond, 16.7 °C (62 °F) on the 14th, 16.7 °C (62 °F) at Quillayute, Washington, on the 17th, and 11.1 °C (52 °F) at Mullan Pass, Idaho, sitting at 1829 meters (6,000 feet), on the 19th. On the flip side, the month ended colder than normal, with daily record low temperatures set at Idaho Falls, at -27.8 °C (-18 °F), on the 26th, and again on the 27th, registering -33.9 °C (-29 °F). On the same day, Meacham dropped to a record -27.8 °C (-18 °F). The regional temperature departures, from the 31 station index, settled-in at -0.4 °C (-0.8 °F). Even with the rain and snow during the month, there were only a few precipitation records: Idaho Falls set consecutive daily records with 0.9 cm (0.34 inches) on the 23rd, and 0.7 cm (0.26 inches) on the 24th, while Rome, Oregon set a daily record of 1.1 cm (0.45 inches) on the 25th. Flooding again occurred in western Washington, including along the Interstate between Seattle and Portland in the vicinity of the Chehalis River. Some flooding, from rain on snow due to warming temperatures, occurred in northern Idaho. In both cases, the flooding was complicated by ice jam releases. Drier conditions developed later in the month, as the jet stream moved north into B.C. Yet, January precipitation was 109 percent of normal at Columbia above Coulee, 104 percent of normal at the Snake River above Ice Harbor, and 109 percent of normal at Columbia above The Dalles.

With the jet stream over Canada, high pressure aloft covered the U.S. part of the Columbia Basin for the start of February. This brought deceptively quiet and mild weather to areas east of the Cascades. It also brought some record warmth to the coast. Astoria reported a record high temperature for the 3rd of the month, at 17.8 °C (64 °F). Much colder temperatures returned to the region the last half of the month. The regional temperatures departed -0.3 °C (-0.6 °F)) from normal, as gauged by 37 stations across the Basin. Six new stations were added to the index. As the month opened up drier than normal, it ran its course

to wetter than normal during the last week. A strong, wet and initially warm weather system brought record daily rainfall to some areas of the region, followed by an equally cold and wet system that brought record daily snowfall. On the 23rd, Chief Joseph Dam reported 1.5 cm (0.60 inches) of rain, Spokane, 1.3 cm (0.48 inches), and Yakima, 0.7 cm (0.28 inches). Three days later, a daily, record snowfall occurred at Kalispell, with 16.5 cm (6.5 inches), and at Sea-Tac, with 5.1 cm (2.1 inches). February precipitation was 65 percent of normal at Columbia above Coulee, 56 percent of normal at the Snake River above Ice Harbor, and 58 percent of normal at Columbia above The Dalles. The colder temperatures of the last part of February dovetailed into colder than normal readings for March.

A series of strong low pressure systems kept much cooler than normal conditions in the Basin for March, as well as delivering moderate to heavy precipitation, especially during the first half of the month. There was a break about mid-month, then a resumption of storminess late month. With very chilly air overhead just about for the whole month, the region had numerous record low temperatures, mainly east of the Cascades. Starting out early, these include a record low of -6.7 °C (20 °F) at Boise and -16.7 °C (2 °F) at Meacham, on the 7th; McCall, Idaho, with -22.2 °C (-8 °F), Rome, Oregon with -16.7 °C (2 °F), both on the 9th; a record low high temperatures of -6.1 °C (21 °F) and record low temperature of -15.0 °C (5 °F) at Spokane, the same scheme at Lewiston, Idaho, except with -0.6 °C and –6.7 °C (31 °F and 20 °F), both on the 10th; a record low of -16.7 °C (2 °F) at Spokane on the 11th, -17.2 °C (1 °F) at Lewiston on the same day; a record low of -24.4 °C (-12 °F) at Meacham and -8.3 °C (17 °F) at Pendleton, both on the 12th, and a record low high temperature of -0.6 °C (31 °F) and low of -17.2 °C (1 °F) at Pullman, also on the 12th. The 37 station index for March 2009s departed 1.4°C (-2.6 °F), making March a quite chilly month, indeed. The departures ranged from 0 °C (0.1 °F) to -22.6 °C (-8.7 °F). The low pressure systems of the month contributed to record daily precipitation, such as: record rainfall of 0.9 cm (0.37 inches) at Ontario, Oregon, and 2.0 cm (0.77 inches) at Winthrop, Washington, on the 2nd; record rainfall of 2.6 cm (1.03 inches) at Mullan Pass, Idaho, on the 5th; on the 6th, a record daily snowfall of 2.5 cm (1 inch) at Boise; a record snowfall of 5 cm (2 inches) at Kalispell on the 8th; a 5.6 cm (2.2 inch) snowfall, a daily record, at SeaTac on the 9th, and late in the month, a record snowfall of 3.8 cm (1.5 inches) at Missoula. All this brought March precipitation totals to 127 percent of normal at Columbia above Coulee, 128 percent of

normal at the Snake River above Ice Harbor, and 130 percent of normal at Columbia above The Dalles. Another break in the weather occurred at the close of March, and led to a quiet first week, or so, of April.

However, the La Niña conditions in the equatorial Pacific continued to govern the mid latitude weather pattern. This produced a swing of weather conditions from initially cold and wet, to warmer and drier, and back to wet and cold, quite typical of La Niña Springs. Most prominent during the month, was the warm weather about mid-month. This was courtesy of a high pressure system. So, from March's extreme chill to April's warmth, we set new records on both counts. In April, SeaTac had a record high of 23.3 °C (74 °F), Wenatchee at 28.3 °C (83 °F), The Dalles with 30.6 °C (87 °F), and Medford at 32.2 °C (90 °F), all on the 20th. The next day, more records fell, with 28.3 °C (83 °F) at Burns, 33.3 °C (92 °F) at Medford, 28.9 °C (84 °F) at Wenatchee, 29.4 °C (85 °F) at The Dalles, 27.8 °C (82 °F) at Portland, 27.2 °C (81 °F) at Salem, and 20.6 °C (69 °F) at Seattle. Not to be outdone, a much colder air mass broke through late in the month, more records fell: This time on the low side. Both Quillayute and Seattle had record low temperatures on the 24th, at -1.1 and 1.1°C (30 and 34 °F), respectively. Stanley and Pocatello, Idaho, had -12.2 and -4.4 °C (10 and 24 °F) as their respective, record-breaking low temperatures on the 25th. For the Basin, April sat at -0.5 °C (-0.9 °F) departure from normal, with the warmest departure range at 1.1 °C (2 °F), according to the 37 station index. Compared to March, and more like February, April was drier than normal. April precipitation was 61 percent of normal at Columbia above Coulee, 100 percent of normal at the Snake River above Ice Harbor, and 86 percent of normal at Columbia above The Dalles. The low pressure of latter part of April carried through into May.

The low helped start out May cool and wet, and by mid month high pressure brought dry and warm weather to the region. The summer-time regime of monsoon moisture from the Southwest U.S., started up later in the month, and this brought back rainfall, as showers and thundershowers. Again, with the back-and-forth rhythm of a La Niña Spring, temperatures went from cool, early on, to quite warm, then back to cool. Record low temperatures hit on the 8th, with Pocatello at -3.9 °C (25 °F), and Idaho Falls with -4.4 °C (24 °F). On the 9th, both Challis and Stanley, Idaho, recorded -8.9 °C (16 °F), and on the 13th, several stations recorded stand-out low temperatures. This included Omak, with -2.2 °C (28 °F), 2.2 °C

(36 °F) at The Dalles, Idaho Falls with -3.9 °C (25 °F), and McCall, Idaho with -7.8 °C (18 °F). The regime reversed on the 18th, with record high temperatures in about the same region where record lows occurred: a record high of 32.8 °C (91 °F) at Pocatello, of 31.1 °C (88 °F) at Missoula, and 35.6 °C (95 °F) at Boise. A record high temperature of 33.3 °C (92 °F) was set at Omak, Washington on the 29th. Regional temperature departures ranged from -0.7 to 3.1 °C (-1.2 °F to 5.5 °F), and this ironed out to 0.8 °C (+1.4 °F) from normal, an overall mild month. While the bulk of the precipitation that fell in May came from the low pressure early in the month, daily record amounts came from the monsoonal precipitation. These records include 1.5 cm (0.60 inches) at Pocatello, on the 24th and 2.6 cm (1.01 inches) at Burns on the 30th. As such, May precipitation was 82 percent of normal at Columbia above Coulee, 91 percent of normal at the Snake River above Ice Harbor, and 91 percent of normal at Columbia above The Dalles. Month-end cool weather continued into June 2009.

With a cool start to the meteorological summer (June 1-August 31), the Columbia Basin saw mainly above normal precipitation, largely over the U.S. districts east of the Cascades. A semi-permanent low pressure area near the Four Corners region supplied the southern Columbia Basin will plenty of showers and thundershowers. These brought precipitation totals above normal, and produced record rainfall. In the north, the Canadian districts had a weak weather system impact them with lighter precipitation, and temperatures nearer to normal. The 37 station temperature index for the region departed 0.1 °C (+0.2 °F), and the range of departures was from -3.8 °C (-6.8 °F (driven by the southern basins) to 2.5 °C (4.5 °F) (driven by B.C. and areas west of the Cascades). Record low temperatures occurred at Rome, Oregon, on the 22nd, with 2.8 °C (37 °F), as well as Eugene, with 3.9 °C (39 °F). A record low of -2.2 °C (28 °F) was set at McCall, Idaho on the 23rd, and at Seattle, on the 27th, with 8.3 °C (47 °F). With active precipitation, record amounts fell at several sites, including Burns, Oregon, with 1.0 cm (0.40 inch); Stanley, Idaho, 1.6 cm (0.62 inch); Rome, Oregon, 3.3 cm (1.30 inches), all on the 5th. Eugene recorded 4.3 cm (1.67 inches), a record for the 13th. Portland received 2.4 cm (0.96 inch), another record for the date, on the 19th. Jerome and Burley, Idaho, reported 2.5 and 1.3 cm (0.98 inch and 0.52 inch), respectively, on the 20th. In all, June precipitation was 69 percent of normal at Columbia above Coulee, 242 percent of normal at the Snake River above Ice Harbor, and 127 percent of normal at

Columbia above The Dalles. As is often the case, a cool June in the U.S. part of the Basin, can turn warm quickly through July, and that was the case this year.

Another low pressure trough started out July, but by mid-month a definitive regime change brought strong high pressure into the Basin. All-time high temperatures were reported in parts of the Pacific Northwest as a result, yet they quickly followed a run of record cool readings. To start the month, Meacham reached -0.6 °C (31 °F), and on the 8th, Mullan Pass reported a record low high temperature of 11.1 °C (52 °F). Record low temperatures were set at Rome, Oregon, with 6.7 °C (44 °F), Butte, with 1.1 °C (34 °F), and Idaho Falls, at 3.3 °C (38 °F), all on the 9th. Pendleton set a record low of 8.3 °C (47 °F) on the 14th, and after that reading record high temperatures took over for many more places. Boise started it off with 41.1 °C (106 °F) on the 18th. Portland had three straight days of record high temperatures, all over 37.8 °C (100 °F), starting on the 27th and running through the 29th: 39.4 °C (103 °F), 41.1 °C (106 °F), and another 41.1 °C (106 °F). For Portland, this tied records from other years that boasted consecutive 100+ °F days, notably in July 1994, August 1977, August 1971, and late June/early July 1942. Other 37.8 °C (100 °F) or better high temperature records were set at 39.4 °C (103 °F) at Vancouver on the 27th, along with 39.4 °C (103 °F) at Salem. On the 28th, these extended to Roseburg and Medford, with 42.2 °C (108 °F), and again at Vancouver with 41.1 °C (106 °F). Even Astoria hit 33.3 °C (92 °F), and Hoquiam recorded 33.9 °C (93 °F) on the 28th. Medford and Roseburg again came back with 42.8 °C (109 °F) and 41.1 °C (106 °F) on the 29th. All time high, not just daily high, temperatures were broken on the 29th at Vancouver, with 42.2 °C (108 °F), SeaTac, 39.4 °C (103 °F), Olympia, 40.0 °C (104 °F), Bellingham at 35.6 °C (96 °F). Rainfall records came with the cooler air-mass of early July: Pocatello saw 2.4 cm (0.94 inch) on the 2nd, and again on the 4th, with 3.3 cm (1.33 inches)). Eugene saw 1.8 cm (0.69 inch) on the 13th. Missoula registered 1.5 cm (0.60 inch) on the 26th. July precipitation was 106 percent of normal at Columbia above Coulee, 58 percent of normal at the Snake River above Ice Harbor, and 85 percent of normal at Columbia above The Dalles.

As August rolled around, the Columbia Basin saw two different types of weather regimes. In the U.S. sector, it was warm and dry for most of the month but in B.C., an unusually strong weather system brought showers and thundershowers. To open the month, we saw a carry-over from a warm July, with record high temperatures set at Spokane, with

43 °C (101 ºF), Wenatchee with 47 °C (107 ºF), Lewiston at 46 °C (106 ºF), Pendleton with 48 °C (108 ºF), and Portland with 39 °C (95 ºF), all on the first of the month. Seattle and Olympia set record highs the following day: 36 and 38 °C (89 and 92 ºF), respectively. More records were broken mid to late in the month, with Walla Walla at 47 °C (107 ºF), Portland at 41 °C (97 ºF), and 46 °C (105 ºF) at Roseburg, on the 19th. Pocatello reached 41 °C (98 ºF) on the 21st and Boise, 44 °C (102 ºF) on the 28th. The Canadian-based weather system brought two day's worth of thunderstorms to the Vancouver, B.C. area: A very unusual event for a North American west coast city due to its maritime influence. Record rainfall accompanied this weather system as it moved inland. Missoula scored a daily record of 5.2 cm (2.03"), and even Pendleton hit with 2.5 cm (1"), both occurring on the 7th. Oceanside, Quillayute in northwest Washington, reported 2.6 cm (1.01") on the 8th, standing as a daily record. August precipitation was 103 percent of normal at Columbia above Coulee, 151 percent of normal at the Snake River above Ice Harbor, and 119 percent of normal at Columbia above The Dalles.

Finally, as the water year came to a close, September brought an early taste of fall, early-on in the month. A strong cold front pushed through the Columbia Basin. This ushered in much cooler than normal air, and we saw record low temperatures, with some record rainfall, too. After the front's passage, it was nothing but high pressure in the upper, generating warm and dry weather, punctuated by numerous record high temperatures. On the rainfall side, we saw Yakima with 0.5 cm (0.21"), Portland at 1.9 cm (0.75"), and North Bend, Oregon, with 1.5 cm (0.58"), all on September 5th. The very next day, Washington took over, with SeaTac at 2.4 cm (0.93"), Olympia with 3.9 cm (1.54"), and Moses Lake at 0.3 cm (0.13"). In the immediate wake of the rainfall and the transitory cold front, low temperatures dropped to form records at 0 °C (32 ºF) at Klamath Falls, Oregon and the same at Rome, Oregon, the former on the 7th, and the latter, a day later. Conversely, and with much more vigor, daily high temperature records spanned the 11th through the 25th: Temperatures were reported at 38 °C (93 ºF) at Portland, 35 °C (88 ºF) at Astoria, 34 °C (87 ºF) at SeaTac and Quillayute, 40 °C (96 ºF) at The Dalles, 29 °C (78 ºF) at Stampede Pass, Washington, 39 °C (94 ºF) at Wenatchee, Missoula with 37 °C (91 ºF), Pendleton with 36 °C (90 ºF), Mullan Pass, Idaho at 29 °C (78 ºF), 36 °C (90 ºF) at Burns, Oregon, and 33 °C (85 ºF) at Challis, Idaho. The early month storm was the only event that brought significant precipitation to the Basin, but

its life span was so short that the rest of the month contributed to 51 percent of normal precipitation at Columbia above Coulee, 25 percent of normal at the Snake River above Ice Harbor, and 47 percent of normal at Columbia above The Dalles.

## Stream Flow

The observed inflow and outflow hydrographs for the Canadian reservoirs for the period 1 July 2008 through 31 July 2009 are shown on Charts 5-7. Libby hydrographs are shown in Chart 8. Observed flow, as well as computed unregulated flow hydrographs for the same 13-month period for Kootenay Lake, Columbia River at Birchbank, Grand Coulee, and The Dalles are shown on Charts 9-12, respectively. Observed and unregulated (USACE) flow hydrographs at The Dalles during the April-July 2009 period, including a plot of flows occurring if regulated only by the four Treaty reservoirs, are provided in Chart 13. The unregulated August 2008 – July 2009 daily average stream flow in the Basin above The Dalles was below normal and approximately 4.2 percent lower than last year's average flow, which was also below normal. The total runoff volume at The Dalles during this same time period was 145.2 $km^3$ (117.7 Maf), which is 85 percent of the 1971-2000 average. Month average unregulated inflows during spring runoff were highest at The Dalles in June 2009 at 90 percent of the 1971-2000 June average. The peak-unregulated discharge for the Columbia River at The Dalles was 16,210 m3/s (572.5 kcfs) on 8 June 2009. The 2008-09 average monthly unregulated stream flows and their percentage of the 1971-2000 average monthly flows are shown in the following tables (metric and English) for the Columbia River at Grand Coulee and The Dalles.

## Columbia River Unregulated Stream Flow

(Source of unregulated flow = National Weather Service Runoff Processor)

| Time Period | Columbia River at Grand Coulee | | | Columbia River at The Dalles | | |
|---|---|---|---|---|---|---|
| | Unregulated Flow | | Percent of Average | Unregulated Flow | | Percent of Average |
| | cfs | $m^3/s$ | | Cfs | $m^3/s$ | |
| Aug-08 | 97,841 | 2,771 | 93 | 130,601 | 3,698 | 95 |
| Sep-08 | 52,466 | 1,486 | 84 | 79,212 | 2,243 | 85 |
| Oct-08 | 42,677 | 1,208 | 95 | 75,356 | 2,134 | 91 |
| Nov-08 | 49,862 | 1,412 | 102 | 97,339 | 2,756 | 103 |
| Dec-08 | 31,671 | 897 | 74 | 69,910 | 1,980 | 71 |
| Jan-09 | 38,857 | 1,100 | 93 | 102,588 | 2,905 | 100 |
| Feb-09 | 29,520 | 836 | 62 | 74,088 | 2,098 | 61 |
| Mar-09 | 42,222 | 1,196 | 68 | 104,263 | 2,952 | 67 |
| Apr-09 | 96,936 | 2,745 | 79 | 211,697 | 5,995 | 89 |
| May-09 | 210,444 | 5,959 | 79 | 389,267 | 11,023 | 90 |
| Jun-09 | 262,903 | 7,445 | 85 | 424,721 | 12,027 | 90 |
| Jul-09 | 142,323 | 4,030 | 74 | 188,268 | 5,331 | 73 |
| **Period Average** | **91,722** | **2,597** | **82** | **162,552** | **4,603** | **85** |

## Seasonal Runoff Forecasts and Volumes

April-August 2009 runoff volumes, adjusted to exclude the effects of regulation of upstream storage, are listed below for eight locations in the Columbia Basin:

| Location | Volume in $km^3$ | Volume in Maf | Percent of 1971-2000 Average |
|---|---|---|---|
| Libby Reservoir Inflow | 5.44 | 4.41 | 71% |
| Duncan Reservoir Inflow | 2.00 | 1.62 | 79% |
| Mica Reservoir Inflow | 10.77 | 8.74 | 77% |
| Arrow Reservoir Inflow | 21.13 | 17.13 | 75% |
| Columbia River at Birchbank | 37.79 | 30.64 | 76% |
| Grand Coulee Reservoir Inflow | 59.25 | 48.04 | 80% |
| Snake River at Lower Granite | 29.88 | 24.22 | 106% |
| Columbia River at The Dalles | 99.36 | 80.55 | 87% |

Forecasts of seasonal runoff volume, based on precipitation and snowpack data, were prepared in 2009 for a large number of locations in the Columbia River Basin and updated each month as the season advanced. Table 1 and Table 1M list the April through August inflow volume forecasts for Mica, Arrow, Duncan, and Libby projects as well as The Dalles. The actual runoff volume for these five locations is also given in Tables 1 and 1M. The forecasts for Mica, Arrow, and Duncan inflow were prepared by B.C. Hydro. The forecasts for the lower Columbia River inflows were prepared by the National Weather Service River Forecast Center, in cooperation with the U.S. Army Corps of Engineers, National Resource Conservation Service, Bureau of Reclamation, and B.C. Hydro. The Libby inflow forecast is prepared by the U.S. Army Corps of Engineers. The 1 April 2009 forecast of January through July runoff for the Columbia River above The Dalles was 113.5 $km^3$ (92.0 Maf) and the actual observed runoff was 111.3 $km^3$ ( 90.2 Maf).

The following tabulations summarize the monthly forecasts since 1970 of the January-July runoff for the Columbia River above The Dalles compared with the actual runoff volume in $km^3$ and Maf. The average January-July runoff volume for the 1971-2000 period is 132.4 $km^3$ (107.3 Maf).

# Historic Seasonal Runoff Forecasts and Volumes

## The Dalles, OR Volume Runoff Forecasts in $km^3$ (Jan-Jul)

| Year | Jan | Feb | Mar | Apr | May | Jun | Actual |
|---|---|---|---|---|---|---|---|
| 1970 | 101.8 | 122.7 | 115.2 | 116.3 | 117.3 | -- | 118.0 |
| 1971 | 136.8 | 159.7 | 155.4 | 165.3 | 164.1 | 166.5 | 169.6 |
| 1972 | 135.8 | 157.9 | 171.1 | 180.2 | 180.1 | 180.1 | 187.1 |
| 1973 | 114.8 | 111.6 | 104.5 | 102.4 | 99.2 | 97.1 | 87.8 |
| 1974 | 151.7 | 172.7 | 180.1 | 183.8 | 181.3 | 181.3 | 192.8 |
| 1975 | 118.5 | 131.0 | 141.5 | 143.9 | 142.1 | 139.4 | 138.6 |
| 1976 | 139.4 | 143.1 | 149.3 | 153.0 | 153.0 | 153.0 | 151.5 |
| 1977 | 93.4 | 76.7 | 69.0 | 71.7 | 66.4 | 70.8 | 66.4 |
| 1978 | 148.0 | 140.6 | 133.2 | 124.6 | 128.3 | 129.5 | 130.3 |
| 1979 | 108.5 | 97.0 | 114.7 | 107.7 | 110.6 | 110.6 | 102.5 |
| 1980 | 109.7 | 109.7 | 109.7 | 110.6 | 111.8 | 120.5 | 118.2 |
| 1981 | 130.7 | 104.2 | 104.2 | 101.0 | 102.6 | 118.3 | 127.5 |
| 1982 | 135.7 | 148.0 | 155.4 | 160.4 | 161.6 | 157.9 | 160.2 |
| 1983 | 135.7 | 133.2 | 139.4 | 149.3 | 149.3 | 146.8 | 146.4 |
| 1984 | 139.4 | 127.0 | 120.4 | 125.8 | 132.0 | 140.6 | 146.9 |
| 1985 | 161.6 | 134.4 | 129.5 | 121.6 | 121.6 | 123.3 | 108.2 |
| 1986 | 119.4 | 115.1 | 127.0 | 130.7 | 133.2 | 133.2 | 133.6 |
| 1987 | 109.7 | 101.0 | 96.2 | 98.7 | 94.6 | 93.5 | 94.4 |
| 1988 | 97.7 | 92.3 | 89.7 | 91.3 | 93.9 | 92.5 | 90.9 |
| 1989 | 124.6 | 125.8 | 116.2 | 122.7 | 121.6 | 119.5 | 111.8 |
| 1990 | 106.7 | 124.6 | 128.3 | 118.4 | 118.4 | 122.7 | 123.0 |
| 1991 | 143.1 | 135.7 | 132.0 | 130.7 | 130.7 | 128.3 | 132.1 |
| 1992 | 114.2 | 109.9 | 103.0 | 87.8 | 87.8 | 83.6 | 86.8 |
| 1993 | 114.2 | 106.7 | 95.3 | 94.5 | 88.7 | 106.2 | 108.5 |
| 1994 | 98.3 | 94.1 | 96.3 | 90.3 | 93.1 | 94.2 | 92.5 |
| 1995 | 124.7 | 122.9 | 116.3 | 122.9 | 122.9 | 120.8 | 128.3 |
| 1996 | 143.1 | 150.5 | 160.4 | 155.4 | 165.3 | 173.9 | 171.8 |
| 1997 | 170.2 | 178.9 | 175.2 | 183.8 | 188.7 | 196.1 | 196.1 |
| 1998 | 106.6 | 117.4 | 113.1 | 112.0 | 109.9 | 124.6 | 128.3 |
| 1999 | 143.1 | 148.0 | 160.4 | 157.9 | 153.0 | 151.7 | 153.1 |
| 2000 | 129.5 | 130.7 | 129.5 | 129.5 | 129.5 | 125.8 | 120.9 |
| 2001 | 99.2 | 81.9 | 72.3 | 69.2 | 69.7 | 68.5 | 71.8 |
| 2002 | 123.3 | 125.8 | 120.0 | 118.9 | 121.1 | 123.3 | 128.0 |
| 2003 | 99.3 | 93.3 | 92.4 | 105.2 | 111.3 | 110.1 | 108.2 |
| 2004 | 127.0 | 123.3 | 114.6 | 103.9 | 98.1 | 105.0 | 102.3 |
| 2005 | 105.6 | 101.6 | 87.2 | 91.0 | 92.1 | 98.4 | 100.3 |
| 2006 | 125.0 | 137.0 | 132.0 | 132.0 | 136.0 | 137.0 | 141.0 |
| 2007 | 129.5 | 124.6 | 123.3 | 123.3 | 122.2 | 118.9 | 118.1 |
| 2008 | 125.8 | 127.0 | 127.0 | 124.6 | 120.0 | 121.1 | 122.4 |
| 2009 | 116.8 | 114.6 | 106.3 | 113.5 | 112.4 | 113.5 | 111.3 |
| Minimum | 93.4 | 76.7 | 69.0 | 69.2 | 66.4 | 68.5 | 66.4 |
| Median | 124.7 | 124.6 | 120.2 | 122.2 | 121.4 | 122.7 | 122.7 |
| Maximum | 170.2 | 178.9 | 180.1 | 183.8 | 188.7 | 196.1 | 196.1 |

## The Dalles, OR Volume Runoff Forecasts in Maf (Jan-Jul)

| Year | Jan | Feb | Mar | Apr | May | Jun | Actual |
|---|---|---|---|---|---|---|---|
| 1970 | 82.5 | 99.5 | 93.4 | 94.3 | 95.1 | -- | 95.7 |
| 1971 | 110.9 | 129.5 | 126.0 | 134.0 | 133.0 | 135.0 | 137.5 |
| 1972 | 110.1 | 128.0 | 138.7 | 146.1 | 146.0 | 146.0 | 151.7 |
| 1973 | 93.1 | 90.5 | 84.7 | 83.0 | 80.4 | 78.7 | 71.2 |
| 1974 | 123.0 | 140.0 | 146.0 | 149.0 | 147.0 | 147.0 | 156.3 |
| 1975 | 96.1 | 106.2 | 114.7 | 116.7 | 115.2 | 113.0 | 112.4 |
| 1976 | 113.0 | 116.0 | 121.0 | 124.0 | 124.0 | 124.0 | 122.8 |
| 1977 | 75.7 | 62.2 | 55.9 | 58.1 | 53.8 | 57.4 | 53.8 |
| 1978 | 120.0 | 114.0 | 108.0 | 101.0 | 104.0 | 105.0 | 105.6 |
| 1979 | 88.0 | 78.6 | 93.0 | 87.3 | 89.7 | 89.7 | 83.1 |
| 1980 | 88.9 | 88.9 | 88.9 | 89.7 | 90.6 | 97.7 | 95.8 |
| 1981 | 106.0 | 84.5 | 84.5 | 81.9 | 83.2 | 95.9 | 103.4 |
| 1982 | 110.0 | 120.0 | 126.0 | 130.0 | 131.0 | 128.0 | 129.9 |
| 1983 | 110.0 | 108.0 | 113.0 | 121.0 | 121.0 | 119.0 | 118.7 |
| 1984 | 113.0 | 103.0 | 97.6 | 102.0 | 107.0 | 114.0 | 119.1 |
| 1985 | 131.0 | 109.0 | 105.0 | 98.6 | 98.6 | 100.0 | 87.7 |
| 1986 | 96.8 | 93.3 | 103.0 | 106.0 | 108.0 | 108.0 | 108.3 |
| 1987 | 88.9 | 81.9 | 78.0 | 80.0 | 76.7 | 75.8 | 76.5 |
| 1988 | 79.2 | 74.8 | 72.7 | 74.0 | 76.1 | 75.0 | 73.7 |
| 1989 | 101.0 | 102.0 | 94.2 | 99.5 | 98.6 | 96.9 | 90.6 |
| 1990 | 86.5 | 101.0 | 104.0 | 96.0 | 96.0 | 99.5 | 99.7 |
| 1991 | 116.0 | 110.0 | 107.0 | 106.0 | 106.0 | 104.0 | 107.1 |
| 1992 | 92.6 | 89.1 | 83.5 | 71.2 | 71.2 | 67.8 | 70.4 |
| 1993 | 92.6 | 86.5 | 77.3 | 76.6 | 71.9 | 86.1 | 88.0 |
| 1994 | 79.7 | 76.3 | 78.1 | 73.2 | 75.5 | 76.4 | 75.0 |
| 1995 | 101.1 | 99.6 | 94.3 | 99.6 | 99.6 | 97.9 | 104.0 |
| 1996 | 116.0 | 122.0 | 130.0 | 126.0 | 134.0 | 141.0 | 139.3 |
| 1997 | 138.0 | 145.0 | 142.0 | 149.0 | 153.0 | 159.0 | 159.0 |
| 1998 | 86.4 | 95.2 | 91.7 | 90.8 | 89.1 | 101.0 | 104.0 |
| 1999 | 116.0 | 120.0 | 130.0 | 128.0 | 124.0 | 123.0 | 124.1 |
| 2000 | 105.0 | 106.0 | 105.0 | 105.0 | 105.0 | 102.0 | 98.0 |
| 2001 | 80.4 | 66.4 | 58.6 | 56.1 | 56.5 | 55.5 | 58.2 |
| 2002 | 100.0 | 102.0 | 97.3 | 96.4 | 98.2 | 100.0 | 103.8 |
| 2003 | 80.5 | 75.6 | 74.9 | 85.3 | 90.2 | 89.3 | 87.7 |
| 2004 | 103.0 | 100.0 | 92.9 | 84.2 | 79.5 | 85.1 | 83.0 |
| 2005 | 85.6 | 82.4 | 70.7 | 73.8 | 74.7 | 79.8 | 81.3 |
| 2006 | 101.0 | 111.0 | 107.0 | 107.0 | 110.0 | 111.0 | 114.7 |
| 2007 | 105.0 | 101.0 | 100.0 | 100.0 | 99.1 | 96.4 | 95.7 |
| 2008 | 102.0 | 103.0 | 103.0 | 101.0 | 97.3 | 98.2 | 99.2 |
| 2009 | 94.7 | 92.9 | 86.2 | 92.0 | 91.1 | 92.0 | 90.2 |
| Minimum | 75.7 | 62.2 | 55.9 | 56.1 | 53.8 | 55.5 | 53.8 |
| Median | 101.0 | 101.0 | 97.5 | 99.1 | 98.4 | 99.5 | 99.5 |
| Maximum | 138.0 | 145.0 | 146.0 | 149.0 | 153.0 | 159.0 | 159.0 |

# V - RESERVOIR OPERATION

## General

The 2008-09 operating year began with Canadian storage at 91.8 percent full. Libby reservoir (Lake Koocanusa) was about 4.6 m (15 ft) from full, elevation 744.93 m (2,444.0 ft), at the start of the operating year (1 August 2008) and releasing water to meet BiOp objectives for flow augmentation for listed salmon species in the U.S.

The 2008–09 operating year water supply in the Columbia Basin above Grand Coulee was below average but about average for the Snake River at Lower Granite. The actual runoff in the Canadian portion of the Columbia basin measured at Birchbank was 75% of normal for January through July 2009. The actual runoff for the overall Columbia basin (U.S. and Canada combined) measured at The Dalles for the January through July 2009 was 84% of normal.

The CRTOC signed four operating agreements during the 1 August 2008 to 31 July 2009 operating year (see Section III Operating Arrangements). At the end of the 2008–09 operating year Canadian storage was at 82.0 percent on 31 July 2009.

## Canadian Storage Operation

At the beginning of the 2008-09 operating year on 1 August 2008, actual Canadian storage provided under Article II of the Columbia River Treaty (Canadian storage) was at 17.6 $km^3$ (14.2 Maf) or 91.8 percent full. It drafted to a minimum of 4.8 $km^3$ (3.8 Maf) on 20 April 2009. Canadian composite storage refilled to 15.7 $km^3$ (12.7 Maf) or 82.0 percent full on 31 July 2009.

As specified in the DOP, the release of Canadian storage is made effective at the Canadian-U.S. border. Accordingly, releases from individual Canadian projects can vary from the release required by the DOP TSR plus supplemental operating agreements, so long as this variance does not impact the ability of the Canadian system to deliver the sum of CRT outflows from Arrow and Duncan reservoirs. Variances from the DOP storage operation are accumulated in respective Flex accounts. An overrun in an account occurs when actual project releases are greater (contents are lower) than those specified by the DOP.

Conversely, an underrun occurs when actual project releases are less (contents are higher) than those specified by the DOP. Flex accounts for Mica, Revelstoke, Arrow, and Duncan are balanced at any point in time (i.e. sum to zero) to ensure that under/overruns do not impact the total CRT release required at the Canadian-U.S. border. The terms under/overrun are used in the description of Mica Reservoir operations below.

## Mica Reservoir

As shown in Chart 5, Mica (Kinbasket) reservoir was at elevation 747.4 m (2,452.1 ft) on 31 July 2008. The reservoir continued to refill to reach a maximum elevation of 751.9 m (2,466.9 ft) on 15 September 2008, 2.47 m (8.1 ft) below full pool. As inflows continued to recede throughout the fall and winter period and outflows increased to meet winter load requirements, the reservoir drafted steadily, reaching 743.0 m (2,437.6 ft) on 31 December 2008.

Influenced by good starting level and relatively low demand for electricity this year, Kinbasket reservoir reached a minimum elevation of 730.4 m (2,396.2 ft) on 9 May 2009, 12.3 m (40.4 ft) higher than the 2008 minimum level of 718.1 m (2,355.9 ft). From late May through early July, Mica generation was reduced to near zero. This reduction shifted generation to the Peace River powerplants to reduce the risk of spill at Williston Reservoir (Peace River) while enabling Kinbasket reservoir to refill for next winter operation. The reservoir continued to fill ending August 31 at elevation 750.9 m (2463.6 ft), 3.47 m (11.4 ft) below full.

Inflow into Mica reservoir was 91 percent of normal over the period August 2008 to December 2008. Over this same period, Mica outflow varied from a monthly average low of about 396 $m^3/s$ (14 kcfs) in August to a monthly average high of about 821 $m^3/s$ (29 kcfs) in December. Inflow into Mica reservoir was about 78 percent of normal over the period January to July 2009. Outflow over this same period varied from a monthly average high of 680 $m^3/s$ (24 kcfs) in January to a monthly average low of 57 $m^3/s$ (2 kcfs) in June.

The Mica project had an underrun of 461.2 cubic hectometers ($hm^3$) (188.5 thousand second-foot-days (ksfd) on 31 July 2008. The maximum underrun for the year was 2085.9 $hm^3$ (852.6 ksfd) on 8 September 2009 and the minimum was -1673.9 $hm^3$ (-684.2 ksfd) on 30 January 2009.

The B.C. Hydro Non-Treaty Storage Agreement (NTSA) active storage account was at 2,452.8 $hm^3$ (1,002.6 ksfd) on 31 July 2008. The corresponding U.S. NTSA account was at 1,904.1 $hm^3$ (778.3 ksfd). The U.S. stored into their non-Treaty account during the 2008-09 operating year resulting in an account balance of 2383.1 $hm^3$ (974.1 ksfd). The combined U.S. and Canada NTSA storage space as of 31 July 2009 was about 88 percent full. The NTSA terminated, with respect to release rights, on 30 June 2004. Under the NTSA Extended Provisions, active storage accounts must be refilled no later than 30 June 2011.

## Revelstoke Reservoir

During the 2008-09 operating year, the Revelstoke project was operated as a run-of-river plant with the reservoir level maintained generally within 0.91 m (3.0 ft) of its normal full pool elevation of 573.02 m (1,880.0 ft). During the spring freshet, March through July, the reservoir operated as low as elevation 571.65 m (1,875.5 ft), or 1.37 m (4.5 ft) below full pool, to provide additional operational space to control high local inflows. Changes in Revelstoke storage levels did not affect CRT storage operations

## Arrow Reservoir

As shown in Chart 6, the Arrow reservoir was at elevation 439.1 m (1,440.7 ft) on 31 July 2008, 1.0 m (3.3 ft) below full pool. Arrow reservoir was drafted in the fall and winter to meet Treaty firm loads reaching 436.0 m (1,430.6 ft) on 31 December 2008, higher than normal for this date. The lack of fall/winter draft is primarily due to storage operation under the Fall Agreement and the near normal inflows into the overall Columbia system resulted in less draft required from Arrow reservoir to meet Treaty obligations. The reservoir continued to draft to reach its minimum level of the year at elevation 429.3 m (1,408.6 ft) on 30 March 2009.

Arrow reservoir levels were relatively high in the spring due to primarily filling of non-Treaty storage. Arrow Lake reservoir refilled up to its Treaty flood control level (maximum possible level) in May. The reservoir continued to fill across June to reach a maximum elevation for the year of 437.6 m (1,435.6 ft) on 30 June 2009, 2.56 m (8.4 ft) from full pool. The last time the reservoir filled to within 1 ft below full was on 6 July 2008.

Local inflow into Arrow reservoir was 91 percent of normal over the period August to December 2008. Arrow outflow varied from a monthly average low of approximately

765 $m^3/s$ (27 kcfs) in November to a monthly average high of 1472 $m^3/s$ (52 kcfs) in December. Local inflow into Arrow reservoir was 81 percent of normal over the period January to July 2009. Outflow over this same period varied from a monthly average high of 1,529 $m^3/s$ (54 kcfs) in January to a monthly average low of 510 $m^3/s$ (18 kcfs) in April.

As in past years, the Non-Power Uses agreement was negotiated with the U.S. in order to manage Arrow Lakes Reservoir outflows to protect whitefish and rainbow trout spawning and incubation downstream of the Hugh Keenleyside Dam. As a result, from 1 January to 19 January 2009, Arrow outflow was held on average 1586 $m^3/s$ (56 kcfs) to maintain low river levels during the whitefish peak spawning period. This operation reduced the number of eggs being dewatered during the incubation and emergence period in February and March 2009. Arrow outflow, from February through March 2009, was held above 991 $m^3/s$ (35 kcfs), on average, to help protect deposited eggs. These flow changes resulted in a Tier 2 protection level for whitefish for the 2008-09 operating year. During April and May 2009, Arrow outflows were maintained at or above 510 $m^3/s$ (18 kcfs), to ensure successful rainbow trout spawning below Arrow, at water levels that could be maintained until hatch. Storage under this agreement, as well as other supplemental agreements helped to increase the Arrow Lakes Reservoir level during the January through August period.

The CRTOC also negotiated and signed other supplemental operating agreements to improve reservoir and river operations in Canada and the U.S. during 2008-09:

- The Libby/Arrow Swap Agreement, signed in August 2008, allowed water exchange between Lake Koocanusa and Arrow Lakes Reservoirs, thereby improving summer recreation levels at Lake Kookanusa in August. This agreement raised the level of the Kookanusa reservoir by about 0.85 m (2.8 ft) and lowered the Arrow Lakes reservoir level by 0.30 m (1 ft) at the end of August. Even with this reduction, the Arrow Lakes reservoir remained well within the desirable recreation range through Labor Day.

- The Fall Storage Agreement, signed in September 2009, allowed Arrow discharges to be reduced in late September through early November, storing additional water in the Arrow Lakes Reservoir. The two countries shared power and fisheries benefits from the agreement.

- CRTOC E-mail Agreement, for flow shaping from 10 January through 3 April 2009, allowed storing of high peak flows at Arrow in January/February for releases in March 2009 providing additional whitefish protection in Canada and reduced high inflows into Grand Coulee.

## Duncan Reservoir

Operation of the Duncan reservoir during the 2008-09 operating year implemented the operational constraints agreed upon in the Duncan Water Use Plan (WUP) and ordered in the Water License Order (issued on 21 December 2007). As shown in Chart 7, the Duncan reservoir refilled to 576.53 m (1,891.5 ft), 0.15 m (0.5 ft) below full pool on 11 August 2008. After the reservoir was drafted to approximately 576.38 m (1,891 ft), Duncan reservoir was operated to pass inflows through to mid-August, when discharges were gradually increased to target a reservoir elevation of 575.46 m (1,888 ft) by the end of August.

Discharges were increased to about 198 $m^3/s$ (7 kcfs) across September to facilitate drafting of the reservoir prior to the start of the kokanee and whitefish spawning downstream of Duncan Dam. For the first 3 weeks of October discharges were reduced to maintain a 73 $m^3/s$ (2.6 kcfs) flow at the Duncan River below the Lardeau confluence (DRL) gauging station to facilitate spawning at lower flows to limit the risk of over-winter dewatering of redds. Discharges were increased in the last week of October to bring DRL to a maximum flow of 110 $m^3/s$ (3.9 kcfs) and maintained until 21 December at which point flows were gradually ramped up to about 227 $m^3/s$ (8 kcfs) to help support whitefish flows downstream of Keenleyside Dam. For the first 3 weeks of January 2009, Duncan discharge was kept fairly high, near 227 $m^3/s$ (8 kcfs), to draft the Duncan reservoir and to help reduce Arrow flows in aid of whitefish spawning.

B.C. Hydro requested a variance to the Duncan Flood Control Curve for 28 February 2009 from 551.0 m (1,807.7 ft) to 552.4 m (1,812.5 ft), which was subsequently approved by the Corps. The additional storage on 28 February increased the ability to maintain a minimum river flow at DRL of 73 $m^3/s$ (2.6 kcfs), for incubation of fish eggs during the March-April period as agreed to under the Duncan WUP. Flows were reduced and held near 185 $m^3/s$ (6.5 kcfs), for the balance of January and February in order to target a flood control level of 552.4 m (1,812.5 ft) on 28 February 2009. Discharges in March through early May

2009 were adjusted as required to provide a minimum flow of 73 $m^3/s$ (2.6 kcfs), at the DRL and to empty the reservoir prior to the freshet. The reservoir drafted to near empty at elevation 547.09 m (1,794.9 ft) on 1 May 2009. Reservoir discharge was reduced to the minimum of 3 $m^3/s$ (0.1 kcfs) on 20 May 2009 to initiate refill. Duncan reservoir continued to pass the minimum flows until late July when discharges were gradually increased to control the rate of refill and minimize the risk of flooding downstream of the dam. The reservoir refilled to a maximum elevation of 575.86 m (1,889.3 ft), 0.82 m (2.7 ft) below full pool on 21 August 2009. Duncan discharges were adjusted as needed across August to target a reservoir elevation of ~575.46 m (~1,888 ft) by the end of August and accommodate ramping tests in September.

## Libby Reservoir

Operation of Libby Dam and Lake Koocanusa is shown in Chart 8 of this document. Lake Koocanusa began July 2008 at elevation 743.6 m (2,439.5 ft), 4.7 m (15.5 ft) from full. Inflow to the reservoir was near 999.1 $m^3/s$ (35 kcfs) at the beginning of July and receded to approximately 339.8 $m^3/s$ (12 kcfs) by the end of the month. Outflow from Libby was 481.4 $m^3/s$ (17 kcfs), at the start of July. On 1 July the State of Montana submitted a System Operations Request (SOR) to the regional forum Technical Management Team (TMT) requesting releases of 481.4 $m^3/s$ (17 kcfs), through 31 July and 339.8 $m^3/s$ (12 kcfs) throughout the month of August. After discussion at TMT, the Corps decided to continue to draft Libby to elevation 743.4 m (2,439 ft), or 6.1 m (20 ft) from full, on 31 August 2008 with releases as flat as possible during this time frame. As a result Libby outflows were reduced from 481.4 $m^3/s$ (17 kcfs), on 11 July to 368.1 $m^3/s$ (13 kcfs) on 12 July. These releases were held through the end of July.

On 1 August 2008 outflows were reduced to 339.8 $m^3/s$ (12 kcfs) and further reduced to 311.5 $m^3/s$ (11 kcfs) on 4 August in order to achieve the 31 August target elevation of 743.4 m (2,439 ft). An Agreement of the CRTOC on the Operation of Canadian Treaty and Libby Storage Reservoirs for the period 2 August 2008 through 31 December 2008 was signed on 6 August. This agreement allowed Libby to store an additional 60 ksfd above its 31 August elevation target of 743.4 m (2,439 ft) and was coordinated with TMT. This additional storage into Libby was offset by allowing Arrow and Duncan to be below their

combined TSR storage amount by an equal amount. Pursuant to this agreement Libby outflows were reduced to 283.2 $m^3/s$ (10 kcfs), and then later adjusted as needed between 226.5 $m^3/s$ and 339.8 $m^3/s$ (8 and 12 kcfs) to reach elevation 744.2 m (2,441.7 ft) on 31 August. The final swap amount was 58.6 ksfd above reservoir elevation 743.4 m (2,439 ft).

Outflows at the beginning of September 2008 were 226.5 $m^3/s$ (8 kcfs). On 6 September the outflow was reduced to the bull trout minimum flow of 169.9 $m^3/s$ (6 kcfs), and was held at that level for the remainder of the month. The reservoir elevation on 30 September was 744.0 m (2,440.8 ft).

In early October, the outflow was reduced to 133.1 $m^3/s$ (4.7 kcfs), which is near minimum project outflow of 4.0 kcfs. In the later part of the month releases were reduced slightly to 127.4 $m^3/s$ (4.5 kcfs).

Outflows from Libby Dam remained at 127.4 $m^3/s$ (4.5 kcfs) until 13 November when weekly and daily load shaping for power objectives began. While load shaping outflow from the dam was generally higher during the week and slightly less on weekends and higher during the day and less at night. All changes in outflow followed the ramp rate restrictions as described in the U.S. Fish and Wildlife Service (USFWS) 2006 Biological Opinion. The average outflow from the dam in November was 240.4 $m^3/s$ (8.5 kcfs). The reservoir elevation on 30 November was 742.1 m (2,434.7 ft).

Daily and weekly load shaping continued at Libby in December, with an average monthly outflow of 511.2 $m^3/s$ (18.1 kcfs). In early December the Corps prepared a water supply forecast (WSF) for Libby inflow for the April through August period. This early season forecast was 7.32 $km^3$ (5.94 Maf), 94 percent of average. Because the forecast was greater than 5.9 Maf, the end of December flood control evacuation requirement was 2.5 $km^3$ (2.0 Maf), and the project was operated to reach an elevation of 734.9 m (2,411 ft) by the end of the month. The reservoir elevation on 31 December 2008 was 734.8 m (2,410.9 ft).

In January through April the dam was operated to target each end of month flood control elevation to meet the objectives of the National Oceanographic and Atmospheric Administration (NOAA) Fisheries Biological Opinion. The January 2009 WSF was 6.82 $km^3$ (5.53 Maf), 87 percent of average. The resultant end of January VARQ upper flood control limit was 739.5 m (2,426.2 ft). After the January WSF was issued, the project

outflow was reduced to minimum outflow or 113.3 $m^3/s$ (4 kcfs). The 31 January reservoir elevation was 734.2 m (2,408.7 ft). The WSF for February and March decreased from the January forecast. The February WSF was 6.71 $km^3$ (5.44 Maf), 86 percent of average, and the March forecast was 6.53 $km^3$ (5.30 Maf), 84 percent of average. The end of February flood control upper limit was 742.6 m (2,436.4 ft) and the 15 and 31 March flood control upper limits were 744.0 m (2,441.1 ft) and 744.5 m (2,442.6 ft), respectively. Due to decreasing forecasts and low reservoir inflows, Libby Dam releases were held at minimum outflow or 113.3 $m^3/s$ (4.0 kcfs) during February and March. The 28 February and 31 March reservoir elevations were 733.4 m (2,406.1 ft) and 732.6 m (2,403.5 ft), respectively. The April WSF had increased to 7.00 $km^3$ (5.67 Maf), 90 percent of average. The resultant flood control upper limits were 741.9 m (2,434.2 ft) for 15 and 30 April. The project continued to release minimum outflows for the entire month and the 30 April reservoir elevation was 733.2 m (2,405.4 ft).

The May 2009 WSF decreased substantially to 6.43 $km^3$ (5.21 Maf), 82 percent of average. In conjunction with the declaration of the Initial Control Flow (ICF) for system refill and following Variable Flow (VARQ) flood control procedures, Libby releases were increased beginning 1 May to pass inflow until reservoir inflows exceeded the calculated VARQ minimum outflow of 379.4 $m^3/s$ (13.4 kcfs). Inflows reached this value on 19 May and project releases were ramped up to 379.4 $m^3/s$ (13.4) kcfs for the remainder of the month. The 31 May reservoir elevation was 736.6 m (2,416.6 ft).

The June 2009 WSF decreased further to 6.24 $km^3$ (5.06 Maf), 80 percent of average. Libby began the month releasing the VARQ minimum outflow of 379.4 $m^3/s$ (13.4 kcfs). On 6 June releases were increased slightly to 382.3 $m^3/s$ (13.5 kcfs), the VARQ minimum discharge based on the June WSF. Based on the established USFWS BiOp procedures to provide sturgeon flow augmentation, the available sturgeon volume was computed to be 0.99 $km^3$ (0.8 Maf). The USFWS requested that this volume begin to be released when Kootenai River temperatures at Bonner's Ferry, Idaho reach 8° C and Koocanusa Reservoir warmed such that 20,000-25,000 cfs could be released through the turbines without decreasing Kootenai River temperatures by more than 1.5° C. Increases in discharge for the sturgeon operation commenced on 10-11 June. Releases were ramped up to full powerhouse outflow near 764.6 $m^3/s$ (27 kcfs) and then held for 7 days. Late in the day on 17 June,

outflows from Libby were decreased to 22 kcfs and further reduced to 20 kcfs on 18 June; this discharge was maintained for 5 days. From 23-24 June outflow was gradually reduced to 481.4 $m^3/s$ (17 kcfs). On 26 June discharges from Libby Dam were decreased to 424.8 $m^3/s$ (15 kcfs), and reduced further to 339.8 $m^3/s$ (12 kcfs) on 30 June. The 30 June reservoir elevation was 741.2 m (2431.9 ft). Libby outflow at the beginning of July was 339.8 $m^3/s$ (12 kcfs). Beginning on 2 July discharges were gradually reduced from 339.8 $m^3/s$ (12 kcfs) to the bull trout minimum flow of 198.2 $m^3/s$ (7 kcfs) on 12 July, exhausting the sturgeon volume. The 7 kcfs outflow was continued through August. The reservoir elevation on 31 July and 31 August were 744.1 m (2441.3 ft) and 744.7 m (2443.1 ft), respectively. On 25 August Lake Koocanusa reached its maximum elevation of 744.7 m (2443.3 ft), 4.8 m (15.7 ft) from full. On 1 September, discharges were reduced to 169.9 $m^3/s$ (6 kcfs), the minimum flow for bull trout in September. Lake Koocanusa elevation was 744.1 m (2441.40 ft) on 30 September.

## Kootenay Lake

As shown in Chart 9, the level of Kootenay Lake at Queens Bay was at elevation 531.45 m (1,743.6 ft) on 31 July 2008. As runoff receded across August, Kootenay Lake reservoir began to draft and discharges were adjusted to control reservoir levels slightly below the IJC limits. When the Kootenay Lake level measured at Nelson was drafted below the trigger elevation of 531.36 m (1,743.32 ft) on 6 August 2008, discharges were adjusted to keep the lake level at or below the control level until the end of August 2008.

Target minimum flows downstream of Brilliant flows are 18 kcfs from December to September and 16 kcfs during October and November. These minimums are subject to water availability.

By 31 December 2008, Kootenay Lake was at an elevation of 531.78 m (1,744.7 ft), 0.18 m (0.6 ft) below the maximum IJC level. Kootenay Lake drafted from January to early April to remain below the IJC Order level and to meet generation requirements. Due to the delayed freshet, Kootenay Lake drafted lower than normal this year to reach a minimum elevation of 530.0 m (1,738.4 ft) on 7 April 2009.

Between March 1 and mid March 2009, Kootenay canal was dewatered to implement urgent repairs to a cracked concrete panel on the right abutment. Kootenay Lake was pre-

drafted below the IJC in advance of the outage followed by a reduction in Brilliant discharges to between 368 to 396 m3/s (13 to 14 kcfs) , significantly below the minimum target of 18 kcfs to prevent further drafting of Kootenay Lake.

The International Kootenay Lake Board of Control, after consultation with FortisBC declared the Commencement of Spring Rise for Kootenay Lake on 8 April 2009. Following the declaration of spring freshet, Kootenay Lake was operated in accordance to the IJC lowering formula. Kootenay Lake discharge was passing the Grohman Narrow maximum flow from mid March. Inflow peaked at 2115.3 $m^3/s$ (74.7 kcfs) on 30 May 2009. Discharge from the lake peaked at 1503.6 $m^3/s$ (53.1 kcfs) on 6 June 2009. Kootenay Lake reached a peak elevation of 532.74 m (1,747.84 ft) on 19 June 2009.

As runoff receded during June, Kootenay Lake Reservoir began to draft and discharges were adjusted to control reservoir levels slightly below the IJC limits. When the Kootenay Lake level measured at Nelson was drafted below the trigger elevation of 531.36 m (1,743.32 ft) on 19 July 2009, discharges were adjusted to keep the lake level at or below the control level until the end of August and target the minimum flow below Brilliant (as flows are available).

# VI - POWER AND FLOOD CONTROL ACCOMPLISHMENTS

## General

During the period covered by this report, Duncan, Arrow, and Mica reservoirs were operated for power, flood control, and other benefits in accordance with the CRT and operating plans and agreements described in Section III Operating Agreements. Consistent with all DOPs prepared since the installation of generation at Mica, the 2008-09 and 2009-10 DOPs were designed to achieve optimum power generation at-site in Canada and downstream in Canada and the U.S., in accordance with paragraph 7 of Annex A of the CRT.

Power operations for the whole of Canadian storage are determined by the ORC, CRCs, Mica/Arrow project operating criteria, and non-power constraints as simulated in the Treaty Storage Regulation study (TSR). The ORC calculation includes the VRCs which are dependent upon the water supply in any given water year and the VRC is updated each month with the development of a new WSF. The monthly VRC calculations for Mica, Arrow and Duncan are shown in Tables 2 – 4 and 2M – 4M. The calculations for Libby VRCs are shown in Tables 5 and 5M. Libby VRCs are used in the preparation of the TSR.

During the period covered by this report, Libby operated for power during October through November 2008 as described in the LOP and 2003 CRT FCOP. Based on the December 2008 forecast of January-July volume runoff of 94 percent of average, the recommended draft for Libby reservoir was 2.47 $km^3$ (2 Maf), to elevation 734.9 m (2,411 ft) on 31 December.

Libby was operated to its VarQ (Variable Flow) flood control storage reservation diagram in December through spring period. Lake Koocanusa was below the end of April flood control elevation because despite Libby Dam passing minimum flow all the way from January through the end of April, there was insufficient inflow to fill up to the flood control elevation. During the refill period from late April through June, Libby Dam operated in strict accordance with the VarQ Operating Procedures and released 0.99 $km^3$ (0.80 Maf) sturgeon flow augmentation (sturgeon flow augmentation completed in early July). The reservoir filled to within 4.8 m (15.7 feet) of full in August 2009.

## Flood Control

The 2009 WSF's averaged below normal across the Columbia River Basin, Upper Columbia Basin, and the Snake River Basin. The reservoir system, including the Columbia River Treaty projects, was required to draft for flood control in preparation for the spring freshet. Inflow forecasts and reservoir regulation modeling were done weekly throughout the winter and spring. Projects were operated according to the May 2003 FCOP. The unregulated peak flow (based on the USACE SSARR program output) at The Dalles, Oregon, shown on Chart 13, was estimated at 16,210 $m^3/s$ (572.5 kcfs) on 8 June 2009, and a regulated peak flow of 9,894 $m^3/s$ (349.4 kcfs) occurred on 29 May 2009 as measured at the United States Geological Survey gage at The Dalles, Oregon. The unregulated (USACE) peak stage at Vancouver, Washington, was calculated to be 6.30 m (20.7 ft) on 8 June 2009, and the highest observed stage was 3.33 m (10.9 ft) on 9 June 2009.

Chart 14 shows the relative filling of Arrow and Grand Coulee during the filling period and compares the regulation to guidelines provided in Chart 6 of the Columbia River Treaty Flood Control Operating Plan. There were no daily operations specified for Arrow, and the projects were able to meet both fish flow and flood control objectives. Influenced by relatively good runoff conditions combined with Non-Treaty storage and Treaty flex operations, Arrow filled up (relative to Grand Coulee) higher than the guidelines shown on the chart.

For Duncan, a request to deviate from flood control for the end of February from elevation 1,807.7 feet to elevation 1,812.5 feet was requested, approved, and implemented

In operating year 2008-09, the Canadian Entity had elected to operate Mica and Arrow to the flood control storage allocations of 4.4 $km^3$ (3.6 Maf) maximum draft at Arrow and 5.03 $km^3$ (4.08 Maf) maximum draft at Mica, as allowed under the 2003 FCOP. This allocation was first incorporated in the AOP for 2006-07.

Computations of the Initial Controlled Flow (ICF) for system flood control operation were made in accordance with the Treaty Flood Control Operating Plan. For 2009, the computed ICF at The Dalles was 8533 $m^3/s$ (301.4 kcfs) based on the January forecast; 8364 $m^3/s$ (295.4 kcfs) based on the February forecast; 7906 $m^3/s$ (279.2 kcfs) based on the March forecast; 8594 $m^3/s$ (303.5 kcfs) based on the April forecast; and 8504 $m^3/s$ (300.3 kcfs) based on the May forecast. As mentioned earlier, the observed daily peak flow

at The Dalles was 9894 $m^3/s$ (349.4 kcfs), and occurred on 29 May 2009. Table 6 shows data for the May ICF computation.

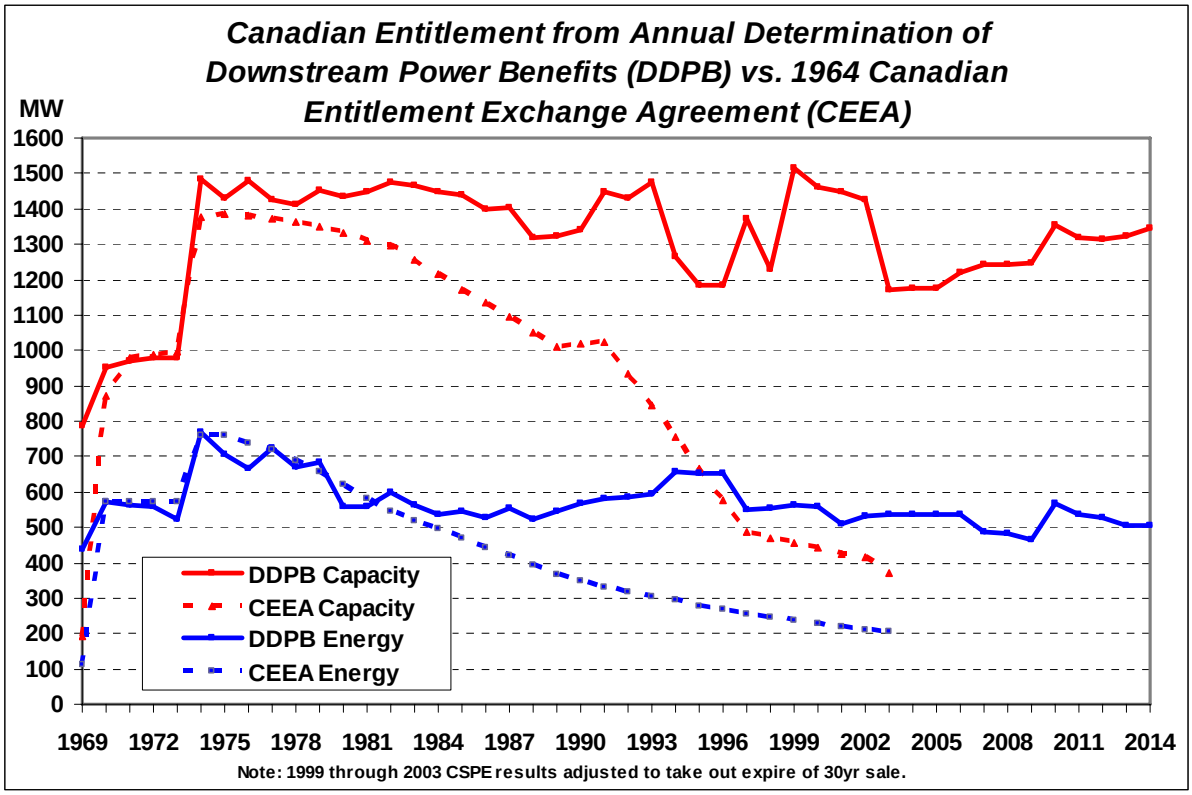
## Canadian Entitlement and Downstream Power Benefits

From 1 August 2008 through 30 September 2009, the U.S. Entity delivered the Canadian Entitlement to downstream power benefits from the operation of Canadian storage to the Canadian Entity, at existing points of interconnection on the Canada-U.S. border. The amounts returned, not including transmission losses and scheduling adjustments, are listed in Section III Operating Arrangements of this report, under the heading Canadian Entitlement.

No Entitlement power was disposed directly in the U.S. during 1 August 2008 through 30 September 2009, as allowed under specific provisions of the 29 March 1999 Agreement on "Disposals of the Canadian Entitlement within the U.S. for 4/1/98 through 9/15/2024."

The following Figure 1 shows the historic Canadian Entitlement amounts from the DDPB studies as compared to the estimated amount under the 1964 Canadian Entitlement Exchange Agreement (CEEA).

Figure 1:



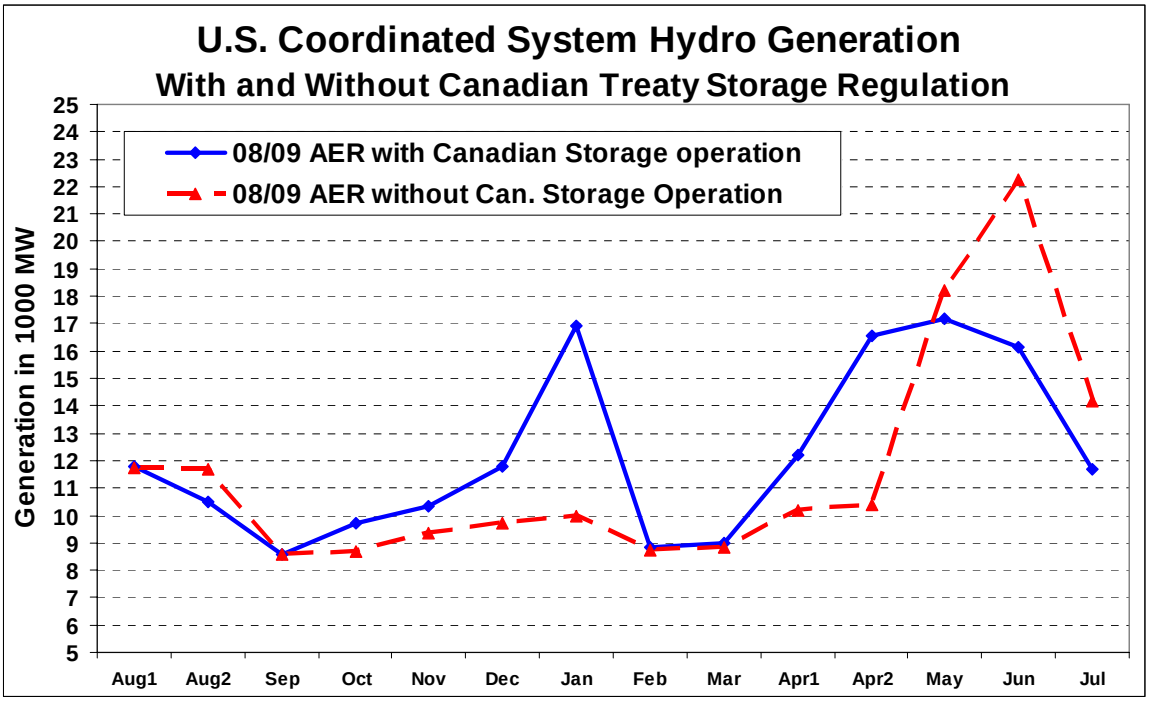
The CEEA estimates of the Canadian Entitlement were based on forecasted load growth that was much higher than the subsequent actual load growth, which is the main reason for the large difference in the Canadian Entitlement between the historic DDPB's and the CEEA estimate.

In accordance with the Canadian Entitlement Allocation Extension Agreement, dated April 1997, the non-federal downstream U.S. projects delivered to BPA their portion of the Canadian Entitlement, and the U.S. Entity granted permission for the non-federal downstream U.S. parties to make use of the U.S. one-half share of the CRT downstream power benefits (U.S. Entitlement).

## Power Generation and Other Accomplishments

Actual U.S. power benefits from the operation of CRT storage are unknown and can only be roughly estimated. Treaty storage has such a large impact on the U.S. system operation that its absence would significantly affect operating procedures, non-power requirements, loads and resources, and market conditions, thus making any benefit analysis highly speculative. Figure 2 shows a rough estimate of the average monthly impact on downstream U.S. power generation during the 2008-09 operating year, with and without the regulation of Canadian storage, based on the PNCA Actual Energy Regulation (AER) that includes minimum flow and spill requirements for U.S. fishery objectives. The increase in average annual U.S. power generation due to the operation of Canadian storage, as measured by the PNCA AER, was 442 aMW. In addition to the increase in average annual U.S. power generation, the Treaty regulation also shifted the timing of generation from the low value freshet period, into higher value winter months. No quantification of this benefit is provided in this report.

Figure 2:




Based on the authority from the 2008-09 and 2009-10 DOPs, the CRTOC completed supplemental operating agreements, described in section III Operating Arrangements, which resulted in power and other benefits both in Canada and the U.S. Other benefits include changes to stream flows below Arrow that enhanced trout and mountain whitefish spawning in Canada and the downstream migration of salmon in the U.S.

In addition, under the Libby Coordination Agreement, the U.S. received one average annual MW from B.C. Hydro. Canada received the benefits of the provisional draft operation at Arrow and related exchanges of power between B.C. Hydro and BPA, where Arrow was drafted twice beginning early September, and a second draft in late November.

Figure 3 compares the actual operation of the composite Canadian storage to the results of the DOP TSR study, and Figure 4 shows the difference in Arrow plus Duncan regulated outflows in the DOP TSR and the actual daily CRT outflows due to these agreements. The daily unregulated stream flow is also shown for comparison purposes.

Figure 5 shows the difference for each period between the final TSR composite storage and the Treaty composite storage including any Supplementary Operating Agreements. The final TSR target results are not available until after-the-fact, thus resulting in some

inadvertent changes. The middle portion of the table shows how the TSR regulation results vary over time due to updated forecasts and unexpected changes in weather. The lower portion shows the amount of storage balances from each Supplementary Operating Agreement that was implemented.

Figure 3

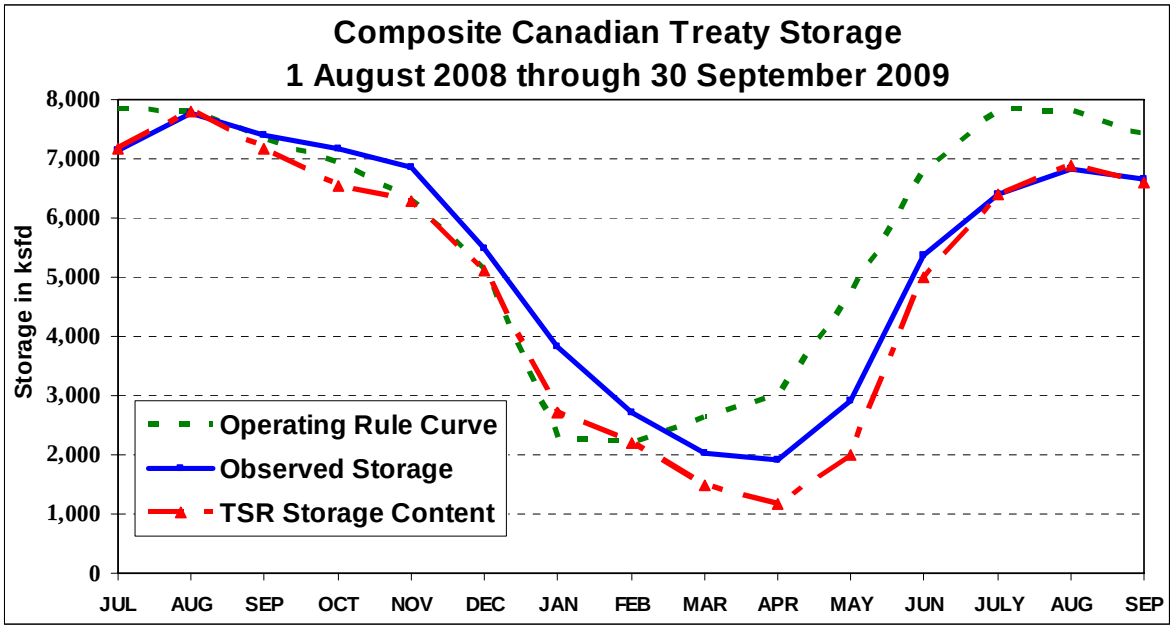


Figure 4

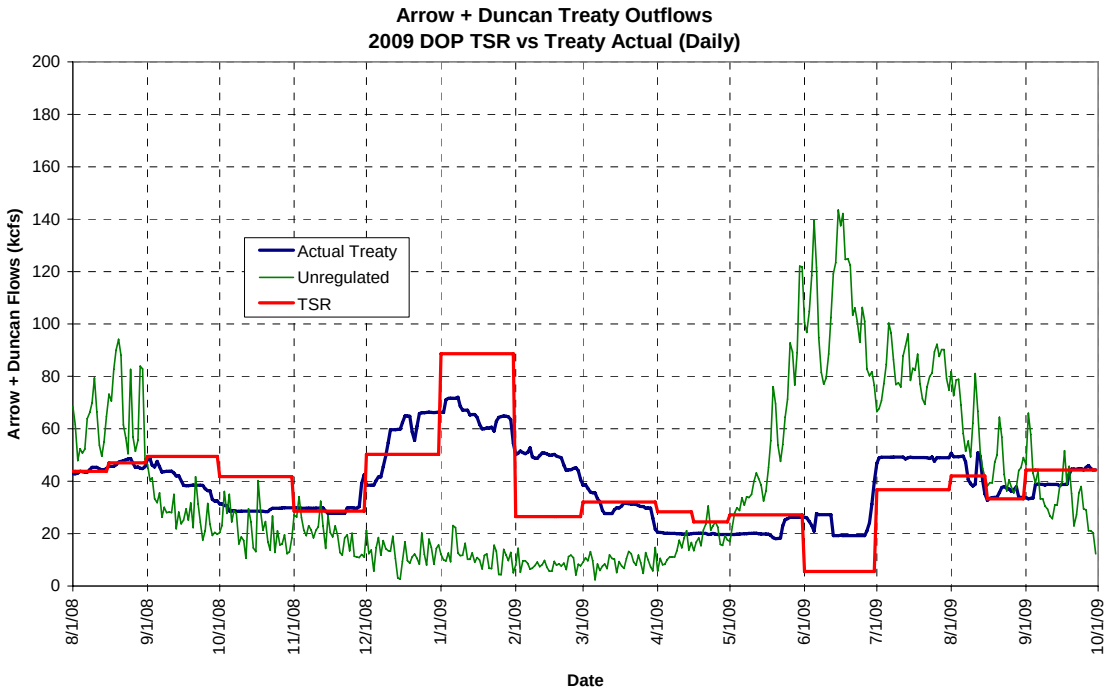



Figure 5 summarizes the Treaty accounting including supplementary operating agreements throughout the year. Section I, shows the difference for each period between the final TSR composite storage and the actual Treaty composite storage, including the supplementary agreements. Section II shows the storage balance for each supplementary agreement as it was implemented. Section III shows how the TSR storage content varies over time due to updated forecasts, unexpected weather events, and other factors. The final TSR target results are not available until after-the-fact, thus resulting in some inadvertent storage, as shown in Section II Line 11.

# Figure 5

## Summary of Treaty Storage Operations
## July 2008 through July 2009
## All units in KSFD

**I. Composite Treaty Storage (ksfd)**

| | 2008 JUL | AU1 | AU2 | SEP | OCT | NOV | DEC | 2009 JAN | FEB | MAR | AP1 | AP2 | MAY | JUN | JUL | AU1 | AU2 | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Treaty Storage Regulation (Final) | 7176.0 | 7421.4 | 7786.1 | 7166.6 | 6539.3 | 6272.9 | 5104.1 | 2703.6 | 2195.0 | 1483.2 | 1249.9 | 1182.0 | 1992.1 | 5002.0 | 6408.8 | 6722.0 | 6893.5 | 6607.9 |
| 2. Actual Treaty Content (w/SOA's) | 7133.1 | 7373.5 | 7760.3 | 7399.8 | 7166.3 | 6859.4 | 5489.6 | 3827.7 | 2710.8 | 2032.3 | 1921.7 | 1922.4 | 2904.2 | 5378.9 | 6413.2 | 6677.5 | 6819.4 | 6649.5 |
| 3. % full (actual Treaty/7814.6 ksfd) | 91.8% | 94.9% | 99.6% | 91.7% | 83.7% | 80.3% | 65.3% | 34.6% | 28.1% | 19.0% | 16.0% | 15.1% | 25.5% | 64.0% | 82.0% | 86.0% | 88.2% | 84.5% |
| 4. Final deviation from TSR | -42.9 | -47.9 | -25.8 | 233.2 | 627.0 | 586.5 | 385.5 | 1124.1 | 515.8 | 549.1 | 671.8 | 740.4 | 912.1 | 376.9 | 4.4 | -44.5 | -74.1 | 41.6 |

**II. Monthly Accounting of Supplemental Operating Agreements Content (ksfd)**

| Balance in each period | 2008 JUL | AU1 | AU2 | SEP | OCT | NOV | DEC | 2009 JAN | FEB | MAR | AP1 | AP2 | MAY | JUN | JUL | AU1 | AU2 | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5. Libby Swap | 0.0 | -60.0 | -60.0 | -27.0 | -27.0 | -13.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6. Libby Coord Agreement (LCA) | 0.0 | 0.0 | 0.0 | -28.0 | 0.0 | -8.0 | -125.0 | -97.0 | -97.0 | -12.0 | 0.0 | 0.0 | 0.0 | 0.0 | -28.0 | -28.0 | -56.0 | -64.0 |
| 7. Fall Storage Arrow + Mica | 0.0 | 0.0 | 0.0 | 267.0 | 588.0 | 634.5 | 503.5 | 487.0 | 34.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8. Jan Storage Shaping at Arrow (JSS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 136.2 | 68.1 | 7.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9. Non Power Uses Flow (NPU) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 504.0 | 504.0 | 504.0 | 504.0 | 504.0 | 504.0 | 504.0 | 0.0 | | | |
| 10. Total | 0.0 | -60.0 | -60.0 | 212.0 | 561.0 | 613.0 | 378.5 | 1030.2 | 509.4 | 499.3 | 504.0 | 504.0 | 504.0 | 504.0 | -28.0 | -28.0 | -56.0 | -64.0 |
| 11. Inadvertent (Line 4 - Line 10) | -42.9 | 12.1 | 34.2 | 21.2 | 66.0 | -26.5 | 7.0 | 93.9 | 6.4 | 49.8 | 167.8 | 236.4 | 408.1 | -127.1 | 32.4 | -16.5 | -18.1 | 105.6 |
| | | | | | | | | | | | (NPU Shaping; inadvertent does not apply.) | | | | | | | |

**III. Summary of TSR Results August 2008-July 2009 (Target TSR in black; Final TSR in bold)**

**Composite Treaty Storage TSR Content (ksfd)**

| TSR Date | 2008 JUL | AU1 | AU2 | SEP | OCT | NOV | DEC | 2009 JAN | FEB | MAR | AP1 | AP2 | MAY | JUN | JUL | AU1 | AU2 | 2009 SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-Aug-08 | 7176.0 | 7503.4 | 7657.0 | 7244.8 | 6768.4 | 6304.2 | 5133.8 | 3002.3 | 2757.7 | 1597.5 | 1404.0 | 1365.1 | 2717.6 | 5926.3 | 7664.6 | | | |
| 21-Aug-08 | | 7421.4 | 7786.1 | 7341.2 | 6885.1 | 6304.2 | 5133.8 | 3002.3 | 2836.9 | 1676.7 | 1483.1 | 1444.2 | 2796.7 | 6005.5 | 7664.6 | | | |
| 8-Sep-08 | | | 7786.1 | 7341.3 | 6900.6 | 6304.2 | 5133.8 | 3002.3 | 2810.1 | 1649.9 | 1456.3 | 1417.4 | 2769.9 | 5978.7 | 7664.6 | | | |
| 25-Sep-08 | | | | 7207.9 | 6710.4 | 6304.2 | 5133.8 | 3002.3 | 2499.4 | 1339.1 | 1145.6 | 1106.7 | 2459.2 | 5668.0 | 7435.6 | | | |
| 8-Oct-08 | | | | 7166.6 | 6681.2 | 6278.1 | 5133.8 | 3002.3 | 2497.6 | 1337.4 | 1143.9 | 1105.0 | 2457.5 | 5666.2 | 7433.8 | | | |
| 24-Oct-08 | | | | | 6617.9 | 6157.8 | 5133.8 | 3002.3 | 2442.7 | 1282.5 | 1089.0 | 1073.6 | 2426.1 | 5634.9 | 7402.5 | | | |
| 7-Nov-08 | | | | | 6539.3 | 6085.0 | 5133.8 | 3002.3 | 2444.9 | 1284.6 | 1091.1 | 1073.6 | 2426.1 | 5634.9 | 7402.5 | | | |
| 19-Nov-08 | | | | | | 6304.2 | 5133.8 | 3002.3 | 2449.5 | 1293.5 | 1107.6 | 1080.9 | 2502.6 | 5677.7 | 7447.0 | | | |
| 9-Dec-08 | | | | | | 6272.9 | 5133.8 | 2686.5 | 2340.8 | 1430.1 | 1242.0 | 1211.6 | 2607.1 | 5735.8 | 7468.3 | | | |
| 17-Dec-08 | | | | | | | 5133.8 | 2679.3 | 2340.8 | 1420.1 | 1233.0 | 1205.2 | 2598.6 | 5726.9 | 7457.6 | | | |
| 13-Jan-09 | | | | | | | 5104.1 | 2715.5 | 2239.8 | 1417.3 | 1227.2 | 1197.5 | 2581.8 | 5712.1 | 7444.0 | | | |
| 26-Jan-09 | | | | | | | | 2711.7 | 2239.8 | 1410.0 | 1222.9 | 1195.0 | 2580.9 | 5716.5 | 7444.8 | | | |
| 11-Feb-09 | | | | | | | | 2703.6 | 2195.0 | 1462.7 | 1272.4 | 1238.5 | 2571.9 | 5601.1 | 7260.1 | | | |
| 23-Feb-09 | | | | | | | | | 2195.0 | 1459.3 | 1266.9 | 1233.8 | 2569.1 | 5597.2 | 7256.2 | | | |
| 11-Mar-09 | | | | | | | | | 2195.0 | 1456.9 | 1622.5 | 1867.3 | 3159.2 | 5898.3 | 7487.0 | | | |
| 25-Mar-09 | | | | | | | | | | 1522.3 | 1683.1 | 1871.9 | 3165.1 | 5903.8 | 7496.0 | | | |
| 10-Apr-09 | | | | | | | | | | 1483.2 | 1260.2 | 1242.0 | 2552.6 | 5505.2 | 7113.7 | | | |
| 24-Apr-09 | | | | | | | | | | | 1249.9 | 1217.4 | 3276.0 | 5608.2 | 7264.0 | | | |
| 12-May-09 | | | | | | | | | | | | 1182.0 | 2180.9 | 5349.7 | 6979.3 | | | |
| 22-May-09 | | | | | | | | | | | | | 2038.3 | 5312.6 | 6979.0 | | | |
| 10-Jun-09 | | | | | | | | | | | | | 1992.1 | 5121.5 | 6763.4 | | | |
| 24-Jun-09 | | | | | | | | | | | | | | 5015.7 | 6422.8 | 6733.1 | 6933.2 | |
| 13-Jul-09 | | | | | | | | | | | | | | 5002.0 | 6466.6 | 6841.4 | 7081.5 | |
| 27-Jul-09 | | | | | | | | | | | | | | | 6389.6 | 6778.9 | 7036.1 | 6922.5 |
| 7-Aug-09 | | | | | | | | | | | | | | | 6408.8 | 6770.8 | 6981.4 | 6749.3 |
| 21-Aug-09 | | | | | | | | | | | | | | | | 6722.0 | 6986.9 | 6790.3 |
| 10-Sep-09 | | | | | | | | | | | | | | | | | 6893.5 | 6663.2 |
| 24-Sep-09 | | | | | | | | | | | | | | | | | | 6689.7 |
| 8-Oct-09 | | | | | | | | | | | | | | | | | | 6607.9 |

At the beginning of the 2008-09 operating year (July 31st), both the TSR storage level for Canadian storage, and the actual Canadian Treaty storage were near full, with the actual being 91.8 percent full. In August 2008 a Libby Arrow Swap Agreement allowed Arrow to release 147 $hm^3$ (60 ksfd) of storage that was returned by 31 December 2008.

In September, under terms of the LCA, Canada released 69 $hm^3$ (28 ksfd) of LCA provisional draft which was returned by late October. Beginning in late September and continuing into early November, the U.S. and Canada utilized a supplemental operating agreement to provisionally store above TSR levels (Fall Storage Agreement) by up to 1552 $hm^3$ (635 ksfd) in November. Canada exercised their LCA provisional draft rights and drafted 306 $hm^3$ (125 ksfd) below TSR by 31 December 2008, with return of the provisional draft in January and March. Also in November, the U.S. and Canada reached agreement to shape flows from December through July to meet multiple system requirements and fishery needs.

In January 2009, there were three agreements implemented to store the additional water: U.S. stored water for Flow Augmentation in Mica; B.C. and U.S. stored at Arrow under a January Storage Shaping (JSS) Agreement; and BC returned LCA. This resulted in an Arrow discharge reduction during January from 2237 $m^3/s$ (79 kcfs) to 1529 $m^3/s$ (54 kcfs) for whitefish spawning. The storage level above TSR reached 2750 $hm^3$ (1124 ksfd) in January as storage was being managed to maintain smooth flow patterns for whitefish in January, to retain provisional storage, and to store April flow augmentation. In February, 1108 $hm^3$ (453 ksfd) of fall Provisional storage was released and approximately half of the JSS storage was returned. Arrow actual outflows reduced to 1161 $m^3/s$ (41.0 kcfs) to balance the needs of Canadian trout spawning and whitefish. The storage level above TSR was reduced to 1262 $hm^3$ (516 ksfd) in February. With most JSS storage, fall provisional draft, and LCA provisional draft returned by the end of March, the Canadian storage ended the month 1343 $hm^3$ (549 ksfd) above the TSR level; only the flow augmentation storage remained. Mica was able to maintain this storage for fish requirements April through June. Outflows at Arrow increased from 510 $m^3/s$ (18 kcfs), in April to 680 $m^3/s$ (24.0 kcfs) in June to balance the needs of B.C. trout spawning, U.S. fisheries, and system load requirements. Flow augmentation was released in July 2009 as inflows receded rapidly, and outflows needed to be maintained at a uniform or greater amount.

The sum of Canadian storage at the end of July was slightly above DOP TSR amounts of 11 $m^3/s$ (4 ksfd), due to inadvertent storage. Canadian storage remained slightly below TSR levels as Canadian Entity exercised LCA provisional draft for a total of 205.5 $hm^3$ (84 ksfd) beginning in July through September followed by a one week return of LCA in the last week of September resulting in a draft balance of 156.6 $hm^3$ (64 ksfd) on September 30, 2009.

Differences between Arrow actual and treaty outflows were due to storage under the 1990 Non-Treaty Agreement and the 2009 Summer Storage Agreement. Beginning September through February, the U.S. stored a total of 548 $hm^3$ (224 ksfd) in Non Treaty Storage with 288 $hm^3$ (117.8 ksfd) in January. This resulted in Arrow actual outflows slightly lower than Arrow treaty outflows, with the maximum difference in January actual outflow 108 $m^3/s$ (3.8 kcfs), lower than Arrow treaty outflows. In June, there was storage under the 2009 Summer Storage Agreement (Not-Treaty), for one week causing the outflow to be slightly lower. This use of non-Treaty storage is separate from and not related to the 1990 NTSA. BC's share was returned in late July for one week, and the U.S. returned over one week in late August through early September. This resulted in the actual Arrow outflows to be higher by 113 $m^3/s$ (4 kcfs) for each week.

# VII – TABLES

## Table 1M (metric): Unregulated Runoff Volume Forecasts

## Cubic Kilometers, 2009

**Most Probable 1-April through 31-August Forecasts in $km^3$**

| First of Month Forecast | Duncan | Arrow | Mica | Libby | Columbia River at The Dalles, Oregon |
|---|---|---|---|---|---|
| January | 2.47 | 28.11 | 13.74 | 6.82 | 101.27 |
| February | 2.41 | 27.19 | 13.24 | 6.71 | 98.31 |
| March | 2.30 | 26.32 | 13.05 | 6.53 | 92.26 |
| April | 2.29 | 26.01 | 12.86 | 7.00 | 101.64 |
| May | 2.20 | 25.07 | 12.49 | 6.43 | 100.41 |
| June | 2.15 | 24.16 | 12.05 | 6.24 | 101.64 |
| Actual | 2.00 | 21.13 | 10.77 | 5.44 | 99.36 |

## Table 1: Unregulated Runoff Volume Forecasts

## Million Acre-feet, 2009

**Most Probable 1-April through 31-August Forecasts in Maf**

| First of Month Forecast | Duncan | Arrow | Mica | Libby | Columbia River at The Dalles, Oregon |
|---|---|---|---|---|---|
| January | 2.00 | 22.79 | 11.14 | 5.53 | 82.10 |
| February | 1.96 | 22.04 | 10.73 | 5.44 | 79.70 |
| March | 1.87 | 21.34 | 10.58 | 5.30 | 74.80 |
| April | 1.86 | 21.08 | 10.43 | 5.67 | 82.40 |
| May | 1.79 | 20.32 | 10.12 | 5.21 | 81.40 |
| June | 1.74 | 19.59 | 9.77 | 5.06 | 82.40 |
| Actual | 1.62 | 17.13 | 8.74 | 4.41 | 80.55 |

# Table 2M (metric): 2009 Mica Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, km3 | | | 11.5 | 11.1 | 10.9 | 10.2 | 9.5 | 7.7 |
| PROBABLE DATE-31JULY INFLOW, hm3 | ** | | 11508.8 | 11050.8 | 10869.8 | 10205.0 | 9491.3 | 7670.1 |
| 95% FORECAST ERROR FOR DATE, hm3 | | | 1804.7 | 1276.1 | 1115.1 | 1028.3 | 982.9 | 970.5 |
| 95% CONF.DATE-31JULY INFLOW, hm3 | 1/ | | 9704.1 | 9774.7 | 9754.7 | 9176.7 | 8508.4 | 6699.6 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, hm3 | 2/ | | 9703.9 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 85.0 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, hm3 | 4/ | | 6410.1 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, hm3 | 5/ | | 5340.7 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | | | | | |
| JAN31 ORC, m | 7/ | | 741.5 | | | | | |
| BASE ECC, m | 8/ | 741.5 | | | | | | |
| LOWER LIMIT, m | | 732.0 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 98.0 | 98.0 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, hm3 | 2/ | | 9509.9 | 9579.2 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 85.0 | 85.0 | | | | |
| MIN MAR1-JUL31 OUTFLOW, hm3 | 4/ | | 6204.6 | 6204.6 | | | | |
| VRC FEB28 RESERVOIR CONTENT, hm3 | 5/ | | 5329.2 | 5259.9 | | | | |
| VRC FEB28 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | | | | |
| FEB28 ORC, m | 7/ | | 741.4 | 741.4 | | | | |
| BASE ECC, m | 8/ | 741.4 | | | | | | |
| LOWER LIMIT, m | | 730.0 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 95.6 | 95.6 | 97.6 | | | |
| ASSUMED APR1-JUL31 INFLOW, hm3 | 2/ | | 9277.0 | 9344.5 | 9520.7 | | | |
| APR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 85.0 | 85.0 | 85.0 | | | |
| MIN APR1-JUL31 OUTFLOW, hm3 | 4/ | | 5334.6 | 5267.0 | 5090.9 | | | |
| VRC MAR31 RESERVOIR CONTENT, hm3 | 5/ | | 4071.6 | 4071.6 | 4071.6 | | | |
| VRC MAR31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | | | |
| MAR31 ORC, m | 7/ | | 740.2 | 740.4 | 741.5 | | | |
| BASE ECC, m | 8/ | 741.4 | | | | | | |
| LOWER LIMIT, m | | 729.7 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 90.7 | 90.7 | 92.5 | 94.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, hm3 | 2/ | | 8801.6 | 8865.7 | 9023.1 | 8699.4 | | |
| MAY MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 85.0 | 85.0 | 85.0 | 85.0 | | |
| MIN MAY1-JUL31 OUTFLOW, hm3 | 4/ | | 5756.8 | 5756.8 | 5756.8 | 5756.8 | | |
| VRC APR30 RESERVOIR CONTENT, hm3 | 5/ | | 5589.7 | 5525.6 | 5368.3 | 5692.0 | | |
| VRC APR30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | | |
| APR30 ORC, m | 7/ | | 740.2 | 740.4 | 741.5 | 740.2 | | |
| BASE ECC, m | 8/ | 745.8 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 71.8 | 71.8 | 73.2 | 75.0 | 79.1 | |
| ASSUMED JUN1-JUL31 INFLOW, hm3 | 2/ | | 6967.4 | 7018.3 | 7140.4 | 6882.5 | 6730.1 | |
| JUN MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 962.8 | 962.8 | 962.8 | 962.8 | 962.8 | |
| MIN JUN1-JUL31 OUTFLOW, hm3 | 4/ | | 5529.3 | 5529.3 | 5529.3 | 5529.3 | 5529.3 | |
| VRC MAY31 RESERVOIR CONTENT, hm3 | 5/ | | 7196.4 | 7145.5 | 7023.5 | 7281.3 | 7433.7 | |
| VRC MAY31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| MAY31 ORC, m | 7/ | | 744.7 | 744.8 | 745.8 | 744.7 | 744.7 | |
| BASE ECC, m | 8/ | 752.9 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 36.4 | 36.4 | 37.0 | 37.9 | 40.0 | 50.6 |
| ASSUMED JUL1-JUL31 INFLOW, hm3 | 2/ | | 3532.2 | 3558.1 | 3609.2 | 3477.8 | 3403.5 | 3390.0 |
| JUL MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 1132.7 | 1132.7 | 1132.7 | 1132.7 | 1132.7 | 1132.7 |
| MIN JUL1-JUL31 OUTFLOW, hm3 | 4/ | | 3033.8 | 3033.8 | 3033.8 | 3033.8 | 3033.8 | 3033.8 |
| VRC JUN30 RESERVOIR CONTENT, hm3 | 5/ | | 8136.2 | 8110.2 | 8056.7 | 8190.5 | 8264.9 | 8278.3 |
| VRC JUN30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| JUN30 ORC, m | 7/ | | 751.2 | 751.2 | 751.5 | 751.6 | 751.2 | 751.2 |
| BASE ECC, m | 8/ | 752.9 | | | | | | |
| JUL 31 ORC, m | | | 2470.1 | 2470.1 | 2470.1 | 2470.1 | 2470.1 | 2470.1 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (8634.54 hm3) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.

# Table 2: 2009 Mica Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, KAF | | | 9330.2 | 8958.9 | 8812.2 | 8273.3 | 7694.7 | 6218.2 |
| PROBABLE DATE-31JULY INFLOW, KSFD | ** | | 4704.0 | 4516.8 | 4442.8 | 4171.1 | 3879.4 | 3135.0 |
| 95% FORECAST ERROR FOR DATE, KSFD | | | 737.7 | 521.6 | 455.8 | 420.3 | 401.7 | 396.7 |
| 95% CONF.DATE-31JULY INFLOW, KSFD | 1/ | | 3966.3 | 3995.2 | 3987.0 | 3750.8 | 3477.7 | 2738.3 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, KSFD | 2/ | | 3966.3 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 3000.0 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, KSFD | 4/ | | 2620.0 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, KSFD | 5/ | | 2182.9 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, FEET | 6/ | | 2443.5 | | | | | |
| JAN31 ORC, FT | 7/ | | 2432.7 | | | | | |
| BASE ECC, FT | 8/ | 2432.7 | | | | | | |
| LOWER LIMIT, FT | | 2401.5 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 98.0 | 98.0 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, KSFD | 2/ | | 3887.0 | 3915.3 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 3000.0 | 3000.0 | | | | |
| MIN MAR1-JUL31 OUTFLOW, KSFD | 4/ | | 2536.0 | 2536.0 | | | | |
| VRC FEB28 RESERVOIR CONTENT, KSFD | 5/ | | 2178.2 | 2149.9 | | | | |
| VRC FEB28 RESERVOIR CONTENT, FEET | 6/ | | 2443.4 | 2442.8 | | | | |
| FEB28 ORC, FT | 7/ | | 2432.4 | 2432.4 | | | | |
| BASE ECC, FT | 8/ | 2432.4 | | | | | | |
| LOWER LIMIT, FT | | 2395.0 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 95.6 | 95.6 | 97.6 | | | |
| ASSUMED APR1-JUL31 INFLOW, KSFD | 2/ | | 3791.8 | 3819.4 | 3891.4 | | | |
| APR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 3000.0 | 3000.0 | 3000.0 | | | |
| MIN APR1-JUL31 OUTFLOW, KSFD | 4/ | | 2180.4 | 2152.8 | 2080.8 | | | |
| VRC MAR31 RESERVOIR CONTENT, KSFD | 5/ | | 1664.2 | 1664.2 | 1664.2 | | | |
| VRC MAR31 RESERVOIR CONTENT, FEET | 6/ | | 2432.5 | 2432.5 | 2432.5 | | | |
| MAR31 ORC, FT | 7/ | | 2428.4 | 2429.0 | 2432.6 | | | |
| BASE ECC, FT | 8/ | 2432.5 | | | | | | |
| LOWER LIMIT, FT | | 2394.1 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 90.7 | 90.7 | 92.5 | 94.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, KSFD | 2/ | | 3597.5 | 3623.7 | 3688.0 | 3555.7 | | |
| MAY MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 3000.0 | 3000.0 | 3000.0 | 3000.0 | | |
| MIN MAY1-JUL31 OUTFLOW, KSFD | 4/ | | 2353.0 | 2353.0 | 2353.0 | 2353.0 | | |
| VRC APR30 RESERVOIR CONTENT, KSFD | 5/ | | 2284.7 | 2258.5 | 2194.2 | 2326.5 | | |
| VRC APR30 RESERVOIR CONTENT, FEET | 6/ | | 2445.5 | 2445.0 | 2443.7 | 2446.4 | | |
| APR30 ORC, FT | 7/ | | 2428.4 | 2429.0 | 2432.7 | 2428.4 | | |
| BASE ECC, FT | 8/ | 2446.9 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 71.8 | 71.8 | 73.2 | 75.0 | 79.1 | |
| ASSUMED JUN1-JUL31 INFLOW, KSFD | 2/ | | 2847.8 | 2868.6 | 2918.5 | 2813.1 | 2750.8 | |
| JUN MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 34000.0 | 34000.0 | 34000.0 | 34000.0 | 34000.0 | |
| MIN JUN1-JUL31 OUTFLOW, KSFD | 4/ | | 2260.0 | 2260.0 | 2260.0 | 2260.0 | 2260.0 | |
| VRC MAY31 RESERVOIR CONTENT, KSFD | 5/ | | 2941.4 | 2920.6 | 2870.7 | 2976.1 | 3038.4 | |
| VRC MAY31 RESERVOIR CONTENT, FEET | 6/ | | 2458.7 | 2458.3 | 2457.3 | 2459.4 | 2460.6 | |
| MAY31 ORC, FT | 7/ | | 2443.2 | 2443.6 | 2446.9 | 2443.2 | 2443.2 | |
| BASE ECC, FT | 8/ | 2470.0 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 36.4 | 36.4 | 37.0 | 37.9 | 40.0 | 50.6 |
| ASSUMED JUL1-JUL31 INFLOW, KSFD | 2/ | | 1443.7 | 1454.3 | 1475.2 | 1421.5 | 1391.1 | 1385.6 |
| JUL MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 40000.0 | 40000.0 | 40000.0 | 40000.0 | 40000.0 | 40000.0 |
| MIN JUL1-JUL31 OUTFLOW, KSFD | 4/ | | 1240.0 | 1240.0 | 1240.0 | 1240.0 | 1240.0 | 1240.0 |
| VRC JUN30 RESERVOIR CONTENT, KSFD | 5/ | | 3325.5 | 3314.9 | 3293.0 | 3347.7 | 3378.1 | 3383.6 |
| VRC JUN30 RESERVOIR CONTENT, FEET | 6/ | | 2466.2 | 2466.0 | 2465.5 | 2466.6 | 2467.2 | 2467.3 |
| JUN30 ORC, FT | 7/ | | 2464.6 | 2464.7 | 2465.6 | 2466.0 | 2464.6 | 2464.6 |
| BASE ECC, FT | 8/ | 2470.1 | | | | | | |
| JUL 31 ORC, FT | | | 2470.1 | 2470.1 | 2470.1 | 2470.1 | 2470.1 | 2470.1 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (3529.2 KSFD) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.
8/ HIGHER OF ARC OR CRC1 IN DOP

# Table 3M (metric): 2009 Arrow Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 Total | FEB 1 Total | MAR 1 Total | APR 1 Total | MAY 1 Total | JUN 1 Total |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, km3 | | | 24.8 | 24.0 | 23.1 | 21.7 | 19.6 | 14.9 |
| & IN hm3 | ** | | 24779.2 | 24043.7 | 23143.1 | 21660.7 | 19649.1 | 14870.9 |
| 95% FORECAST ERROR FOR DATE, IN hm3 | | | 3626.0 | 2680.3 | 2333.4 | 1982.3 | 1767.6 | 1660.2 |
| 95% CONF.DATE-31JULY INFLOW, hm3 | 1/ | | 21153.1 | 21363.4 | 20809.8 | 19678.4 | 17881.6 | 13210.7 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, hm3 | 2/ | | 21153.1 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, hm3 | 3/ | | 8936.9 | | | | | |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 4551.4 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, hm3 | 5/ | | 1092.9 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | | | | | |
| JAN31 ORC, m | 7/ | | 423.2 | | | | | |
| BASE ECC, m | 8/ | 432.0 | | | | | | |
| LOWER LIMIT, m | | 421.8 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 97.7 | 97.7 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, hm3 | 2/ | | 20666.7 | 20872.2 | | | | |
| MIN MAR1-JUL31 OUTFLOW, hm3 | 3/ | | 8594.4 | 8634.8 | | | | |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 4579.5 | 4579.5 | | | | |
| VRC FEB28 RESERVOIR CONTENT, hm3 | 5/ | | 1265.1 | 1100.0 | | | | |
| VRC FEB28 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | | | | |
| FEB28 ORC, m | 7/ | | 423.6 | 423.2 | | | | |
| BASE ECC, m | 8/ | 432.2 | | | | | | |
| LOWER LIMIT, m | | 420.1 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 94.8 | 94.8 | 97.1 | | | |
| ASSUMED APR1-JUL31 INFLOW, hm3 | 2/ | | 20053.1 | 20252.5 | 20206.2 | | | |
| MIN APR1-JUL31 OUTFLOW, hm3 | 3/ | | 8215.2 | 8255.6 | 8406.5 | | | |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 5032.7 | 4961.0 | 4562.9 | | | |
| VRC MAR31 RESERVOIR CONTENT, hm3 | 5/ | | 1952.6 | 1721.9 | 1521.1 | | | |
| VRC MAR31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | | | |
| MAR31 ORC, m | 7/ | | 425.4 | 424.8 | 424.3 | | | |
| BASE ECC, m | 8/ | 432.7 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 87.9 | 87.9 | 90.1 | 92.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, hm3 | 2/ | | 18593.7 | 18778.4 | 18749.5 | 18261.7 | | |
| MIN MAY1-JUL31 OUTFLOW, hm3 | 3/ | | 7846.0 | 7873.2 | 7974.9 | 7886.9 | | |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 5032.7 | 4961.0 | 4548.7 | 5032.7 | | |
| VRC APR30 RESERVOIR CONTENT, hm3 | 5/ | | 3042.8 | 2813.6 | 2532.0 | 3415.7 | | |
| VRC APR30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | | |
| APR30 ORC, Fm | 7/ | | 428.1 | 427.5 | 426.8 | 428.9 | | |
| BASE ECC, m | 8/ | 430.3 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL | | | 65.3 | 65.3 | 66.9 | 68.9 | 74.3 | |
| ASSUMED JUN1-JUL31 INFLOW, hm3 | 2/ | | 13813.0 | 13950.3 | 13921.6 | 13558.3 | 13286.0 | |
| MIN JUN1-JUL31 OUTFLOW, hm3 | 3/ | | 7462.1 | 7462.1 | 7462.1 | 7462.1 | 7462.1 | |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 3321.7 | 3273.6 | 2887.7 | 3321.7 | 3321.7 | |
| VRC MAY31 RESERVOIR CONTENT, hm3 | 5/ | | 5728.7 | 5543.3 | 5186.1 | 5983.4 | 6255.7 | |
| VRC MAY31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| MAY31 ORC, m | 7/ | | 433.9 | 433.7 | 432.9 | 433.9 | 433.3 | |
| BASE ECC, m | 8/ | 436.2 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 30.5 | 30.5 | 31.3 | 32.3 | 34.8 | 46.8 |
| ASSUMED JUL1-JUL31 INFLOW, hm3 | 2/ | | 6451.7 | 6515.8 | 6513.3 | 6336.4 | 6222.7 | 6182.6 |
| MIN JUL1-JUL31 OUTFLOW, hm3 | 3/ | | 3792.2 | 3792.2 | 3792.2 | 3792.2 | 3792.2 | 3792.2 |
| UPSTREAM DISCHARGE, hm3 | 4/ | | 704.4 | 694.3 | 575.4 | 528.0 | 704.4 | 704.4 |
| VRC JUN30 RESERVOIR CONTENT, hm3 | 5/ | | 7230.2 | 7255.6 | 7349.6 | 7268.1 | 7280.8 | 7268.1 |
| VRC JUN30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| JUN30 ORC, m | 7/ | | 437.2 | 437.2 | 437.4 | 437.2 | 437.3 | 437.2 |
| BASE ECC, m | 8/ | 437.6 | | | | | | |
| JUL 31 ECC, m | | | 1444.0 | 1444.0 | 1444.0 | 1444.0 | 1444.0 | 1444.0 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ CUMMULATIVE MINIMUM OUTFLOW FROM DATE TO JULY, USING POWER DISCHARGE REQUIREMENTS
4/ UPSTREAM DISCHARGE REQUIREMENT. 5/ MAXIMUM(FULL CONTENT (8757.85 hm3 ) MINUS 2/ PLUS 3/ MINUS /4 OR LOWER LIMIT) 6/ ELEV. FROM 5/, INTERP. FROM STORAGE CONTENT TABLE
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.

# Table 3: 2009 Arrow Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 Total | FEB 1 Total | MAR 1 Total | APR 1 Total | MAY 1 Total | JUN 1 Total |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, KAF | | | 20088.6 | 19492.4 | 18762.2 | 17560.5 | 15929.6 | 12055.9 |
| & IN KSFD | ** | | 10128.0 | 9827.4 | 9459.3 | 8853.4 | 8031.2 | 6078.2 |
| 95% FORECAST ERROR FOR DATE, IN KSFD | | | 1482.1 | 1095.5 | 953.7 | 810.2 | 722.5 | 678.6 |
| 95% CONF.DATE-31JULY INFLOW, KSFD | 1/ | | 8645.9 | 8731.9 | 8505.6 | 8043.2 | 7308.7 | 5399.6 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, KSFD | 2/ | | 8645.9 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, KSFD | 3/ | | 3652.8 | | | | | |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 1860.3 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, KSFD | 5/ | | 446.7 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, FEET | 6/ | | 1388.3 | | | | | |
| JAN31 ORC, FT | 7/ | | 1388.3 | | | | | |
| BASE ECC, FT | 8/ | 1417.4 | | | | | | |
| LOWER LIMIT, FT | | 1383.9 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 97.7 | 97.7 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, KSFD | 2/ | | 8447.1 | 8531.1 | | | | |
| MIN MAR1-JUL31 OUTFLOW, KSFD | 3/ | | 3512.8 | 3529.3 | | | | |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 1871.8 | 1871.8 | | | | |
| VRC FEB28 RESERVOIR CONTENT, KSFD | 5/ | | 517.1 | 449.6 | | | | |
| VRC FEB28 RESERVOIR CONTENT, FEET | 6/ | | 1389.8 | 1388.4 | | | | |
| FEB28 ORC, FT | 7/ | | 1389.8 | 1388.4 | | | | |
| BASE ECC, FT | 8/ | 1418.0 | | | | | | |
| LOWER LIMIT, FT | | 1378.4 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 94.8 | 94.8 | 97.1 | | | |
| ASSUMED APR1-JUL31 INFLOW, KSFD | 2/ | | 8196.3 | 8277.8 | 8258.9 | | | |
| MIN APR1-JUL31 OUTFLOW, KSFD | 3/ | | 3357.8 | 3374.3 | 3436.0 | | | |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 2057.0 | 2027.7 | 1865.0 | | | |
| VRC MAR31 RESERVOIR CONTENT, KSFD | 5/ | | 798.1 | 703.8 | 621.7 | | | |
| VRC MAR31 RESERVOIR CONTENT, FEET | 6/ | | 1395.7 | 1393.7 | 1392.1 | | | |
| MAR31 ORC, FT | 7/ | | 1395.7 | 1393.7 | 1392.1 | | | |
| BASE ECC, FT | 8/ | 1419.5 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 87.9 | 87.9 | 90.1 | 92.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, KSFD | 2/ | | 7599.8 | 7675.3 | 7663.5 | 7464.1 | | |
| MIN MAY1-JUL31 OUTFLOW, KSFD | 3/ | | 3206.9 | 3218.0 | 3259.6 | 3223.6 | | |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 2057.0 | 2027.7 | 1859.2 | 2057.0 | | |
| VRC APR30 RESERVOIR CONTENT, KSFD | 5/ | | 1243.7 | 1150.0 | 1034.9 | 1396.1 | | |
| VRC APR30 RESERVOIR CONTENT, FEET | 6/ | | 1404.5 | 1402.7 | 1400.4 | 1407.3 | | |
| APR30 ORC, FT | 7/ | | 1404.5 | 1402.7 | 1400.4 | 1407.3 | | |
| BASE ECC, FT | 8/ | 1411.6 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL | | | 65.3 | 65.3 | 66.9 | 68.9 | 74.3 | |
| ASSUMED JUN1-JUL31 INFLOW, KSFD | 2/ | | 5645.8 | 5701.9 | 5690.2 | 5541.7 | 5430.4 | |
| MIN JUN1-JUL31 OUTFLOW, KSFD | 3/ | | 3050.0 | 3050.0 | 3050.0 | 3050.0 | 3050.0 | |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 1357.7 | 1338.0 | 1180.3 | 1357.7 | 1357.7 | |
| VRC MAY31 RESERVOIR CONTENT, KSFD | 5/ | | 2341.5 | 2265.7 | 2119.7 | 2445.6 | 2556.9 | |
| VRC MAY31 RESERVOIR CONTENT, FEET | 6/ | | 1424.2 | 1422.9 | 1420.4 | 1425.9 | 1427.7 | |
| MAY31 ORC, FT | 7/ | | 1423.6 | 1422.9 | 1420.4 | 1423.6 | 1421.5 | |
| BASE ECC, FT | 8/ | 1431.0 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 30.5 | 30.5 | 31.3 | 32.3 | 34.8 | 46.8 |
| ASSUMED JUL1-JUL31 INFLOW, KSFD | 2/ | | 2637.0 | 2663.2 | 2662.2 | 2589.9 | 2543.4 | 2527.0 |
| MIN JUL1-JUL31 OUTFLOW, KSFD | 3/ | | 1550.0 | 1550.0 | 1550.0 | 1550.0 | 1550.0 | 1550.0 |
| UPSTREAM DISCHARGE, KSFD | 4/ | | 287.9 | 283.8 | 235.2 | 215.8 | 287.9 | 287.9 |
| VRC JUN30 RESERVOIR CONTENT, KSFD | 5/ | | 2955.2 | 2965.6 | 3004.0 | 2970.7 | 2975.9 | 2970.7 |
| VRC JUN30 RESERVOIR CONTENT, FEET | 6/ | | 1434.3 | 1434.4 | 4135.0 | 1434.5 | 1434.6 | 1434.5 |
| JUN30 ORC, FT | 7/ | | 1434.3 | 1434.4 | 1435.0 | 1434.5 | 1434.6 | 1434.5 |
| BASE ECC, FT | 8/ | 1435.6 | | | | | | |
| JUL 31 ECC, FT | | | 1444.0 | 1444.0 | 1444.0 | 1444.0 | 1444.0 | 1444.0 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ CUMMULATIVE MINIMUM OUTFLOW FROM DATE TO JULY, USING POWER DISCHARGE REQUIREMENTS
4/ UPSTREAM DISCHARGE REQUIREMENT. 5/ MAXIMUM(FULL CONTENT (3579.6 KSFD ) MINUS 2/ PLUS 3/ MINUS /4 OR LOWER LIMIT) 6/ ELEV. FROM 5/, INTERP. FROM STORAGE CONTENT TABLE
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.
8/ HIGHER OF THE ARC OR CRC1 IN DOP

# Table 4M (metric): 2009 Duncan Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, km3 | | | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| & IN hm3 | ** | | 2145.7 | 2097.0 | 2008.4 | 1903.7 | 1743.0 | 1296.7 |
| 95% FORECAST ERROR FOR DATE, IN hm3 | | | 309.7 | 256.1 | 256.1 | 231.3 | 210.6 | 190.0 |
| 95% CONF.DATE-31JULY INFLOW, hm3 | 1/ | | 1835.9 | 1840.9 | 1752.4 | 1672.4 | 1532.3 | 1106.7 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, hm3 | 2/ | | 1835.9 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 2.8 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, hm3 | 4/ | | 521.4 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, hm3 | 5/ | | 412.3 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | | | | | |
| JAN31 ORC, m | 7/ | | 556.1 | | | | | |
| BASE ECC, m | 8/ | 566.2 | | | | | | |
| LOWER LIMIT, m | | 553.2 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 98.1 | 98.1 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, hm3 | 2/ | | 1800.9 | 1805.8 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 2.8 | 2.8 | | | | |
| MIN MAR1-JUL31 OUTFLOW, hm3 | 4/ | | 514.0 | 534.1 | | | | |
| VRC FEB28 RESERVOIR CONTENT, hm3 | 5/ | | 439.9 | 455.1 | | | | |
| VRC FEB28 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | | | | |
| FEB28 ORC, m | 7/ | | 551.0 | 552.2 | | | | |
| BASE ECC, m | 8/ | 563.3 | | | | | | |
| LOWER LIMIT, m | | 549.7 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 95.7 | 95.7 | 97.6 | | | |
| ASSUMED APR1-JUL31 INFLOW, hm3 | 2/ | | 1756.9 | 1761.8 | 1710.4 | | | |
| APR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 2.8 | 2.8 | 2.8 | | | |
| MIN APR1-JUL31 OUTFLOW, hm3 | 4/ | | 505.7 | 522.1 | 583.5 | | | |
| VRC MAR31 RESERVOIR CONTENT, hm3 | 5/ | | 475.6 | 487.1 | 599.9 | | | |
| VRC MAR31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | | | |
| MAR31 ORC, m | 7/ | | 551.0 | 552.2 | 554.4 | | | |
| BASE ECC, m | 8/ | 558.4 | | | | | | |
| LOWER LIMIT, m | | 547.1 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 89.7 | 89.7 | 91.6 | 93.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, hm3 | 2/ | | 1646.8 | 1651.2 | 1605.2 | 1568.8 | | |
| MAY MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 51.0 | 51.0 | 51.0 | 51.0 | | |
| MIN MAY1-JUL31 OUTFLOW, hm3 | 4/ | | 496.9 | 504.0 | 530.9 | 507.7 | | |
| VRC APR30 RESERVOIR CONTENT, hm3 | 5/ | | 576.9 | 579.6 | 652.5 | 665.7 | | |
| VRC APR30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | | |
| APR30 ORC, m | 7/ | | 551.0 | 552.2 | 554.4 | 554.7 | | |
| BASE ECC, m | 8/ | 559.6 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 67.5 | 67.5 | 69.0 | 70.6 | 75.3 | |
| ASSUMED JUN1-JUL31 INFLOW, hm3 | 2/ | | 1239.2 | 1242.6 | 1209.1 | 1180.7 | 1153.8 | |
| JUN MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 56.6 | 56.6 | 56.6 | 56.6 | 56.6 | |
| MIN JUN1-JUL31 OUTFLOW, hm3 | 4/ | | 360.4 | 367.5 | 394.4 | 371.1 | 374.8 | |
| VRC MAY31 RESERVOIR CONTENT, hm3 | 5/ | | 848.0 | 851.7 | 912.1 | 917.2 | 947.8 | |
| VRC MAY31 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| MAY31 ORC, m | 7/ | | 563.6 | 563.6 | 564.6 | 564.7 | 565.2 | |
| BASE ECC, m | 8/ | 565.9 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 32.5 | 32.5 | 33.3 | 34.0 | 36.3 | 48.2 |
| ASSUMED JUL1-JUL31 INFLOW, hm3 | 2/ | | 596.7 | 598.2 | 583.5 | 568.6 | 556.4 | 614.3 |
| JUL MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 79.3 | 79.3 | 79.3 | 79.3 | 79.3 | 79.3 |
| MIN JUL1-JUL31 OUTFLOW, hm3 | 4/ | | 213.1 | 217.7 | 234.6 | 219.9 | 222.2 | 219.9 |
| VRC JUN30 RESERVOIR CONTENT, hm3 | 5/ | | 1343.2 | 1346.4 | 1377.9 | 1378.2 | 1392.6 | 1332.4 |
| VRC JUN30 RESERVOIR CONTENT, METERS | 6/ | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| JUN30 ORC, m | 7/ | | 571.2 | 571.2 | 571.4 | 571.4 | 571.4 | 571.4 |
| BASE ECC, m | 8/ | 571.4 | | | | | | |
| JUL 31 ECC, m | | | 576.7 | 576.7 | 576.7 | 576.7 | 576.7 | 576.7 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (1726.81 hm3) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE.
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.

# Table 4: 2009 Duncan Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, KAF | | | 1739.5 | 1700.0 | 1628.2 | 1543.3 | 1413.0 | 1051.2 |
| & IN KSFD | ** | | 877.0 | 857.1 | 820.9 | 778.1 | 712.4 | 530.0 |
| 95% FORECAST ERROR FOR DATE, IN KSFD | | | 126.6 | 104.7 | 104.7 | 94.5 | 86.1 | 77.6 |
| 95% CONF.DATE-31JULY INFLOW, KSFD | 1/ | | 750.4 | 752.4 | 716.2 | 683.6 | 626.3 | 452.4 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 100.0 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, KSFD | 2/ | | 750.4 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 100.0 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, KSFD | 4/ | | 213.1 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, KSFD | 5/ | | 168.5 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, FEET | 6/ | | 1824.4 | | | | | |
| JAN31 ORC, FT | 7/ | | 1824.4 | | | | | |
| BASE ECC, FT | 8/ | 1857.5 | | | | | | |
| LOWER LIMIT, FT | | 1814.9 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 98.1 | 98.1 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, KSFD | 2/ | | 736.1 | 738.1 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 100.0 | 100.0 | | | | |
| MIN MAR1-JUL31 OUTFLOW, KSFD | 4/ | | 210.1 | 218.3 | | | | |
| VRC FEB28 RESERVOIR CONTENT, KSFD | 5/ | | 179.8 | 186.0 | | | | |
| VRC FEB28 RESERVOIR CONTENT, FEET | 6/ | | 1826.1 | 1827.1 | | | | |
| FEB28 ORC, FT | 7/ | | 1807.8 | 1811.6 | | | | |
| BASE ECC, FT | 8/ | 1848.0 | | | | | | |
| LOWER LIMIT, FT | | 1803.4 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 95.7 | 95.7 | 97.6 | | | |
| ASSUMED APR1-JUL31 INFLOW, KSFD | 2/ | | 718.1 | 720.1 | 699.1 | | | |
| APR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 100.0 | 100.0 | 100.0 | | | |
| MIN APR1-JUL31 OUTFLOW, KSFD | 4/ | | 206.7 | 213.4 | 238.5 | | | |
| VRC MAR31 RESERVOIR CONTENT, KSFD | 5/ | | 194.4 | 199.1 | 245.2 | | | |
| VRC MAR31 RESERVOIR CONTENT, FEET | 6/ | | 1828.2 | 1828.9 | 1835.5 | | | |
| MAR31 ORC, FT | 7/ | | 1807.8 | 1811.6 | 1819.0 | | | |
| BASE ECC, FT | 8/ | 1832.1 | | | | | | |
| LOWER LIMIT, FT | | 1795.1 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 89.7 | 89.7 | 91.6 | 93.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, KSFD | 2/ | | 673.1 | 674.9 | 656.1 | 641.2 | | |
| MAY MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 1800.0 | 1800.0 | 1800.0 | 1800.0 | | |
| MIN MAY1-JUL31 OUTFLOW, KSFD | 4/ | | 203.1 | 206.0 | 217.0 | 207.5 | | |
| VRC APR30 RESERVOIR CONTENT, KSFD | 5/ | | 235.8 | 236.9 | 266.7 | 272.1 | | |
| VRC APR30 RESERVOIR CONTENT, FEET | 6/ | | 1834.1 | 1834.2 | 1838.4 | 1839.1 | | |
| APR30 ORC, FT | 7/ | | 1807.8 | 1811.6 | 1819.0 | 1819.8 | | |
| BASE ECC, FT | 8/ | 1835.8 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 67.5 | 67.5 | 69.0 | 70.6 | 75.3 | |
| ASSUMED JUN1-JUL31 INFLOW, KSFD | 2/ | | 506.5 | 507.9 | 494.2 | 482.6 | 471.6 | |
| JUN MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 2000.0 | 2000.0 | 2000.0 | 2000.0 | 2000.0 | |
| MIN JUN1-JUL31 OUTFLOW, KSFD | 4/ | | 147.3 | 150.2 | 161.2 | 151.7 | 153.2 | |
| VRC MAY31 RESERVOIR CONTENT, KSFD | 5/ | | 346.6 | 348.1 | 372.8 | 374.9 | 387.4 | |
| VRC MAY31 RESERVOIR CONTENT, FEET | 6/ | | 1849.0 | 1849.2 | 1852.4 | 1852.6 | 1854.2 | |
| MAY31 ORC, FT | 7/ | | 1849.0 | 1849.0 | 1852.4 | 1852.6 | 1854.2 | |
| BASE ECC, FT | 8/ | 1856.5 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 32.5 | 32.5 | 33.3 | 34.0 | 36.3 | 48.2 |
| ASSUMED JUL1-JUL31 INFLOW, KSFD | 2/ | | 243.9 | 244.5 | 238.5 | 232.4 | 227.4 | 251.1 |
| JUL MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 2800.0 | 2800.0 | 2800.0 | 2800.0 | 2800.0 | 2800.0 |
| MIN JUL1-JUL31 OUTFLOW, KSFD | 4/ | | 87.1 | 89.0 | 95.9 | 89.9 | 90.8 | 89.9 |
| VRC JUN30 RESERVOIR CONTENT, KSFD | 5/ | | 549.0 | 550.3 | 563.2 | 563.3 | 569.2 | 544.6 |
| VRC JUN30 RESERVOIR CONTENT, FEET | 6/ | | 1874.0 | 1874.1 | 1875.6 | 1875.6 | 1876.3 | 1873.4 |
| JUN30 ORC, FT | 7/ | | 1874.0 | 1874.1 | 1874.7 | 1874.7 | 1874.7 | 1874.7 |
| BASE ECC, FT | 8/ | 1874.7 | | | | | | |
| JUL 31 ECC, FT | | | 1892.0 | 1892.0 | 1892.0 | 1892.0 | 1892.0 | 1892.0 |

** FORECAST START DATE IS 1FEB OR LATER. OBSERVED INFLOW FROM 1JAN-DATE IS SUBTRACTED.
1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW). 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (705.8 KSFD) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE.
7/ LOWER OF ELEV. FROM 6/ OR BASE ECC (INTIAL), NOT LESS THAN LOWER LIMIT, BUT NOT MORE THAN FLOOD CONTROL.
8/ HIGHER OF ARC OR CRC1 IN DOP

# Table 5M (metric) – 2009 Libby Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE DATE-31JULY INFLOW, km3 | | | 6.9 | 6.8 | 6.5 | 6.9 | 6.4 | 6.2 |
| PROBABLE DATE-31JULY INFLOW, hm3 | | | 6926.1 | 6754.6 | 6515.3 | 6927.3 | 6407.9 | 6242.7 |
| 95% FORECAST ERROR FOR DATE, hm3 | | | 1593.7 | 1195.2 | 1118.8 | 1084.3 | 980.6 | 941.2 |
| OBSERVED JAN1-DATE INFLOW, IN hm3 | | | 0.0 | 202.3 | 362.6 | 555.1 | 935.1 | 2206.8 |
| 95% CONF.DATE-31JULY INFLOW, hm3 | 1/ | | 5332.4 | 5357.1 | 5033.9 | 5288.1 | 4492.4 | 3094.9 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 96.9 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, hm3 | 2/ | | 5167.0 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 113.3 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, hm3 | 4/ | | 2666.8 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, hm3 | 5/ | | 3642.0 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, METERS | 6/ | | 734.7 | | | | | |
| JAN31 ORC, m | 7/ | | 734.1 | | | | | |
| BASE ECC, m | 9/ | 735.8 | | | | | | |
| LOWER LIMIT, m | | 722.7 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 94.1 | 97.1 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, hm3 | 2/ | | 5017.7 | 5201.7 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 113.3 | 113.3 | | | | |
| MIN MAR1-JUL31 OUTFLOW, hm3 | 4/ | | 2392.8 | 2392.8 | | | | |
| VRC FEB28 RESERVOIR CONTENT, hm3 | 5/ | | 3517.2 | 3333.2 | | | | |
| VRC FEB28 RESERVOIR CONTENT, METERS | 6/ | | 733.7 | 732.4 | | | | |
| FEB28 ORC, m | 7/ | | 733.2 | 732.4 | | | | |
| BASE ECC, m | 9/ | 734.9 | | | | | | |
| LOWER LIMIT, m | | 707.4 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 90.6 | 93.5 | 96.3 | | | |
| ASSUMED APR1-JUL31 INFLOW, hm3 | 2/ | | 4831.1 | 5008.9 | 4847.7 | | | |
| APR MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 113.3 | 113.3 | 113.3 | | | |
| MIN APR1-JUL31 OUTFLOW, hm3 | 4/ | | 2089.4 | 2089.4 | 2089.4 | | | |
| VRC MAR31 RESERVOIR CONTENT, hm3 | 5/ | | 3400.5 | 3222.7 | 3383.9 | | | |
| VRC MAR31 RESERVOIR CONTENT, METERS | 6/ | | 732.9 | 731.6 | 732.8 | | | |
| MAR31 ORC, m | 7/ | | 732.3 | 731.6 | 732.3 | | | |
| BASE ECC, m | 9/ | 734.0 | | | | | | |
| LOWER LIMIT, m | | 697.5 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 82.4 | 85.0 | 87.6 | 93.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, hm3 | 2/ | | 4393.8 | 4553.6 | 4409.8 | 4960.2 | | |
| MAY MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 113.3 | 113.3 | 113.3 | 113.3 | | |
| MIN MAY1-JUL31 OUTFLOW, hm3 | 4/ | | 1795.8 | 1795.8 | 1795.8 | 1795.8 | | |
| VRC APR30 RESERVOIR CONTENT, hm3 | 5/ | | 3544.1 | 3384.4 | 3528.2 | 2977.8 | | |
| VRC APR30 RESERVOIR CONTENT, METERS | 6/ | | 734.0 | 732.8 | 733.8 | 729.7 | | |
| APR30 ORC, m | 7/ | | 731.9 | 731.9 | 731.9 | 729.7 | | |
| BASE ECC, m | 9/ | 731.4 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 55.2 | 57.0 | 58.7 | 60.9 | 67.0 | |
| ASSUMED JUN1-JUL31 INFLOW, hm3 | 2/ | | 2943.5 | 3053.6 | 2955.0 | 3220.5 | 3009.8 | |
| JUN MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 283.2 | 283.2 | 283.2 | 283.2 | 283.2 | |
| MIN JUN1-JUL31 OUTFLOW, hm3 | 4/ | | 1492.4 | 1492.4 | 1492.4 | 1492.4 | 1492.4 | |
| VRC MAY31 RESERVOIR CONTENT, hm3 | 5/ | | 4691.1 | 4581.0 | 4679.6 | 4414.2 | 4624.8 | |
| VRC MAY31 RESERVOIR CONTENT, METERS | 6/ | | 741.3 | 740.7 | 741.2 | 739.6 | 740.9 | |
| MAY31 ORC, m | 7/ | | 739.3 | 739.3 | 739.3 | 739.3 | 739.3 | |
| BASE ECC, m | 9/ | 738.9 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 19.7 | 20.4 | 21.0 | 21.8 | 24.0 | 35.8 |
| ASSUMED JUL1-JUL31 INFLOW, hm3 | 2/ | | 1050.6 | 1092.9 | 1057.2 | 1152.8 | 1078.2 | 1108.1 |
| JUL MINIMUM FLOW REQUIREMENT, m3/s | 3/ | | 283.2 | 283.2 | 283.2 | 283.2 | 283.2 | 283.2 |
| MIN JUL1-JUL31 OUTFLOW, hm3 | 4/ | | 758.4 | 758.4 | 758.4 | 758.4 | 758.4 | 758.4 |
| VRC JUN30 RESERVOIR CONTENT, hm3 | 5/ | | 5850.1 | 5807.7 | 5843.5 | 5747.8 | 5822.4 | 5792.6 |
| VRC JUN30 RESERVOIR CONTENT, METERS | 6/ | | 747.9 | 747.7 | 747.9 | 747.4 | 747.8 | 747.6 |
| JUN30 ORC, m | 7/ | | 747.9 | 747.7 | 747.9 | 747.4 | 747.8 | 747.6 |
| BASE ECC, m | 9/ | 749.5 | | | | | | |
| JUL 31 ORC, m | | | 749.5 | 749.5 | 749.5 | 749.5 | 749.5 | 749.5 |
| JAN1-JUL31 FORECAST,-EARLYBIRD, km3 | 8/ | | 116.8 | 114.6 | 106.3 | 114.6 | 112.4 | 113.5 |

1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW) MINUS OBSERVED INFLOW. 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (2510.5 KSFD) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE.A143
7/ LOWER OF ELEV. FROM 6/ OR BASE VRC DETERMINED PRIOR TO YEAR (INTIAL),BUT NOT LESS THAN LOWER LIMIT
8/ MEASURED AT THE DALLES USED TO CALCULATE THE POWER DISCHARGE REQUIREMENTS FOR 3/.
9/ HIGHER OF ARC OR CRC1 IN DOP

# Table 5 - 2009 Libby Reservoir Variable Refill Curve

| | | INITIAL | JAN 1 | FEB 1 | MAR 1 | APR 1 | MAY 1 | JUN 1 |
|---|---|---|---|---|---|---|---|---|
| PROBABLE JAN-31JULY INFLOW, KAF | | | 5615 | 5476 | 5282 | 5616 | 5195 | 5061 |
| PROBABLE JAN-31JULY INFLOW, KSFD | | | 2830.9 | 2760.8 | 2663 | 2831.4 | 2619.1 | 2551.6 |
| 95% FORECAST ERROR FOR DATE, KSFD | | | 651.4 | 488.5 | 457.3 | 443.2 | 400.8 | 384.7 |
| OBSERVED JAN1-DATE INFLOW, IN KSFD | | | 0 | 82.7 | 148.2 | 226.9 | 382.2 | 902 |
| 95% CONF.DATE-31JULY INFLOW, KSFD | 1/ | | 2179.5 | 2189.6 | 2057.5 | 2161.4 | 1836.2 | 1265 |
| ASSUMED FEB1-JUL31 INFLOW, % OF VOL. | | | 96.9 | | | | | |
| ASSUMED FEB1-JUL31 INFLOW, KSFD | 2/ | | 2111.9 | | | | | |
| FEB MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 4000 | | | | | |
| MIN FEB1-JUL31 OUTFLOW, KSFD | 4/ | | 1090 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, KSFD | 5/ | | 1488.6 | | | | | |
| VRC JAN31 RESERVOIR CONTENT, FEET | 6/ | | 2410.3 | | | | | |
| JAN31 ORC, FT | 7/ | | 2408.5 | | | | | |
| BASE ECC, FT | 9/ | 2413.9 | | | | | | |
| LOWER LIMIT, FT | | 2371.2 | | | | | | |
| ASSUMED MAR1-JUL31 INFLOW, % OF VOL. | | | 94.1 | 97.1 | | | | |
| ASSUMED MAR1-JUL31 INFLOW, KSFD | 2/ | | 2050.9 | 2126.1 | | | | |
| MAR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 4000 | 4000 | | | | |
| MIN MAR1-JUL31 OUTFLOW, KSFD | 4/ | | 978 | 978 | | | | |
| VRC FEB28 RESERVOIR CONTENT, KSFD | 5/ | | 1437.6 | 1362.4 | | | | |
| VRC FEB28 RESERVOIR CONTENT, FEET | 6/ | | 2407.3 | 2403 | | | | |
| FEB28 ORC, FT | 7/ | | 2405.5 | 2403 | | | | |
| BASE ECC, FT | 9/ | 2411.1 | | | | | | |
| LOWER LIMIT, FT | | 2320.8 | | | | | | |
| ASSUMED APR1-JUL31 INFLOW, % OF VOL. | | | 90.6 | 93.5 | 96.3 | | | |
| ASSUMED APR1-JUL31 INFLOW, KSFD | 2/ | | 1974.6 | 2047.3 | 1981.4 | | | |
| APR MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 4000 | 4000 | 4000 | | | |
| MIN APR1-JUL31 OUTFLOW, KSFD | 4/ | | 854 | 854 | 854 | | | |
| VRC MAR31 RESERVOIR CONTENT, KSFD | 5/ | | 1389.9 | 1317.2 | 1383.1 | | | |
| VRC MAR31 RESERVOIR CONTENT, FEET | 6/ | | 2404.6 | 2400.4 | 2404.2 | | | |
| MAR31 ORC, FT | 7/ | | 2402.5 | 2400.4 | 2402.5 | | | |
| BASE ECC, FT | 9/ | 2408.2 | | | | | | |
| LOWER LIMIT, FT | | 2288.5 | | | | | | |
| ASSUMED MAY1-JUL31 INFLOW, % OF VOL. | | | 82.4 | 85 | 87.6 | 93.8 | | |
| ASSUMED MAY1-JUL31 INFLOW, KSFD | 2/ | | 1795.9 | 1861.2 | 1802.4 | 2027.4 | | |
| MAY MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 4000 | 4000 | 4000 | 4000 | | |
| MIN MAY1-JUL31 OUTFLOW, KSFD | 4/ | | 734 | 734 | 734 | 734 | | |
| VRC APR30 RESERVOIR CONTENT, KSFD | 5/ | | 1448.6 | 1383.3 | 1442.1 | 1217.1 | | |
| VRC APR30 RESERVOIR CONTENT, FEET | 6/ | | 2408 | 2404.2 | 2407.6 | 2394.1 | | |
| APR30 ORC, FT | 7/ | | 2401.2 | 2401.2 | 2401.2 | 2394.1 | | |
| BASE ECC, FT | 9/ | 2399.5 | | | | | | |
| ASSUMED JUN1-JUL31 INFLOW, % OF VOL. | | | 55.2 | 57 | 58.7 | 60.9 | 67 | |
| ASSUMED JUN1-JUL31 INFLOW, KSFD | 2/ | | 1203.1 | 1248.1 | 1207.8 | 1316.3 | 1230.2 | |
| JUN MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 10000 | 10000 | 10000 | 10000 | 10000 | |
| MIN JUN1-JUL31 OUTFLOW, KSFD | 4/ | | 610 | 610 | 610 | 610 | 610 | |
| VRC MAY31 RESERVOIR CONTENT, KSFD | 5/ | | 1917.4 | 1872.4 | 1912.7 | 1804.2 | 1890.3 | |
| VRC MAY31 RESERVOIR CONTENT, FEET | 6/ | | 2432.2 | 2430 | 2431.9 | 2426.6 | 2430.9 | |
| MAY31 ORC, FT | 7/ | | 2425.6 | 2425.6 | 2425.6 | 2425.6 | 2425.6 | |
| BASE ECC, FT | 9/ | 2424.2 | | | | | | |
| ASSUMED JUL1-JUL31 INFLOW, % OF VOL. | | | 19.7 | 20.4 | 21 | 21.8 | 24 | 35.8 |
| ASSUMED JUL1-JUL31 INFLOW, KSFD | 2/ | | 429.4 | 446.7 | 432.1 | 471.2 | 440.7 | 452.9 |
| JUL MINIMUM FLOW REQUIREMENT, CFS | 3/ | | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 |
| MIN JUL1-JUL31 OUTFLOW, KSFD | 4/ | | 310 | 310 | 310 | 310 | 310 | 310 |
| VRC JUN30 RESERVOIR CONTENT, KSFD | 5/ | | 2391.1 | 2373.8 | 2388.4 | 2349.3 | 2379.8 | 2367.6 |
| VRC JUN30 RESERVOIR CONTENT, FEET | 6/ | | 2453.8 | 2453.1 | 2453.7 | 2452 | 2453.3 | 2452.8 |
| JUN30 ORC, FT | 7/ | | 2453.8 | 2453.1 | 2453.7 | 2452 | 2453.3 | 2452.8 |
| BASE ECC, FT | 9/ | 2459.0 | | | | | | |
| JUL 31 ORC, FT | | | 2459 | 2459 | 2459 | 2459 | 2459 | 2459 |
| JAN1-JUL31 FORECAST,-EARLYBIRD,MAF | 8/ | | 94.7 | 92.9 | 86.2 | 92.9 | 91.1 | 92 |

1/ PROBABLE INFLOW MINUS (95% ERROR & JAN1-DATE INFLOW) MINUS OBSERVED INFLOW. 2/PRECEEDING LINE TIMES 1/.
3/ POWER DISCHARGE REQUIREMENTS. 4/ CUMULATIVE MINIMUM OUTFLOW FROM 3/,DATE TO JULY.
5/ FULL CONTENT (2510.5 KSFD) PLUS 4/ MINUS /2. 6/ ELEV FROM 5/, INTERP FROM STORAGE CONTENT TABLE.A143
7/ LOWER OF ELEV. FROM 6/ OR BASE VRC DETERMINED PRIOR TO YEAR (INTIAL),BUT NOT LESS THAN LOWER LIMIT
8/ MEASURED AT THE DALLES USED TO CALCULATE THE POWER DISCHARGE REQUIREMENTS FOR 3/.
9/ HIGHER OF ARC OR CRC1 IN DOP

# Table 6: Computation of Initial Controlled Flow

# Columbia River at The Dalles, OR

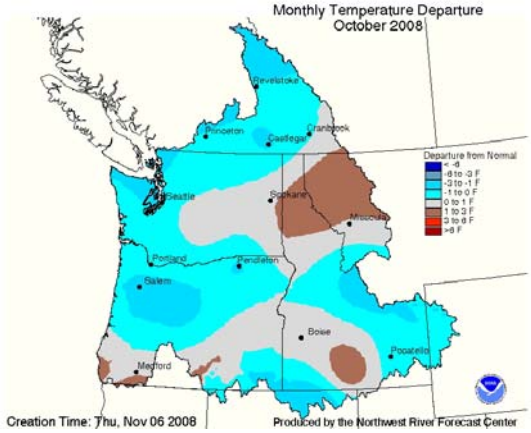
# Metric and English Units, 1 May 2009

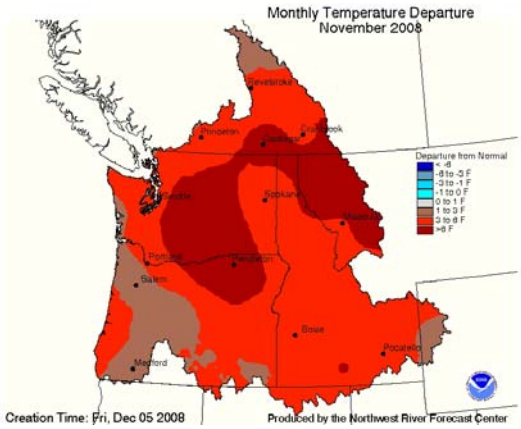
| **Upstream Storage Corrections in km$^3$ and Maf** | Metric (km$^3$) | | English (Maf) | |
|---|---|---|---|---|
| Mica | 7.239 | | 5.869 | |
| Arrow | 4.441 | | 3.600 | |
| Duncan | 1.718 | | 1.393 | |
| Libby | 2.709 | | 2.196 | |
| Hungry Horse | 1.071 | | 0.868 | |
| Flathead Lake | 0.617 | | 0.500 | |
| Noxon Rapids | 0.000 | | 0.000 | |
| Pend Oreille Lake | 0.617 | | 0.500 | |
| Grand Coulee | 2.946 | | 2.388 | |
| Brownlee | 0.405 | | 0.328 | |
| Dworshak | 1.428 | | 1.158 | |
| John Day | 0.195 | | 0.158 | |
| Total Upstream Storage Corrections | 23.384 | | 18.958 | |
| 1-May Forecast of TDA May – Aug Runoff Volume | | 85.116 | | 69.005 |
| Less Estimated Depletions | | -2.061 | | -1.671 |
| Less Total Upstream Storage Corrections | | -23.384 | | -18.958 |
| Forecast of Adjusted Residual Runoff Volume | | 59.671 | | 48.376 |
| Computed Initial Controlled Flow from Chart 1 of the Flood Control Operating Plan, km$^3$/s and kcfs | | 91.537 | | 300 |

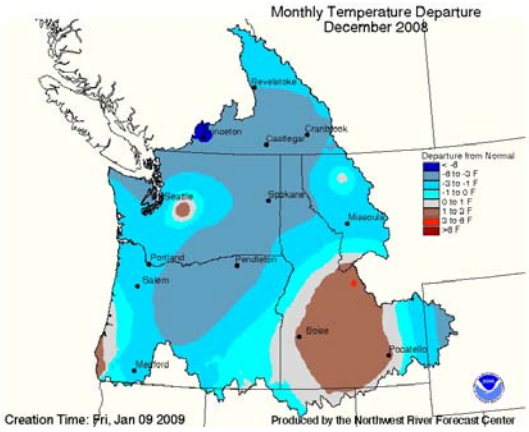
# VIII - CHARTS

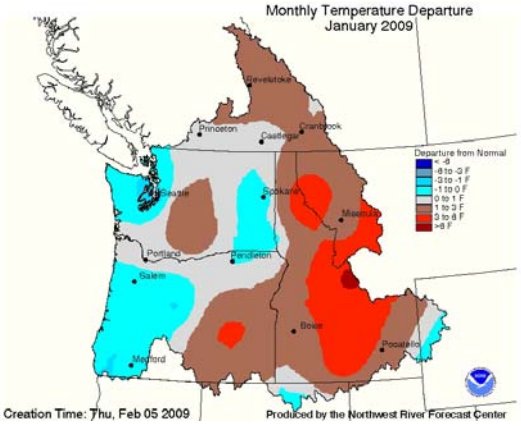
## Chart 1: Pacific Northwest Monthly Temperature Departures

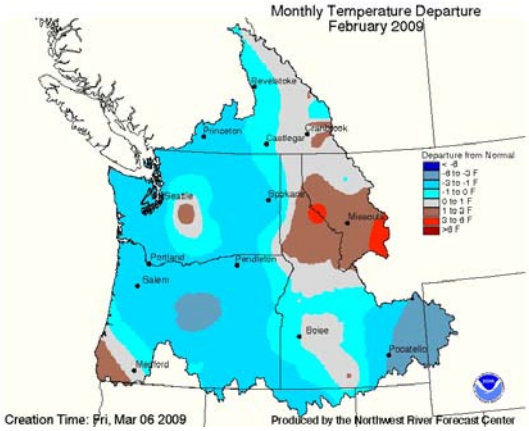
October - March

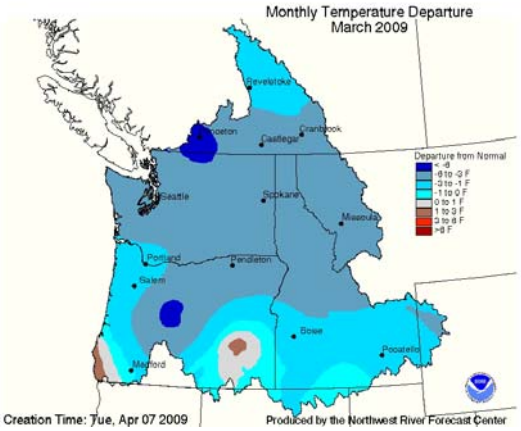


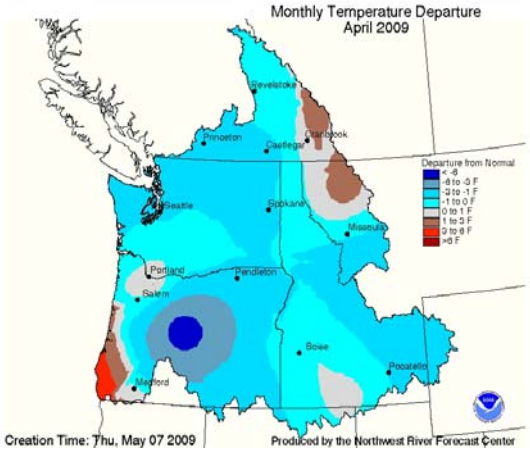



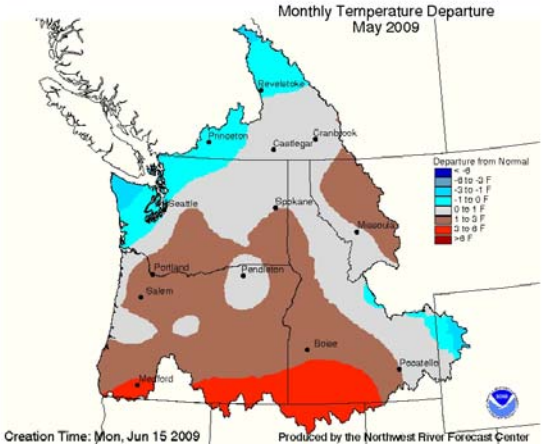



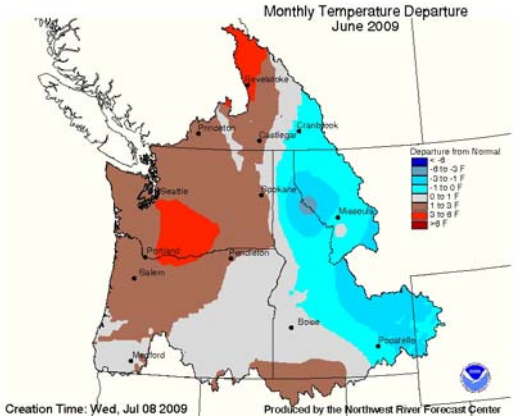



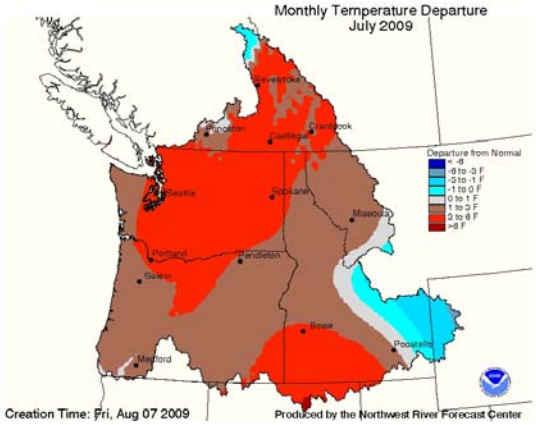
# Chart 1: Pacific Northwest Monthly Temperature Departures (Continued)

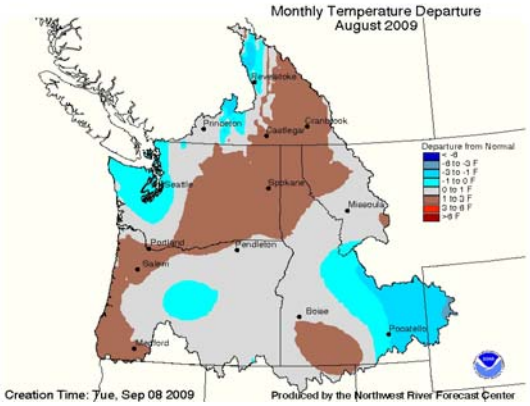
April – September



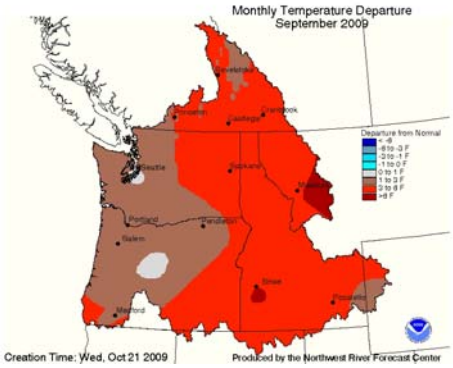
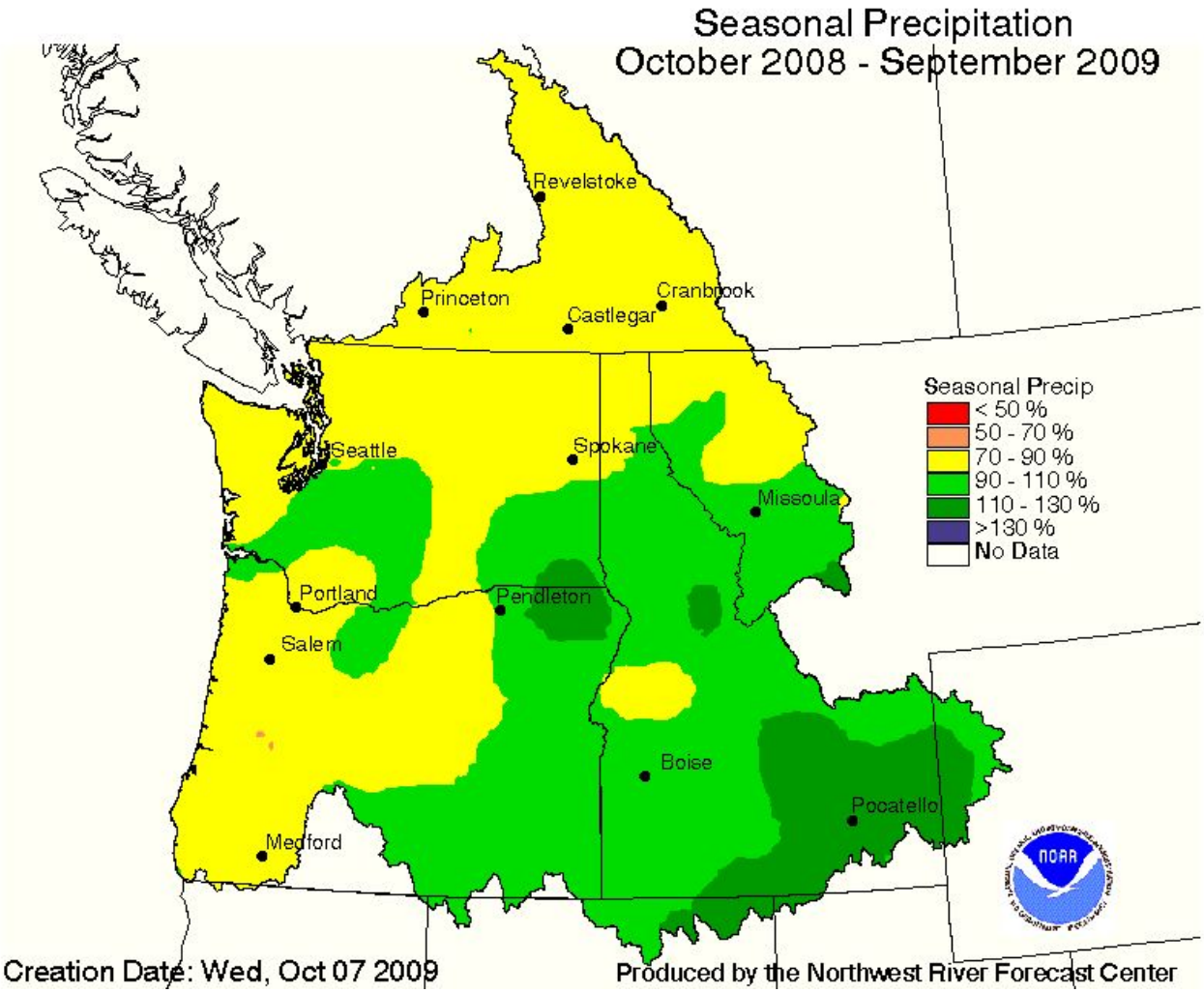



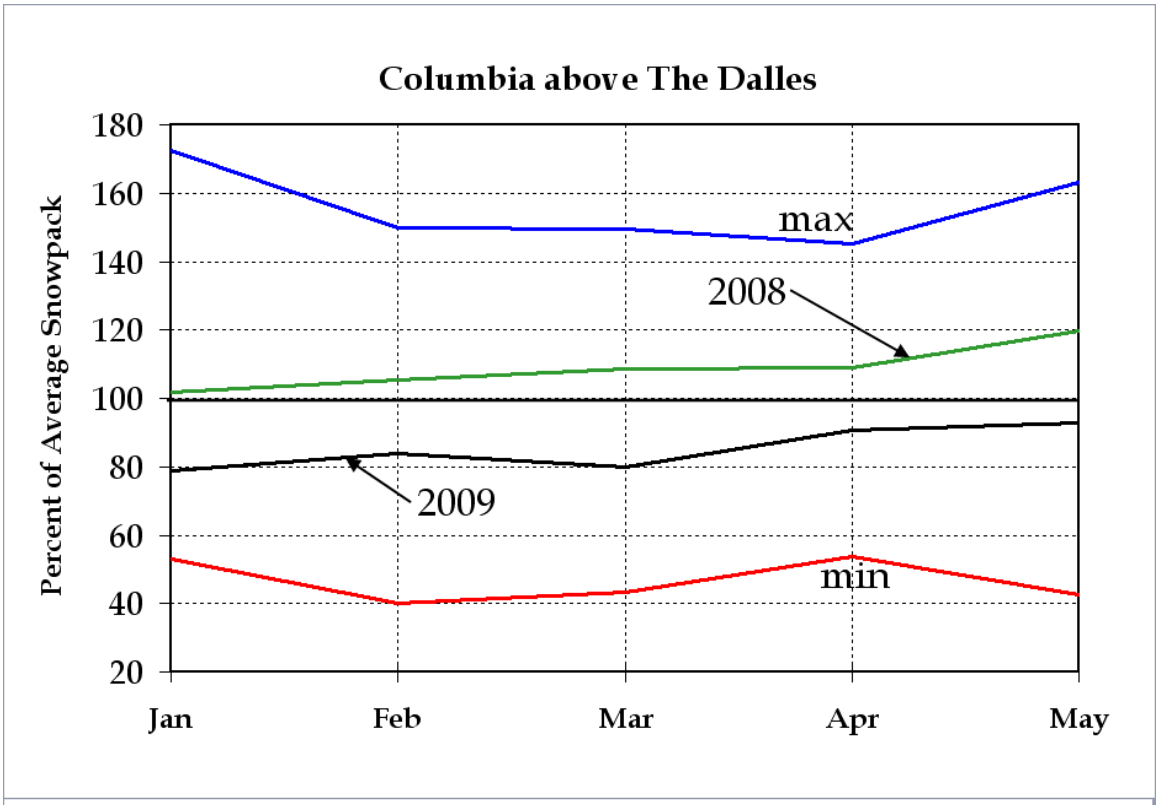
**Chart 2: Seasonal Precipitation**

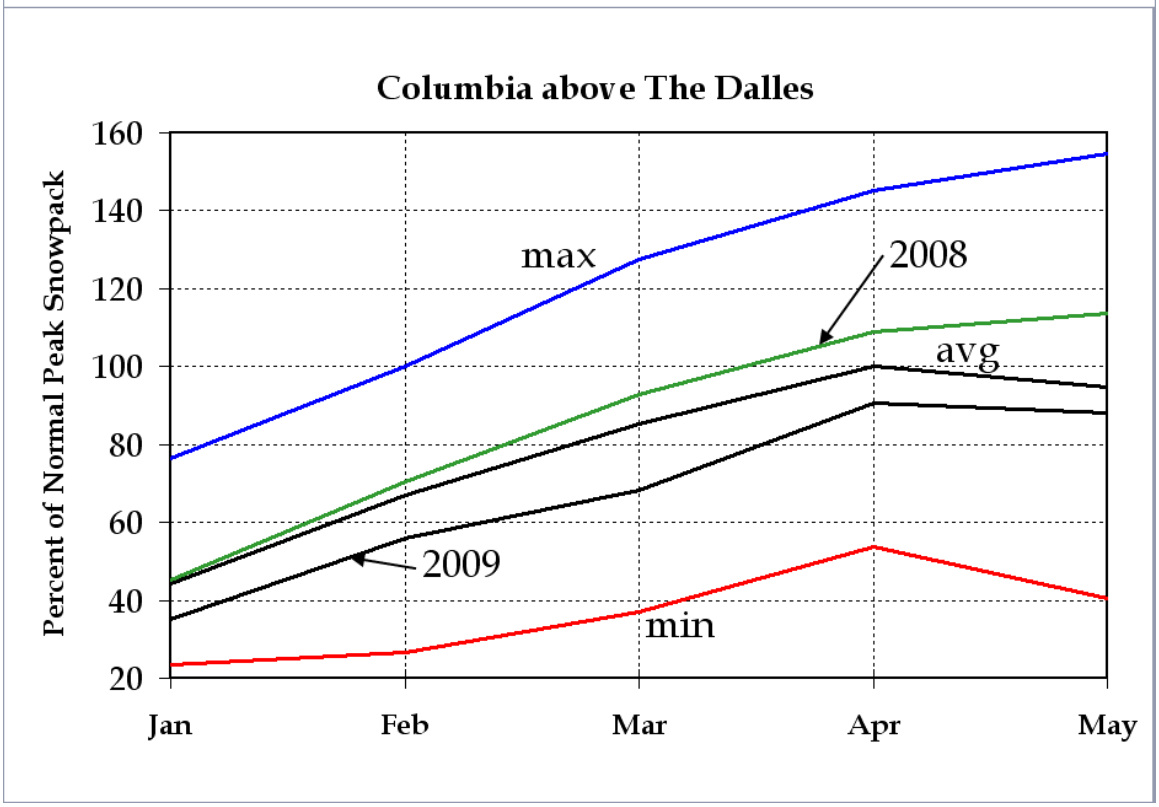
**Columbia River Basin**

**October 2008 – September 2009**



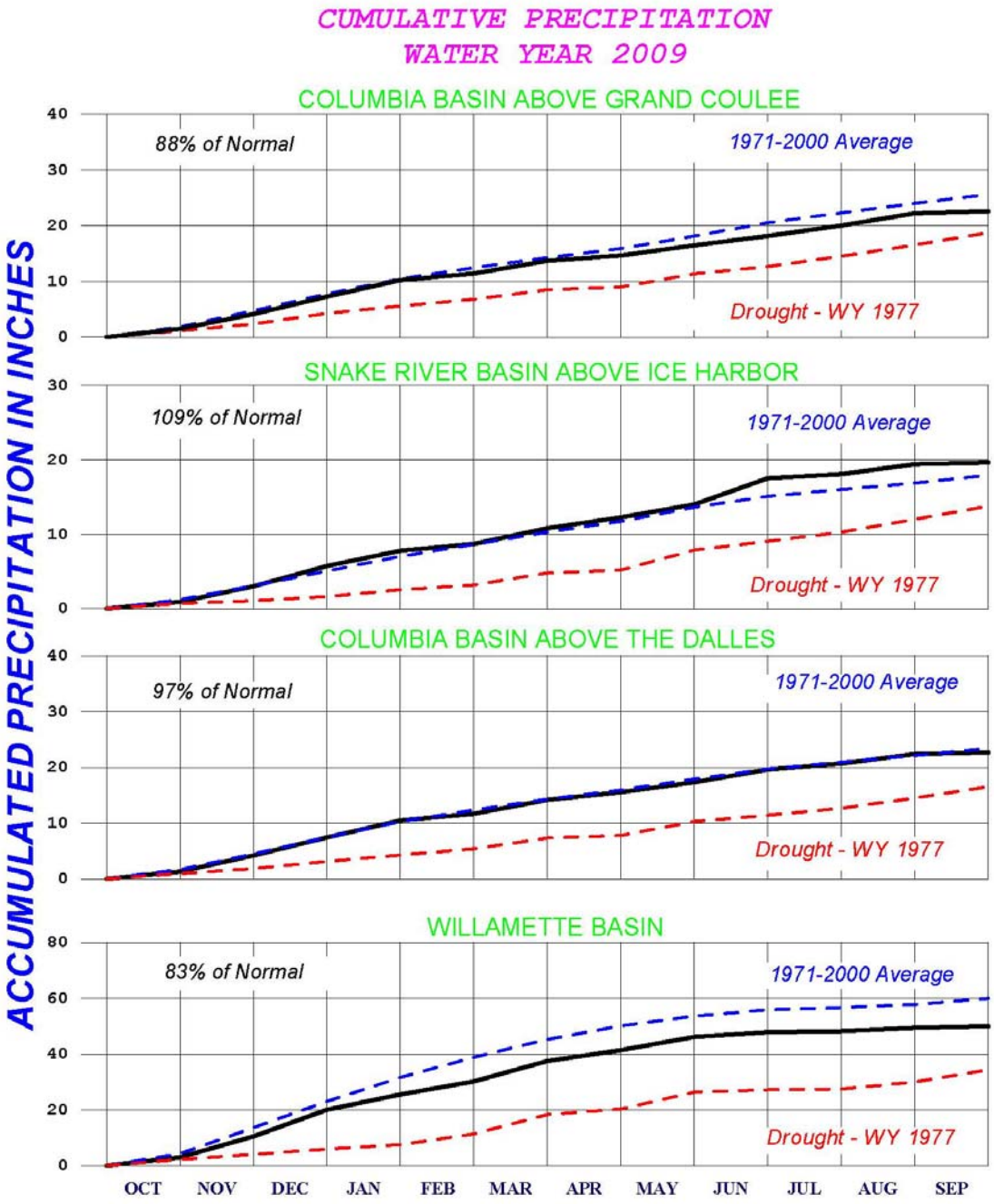
## Chart 3: Columbia Basin Snowpack



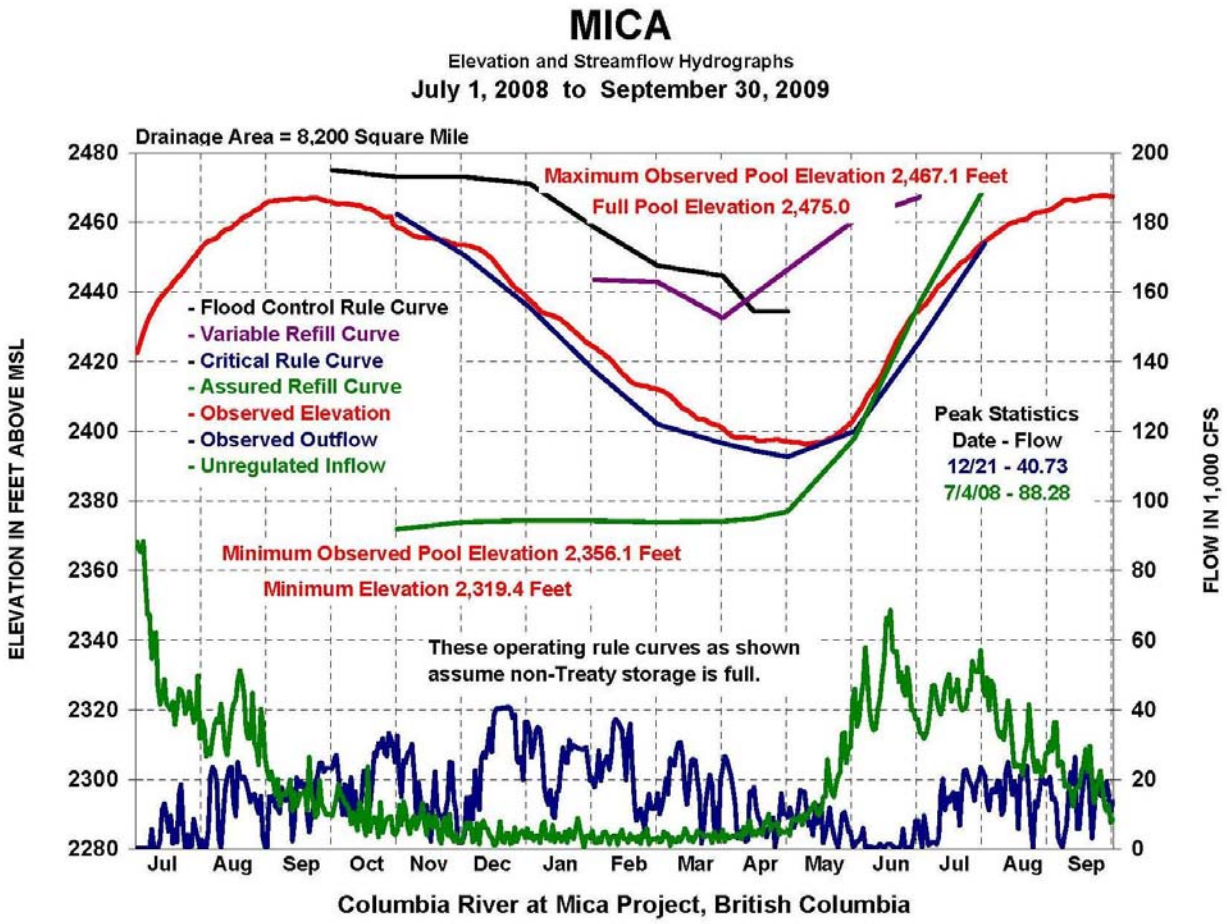
## Chart 4: Accumulated Precipitation for WY 2009

## At Primary Columbia River Basins



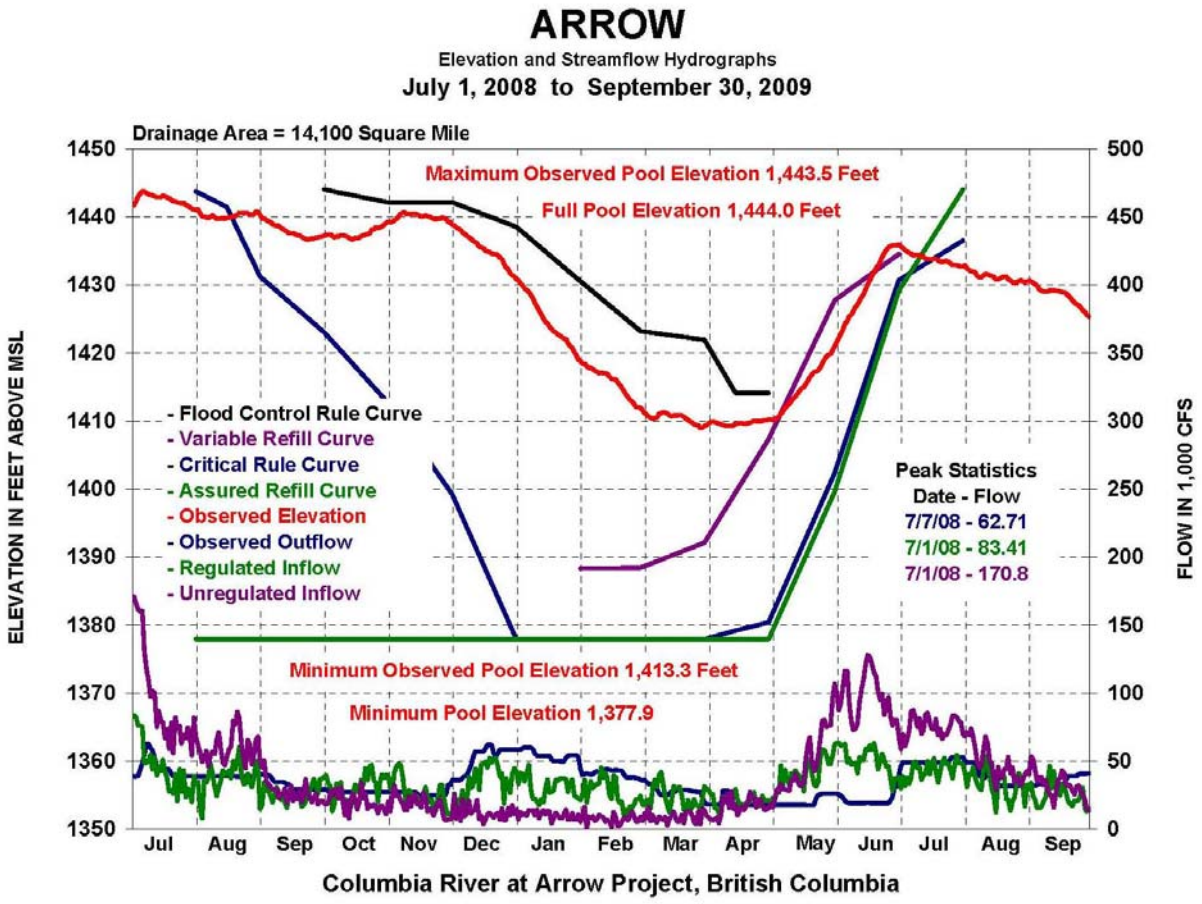
# Chart 5: Regulation of Mica

# 1 August 2008 – September 2009



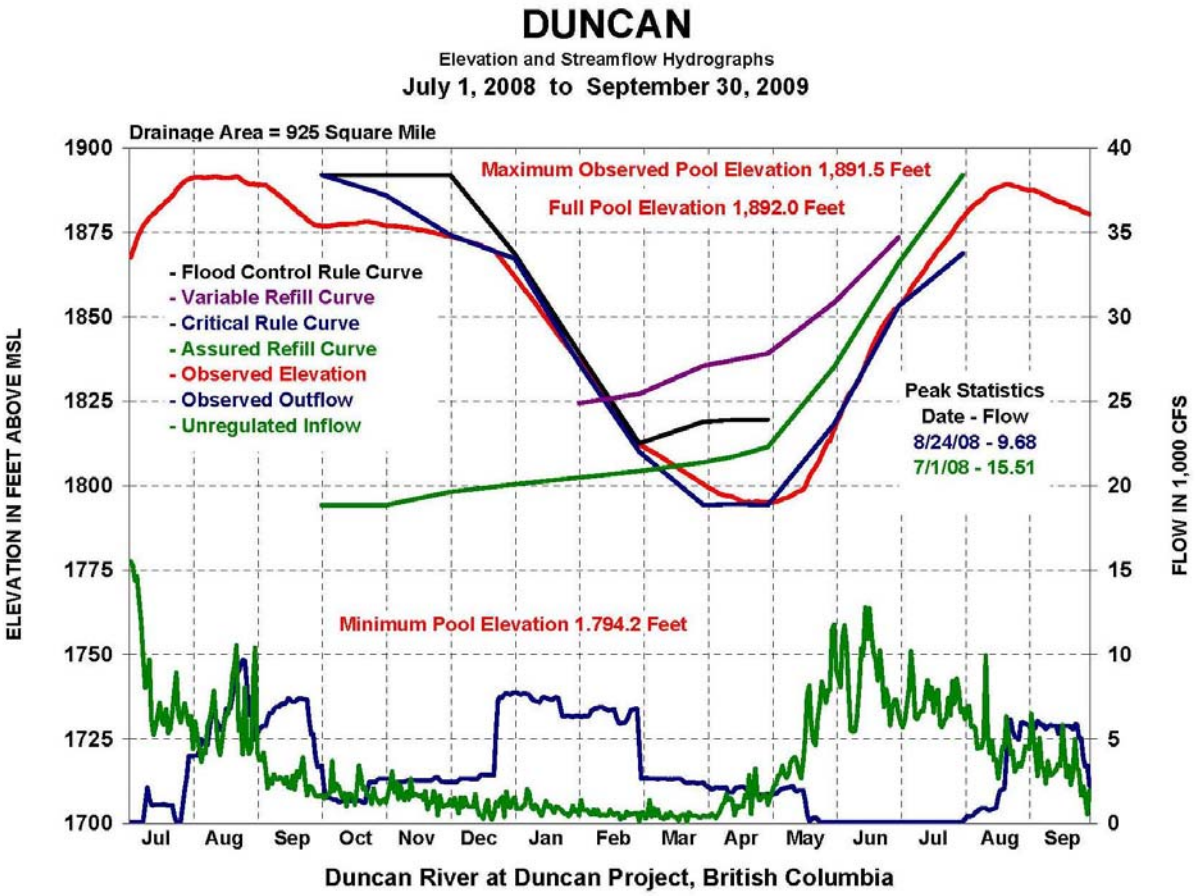
# Chart 6: Regulation of Arrow

# 1 August 2008 – September 2009



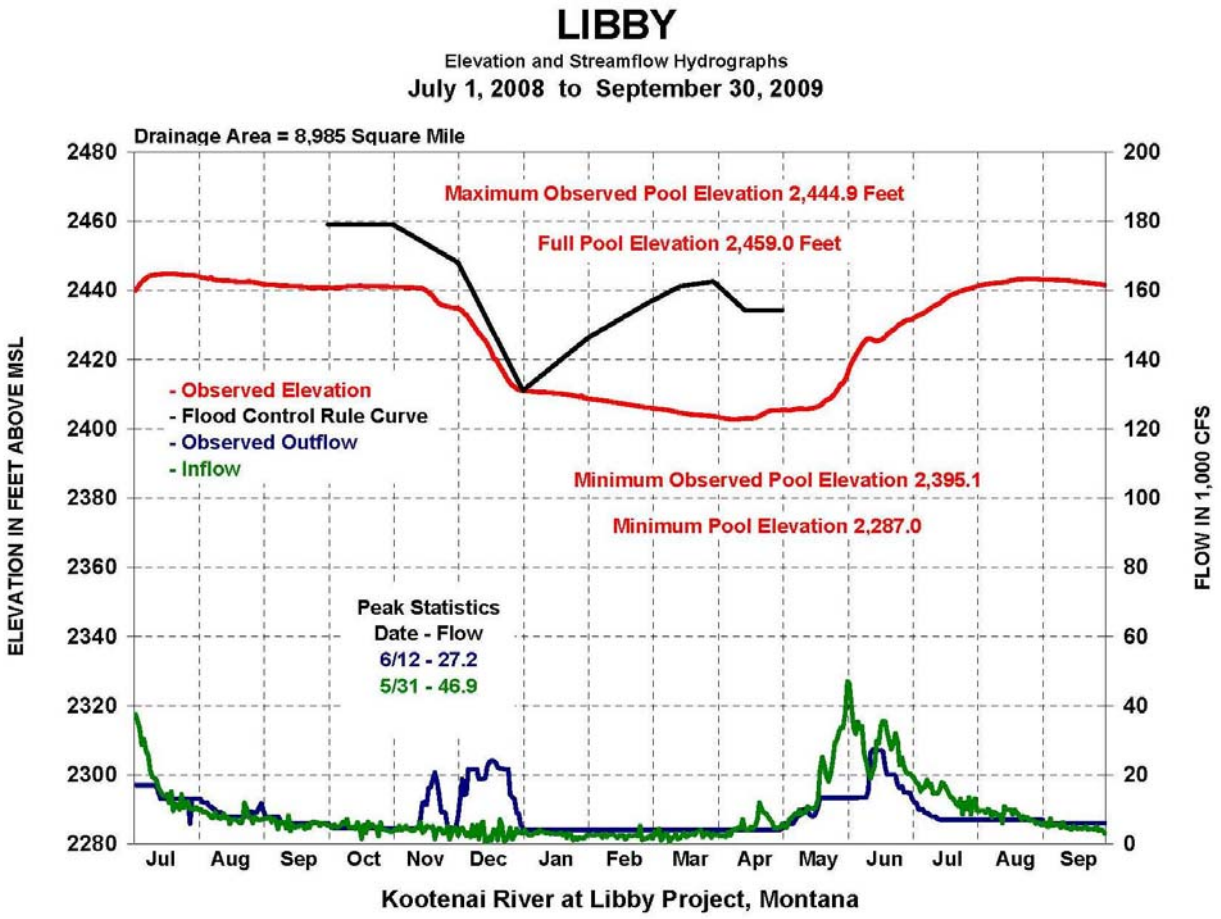
# Chart 7: Regulation of Duncan

# 1 August 2007 – September 2008



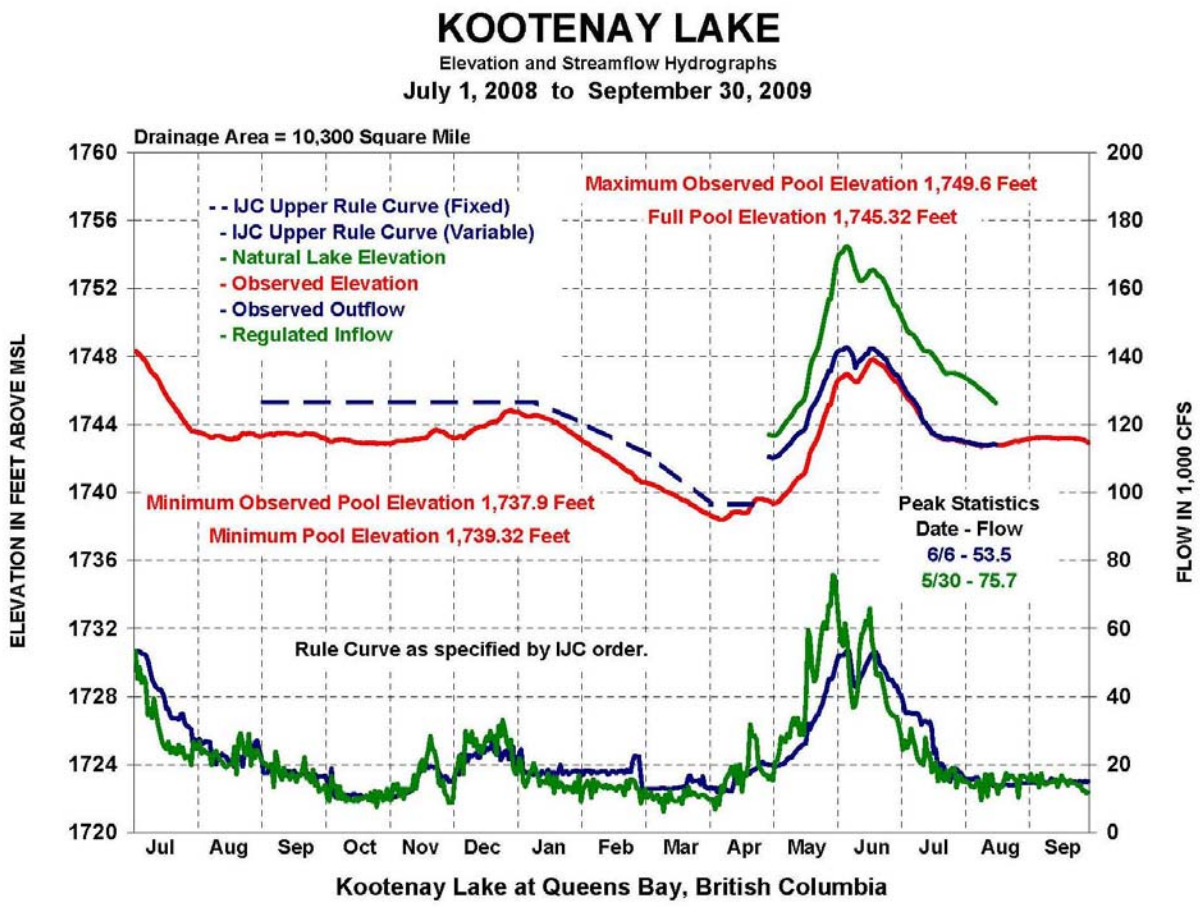
# Chart 8: Regulation of Libby

# 1 August 2008 – September 2009



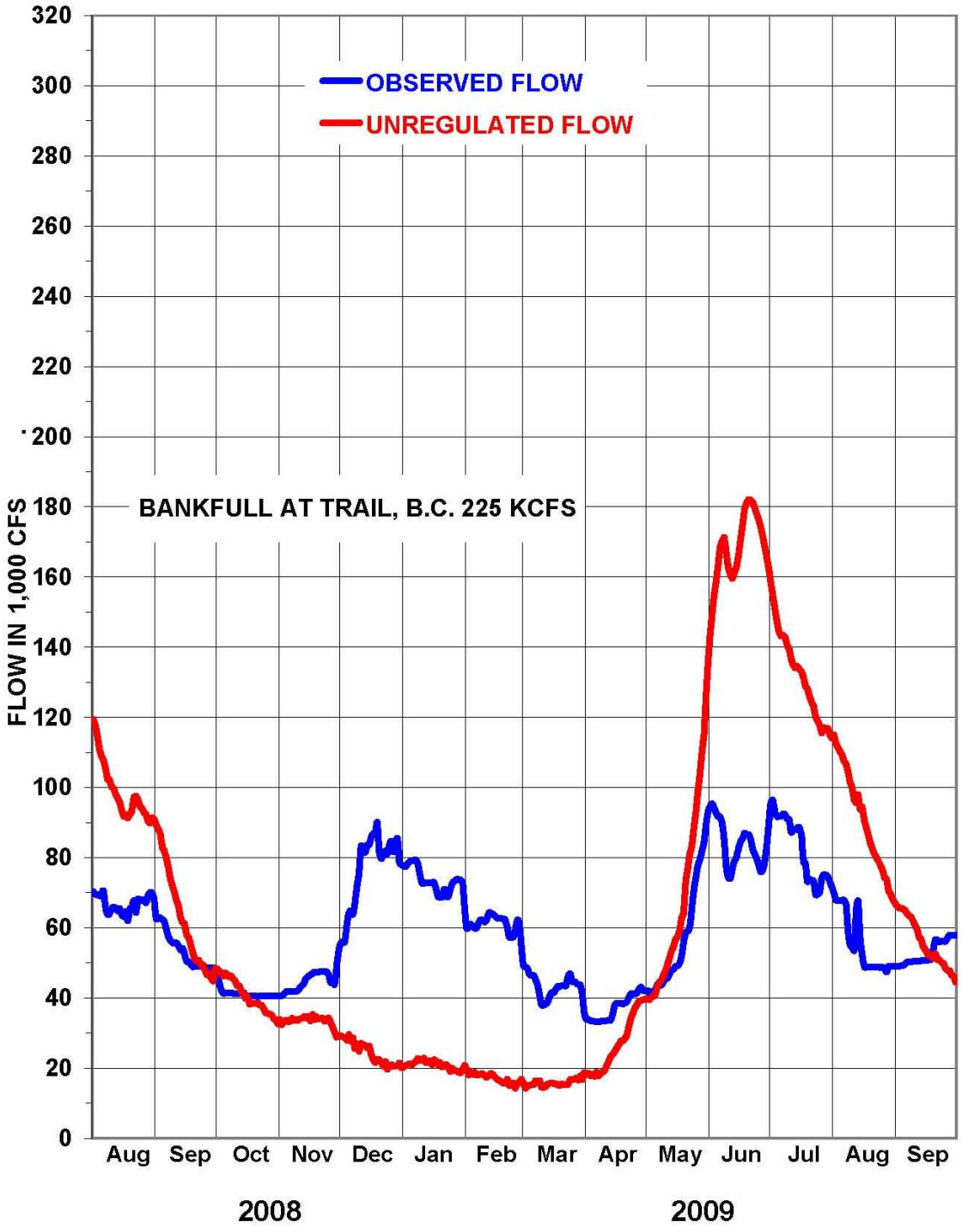
## Chart 9: Regulation of Kootenay Lake

## 1 August 2008 – September 2009



## Chart 10: Columbia River at Birchbank

## 1 August 2008 – 30 September 2009



# Chart 11: Regulation of Grand Coulee

# 1 August 2007 – 30 September 2008

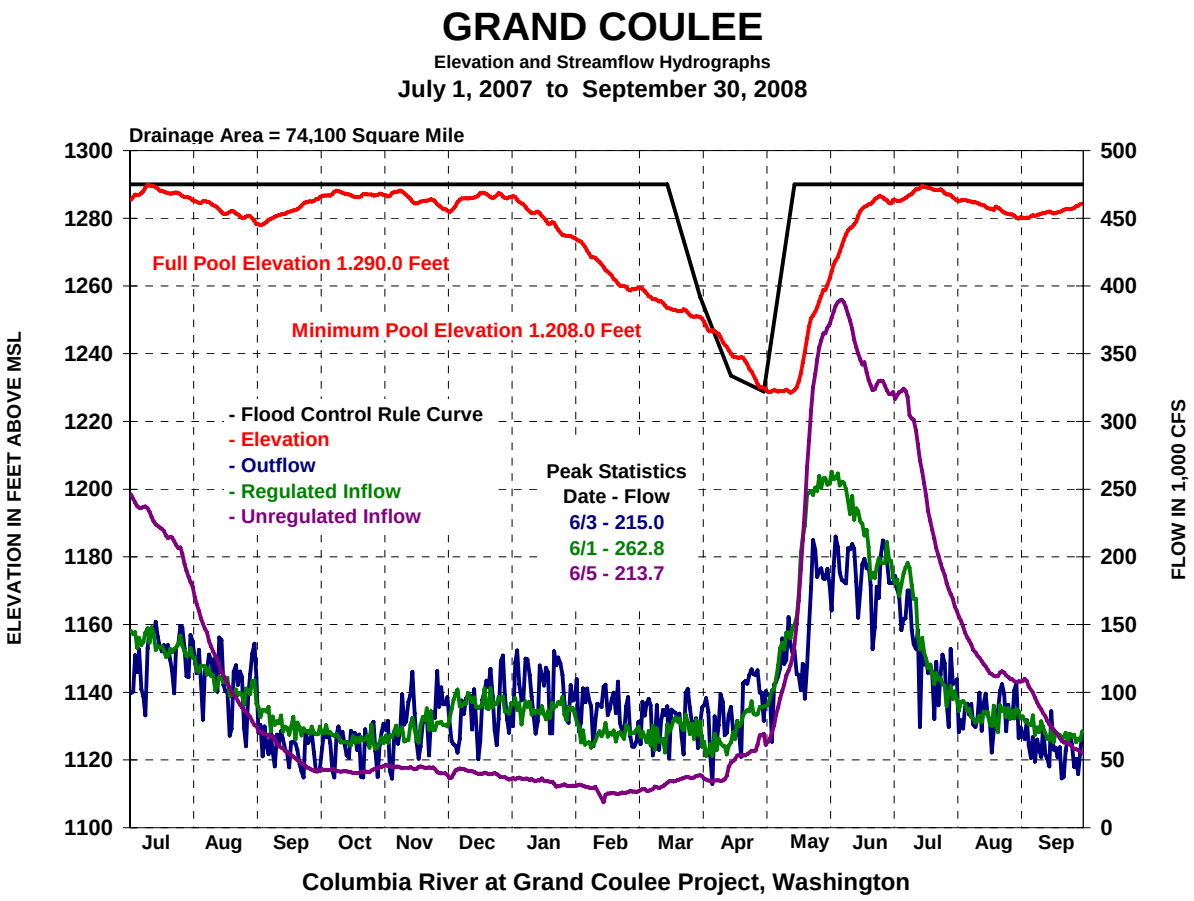
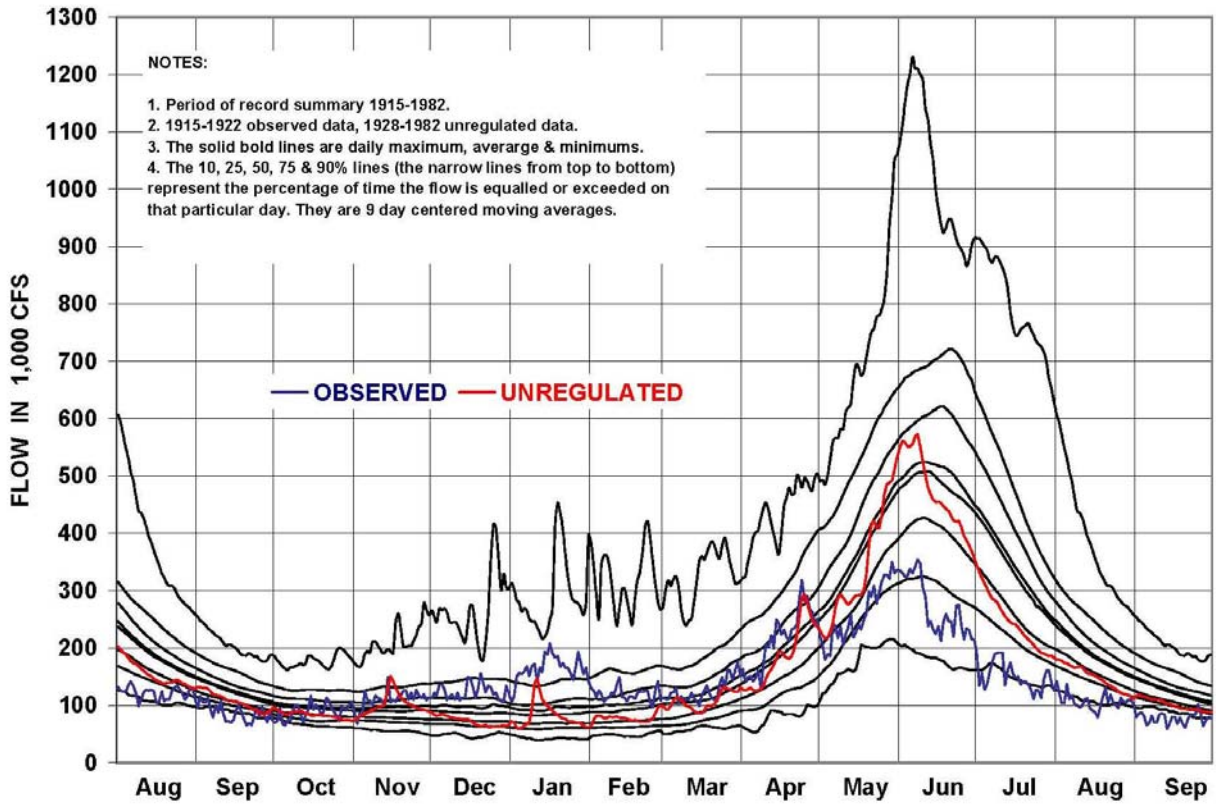


**Chart 12: Columbia River at The Dalles**

**(Summary Hydrograph)**

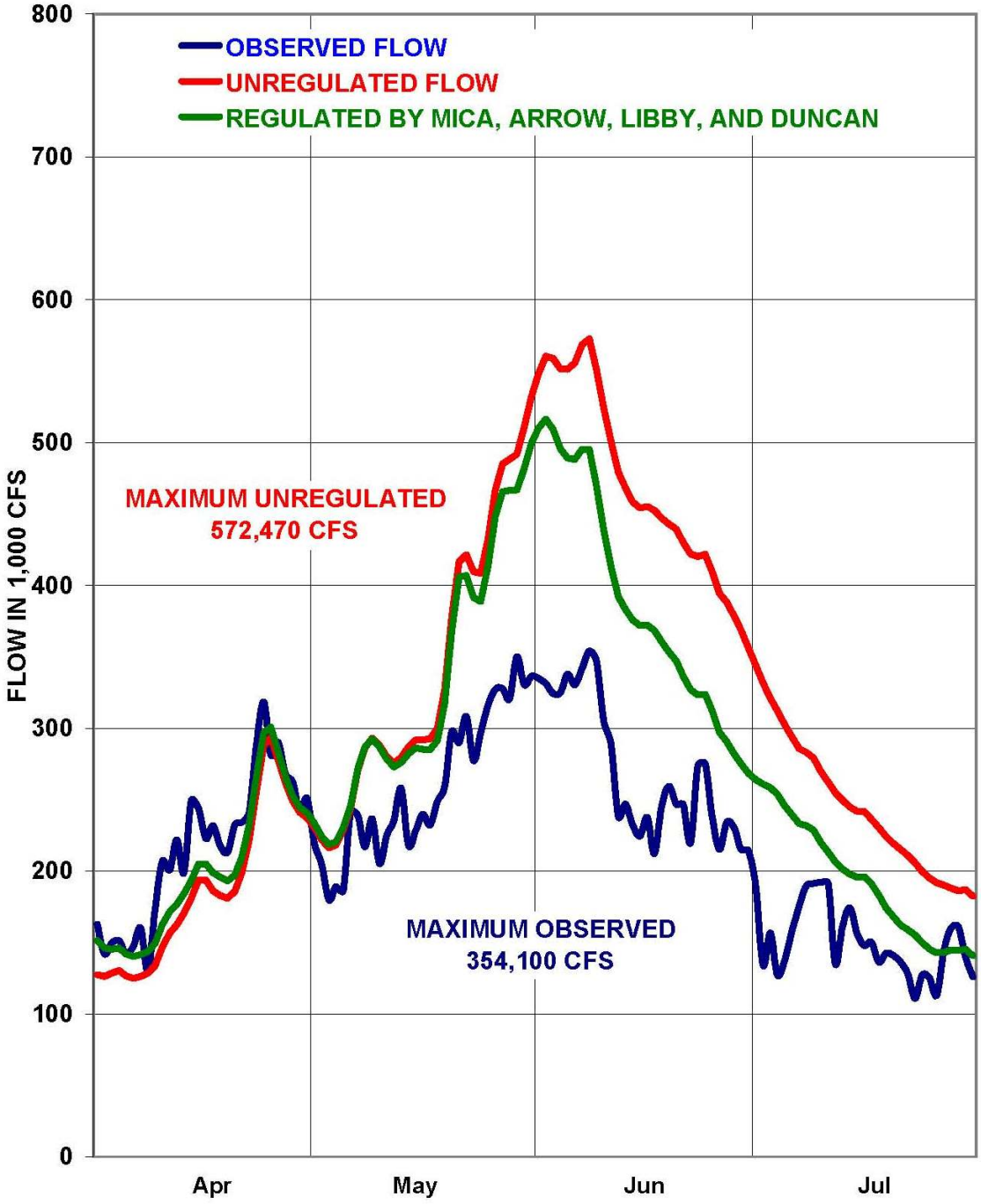
**1 August 2008 – 30 September 2009**

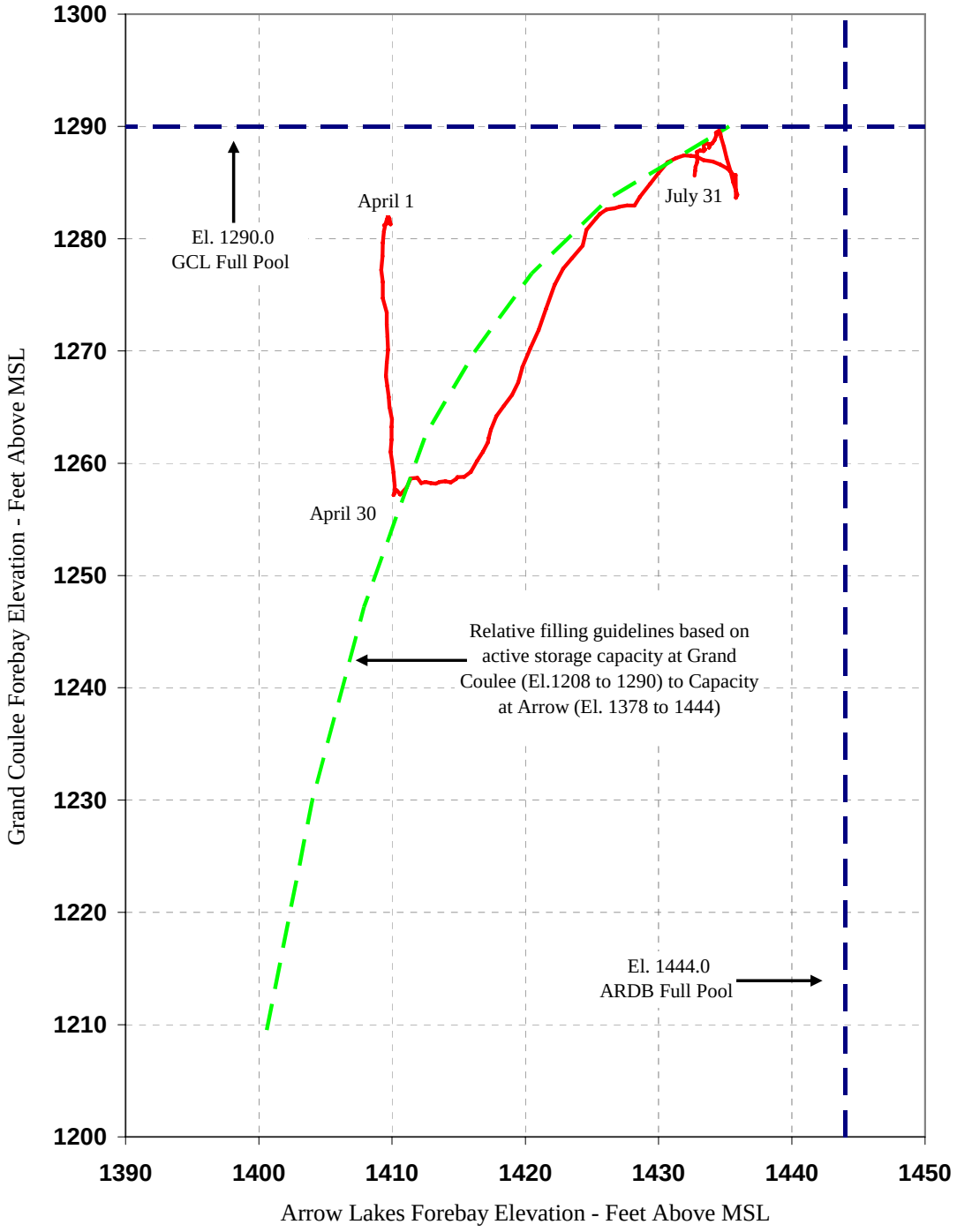


## Chart 13: Columbia River at The Dalles

## Re-Regulation Plot

## 1 April 2009 – 31 July 2009



# Chart 14: 2009 Relative Filling

# Arrow and Grand Coulee