THE COLUMBIA RIVER SYSTEM THE INSIDE STORY

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THE COLUMBIA RIVER SYSTEM: THE INSIDE STORY

U.S. DEPARTMENT OF ENERGY, BONNEVILLE POWER ADMINISTRATION

U.S. DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS, NORTH PACIFIC DIVISION

U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, PACIFIC NORTHWEST REGION

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Published September 1991

This document was published for the Columbia River System Operation Review, a joint project of the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration.

Writing by Resource Writers Inc. with the assistance of agency staff.

Photo credits: U.S. Bureau of Reclamation
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I. Introduction

Federal water projects, including Lower Granite Dam above, were constructed on the Columbia River and its tributaries from the 1930's to the mid-1970's.

The Columbia River is one of the greatest natural resources in the western United States. The river and its tributaries touch the lives of nearly every resident of the Northwest—from providing the world-famous Pacific salmon to supplying the clean natural fuel for over 75 percent of the region's electrical generation.

Since early in the century, public and private agencies have labored to capture the benefits of this dynamic river. Today, dozens of major water resource projects throughout the region are fed by the waters of the Columbia Basin river system. And through cooperative efforts, the floods that periodically threaten developments near the river can be controlled.

This publication presents a detailed explanation of the planning and operation of the multiple-use dams and reservoirs of the Columbia River system. It describes the river system, those who operate and use it, the agreements and policies that guide system operations, and annual planning for multiple-use operation. A glos-

sary and a reference list can be found at the end of the document.

The Inside Story was written for participants in the System Operation Review being conducted jointly by the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Bonneville Power Administration. The review is the environmental analysis that is required to consider major changes in Columbia River system operations. These include development of a multiple-use operating strategy for the river system, and renegotiation and renewal of the Pacific Northwest Coordination Agreement and other agreements related to the Columbia River Treaty between the United States and Canada. These complex agreements, which will expire over the next decade, are explained in the following pages.

If you have questions or comments about the Columbia River system or the System Operation Review, we invite you to contact the Interagency Team. The address and phone number of the team are on the inside cover of this publication.

For centuries, the Columbia River has provided a bounty of benefits to inhabitants of the Pacific Northwest. Celilo Falls, shown here, was a Native American fishing ground before The Dalles Dam was built.

The Inside Story was written for participants in the System Operation Review. This review is intended to yield a multiple-use operating strategy for the Columbia River system.

Electricity generated on the river powers homes and businesses throughout the Northwest.

The river and its reservoirs provide countless recreational opportunities for residents and visitors to the Northwest.

II. The Columbia River System

A. The Basin

The Columbia River is the fourth largest river in North America. The river and its tributaries are the dominant water system in the Pacific Northwest. The system drains 219,000 square miles in seven western states: Washington, Oregon, Idaho, Montana, Wyoming, Nevada, and Utah. The Columbia River Basin drainage also covers 39,500 square miles in British Columbia.

The Columbia River originates at Columbia Lake on the west slope of British Columbia's Rocky Mountain Range. The river flows from Canada into the United States and eventually becomes the border between Oregon and Washington. The Columbia River is 1,214 miles long; it flows into the Pacific Ocean near Astoria, Oregon.

The Rocky Mountains to the east and north, the Cascade Range on the west, and the Great Basin to the south are the principal boundaries of the Columbia Basin. Within the drainage,

there are numerous subbasins formed by tributaries of the mainstem river. The three major tributaries in the United States are the Kootenai, the Clark Fork-Pend Oreille, and the Snake.

The Highs and Lows of Streamflows. About 25 percent of the Columbia River flow comes from Canada. Before any dams were built, natural **streamflow** at the border ranged from as low as 14,000 cubic feet per second (cfs) to 550,000 cfs. This enormous variation in flow is seasonal. Most of the annual precipitation in the Columbia River Basin occurs in the winter; the largest share falls in the mountains as snow. The moisture that is stored during the winter in the snowpack is released in the spring and early summer, and about 60 percent of the natural runoff in the basin occurs during May, June, and July.

The Columbia River has an average annual runoff at its mouth of about 198 million **acre-feet** (275,000 cfs), making it second only to the Missouri-Mississippi River system in the

Streamflow: Streamflow refers to the rate and volume of water flowing in various sections of the river. Streamflow records are compiled from measurements taken at particular points on the river such as The Dalles, Oregon.

Acre-feet: A common measure of the volume of water in the river system. It is the amount of water it takes to cover one acre to a depth of one foot.

Columbia River Uses

The people of the Northwest use the Columbia River in eight primary ways. The water projects make up a multiple-use system.

The Columbia River Basin

Major Federal Dams

The Columbia drains 258,500 square miles in the United States and Canada.

In spring, the powerful Columbia River is fueled by seasonal rainfall and snowmelt.

Today, dozens of major water resource projects throughout the region are fed by the Columbia River.

Columbia River Streamflows

Flow on the Columbia River is generally measured at The Dalles, Oregon. Historic records show an annual pattern, with peak flows in late spring.

Columbia River dams provide flood control, irrigation, navigation, power generation, and recreation benefits to the Northwest.

United States in runoff. The Canadian portion of the basin generally contributes about 50.2 million acre-feet annually.

For operational purposes, runoff is measured at The Dalles, Oregon. Here the annual average is 134 million acre-feet (184,000 cfs).

Since the 1930's, the Columbia River has been harnessed for the benefit of the Northwest. Federal agencies have built 30 major dams on the river and its tributaries. Dozens of non-Federal projects have been developed as well. The dams provide flood control, irrigation, navigation, and recreation benefits. In addition, they form one of the largest hydroelectric systems in the world.

B. Uses of the River System

There are eight primary uses of the Columbia River system.

- **Navigation.** The Columbia and Snake Rivers can be navigated as far upstream as Lewiston, Idaho, 465 miles from the Pacific Ocean. Four Federal

dams on the mainstem of the Columbia River—Bonneville, The Dalles, John Day, and McNary—have navigation locks through which boats and barges can pass. Locks at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams accommodate river traffic on the lower Snake River.

- **Flood control.** Because the Columbia River's flow varies so widely, the river is subject to severe floods. Controlling the damaging flood waters was one of the original purposes for many of the dams on the river. Flood control remains a high priority for system operations during high runoff years.

- **Irrigation.** Six percent of the Columbia Basin's water is diverted for agriculture. Growers in arid parts of eastern Washington, northeastern Oregon, and southern Idaho depend on this water to produce wheat, corn, potatoes, peas, alfalfa, apples, grapes, and a vast assortment of other crops.

- **Electric power generation.** The hydroelectric dams on the Columbia and Snake Rivers produce an average of 18,500 **megawatts** of electricity annually and are the foundation of the Northwest's power supply. Power

Megawatt: A measure of electrical power equal to one million watts. Megawatts delivered over time are measured in megawatt-hours.

BPA Transmission Grid

Power is delivered to cities around the region over a network of transmission lines. The BPA transmission grid interconnects with Canada to the north and California to the south.

lines originate at generators at the dams and extend outward to utility customers throughout the region and beyond. The **transmission grid** in the Northwest is interconnected with Canada to the north, with California to the south, and with Utah and other states to the east. Power produced at dams in the Northwest serves customers locally and thousands of miles away.

- **Fish migration.** The Columbia River is famous for its salmon runs.

Federal dams in the lower Columbia and Snake Rivers have **fish ladders** and other facilities to help anadromous fish migrate up and down the river. Indian Tribes, commercial fishermen, and sport anglers share the salmon and steelhead in the river. Nearly 10 million pounds of steelhead trout and chinook, coho, chum, and sockeye salmon were caught in 1989. Fish hatcheries are an important part of the river system.

**Nearly
10 million
pounds of
steelhead trout
and salmon
were harvested
in 1989.**

Barges travel up and down the river, transporting fuel, fertilizers, and agricultural products.

Marinas and boat launches give recreational boaters ready access to the reservoirs.

Transmission Grid: The network of high-voltage transmission lines that serves the region, carrying power from generating plants to cities.

Fish Ladder: A series of stair-step pools that enable salmon to get past the dams. Swimming from pool to pool, salmon work their way up the ladder to the top where they continue upriver.

Columbia Basin Fish Facilities

Name	Location	Type	In-Service Date	Managing Agency
Bonneville Dam	Oregon-Washington	Ladders/Screens	1938	Corps of Engineers
Bonneville Hatchery	Oregon	Hatchery	1909	Oregon Fish & Wildlife
Clearwater	Idaho	Hatchery	1987	Idaho Fish & Game
Dworshak	Idaho	Hatchery	1982	U.S. Fish & Wildlife
Entiat	Washington	Hatchery	1941	U.S. Fish & Wildlife
Hagerman	Idaho	Hatchery	1984	U.S. Fish & Wildlife
Ice Harbor	Washington	Ladder	1961	Corps of Engineers
Irrigon	Oregon	Hatchery	1985	Oregon Fish & Wildlife
John Day Dam	Oregon-Washington	Ladders/Screens	1968	Corps of Engineers
Leaberg	Oregon	Hatchery	1953	Oregon Fish & Wildlife
Leavenworth	Washington	Hatchery	1940	U.S. Fish & Wildlife
Little Goose Dam	Washington	Ladder/Screens	1970	Corps of Engineers
Looking Glass	Idaho	Hatchery	1982	Idaho Fish & Game
Lost Creek	Oregon	Hatchery	1973	Oregon Fish & Wildlife
Lower Granite Dam	Columbia R.	Ladder/Screens	1975	Corps of Engineers
Lower Monumental Dam	Washington	Ladder	1969	Corps of Engineers
Lyons Ferry	Washington	Hatchery	1983	Wash. Dept. Fish
Magic Valley	Idaho	Hatchery	1986	Idaho Fish & Game
Marion Forks	Oregon	Hatchery	1950	Oregon Fish & Wildlife
McCall	Idaho	Hatchery	1981	Idaho Fish & Game
McKenzie	Oregon	Hatchery	1902	Oregon Fish & Wildlife
McNary Dam	Oregon-Washington	Ladders/Screens	1953	Corps of Engineers
Sawtooth	Idaho	Hatchery	1984	Idaho Fish & Game
South Santiam	Oregon	Hatchery	1923	Oregon Fish & Wildlife
Spring Creek	Oregon	Hatchery	1901	U.S. Fish & Wildlife
The Dalles Dam	Oregon-Washington	Ladders	1957	Corps of Engineers
Wallowa	Oregon	Hatchery	1985*	Oregon Fish & Wildlife
Willamette	Oregon	Hatchery	1955	Oregon Fish & Wildlife
Winthrop	Washington	Hatchery	1940	U.S. Fish & Wildlife

*Hatchery built in 1920 - modified in 1985

The region's fish and wildlife planners have recognized the importance of fish by calling for construction of fish facilities.

The Columbia River is a popular destination for sightseers.

- **Fish and wildlife habitat.** The Columbia Basin is alive with fish and wildlife. State and Federal laws require protection of the habitat that supports these animals. The region has spent millions of dollars restoring fish runs and is now considering programs to reestablish wetlands, control erosion on streambanks, and acquire harvest rights for old growth timber to protect wildlife habitat.

- **Recreation.** The rivers and reservoirs in the Columbia Basin attract boaters, sport anglers, swimmers, and campers throughout the year. Thousands of sightseers visit the river and the projects. The wind in the Columbia River Gorge has made the area a world-class destination for windsurfers.

- **Water supply and quality.** The Columbia River system supplies

water to numerous municipalities and industries. While municipal and industrial uses do not consume a significant portion of the river's water, these withdrawals are considered in system operations. Of particular importance to these users is maintaining the high quality of Columbia River water so that it continues to provide an attractive source of supply for municipal and industrial purposes.

C. The Dams and Water Projects

The projects on the Columbia River and its tributaries fall into two major categories: storage and run-of-river. It is important to understand the difference between the two.

Storage Projects. The main purpose of storage reservoirs is to adjust the river's natural flow patterns to conform more closely to water uses. Water from rain and snowmelt is put into storage until it is needed. More water is produced during the spring snowmelt than is required for power production, irrigation, and other uses. Reservoirs capture the runoff and store it until the late summer, fall, and winter when it is released.

Storage dams hold back the heavy spring and summer snowmelt run-offs to help prevent flooding. In the fall and winter when streamflows would ordinarily be low, water is gradually released from the reservoirs for many river uses.

Reservoir levels at storage projects vary greatly during normal river operations. There is a significant difference between a storage reservoir when it is full and when it is down to its lowest operating level. For example, Hungry Horse operates over a range of 224 feet; Libby, 172 feet; Dworshak, 155 feet; and Grand Coulee, 82 feet.

Run-of-River Projects. These projects have limited storage and were developed primarily for navigation and hydropower generation. All run-of-river projects provide **hydraulic head** for power generation and many also give sufficient water depth over rapids and other obstacles to permit barge navigation. Run-of-river projects pass water at the dam at nearly the same rate it enters. Water that backs up behind run-of-river projects is referred to as **pondage**. Reservoir levels behind these projects vary only three to five feet in normal operations.

Diversion projects may be either storage or run-of-river dams. They include irrigation canals and pumping systems that take water from the river and its reservoirs to nourish crops. These projects, such as Reclamation's massive Columbia Basin and Minidoka irrigation projects, have turned hundreds of thousands of acres of arid land into productive farmland. Much of the water that is diverted for irrigation eventually finds its way back into the river downstream.

Hydraulic Head: The vertical distance from the reservoir level behind the dam to the river level below the dam. With higher head, more energy can be produced with the same flow of water.

Pondage: The pool of water behind a run-of-river dam that is much smaller than a storage reservoir.

Storage and Run-of-River Projects

Storage projects are important for regulating river flow to serve multiple uses, run-of-river projects are primarily for navigation and power generation.

Storage reservoirs help adjust the river's natural flow to conform to the various needs of water users.

Major Northwest Dams. The dams on this map generally represent the largest projects and those that have a significant role in river system management. A complete list of projects in the basin can be found in Appendix A. Acronyms and abbreviations are defined on page 81.

Major Northwest Dams

1	BONNEVILLE	30	DWORSHAK
	Columbia River, USCE		N. F. Clearwater River, USCE
2	THE DALLES	31	HELLS CANYON
	Columbia River, USCE		Snake River, IP
3	JOHN DAY	32	OXBOW
	Columbia River, USCE		Snake River, IP
4	McNARY	33	BROWNLEE
	Columbia River, USCE		Snake River, IP
5	PRIEST RAPIDS	34	BLACK CANYON
	Columbia River, Grant Co. PUD		Payette River, USBR
6	WANAPUM	35	BOISE RIVER DIVERSION
	Columbia River, Grant Co. PUD		Boise River, USBR
7	ROCK ISLAND	36	ANDERSON RANCH
	Columbia River, Chelan Co. PUD		Boise River, USBR
8	ROCKY REACH	37	MINIDOKA
	Columbia River, Chelan Co. PUD		Snake River, USBR
9	WELLS	38	PALISADES
	Columbia River, Douglas Co. PUD		Snake River, USBR
10	CHIEF JOSEPH	39	PELTON
	Columbia River, USCE		Deschutes River, PGE
11	GRAND COULEE	40	ROUND BUTTE
	Columbia River, USBR		Deschutes River, PGE
12	KEENLEYSIDE	41	BIG CLIFF
	Columbia River, BC Hydro		N. Santiam River, USCE
13	REVELSTOKE	42	DETROIT
	Columbia River, BC Hydro		N. Santiam River, USCE
14	MICA	43	FOSTER
	Columbia River, BC Hydro		S. Santiam River, USCE
15	CORRA LINN	44	COUGAR
	Kootenay River, WKP&L		McKenzie River, USCE
16	DUNCAN	45	GREEN PETER
	Duncan River, BC Hydro		M. Santiam River, USCE
17	LIBBY	46	DEXTER
	Kootenai River, USCE		Willamette River, USCE
18	BOUNDARY	47	LOOKOUT POINT
	Pend Oreille River, SCL		Willamette River, USCE
19	ALBENI FALLS	48	HILLS CREEK
	Pend Oreille River, USCE		Willamette River, USCE
20	CABINET GORGE	49	MERWIN
	Clark Fork River, WWP		Lewis River, PP&L
21	NOXON RAPIDS	50	YALE
	Clark Fork River, WWP		Lewis River, PP&L
22	KERR	51	SWIFT
	Flathead River, MPC		Lewis River, PP&L
23	HUNGRY HORSE	52	MAYFIELD
	Flathead River, USBR		Cowlitz River, TCL
24	CHANDLER	53	MOSSYROCK
	Yakima River, USBR		Cowlitz River, TCL
25	ROZA	54	GORGE
	Yakima River, USBR		Skagit River, SCL
26	ICE HARBOR	55	DIABLO
	Snake River, USCE		Skagit River, SCL
27	LOWER MONUMENTAL	56	ROSS
	Snake River, USCE		Skagit River, SCL
28	LITTLE GOOSE	57	CULMBACK
	Snake River, USCE		Sultan River, Snohomish Co. PUD
29	LOWER GRANITE	58	LOST CREEK
	Snake River, USCE		Rogue River, USCE
		59	LUCKY PEAK
			Boise River, USCE

SASKATCHEWAN

MONTANA

WYOMING

The Columbia Basin and Minidoka Projects

The **Columbia Basin Project**, which began in the late 1930's, uses water that is diverted from Roosevelt Lake behind Grand Coulee Dam to irrigate crops. Water is drawn from Roosevelt Lake by giant pumps and lifted into Banks

Lake, which was formed by damming both ends of a natural geologic formation called the Grand Coulee. The water then flows through a system of tunnels and canals to irrigate croplands many miles away. The project currently

provides water to over 500,000 acres and has the potential to be expanded in the future to 1.1 million acres.

The **Minidoka Project** consists of six storage dams and reservoirs and two diversion dams. Four of the facilities are on the upper Snake River in Idaho, and two reservoirs—Jackson Lake and Grassy Lake—are in Wyoming. The project dates back to 1909. American Falls Dam, which backs up the largest of the reservoirs, was built in 1927. Thousands of miles of distribution canals in the Minidoka Project provide irrigation service to more than 1.1 million acres of farmland.

Water from irrigation projects nurtures crops many miles away.

Columbia River Runoff and Storage Compared to the Colorado and Missouri Rivers

The Columbia River has high runoff and a small amount of storage compared to two other large river systems: the Colorado and the Missouri.

Projects Under Study in the System Operation Review. The System Operation Review focuses on 14 Federal hydro projects. These large-scale facilities play a key role in the multi-purpose use of the Columbia River system. They include dams and reservoirs, navigation channels and locks, hydroelectric power plants, high-voltage power lines and substations, fish ladders and bypass facilities, irrigation diversions and pumps, parks and recreation facilities, boat launches, lands that are dedicated to the projects, and areas set aside to replace wildlife habitat.

Storage is the key to the operation of a multiple-use river system. The total water storage in the Columbia River system is 55 million acre-feet, of which 42 million acre-feet are available for coordinated operations. This is an enormous amount of water, but it is only about 30 percent of an average year's runoff at The Dalles. By

comparison, dams on the Missouri River system hold two to three times its annual runoff. While there is a large amount of storage on the Columbia River, there is not the degree of control that exists on the Missouri and Colorado River systems.

Of the 14 projects in the System Operation Review, five are storage dams. They are Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak. The combined storage in the reservoirs behind these dams is about 16 million acre-feet. Three Canadian dams—Mica, Duncan, and Keenleyside—add another 20.5 million acre-feet of storage. These eight projects are particularly beneficial because they are strategically located in the middle and upper basin to capture runoff for later release to augment downstream flows.

The remaining nine projects in the System Operation Review are run-of-river dams. They are Bonneville,

Columbia River System Storage Space

A few key reservoirs, including three in Canada and five in the U.S., hold most of the storage in the Columbia River Basin.

Canadian and U.S. Storage

Storage at all projects on the major tributaries and the mainstem Columbia River totals 55.3 million acre-feet. As this diagram shows, most storage has been developed on the upper Columbia system; only about 8 percent of the capacity is in the lower Columbia River below its junction with the Snake River.

Projects in the System Operation Review.

McNARY

- Columbia River, Oregon/Washington
- Corps of Engineers
- In service November 6, 1953
- 1,133,000 kilowatts of capacity
- Purposes include power, recreation, and navigation
- Run-of-river dam
- Average annual discharge of 169,800 cfs

JOHN DAY

- Columbia River, Oregon/Washington
- Corps of Engineers
- In service July 16, 1968
- 2,484,000 kilowatts of capacity
- Purposes include power, recreation, navigation, flood control, and irrigation
- Run-of-river dam
- Average annual discharge of 172,400 cfs

THE DALLES

- Columbia River, Oregon/Washington
- Corps of Engineers
- In service May 13, 1957
- 2,052,000 kilowatts of capacity
- Purposes include power, recreation, and navigation
- Run-of-river dam
- Average annual discharge of 177,900 cfs

BONNEVILLE

- Columbia River, Oregon/Washington
- Corps of Engineers
- In service June 6, 1938
- 1,078,000 kilowatts of capacity
- Purposes include power, recreation, and navigation
- Run-of-river dam
- Average annual discharge of 183,300 cfs

ICE HARBOR

- Snake River, Washington
- Corps of Engineers
- In service December 18, 1961
- 643,000 kilowatts of capacity
- Purposes include power, recreation, and navigation
- Run-of-river dam
- Average annual discharge of 47,680 cfs

CHIEF JOSEPH

- Columbia River, Washington
- Corps of Engineers
- In service August 20, 1955
- 2,075,000 kilowatts of capacity
- Purposes include power and recreation
- Run-of-river dam
- Average annual discharge of 108,000 cfs

LOWER MONUMENTAL

- Snake River, Washington
- Corps of Engineers
- In service May 28, 1969
- 930,000 kilowatts of capacity
- Purposes include power, recreation, navigation, and irrigation
- Run-of-river dam
- Average annual discharge of 47,670 cfs

RAND COULEE

- Columbia River, Washington
- Bureau of Reclamation
- In service September 28, 1941
- 1,003,000 kilowatts of capacity
- Purposes include power, recreation, navigation, flood control, and irrigation
- Storage dam
- Average annual discharge of 107,700 cfs
- 19 million acre-feet of storage in Lake Roosevelt

ALBENI FALLS

- Pend Oreille River, Idaho
- Corps of Engineers
- In service April 1, 1955
- 43,000 kilowatts of capacity
- Purposes include power, recreation, navigation, and flood control
- Storage dam
- Average annual discharge of 25,340 cfs
- 1.16 million acre-feet of storage in Lake Pend Oreille

LIBBY

- Kootenai River, Montana
- Corps of Engineers
- In service August 13, 1975
- 604,000 kilowatts of capacity
- Purposes include power, recreation, navigation, and flood control
- Storage dam
- Average annual discharge of 11,350 cfs
- 4.98 million acre-feet of storage in Lake Koocanusa

HUNGRY HORSE

- Flathead River (South Fork), Montana
- Bureau of Reclamation
- In service October 29, 1952
- 328,000 kilowatts of capacity
- Purposes include power, recreation, navigation, flood control, and irrigation
- Storage dam
- Average annual discharge of 3,517 cfs
- 3.16 million acre-feet of storage in Hungry Horse Reservoir

DWORSHAK

- Clearwater River (North fork), Idaho
- Corps of Engineers
- In service March 1, 1973
- 400,000 kilowatts of capacity
- Purposes include power, recreation, navigation, and flood control
- Storage dam
- Average annual discharge of 5,820 cfs
- 2.02 million acre-feet of storage in Dworshak Reservoir

LOWER GRANITE

- Snake River, Washington
- Corps of Engineers
- In service April 3, 1975
- 932,000 kilowatts of capacity
- Purposes include power, recreation, navigation, and irrigation
- Run-of-river dam
- Average annual discharge of 49,680 cfs

LITTLE GOOSE

- Snake River, Washington
- Corps of Engineers
- In service May 26, 1970
- 932,000 kilowatts of capacity
- Purposes include power, recreation, and navigation
- Run-of-river dam
- Average annual discharge of 47,230 cfs

The complex operation at each dam and its effect on other projects on the river make coordination essential. Coordinated planning and operations maximize benefits.

**Coordination
increases the
benefits the
river provides.**

Multiple Uses: The Columbia River and the reservoir system are used for a variety of purposes. Thus, the river is often referred to as a multiple-use or a multi-use system.

Chief Joseph, McNary, The Dalles, John Day, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor.

D. The Coordinated Columbia River System

Operations on the Columbia River must take into account diverse interests and a broad spectrum of agencies and river users. This fact demands an integrated approach to planning and operations among the projects. This is known as "coordination."

The Coordinated Columbia River System refers to projects operated under three separate but related arrangements: the Pacific Northwest Coordination Agreement, the Columbia River Treaty, and Federal flood control statutes. In general, the planning and operations described throughout this document refer to the Coordinated Columbia River System.

Not all the projects in the system are covered by all three arrangements and authorities. But all are operated in a coordinated manner that combines the **multiple uses** and increases the benefits to the people of the western United States and Canada.

A fish counter tallies the number of fish that pass up the ladder at each dam. Fish protection figures prominently in all operating decisions.

Planning accounts for water removed from the river system to irrigate crops.

The maintenance of major equipment such as rewinding a generator at Hungry Horse Dam is also considered in planning for coordinated river operations.

III. The Agencies and the Operating Agreements

A. The Project Operators

The Corps, Reclamation, and BPA play critical roles in directing river operations.

Priority Rights: Publicly owned entities have priority over private entities to purchase the power generated at Federal projects. This priority right, granted by Federal law, is called "preference"; public and cooperative utilities that purchase power from BPA are called "preference customers."

Operating Requirements: These are the limits within which a reservoir or dam must be operated. Some requirements are established by Congress when a project is authorized; others evolve with operating experience.

Three Federal agencies, the U.S. Army Corps of Engineers (Corps), the U.S. Bureau of Reclamation (Reclamation), and the Bonneville Power Administration (BPA), play critical roles in directing operation of the Coordinated Columbia River System.

U.S. Army Corps of Engineers. The Corps operates 12 of the 14 projects under study in the System Operation Review and thus has a major part in coordinating multiple-purpose use of the system. The Corps is responsible for flood control at all major reservoirs in the Columbia River Basin. In addition, the Corps maintains navigation channels to accommodate barges and other river traffic.

U.S. Bureau of Reclamation. Reclamation operates Grand Coulee and Hungry Horse Dams, two of the storage projects that are included in the System Operation Review. Because of its size and key location, Grand Coulee Dam plays a prominent role in the

coordinated operation of the Columbia River system. Reclamation also operates numerous water resource projects throughout the Columbia Basin, which provide irrigation and other multiple uses.

Bonneville Power Administration. BPA was created in 1937. The agency markets and distributes power generated at Federal dams on the Columbia River and its tributaries. The agency sells power from the dams and other generating plants to public and private utilities and direct service industries, and it builds and operates transmission lines that deliver the electricity. Federal law requires BPA to give **priority rights** to electricity produced at the Federal dams to publicly owned utilities and to entities in the Northwest.

The Corps and Reclamation develop **operating requirements** for their projects, and within these limits, BPA schedules and dispatches power. This process requires continuous communication and coordination among the three agencies.

Irrigation Districts. Irrigation districts also operate and maintain water resource facilities in the basin, such as storage and diversion dams, pumping plants, and canal and pipeline distribution systems. Some irrigation district facilities are privately owned, and some were constructed by Reclamation and are operated by the districts under contract.

Public and private utilities. Public utility districts, municipal utilities, and investor-owned utility companies also own and operate dams and generating projects in the Coordinated Columbia River System. These owners plan and coordinate their operations with the Federal agencies.

British Columbia Hydro and Power Authority. B.C. Hydro is a Canadian member of the reservoir management team. This Canadian crown corporation controls projects on the upper Columbia River in Canada that provide storage for flood control and power generation. These huge projects contain over one-third of the storage on the system and are operated for the joint benefit of Canada and the United States.

B. The Forecasters, Regulators, and River Users

There are many other agencies and organizations that have no operating responsibilities with regard to Federal projects, but which play a part or have a major stake in how the Columbia River system is managed. These agencies are listed on the next page. Appendix B provides a more in-depth look at what they do.

Operators need accurate forecasts of weather and water conditions in the Columbia River Basin in order to manage the coordinated system for maximum benefit. There are two general types of forecasts required: water supply forecasts, which predict the amount of runoff expected; and

Many agencies and organizations have a stake in river management.

Water from snowmelt and rainfall is the essential ingredient in all river operations. The depth and water content of the winter snowpack are used to forecast the volume of spring runoff.

Dynamic policies govern planning and operations.

Authorizing Legislation: Congress must approve the construction of all Federal water projects. The legislation that authorizes the project spells out its purposes, the agency in charge of construction and operation, and the terms of financing under which it will be built and operated.

The U.S. Soil Conservation Service performs snow course surveys to collect data about the annual snowpack. The measurements are analyzed and translated along with other data into forecasts of the volume of runoff that can be anticipated in the Columbia River system.

rate-of-flow forecasts, which project streamflows. Several organizations have a hand in collecting and analyzing information that goes into these forecasts. Among them are:

- Columbia River Forecasting Service.
- National Weather Service's Northwest River Forecast Center.
- U.S. Geological Survey.
- U.S. Soil Conservation Service.
- Columbia River Water Management Group.
- Northwest Power Pool.

Among the agencies that act in a regulatory or advisory capacity to Columbia Basin project operators are:

- Federal Energy Regulatory Commission (FERC).
- State water resource agencies.
- National Marine Fisheries Service.
- U.S. Fish and Wildlife Service.
- State fish and game agencies.
- Indian Tribes.

There are dozens of agencies, organizations, and coalitions that use the river and its resources or have an interest in the way the river system is managed. Their opinions on

Columbia River water management issues are diverse, and representatives from many of these groups participate in public hearings, meetings, and other forums that address river operations.

C. The Operating Agreements and Guidelines

Planning and operations on the Coordinated Columbia River System are guided by a complex and inter-related set of laws, treaties, agreements, and guidelines. While some of the laws have been in effect for many decades, the governing policies are dynamic, and important additions have been made in recent years.

Congress specified the major intended uses in the **authorizing legislation** for each Federal hydro project. Most were authorized for one or more purposes including flood control, navigation, irrigation, and power production. However, the laws seldom contain explicit provisions for

operating individual projects or for their coordinated operation within the total system. The Corps and Reclamation are responsible for deciding how to operate their projects based on principles of multiple-use operation, their agency charters, operating experience, and public concerns. The Federal agencies and other project operators have developed principles and agreements among themselves; some are in formal contracts, and some are informal.

Among the laws and agreements that have a direct bearing on system operation are the following:

National Environmental Policy Act. The 1969 National Environmental Policy Act (NEPA) requires environmental scrutiny of actions proposed by Federal agencies. Under NEPA, an environmental assessment or environmental impact statement (EIS) must be prepared, and public hearings held, for any proposed action that might affect the environment. Renewal of the expiring power agreements being considered in the System Operation Review and significant modification of existing operations fall under the

provisions of NEPA.

Columbia River Treaty. The Columbia River Treaty between the United States and Canada provided for building four storage reservoirs: three in Canada (Mica, Keenleyside, and Duncan) and one in the United States (Libby). The reservoirs built and operated under the Treaty represent almost half the water storage on the Coordinated Columbia River System.

The Columbia River Treaty, signed in 1961 and put into effect in 1964, grew from the recommendations of an **International Joint Commission** which studied whether an extension of the use of the Columbia River would be practical and in the interests of both nations.

Concurrent with the Commission's study, the Corps began updating its master plan for development on the Columbia River. Both efforts indicated that additional storage on the upper reaches of the river would be of joint benefit for flood control and power production.

The Treaty dams added much needed **flood control** along the entire

International Joint Commission: The IJC was established to study and resolve issues on river basins shared by Canada and the U.S. In 1944, the IJC was asked to study expanding the uses of the Columbia River. The Commission formed an engineering board, and the board's report led to the Columbia River Treaty.

Flood Control: Streamflows in the Columbia River Basin can now be managed to keep water below damaging flood levels in most years. This level of flood control is possible because storage reservoirs on the river can capture and store heavy runoff as it happens.

The Treaty dams added much needed flood control.

Mica Dam, shown here under construction, is one of three Canadian projects that are among the most recent major water projects built on the river system. They have greatly increased the ability to control streamflows.

The Coordination Agreement calls for annual planning of reservoir operations.

Federal Project Operators: The U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation operate Federal water projects in the Columbia River system and are known as the project operators.

Parties to the Coordination Agreement have developed and use a variety of computer modeling techniques to plan for upcoming power production and to guide system operation.

river, and they also made it possible to deliver it with more reliability. The benefits of the projects were divided between the two nations in related agreements. The Treaty does not specify an end-date. Instead, either country has the option to terminate the Treaty after 2024.

Pacific Northwest Coordination Agreement. The Coordination Agreement was inspired by the Columbia River Treaty. It is a complex contract for planned operation among the **Federal project operators** and power generating utilities of the Pacific Northwest. It was signed in 1964 and expires in 2003.

The Coordination Agreement calls for annual planning, which must accommodate all the authorized purposes of the Columbia River hydro projects. It also must recognize project and system requirements that are frequently changing to serve multiple river uses. Individual project owners set requirements for using their own reservoirs. All Coordination Agreement parties coordinate to meet system requirements. Power

generation, which is planned under terms of the Agreement, complies with these requirements. The Coordination Agreement planning process, which establishes day-to-day power operations and associated transactions, is spelled out in Section G. of Chapter V.

Parties to the Pacific Northwest Coordination Agreement

- **Federal Agencies:** BPA, Corps, and Reclamation.
- **Private Utilities:** Portland General Electric, Pacific Power & Light, Puget Sound Power & Light, Washington Water Power, and Montana Power.
- **Municipal Utilities:** Seattle City Light, Tacoma City Light, and Eugene Water & Electric Board.
- **Public Utility Districts:** Grant County PUD, Chelan County PUD, Douglas County PUD, Pend Oreille County PUD, Snohomish County PUD, and Cowlitz County PUD.
- **Private Company:** Colockum Transmission Company, a subsidiary of Aluminum Company of America (ALCOA).

Columbia Storage Power Exchange and the Canadian Entitlement Allocation Agreements. Water released from reservoirs in Canada is used to produce power at dams in the United States. The Columbia River Treaty divides power benefits between Canada and the United States. Canada sold its share of the power for the first 30 years of project operation. Forty-one utilities in the United States formed the Columbia Storage Power Exchange (CSPE) to purchase the Canadian power benefits, beginning in 1968. **CSPE utilities** receive Canadian power from BPA and three mid-Columbia public utility districts with projects on the mainstem Columbia River.

The Canadian Entitlement Allocation Agreements are contracts that divide the Treaty's power benefits and obligations among the non-Federal beneficiaries in the United States. There are five Allocation Agreements, one for each of the five public utility district-owned dams on the mid-Columbia. These dams are Wells, owned by Douglas County PUD; Rocky Reach and Rock Island, owned by Chelan County PUD; and Wanapum and Priest Rapids, owned by Grant County PUD.

The agreements determined how much power each of the five utilities will generate from Canadian flows for delivery to the CSPE utilities. These agreements, which begin to expire in 1998, are being renegotiated to establish future obligations regarding Columbia River Treaty power benefits.

Non-Treaty Storage Agreement. In 1984, BPA and B.C. Hydro signed a 10-year agreement to coordinate the use of an additional portion of the water stored in the reservoir behind Mica Dam in southeastern British Columbia. Since this was water storage not covered in the Columbia River Treaty, the agreement is referred to as the "Non-Treaty Storage Agreement."

The two agencies agreed in 1990 to expand the Non-Treaty Storage Agreement and extend it until 2003. The new agreement more than doubles the amount of water storage covered under the previous agreement, from 2 million acre-feet to 4.5 million acre-feet. The power generating capability represented by the storage will be shared equally by BPA and B.C. Hydro.

In addition to BPA and B.C. Hydro, the owners of the five non-Federal mid-Columbia hydroelectric

CSPE Utilities: The Columbia Storage Power Exchange is made up of four private utilities and 37 public utilities in the Northwest. In 1968, these utilities purchased Canada's downstream power benefits for 30 years with tax-exempt revenue bonds.

Allocation agreements divide the power benefits and obligations among U.S. parties.

Storage Allocation at Mica Dam

The Columbia River Treaty and subsequent storage agreements govern how water held behind Canadian dams will be used. Mica Dam, the largest of the Treaty storage projects, is located near the headwaters of the Columbia and plays a pivotal role in storage operations.

The Northwest Power Planning Council is responsible for preparing a Fish and Wildlife Program, which is intended to protect, mitigate, and enhance the Columbia River Basin's anadromous fish runs. The program was adopted in November 1982 and amended in October 1984 and February 1987.

The Northwest Power Act called for a Fish and Wildlife Program.

projects and their power purchasers are interested parties to the Non-Treaty Storage Agreement and share its obligations and benefits. BPA has completed a companion agreement with these owners, and with many of the utilities that purchase power from these projects, because the hydropower benefits represented by the new Non-Treaty Storage Agreement depend on the cooperation of the mid-Columbia dam operators.

In October 1990, BPA signed a related agreement with the Columbia Basin Fish and Wildlife Authority, which represents Northwest fish and wildlife agencies and 13 Indian Tribes. That pact aims at assuring, through operating guidelines and regular communication, that use of non-Treaty storage water will pose no significant risks to fish.

Pacific Northwest Electric Power Planning and Conservation Act of 1980. The Northwest Power Act was passed by Congress on December 5, 1980. This law created the eight-member Northwest Power Planning Council. The governors of the four

Northwest states—Idaho, Montana, Oregon, and Washington—each appoint two members. The Council was entrusted with adopting a Fish and Wildlife Program for the Columbia Basin by November 1982 and preparing a 20-year Regional Electric Power and Conservation Plan by April 1983. The plans are periodically updated.

The Council's Fish and Wildlife Program established a number of goals for restoring and protecting fish populations in the basin. These goals have led to changes in how the Coordinated Columbia River System is operated. One of the most notable is the Water Budget, which provides for the release of specific amounts of water in the upper Columbia and on the Snake River to aid the spring downstream migration of juvenile salmon.

Other Agreements. There are two other agreements that enhance fish survival. The Vernita Bar Agreement and the Long-Term Spill Agreement modify river operations at certain times of the year for the benefit of salmon and steelhead; see Section B. in Chapter V. for more detail.

Some wild fish runs are so depleted that petitions were filed seeking to have five species declared threatened or endangered under Federal law.

Endangered Species Act. In 1990, five species of salmon that live in the Columbia and Snake Rivers were petitioned for protection under the Federal Endangered Species Act. A regional task force called the Salmon Summit, made up of utilities, government leaders, environmental groups, irrigators, navigation interests, and others, began work to develop a plan to conserve and protect these fish. Some protective measures, including increased **flow** and **reservoir drawdowns**, have been implemented, and others are under study. These measures require changes in system operations and affect other river uses.

Flow: Agencies have agreed to increase the flow to levels exceeding those needed for other uses at certain times and at certain places to aid migrating fish.

Reservoir Drawdown: The water levels in a reservoir can be lowered, or drawn down, by releases from the dam. These drawdowns have the effect of speeding up the water that flows through a reservoir by decreasing its cross-sectional area.

***The
Endangered
Species Act is
having an
effect on river
operations.***

IV. System Operation— The Big Picture

A. Hydrology of the Basin

***Runoff from
rainfall and
snowmelt fuels
the Columbia
River system.***

The climate in the Columbia River Basin ranges from a moist, mild maritime condition near the mouth of the river to a near desert climate in some of the inland valleys. The Cascade Mountain Range separates the coast from the interior of the basin and has a strong influence on the climate of both areas.

There are two important runoff patterns in the basin: the snowmelt runoff in the interior east of the Cascade Mountain Range, and the rainfall runoff of the coastal drainages west of the Cascades. In both areas, most of the precipitation occurs during the winter months.

East of the Cascades, most of the precipitation falls as snow in the mountains. Snow accumulates and water is held in natural storage until temperatures rise, causing the spring runoff. Streamflows begin to rise in

mid-April, reaching a **peak flow** during May or early June. Fluctuations in streamflow are caused by variations in sunlight and air temperature. Occasionally, rainfall adds to the runoff. Rain and snowmelt over the low-lying portions of the basin in the winter can raise streamflows and cause flooding along the lower Columbia and in some of the tributaries.

West of the Cascades, winter storms tend to bring rain rather than snow. River levels can rise within hours during major storms. Peak flows near the mouth of the Willamette Basin, which drains over 11,000 square miles, can occur within a few days of large rainstorms, with upstream points flooding within hours of a major storm. Most of the runoff occurs in the winter, from November through March, but moderate streamflows continue through the spring and early summer fed by late snowmelt from high areas and groundwater outflows.

Peak Flow: The maximum rate of flow during a specified time period at a particular location on a stream or river.

B. The Driving Functions of System Operation

Historically, the two dominant functions of the reservoir system in the Columbia River Basin have been power generation and flood control. Others added in recent years include the need to maintain high flows in certain seasons to aid the downstream migration of juvenile salmon and steelhead and the need to maintain higher lake levels for **resident fish** and summer recreation.

The demand for water from the reservoirs for power generation occurs throughout the year. It reaches a peak in the winter, when homes and businesses need heating. **Demand** is lowest in summer. Thus, from the standpoint of power generation, the objective of reservoir operation is to store snowmelt runoff in the spring and early summer, for release from storage in the fall and winter when streamflows are lower and demand is higher.

This operation is generally compatible with flood control requirements. The primary goal of flood control is to reduce high streamflows during the spring to protect areas below dams, such as the intensively developed reach of the Columbia River below Bonneville Dam.

The major migration of salmon and steelhead both upstream and downstream occurs during the spring and summer. To improve juvenile fish survival, changes have been made in the operation of run-of-river projects and at upstream storage reservoirs.

C. Overview of System Operation

All major dams and reservoirs in the Columbia River system are operated in coordination with one another to maximize the benefits provided by

Libby Dam, completed in 1975, is the key to controlling high spring runoff on the Kootenai River in Montana.

***Flood control
is a vital
function of the
reservoir
system.***

Resident Fish Fish that are permanent inhabitants of a water body. Resident fish include trout, bass, and perch.

Demand The amount of power being used at any given time. Demand in the Northwest is seasonal, with the highest use in the winter for heating and the lowest in the summer when temperatures are warmer.

Most of the water in the Columbia River system is stored naturally as snow until spring temperatures warm it and the melt begins.

Rule curves specify reservoir levels by month to meet project purposes.

Drafting: The process of releasing water from storage in a reservoir. Operators begin drafting reservoirs—through turbines or over the spillway of a dam—to lower the level for a number of reasons, including flood control or downstream flows for fish or power generation

Snowpack: The accumulation of snow in the mountains that builds up during the late fall and winter

the storage reservoirs. All of the projects included in the System Operation Review are located east of the Cascade Mountains. The information below pertains to these reservoirs.

Reservoirs in a Nutshell. In the late spring and summer, the reservoirs east of the Cascades fill with water. They are held as full as possible through the summer to enhance recreation and conserve water for later use. Some drawdown of reservoir storage, however, may occur in the summer for irrigation, water supply, and power generation.

Drafting of the reservoir system accelerates early in the fall, when temperatures and streamflows begin to drop. At this time, power demand increases and recreational use of the lakes and reservoirs decreases. Drawdown must also begin in the fall so there is storage space available for winter flood control.

The reservoirs reach their lowest elevations in March to early May. Snowmelt typically begins to increase significantly about mid-April and reaches a peak in June. A portion of the resulting high flows is stored to reduce flood danger and to refill the reservoirs.

Rule Curves. Reservoirs are operated according to guidelines called rule curves. Rule curves specify reservoir water levels that are desirable for each month and provide guidance in meeting project purposes. They assure adequate space is available for flood control, that there is enough water to

meet electric power demands and to protect migrating fish, and also to provide reasonable assurance that reservoirs will refill each year.

System operators develop rule curves at the start of each operating year and update them as the year progresses and more information on **snowpack** and streamflow becomes available. Each reservoir has several sets of curves. Some curves set a maximum elevation, while others set a minimum. The curves are used to operate individual reservoirs as well as the total coordinated reservoir system.

Three Seasons of Operation. The operating year for the Columbia River system can be divided into three seasons:

August through December: in the fixed drawdown period, reservoirs are operated according to predetermined rule curves because runoff forecasts from the snowpack are not available until January.

January through March: in the variable drawdown period, operation of the reservoirs is guided by the runoff forecasts. During this period, reservoirs are drafted to provide flood control space and to meet power needs. They are also drafted to generate as much additional energy as possible. But enough water must be retained in storage for spring fish flows and to ensure a high likelihood of reservoir refill by summer.

April through July: in the refill season, reservoirs store spring runoff. This is also the season when water is

Three Seasons of Reservoir Operation

August through December

Fixed Drawdown: During the late summer and fall when the volume of the next spring runoff is unknown, reservoir operations are guided by fixed rule curves that follow historical patterns.

January through March

Variable Drawdown: Spring runoff forecasts are available beginning in January. They are the basis for rule curves that guide operations through the runoff and refill season.

April through July

Refill Season: Operators focus on capturing enough runoff to refill reservoirs by the end of July. When runoff is low, reservoirs may not refill, and future operations are partially shaped by how low reservoir levels are on July 31.

Reservoirs are operated seasonally based in part on historical runoff patterns.

Streamflow studies are made before each new operating year.

Nonfirm Energy: Energy planners separate energy from the hydro system into firm and nonfirm. Firm energy is produced on a guaranteed basis with critical water conditions. Nonfirm energy is the energy that can be generated with water that is available in excess of what is needed for firm energy generation.

Firm Energy Demand: The amount of energy the system will be called upon to produce to meet the region's expected load.

released to help young salmon and steelhead migrate to the sea. Operations for flood control and power sales continue as needed.

Before each new operating year begins in August, streamflow studies are made to derive the rule curves for the multipurpose operation of the dams on the river and to predict how much energy could be produced during the coming year under different water conditions. Once the basic operating guidelines are set, actual operation of the system over the year is based on meeting several related but sometimes conflicting objectives:

- Providing adequate flood storage space for control of the spring runoff.
- Maintaining a high probability that reservoirs will refill to meet recreation needs and to provide water for next year's power operations.
- Providing flows to aid downstream migration of juvenile fish.
- Maximizing power generation within the requirements imposed by other objectives.

Because natural streamflows are

When runoff is high, BPA markets extra power to customers within and outside the region.

typically very low in the late summer and fall, and because of the uncertainty regarding future runoff, reservoir operation in August through December typically follows operating curves quite closely. Sometimes more rain causes higher flows in the fall. This water can be used to produce **nonfirm energy**, or the water can be left in storage for future use. If abundant water is available from January through March, the water will either be used to generate nonfirm energy or be stored, depending on flood control needs.

In a year with a lighter than normal snowpack, it may be necessary to draft reservoirs to levels jeopardizing refill in order to get enough power to meet **firm energy demand** in the region or to meet other obligations, such as the Water Budget. In about one year in four, runoff is so low that reservoirs in the system fail to refill. If this occurs, optional power sales cease, and power generation from the hydro system is limited to what was committed to in annual Coordination Agreement planning (see Section G. in Chapter V).

Historical patterns are well established, but there is always uncertainty about future runoff.

Forecasts of high runoff mean reservoirs must be drafted during the winter so there is adequate space to control flood waters in the spring.

Indicators, like this one at Libby Dam, are used to gauge the water level at each reservoir. Efforts are made to refill the reservoirs every year. Runoff is usually adequate to refill reservoirs about three out of every four years.

V. System Operation— The Details

Most operating requirements are defined by river flow or water surface elevation.

Operation of the Columbia River system must take into account operating requirements that exist for each project. When a water project is designed, operating requirements that relate to the physical features and functions of a dam and its surrounding environment are often defined. For example, a requirement may specify the lowest allowable reservoir elevation for a project for use of a boat ramp or to accommodate wildlife concerns. Sometimes requirements are included in the authorizing legislation for Federal projects or in the FERC operating license for non-Federal projects.

Almost all operating requirements are defined in terms of river flow or water surface elevation (lake or downstream). Operating require-

ments for project flows include: minimum instantaneous discharge, minimum daily discharge, and maximum hourly and daily rates of change. Operating requirements for reservoir elevations include: minimum and maximum reservoir levels, downstream water surface elevations, and maximum hourly and daily rates of change.

Operating requirements can be either site-specific or systemwide. Most are site-specific, meaning they apply to only one project or one location on the river. Systemwide requirements affect more than one project.

Flows for Steelhead. Sometimes a project's limits and requirements are defined after it is authorized. For example, at Dworshak Dam, a "prime steelhead harvest season" was established for a 45-day period beginning

The Columbia River historical runoff record, as measured at The Dalles, Oregon, is depicted on the hydrograph that begins at the bottom of this page and continues throughout this chapter. The flow is shown in thousands of cubic feet per second.

October 1. The requirement (set after the project was authorized but before it was built) increased public support for the project because it provided for a period of nearly natural streamflows below the dam for steelhead fishing. New requirements also are developed through studies and discussions with the public and other agencies.

In the following pages, the categories of operating requirements that must be factored into Columbia River system planning and operation each year are outlined in detail.

A. Flood Control

The Pacific Northwest has two principal flood seasons. November through March is the rain-produced flood period. These floods occur most frequently on streams west of the Cascade Mountains.

May through July is the snowmelt flood period. East of the Cascades, snowmelt floods dominate the runoff pattern for the Columbia Basin. The most serious snowmelt floods

Most snowmelt runoff in the basin occurs from May through July.

Operating Requirements at Grand Coulee

There are many operating requirements for each Federal project. The requirements at Grand Coulee specify reservoir elevations and discharge limits which operators must follow.

The Columbia River community of Vanport, Oregon, was destroyed by a flood in 1948. It was never rebuilt. Once common occurrences floods on the lower river can now be kept in check by reservoir operations upstream.

Snowmelt and rainfall can combine to produce devastating floods.

Kootenai and Kootenay. The Kootenai River is a tributary of the Snake River. The Kootenay River is a tributary of the Columbia River. Both rivers are subject to flooding during the spring snowmelt season.

develop when extended periods of warmer weather combine with a large accumulation of winter snow. Some of the worst floods result when heavy rains fall during a heavy snowmelt.

Flood damage potential is greatest in the lower Columbia from the Portland-Vancouver area to the mouth of the river. This area suffers winter rainfall floods from the Willamette River as well as snowmelt floods from the Columbia.

Flood damage in the past has also occurred along the Flathead River near Kalispell, Montana; the **Kootenai** River between Bonners Ferry, Idaho, and **Kootenay** Lake; the Pend Oreille River below Albeni Falls; the Columbia River near Kennewick-Pasco-Richland, Washington; and the lower Clearwater River near Lewiston, Idaho. Although many streams in the basin remain uncontrolled, reservoirs

on the major rivers are now able to minimize flood damage in most of these areas.

Organizing for Flood Control. Early efforts to control floods in the region were organized locally in places subject to frequent damage. Levees and floodwalls were built to protect floodprone areas along the lower Columbia River and elsewhere.

After the tragic flood of 1948 that destroyed Vanport, Oregon, the Corps developed a multiple-use reservoir storage plan for the Columbia River Basin, with flood control as a major objective. This plan has evolved over the years, with the projects authorized by the Columbia River Treaty bringing the system up to the desired level of protection.

Presently, up to 39.7 million acre-feet of storage space can be made available for flood control from the

Coordinated Columbia River System, including 20.5 million acre-feet at the three Canadian Treaty projects. This reservoir storage is supplemented by a system of local **levees, flood walls, and bank protection**. In addition, many areas have adopted measures such as land use regulation and improved land treatment practices to minimize flood damage potential.

Flood Control Operation. Floods occur when rivers overflow their banks. The objective of any flood control operation is to capture enough runoff in reservoirs to keep streamflows from reaching damaging levels. Timing is critical. Filling of storage reservoirs must be timed so flows are reduced when runoff is highest.

In many parts of the country, floods can occur in any season, so flood control space must be available year-round. In the Columbia River Basin, however, flood flows are limited to two periods: rain-induced floods in the winter, and snowmelt floods in the spring and early summer. Furthermore, the magnitude of the greatest source of flooding on the Columbia—snowmelt—can be predicted several months in advance with fairly high accuracy.

As a result, **flood control storage space** in Columbia River reservoirs is kept only during those months when flood risk exists, and the amount of space needed depends on how much runoff is expected. This situation makes it possible to use reservoir space for storing water for hydropower, irrigation, recreation, and other purposes during periods when there is no flood risk and to use the space jointly for flood control and the other purposes during the flood season. This is the concept of joint-use storage that is put into practice for the reservoirs of the Coordinated Columbia River System.

Levees, Flood Walls, and Bank Protection. A levee is a raised embankment built to keep out flood waters. Flood walls, such as the concrete seawall along the Willamette River in downtown Portland, are barriers constructed to hold out high water. The soil on river banks is protected from erosion in a variety of ways. River grasses and trees are cultivated in some areas, and fine mesh screens are laid on banks in other areas to keep soil in place. Rock revetments are also used to protect against fast moving streams or vigorous wave action.

Flood Control Storage Space: The space that is provided in a storage reservoir to allow for the capture of runoff that could otherwise cause flood damage.

Timing is critical to keep rivers from overflowing their banks.

Flood control operations reduce the probability of property damage by capturing excess runoff in reservoirs and releasing it over time.

The reservoir system is operated in most years to limit peak flows to 450,000 cubic feet per second at The Dalles, Oregon.

Operating Objectives. Flood control operation has two objectives: operating the total reservoir system to minimize damaging flows on the lower Columbia River, and operating individual reservoirs to minimize damage to local areas.

The first objective—system flood control—reduces peak flows on the lower Columbia. Streamflow measured at The Dalles, Oregon, is the control point for this operation. The target flow level varies, depending on the runoff forecast. In years of low to moderate runoff, the reservoir system can be operated to limit peak flows to a maximum of 450,000 cfs at The Dalles, the level above which damage begins to occur in areas not protected by levees.

There are over 20 levee systems along the lower Columbia, with varying protection capabilities. Some are designed to sustain flows of 800,000 cfs or more. Others can fail at flows as low as 600,000 cfs, which is considered the “major damage”

threshold for the lower Columbia.

Control to this level can be accomplished in high runoff years using a combination of space in United States reservoirs and the 8.4 million acre-feet of Canadian Treaty storage that is available at no additional cost. To control very large floods, the U.S. may choose to pay for additional storage in Canadian reservoirs.

The second objective—controlling local floods—requires consideration in both winter and spring. Each reservoir’s fall and winter drawdown schedule is designed to provide space for controlling local rainfall floods as well as snowmelt floods. Generally, during spring floods, storage of runoff for system control provides protection for local areas as well.

Flood Control Rule Curves. Flood control rule curves, also called Upper Rule Curves, specify the amount of storage that must be evacuated during the fall and winter to meet the objectives outlined above. These curves indicate the maximum reservoir

Levee systems provide another method of flood protection. There are over 20 levee systems in the lower Columbia River, and in high water years, they add another layer of security for residents in flood prone areas.

elevation that must not be exceeded. The elevation depends on the magnitude of the flood threat at that particular time.

Flood control rule curves have a fixed component, which usually defines operation during September through December, when less predictable floods occur. Evacuation of reservoirs must begin in this period to ensure that space will be available when needed to control floods. Run-off forecasts are not available during this period, so the curve is based on a statistical analysis of historical events.

The variable component of flood control rule curves defines operation from January through April, when spring snowmelt flooding is more predictable. In January, forecasts of seasonal runoff become available. This allows the variable portion of each project's flood control rule curve to be defined. It is based on the amount of runoff expected to occur, and thus it indicates the amount of reservoir storage space needed to control floods for the rest of the **operating year**.

The flood control rule curve is developed using the project's **storage reservation diagram**, which specifies the amount of storage required to protect against a wide range of runoff forecasts. The flood control curves are updated monthly as revised forecasts become available.

Flood Control During Refill. From April through July, reservoirs are allowed to refill gradually, at a rate that maintains downstream flows at acceptable levels. To guide this operation, the Corps uses a computer model that forecasts runoff and simulates reservoir operation on a daily basis. In moderate to high runoff years, careful monitoring is required to ensure that damaging flows do not occur.

Flood Control Requirements

The storage reservation diagram is one of the tools operators use to assure there is adequate flood control space in each reservoir. The diagram shown here specifies the amount of storage required to protect against a range of runoff forecasts, from a dry to a wet year.

Flood control needs are balanced with the goal of refilling reservoirs.

Operating Year: Detailed operations are planned over a 12-month period. The operating year begins on August 1 and ends on July 31.

Storage Reservation Diagram: Each storage reservoir has its own storage reservation diagram, which shows the pool levels that need to be maintained given various runoff predictions.

Rushing water attracts fish to fish ladder entrances.

Anadromous Fish: Certain species of fish are born in freshwater and as juveniles, migrate to saltwater. They reach adulthood at sea, and return to their freshwater birthplace to reproduce. These fish are called anadromous.

Ratepayer-funded hatcheries put millions of salmon smolts into the river each year. This practice augments the natural fish stocks that have declined rapidly in recent years.

All Federal dams on the lower Columbia and lower Snake Rivers have fish ladders similar to this one to aid fish migrating up the river.

In other years, cool weather and other conditions result in a prolonged runoff, so the potential for flood conditions is never realized. In those years, other considerations, such as refill requirements, water releases for fish, and power generation opportunities, heavily influence refill operation.

Actual Operation. Flood control rule curves define the minimum amount of storage space that must be provided at each project to meet system and local flood control needs. In actual operation, reservoir levels tend to be somewhere between the flood control rule curves and the somewhat lower limits established for power operation. The rule curves for power generation are described in Section G.

B. Fish and Wildlife

The Columbia River Basin is world-renowned as a producer of salmon and steelhead, two types of **anadromous fish**. But the abundance of these fisheries is not what it used to be. Irrigation, timber harvesting, commercial fishing, mining, pollution, power production, flood control, and other factors related to human population increases have contributed to the decline of the anadromous fish population in the basin.

Blockage of the upstream passage of adult fish by the dams was recognized before construction began. To reduce this effect, fish ladders were built at middle and lower Columbia

and lower Snake River dams. The dams are operated to provide rushing water near the fish ladders. This attracts migrating fish to ladder entrances.

Dams have delayed **fish migration** and blocked access to hundreds of miles of spawning and rearing areas. Many juvenile fish are killed when they pass through reservoirs or turbines as they migrate downstream.

Because of the value of salmon and steelhead to the Northwest economy and the intense public concern for these fish, numerous efforts have been launched to protect and enhance them. The Council's Fish and Wildlife Program has provided for building bypass facilities, primarily to aid downstream migration of juvenile fish. It has led to construction of more fish hatcheries, habitat improvements, and screening of irrigation diversions. The program has also helped forge agreements that change the way the river is operated so fish and wildlife are better protected.

The Water Budget. In the early 1980's, the Council, in consultation with Congressional leaders, project operators, fishery agencies, Indian Tribes, and Northwest utilities, decided to establish the Water Budget. It is a specific amount of water used to increase river flow during the spring, the major juvenile fish migration period. The Fish Passage Center, representing fisheries agencies and Tribes, requests reservoir operators to release the water between April 15 and June 15 to aid fish migration.

The increased flow helps "flush" fish down the river and reduces their exposure to predators and other hazards in reservoirs. Under the Water Budget agreement, up to 4.64 million acre-feet of water can be released each

Screens are placed at the entrance to irrigation canals to keep fish from being diverted into channels that carry water away from the river.

Bypass facilities aid downstream migration of juvenile fish.

Fish Migration: Anadromous fish migrate both up and downriver. When juveniles move to the ocean, it is called outmigration; when adults return to spawning grounds, it is sometimes referred to as immigration.

Water Budget

April 15-June 15

The Water Budget, begun in 1982, provides additional flow in the spring to move juvenile salmon downriver to the ocean. Some of the water is stored at upstream projects on the Snake and Columbia Rivers until it is called for by the Fish Passage Center.

The Water Budget provides higher flows to aid migrating fish.

Freshet: The heavy runoff that occurs in the river when streams are at their peak with spring snowmelt. Before the dams were built, these freshets moved spring juvenile salmon quickly downriver.

Spill: Water released from a dam over the spillway instead of being directed into the turbines.

year to help young salmon and steelhead travel through the reservoirs of the lower Snake River and the middle and lower Columbia River. Providing the Water Budget means that power generation is sometimes reduced during the winter to ensure enough water is available in the spring.

Water Budget releases partially restore the effects of a spring **freshet**, the kind of heavy runoff that occurred before the dams were built. In years when runoff is low, the Water Budget is especially important to help migrating fish move downriver. The Water Budget is used to achieve target flows at specific points on the river system. Currently, Priest Rapids Dam on the Columbia River and Lower Granite Dam on the Snake River are the monitoring points. Since Priest Rapids and Lower Granite have no storage of their

own, the Water Budget flows must come from natural flows and releases from upstream storage projects, such as Grand Coulee, Dworshak, and Brownlee.

The Water Budget is not a site-specific requirement at any upstream project. It is a systemwide requirement that is built into the rules that guide project operations.

Long-Term Spill Agreement. In 1989, fisheries agencies, Indian Tribes, and BPA signed a Long-Term **Spill** Agreement, which established a plan for spilling water to protect juvenile salmon and steelhead migrating from their spawning grounds to the ocean. The Council's Fish and Wildlife Program calls for a 90 percent salmon survival rate at each dam on the Columbia River by using spill during most of the spring and summer migration.

The spill agreement provides that a specific amount of water be passed over the spillways of four Corps projects—Lower Monumental, Ice Harbor, John Day, and The Dalles—in the spring and summer to protect young fish. When water is spilled, fish are drawn with it, passing them over the spillways instead of through the turbines.

The spill agreement was adopted as a temporary measure to improve juvenile fish passage for 10 years or until permanent juvenile fish bypass facilities, such as screens, can be installed at these dams. The Corps did not sign this agreement and retains the authority to decide if and when spill will occur at its projects from year to year.

The Water Budget and spill are both measures to help fish, but they are quite different. The Water Budget moves fish between dams, while spill is used to move fish over dams.

Vernita Bar Agreement. Under an agreement signed in 1988, operators provide certain flow levels from fall to early spring to protect and preserve salmon spawning and hatching at Vernita Bar below Priest Rapids Dam. This is the last remaining major **fall chinook salmon** spawning area on the mainstem of the Columbia River.

In the past, operators of Federal projects had informally cooperated to ensure lower flows over Vernita Bar during the fall spawning period and higher flows in the winter while eggs are incubating. The Vernita Bar Agreement made formal the efforts by Grant County PUD, BPA, and others to deliver flows needed to encourage and protect salmon spawning at this location.

Other Fish and Wildlife Measures.

Five Corps projects (Bonneville, John Day, McNary, Little Goose, and Lower

Fall Chinook Salmon: This salmon stock returns from the ocean in late summer and early fall to head upriver to its spawning grounds, distinguishing it from other stocks which migrate in different seasons.

When water is spilled, fish are drawn over the spillways and away from turbines.

The fall chinook spawning grounds at Vernita Bar upstream from the Tri-Cities, Washington, are protected by a special agreement, known as the Vernita Bar Agreement.

Dam Cross-sections Showing Various Pathways for Fish

This cross-section of a typical run-of-river dam shows the water intake (penstock), the turbine generator which is spun by the falling water, and the water outlet (tailrace).

The spillway is the overflow structure on the dam where water passes over and down a concrete chute. The amount of water passing over the spillway is controlled through gates.

**Left
uncontrolled,
squawfish will
dine heavily on
juvenile
salmon.**

Squawfish: A giant member of the minnow family, the northern squawfish is native to the Columbia River and its tributaries. Studies show a squawfish can eat up to 15 young salmon a day.

Flip Lip: A structural device that redirects water as it comes over the spillway of a dam. Flip lips reduce deep plunging of water into the pool below, this keeps the water from becoming supersaturated with nitrogen. Fish are naturally attracted to the rapidly moving water at the base of the dam, but can succumb to gas-bubble disease when the water is supersaturated with gas.

Granite Dams) have been equipped with bypass facilities. These divert juvenile fish away from turbine intakes and into special conduits or sluiceways where they can either be bypassed around the dam or collected for transport downstream. Barges or tank trucks are used to move the fish from the collector dams (McNary, Little Goose, and Lower Granite) to release sites below Bonneville Dam.

Putting Bounties on Squawfish. A pilot project to control **squawfish**, a prime predator of juvenile fish, was conducted in 1990 at the John Day reservoir. It has since been expanded to seven other reservoirs and the Columbia River below Bonneville Dam. Commercial and sport anglers are paid a bounty for each squawfish caught and turned in at a squawfish check station. This project shows

great promise for increasing juvenile salmon survival.

Controlling Fish-killing Gases. Project operators are working to solve the problem of nitrogen supersaturation. When runoff is high and water is spilled that would otherwise go through turbines, large amounts of air become trapped in the water. This water, which is supersaturated with dissolved gases (principally nitrogen), can kill fish. **Flip lips** have been installed on the spillways at some of the dams to reduce the plunge of water into the basin below.

Project operators also work with fisheries agencies to reduce nitrogen supersaturation with "spill transfers." Supersaturation and spill are reduced and power generation is increased at one project where gas entrainment is a problem to migrating fish. Power

Fish ladders are a series of gradual steps that enable fish to swim around or over a dam. Ladders are in place at all Federal projects on the lower Columbia and lower Snake Rivers.

Bypass systems are pathways made up of pipes and conduits that carry juvenile fish that enter the penstocks away from turbines and around a dam. In some cases, bypasses guide fish to collection points where they are loaded into barges or trucks and transported downstream below other dams.

generation is decreased and spill increased at another project where fish have already migrated. The total outflows at both projects remain constant. Research on the effects of gas supersaturation on fish life is continuing so additional measures to reduce this problem can be found.

Salmon Summit Spawns Actions.

As a result of the Salmon Summit, specific actions to protect dwindling salmon stocks are being taken in 1991. These include augmenting Snake River flows and expanding the squawfish control program. Long-term conservation plans to protect and enhance these fish stocks are being discussed by Salmon Summit parties and the Northwest Power Planning Council.

Nurturing the Natives. Rivers and reservoirs are also home to native freshwater fish that do not migrate to

With the attention on wild salmon stocks, river managers and others in the region are exploring new methods for improving juvenile salmon migration.

The region is committed to protecting dwindling salmon stocks.

Many species of waterfowl, such as these Canada geese, rely on the banks of the Columbia River and its tributaries for food and nesting.

There are special operating requirements at some projects to protect native fish and waterfowl habitat.

Life Cycle of Columbia River Anadromous Fish

Salmon are anadromous fish, which means they are born in freshwater, migrate downstream to the ocean where they spend most of their lives in saltwater, and then return to freshwater to reproduce (spawn). Steelhead are anadromous rainbow trout. Both salmon and steelhead are strongly affected by the natural ups and downs of river flows that occur with the changes of seasons.

Salmon and steelhead hatch in the freshwaters of the Columbia River and its tributaries. About 50 days after eggs are laid, embryonic fish called alevins emerge. Alevins live on nutrients stored in their yolk sac until they grow large enough to find food on their own.

As young fish, or fry, they eat insects and organic matter. They quickly grow to three or four inches before seeking sheltered spots in freshwater streams to spend the winter.

As winter ends, their bodies begin changing to adapt to seawater, and the young salmon and steelhead, now called smolts, are ready to begin their migration—down the tributaries to the

Columbia River and out to sea. Most of the young fish migrate out of the river during spring and early summer, when natural water flows are highest. Once they arrive in the ocean, a trip that can take a month or two, the fish feed voraciously and grow into adults. Many are caught during the two to five years the salmon spend in the ocean.

Fish that have grown to maturity and survived the many dangers and predators at sea then begin their return journey. They undergo another set of physiological changes to allow them to return to freshwater and swim up the river. Most adults return to the same streams and tributaries where they were spawned, guided by complex homing instincts.

Once they arrive, the adult fish spawn, releasing and fertilizing their eggs. Female fish cover their nests, called redds, with gravel from the streambed. Adult salmon die after spawning, but some steelhead survive and may return to spawn again.

thesea. These are resident fish, such as trout and bass. System operators monitor water levels in the reservoirs to protect the shallow spawning habitat of resident fish as much as possible.

In the early spring, when geese are selecting their nesting sites, special operating requirements are put into effect at certain projects to keep geese away from areas that may later be inundated. For example, a reservoir level is raised periodically to keep geese from nesting too low on the bank of the reservoir, or the discharge from the dam is increased to keep geese from nesting too low on the river bank downstream. Other wildlife protection measures are currently being considered by the Council.

C. Navigation

Construction of dams greatly improved conditions for navigation on the lower Columbia and Snake Rivers, and river traffic has been extended and increased with the completion of each dam. The Columbia-Snake River Waterway from the Pacific Ocean to Lewiston, Idaho, has been developed in two segments. The first is the 40-foot-deep open river channel for ocean-going vessels, which extends 106 miles from the ocean to Portland, Oregon, and Vancouver, Washington. The second is the 14-foot-deep barge channel that extends 359 miles from Vancouver to Lewiston.

Navigation above Bonneville Dam is made possible by the eight-dam complex of locks and reservoirs from Bonneville to Lower Granite Dam near Lewiston. The channel accommodates shallow-draft tugs, barges, log rafts, and recreation boats and connects the agricultural interior basin with deep-water ports on the lower Columbia River.

Meeting Navigation Needs. Barges and other traffic plying the Columbia and Snake Rivers need minimum water depths to navigate successfully. Unlike other uses, navigation has depth requirements that do not vary with the seasons. Dam operators must regulate water releases and maintain reservoir levels to provide minimum navigation depths all year.

Operating requirements for navigation are based on the waterway's two segments. In the first segment, the open river channel from the ocean, navigation requirements can usually be met by natural river flows, without

Locks: The key to inland navigation on the Columbia-Snake River Waterway, locks raise and lower ships between pools on the river, i.e., from below a dam to the pool above it. On the trip from the ocean to Lewiston, Idaho, vessels travel from sea level through eight locks to an elevation of over 700 feet.

The river provides transportation for agricultural products from the interior basin.

Navigation Segments

A 40-foot-deep channel accommodates large ships 106 miles inland on the Columbia River to Vancouver, Washington. A combination of dams, locks, and dredging keeps a channel of 14 feet open to Lewiston, Idaho, on the Snake River, an additional 359 miles upriver.

Major Irrigation Areas in the Columbia River Basin

The Columbia and its tributaries provide a vital source of water for farmland in the U.S. and Canada.

Water from the Columbia River system irrigates about 7.8 million acres of farmland, the areas that are shaded on this map.

any special releases. Periodic **dredging** maintains the channel depth to support navigation even at normal low flows.

In the second segment, the barge channel to Lewiston, maximum and minimum reservoir elevations have been established to maintain the authorized channel depth. Thus, navigation requirements are fully met within the flexibility provided under normal system operation.

D. Irrigation

Irrigation has brought agricultural prosperity to vast arid areas of the Northwest. About 7.8 million acres are irrigated in the Columbia River Basin. Of this, 7.6 million acres are in the United States, and 0.2 million are in Canada. Besides agriculture, these figures cover irrigated lands in urban use, forest nurseries and seed orchards, recreation sites, and other non-agricultural uses.

Dredging: The Corps regularly removes sediment from the river bottom to keep the channel at the proper depth for navigation. The continual moving and shifting of sediment makes dredging an ongoing activity.

Irrigation uses approximately 6 percent of Columbia Basin flow. Much of this water eventually finds its way back into the rivers as irrigation return flows.

Water releases for irrigation are scheduled on a local basis, not as a centralized system function. Reclamation, local irrigation districts, and water companies operate most of the irrigation reservoirs in the Columbia River system.

These projects are generally operated to benefit local water users. The effect on the overall water supply from individual projects is minor. But the combined impact on the river system is important. Storing water in reservoirs to meet irrigation demands alters river flows for other uses. The effects are much larger proportionally on some tributaries, such as the Snake River, than on the main-stem Columbia.

All of these effects are accounted for in the annual studies used to guide the operation of the Columbia River system. Operating requirements for irrigation aim to have the reservoirs capture and hold as much runoff as possible during the fall, winter, and early spring.

The Growing Season. In the early part of the irrigation season, demands for water are often met by diverting natural streamflows. When natural streamflows are no longer adequate, the reservoirs are drafted to supply irrigation water. Releases continue throughout the growing season, which usually ends in September. During the winter, some projects release small amounts of water for resident fish and livestock watering. Many of the reservoirs constructed primarily for irrigation were later modified to include flood control, power, recreation, and other purposes.

Since water conditions vary greatly from year to year, demands for irrigation water also vary, as does the ability to refill the storage space in reservoirs. Sometimes it is necessary to hold water in excess of irrigation demands in a reservoir from one year to the next to assure meeting demands in subsequent low-water years.

Holding water from one year to the next depends on the available storage and competing uses for the storage. For example, in some years water in storage may need to be evacuated for flood control and so may not be available for irrigation.

When dry conditions persist over several years, there may not be enough water to meet all irrigation demands. In such cases, supplies to some users may be curtailed, depending on their water rights and storage rights, as determined by state water resource agencies.

When natural streamflows are inadequate, water is released from reservoirs to supply irrigators.

Irrigation projects supply water for a variety of crops, including orchards, nursery stock, and wheat. Many agricultural products grown in the Northwest are exported to other parts of the country and abroad and return significant economic benefit to the region.

Recreational use of the Columbia River and the regional reservoirs is increasing as the region's population grows and more visitors are drawn to the Columbia River every year. Most river programs in the Columbia River Gorge is known around the world as a mecca for windsurfers.

E. Recreation

The public uses the projects for fishing, watersports, picnicking, camping, and sightseeing.

Recreation facilities are available at many locations in the Columbia River Basin. Recreation was not identified as a major project purpose when most of the dams were built, but it has become increasingly important. It was often a key selling point to win local support for the construction of a dam. The public uses the water projects for fishing, swimming, waterskiing, picnicking, camping, rafting, boating, and sightseeing.

Recreational use of the reservoirs occurs mostly in the summer and early fall. The goal of operators is to keep storage reservoirs as full and stable as possible without jeopardizing other project uses.

Normal power generation and flood control operations are often

compatible with recreational needs at reservoirs during the summer. If runoff is low or delayed, if there are unexpected shutdowns of thermal power plants, or if forecasts prove wrong, however, reservoir levels may have to be drawn down to provide water for power generation for part or all of the summer to meet regional loads. Or, if flood control space must be provided at a reservoir in June to protect against a late runoff, refill of the reservoir could be delayed until July or early August.

Outflows from dams affect recreation activities in the river reaches below them. The amount of flow and the rate at which it changes play a large part in the success of activities such as fishing, rafting, and swimming. Reservoir operators often provide certain flows at the request of organizers of special recreational events. During

certain recreation seasons, there are limits on flow amounts and hourly changes to flows.

F. Water Supply and Water Quality

Use of reservoir storage to meet municipal and industrial water supply needs is of relatively minor consequence in the Columbia River system. The Columbia River does supply water to some cities and industries by **diversion**, but these diversions are small and have little measurable impact on system operation.

The quality of water in the Columbia River is generally very good, but there are some exceptions. Pesticide runoff in areas of heavy agriculture jeopardizes wildlife populations. Changes in reservoir operation to alleviate water quality problems are minor compared to operational changes to meet other needs. Nevertheless, there are certain water quality requirements in the tributaries and on the mainstem Columbia River that must be included in the multipurpose goals of the system.

In the tributaries, streamflows from reservoir projects must be adequate to maintain water quality requirements for aquatic life, as well as for municipal or industrial use and for water recreation. Minimum outflow requirements are specified for each project based on downstream conditions. Sometimes requirements vary with the seasons.

Adjusting Water Temperatures. Water temperature is an important consideration in project operation. In winter, stored water can be warmer than natural flows. In summer, the sun heats up surface waters in the

Diversion: Refers to taking water out of the river channel for municipal, industrial, or agricultural use. Water is diverted by pumping directly from the river or by filling canals.

Water quality must be high to sustain aquatic life and recreation.

Water from the Columbia River quenches the thirst of many residents in the region. Unlike many other rivers, it remains an excellent source of domestic water supply.

Speaking the Power Planners' Language

Planners categorize power according to a number of factors, such as whether generation can be guaranteed under various circumstances and whether the energy is surplus to the needs of Northwest customers. Some common terms are defined below.

Capacity and Energy: *Capacity* refers to the maximum amount of power a generator can produce or a power line can carry at any instant. A generator with a *capacity* of 100 megawatts can produce that amount of power when needed. However, it may rarely be run at full capacity. The same is true of an automobile engine with 350 horsepower; it can produce that maximum horsepower, but is not often required to do so. Excess capacity makes it possible to meet upswings or peaks in utility system load. *Energy* is the actual measure of generation or consumption over time. One kilowatt-hour is 1,000 watts of energy for one hour. Both a 100-watt light bulb burning for 10 hours and a 1,000-watt hair dryer for one hour are measured as one kilowatt-hour.

Firm and Nonfirm Energy: These are terms planners use to distinguish generation that is guaranteed—given the region's worst historical water conditions—from generation that depends upon better than worst-case streamflows. *Firm* energy is available even if the lowest recorded streamflows recur; *nonfirm* energy can be produced when streamflows are better than worst case, which is usually what happens. Nonfirm is also called secondary energy.

Firm surplus and firm deficit: These terms refer to supply and demand conditions. BPA has a *firm surplus* when the amount of energy the system can produce on a firm basis exceeds anticipated demand from BPA's customers. There is a *firm deficit* when the anticipated demand exceeds the firm energy that the system can produce.

Hydropower generation is the backbone of the region's electricity supply.

Temperature Control: The Corps and Reclamation have installed equipment at some dams that can regulate the temperature of water released from the reservoirs. This allows water temperature downstream in the river to be controlled. Temperature control is achieved by drawing water from different elevations in a reservoir. Cold water is drawn from deep in the reservoir; warm water is drawn from near the surface.

reservoirs, while the natural streams are often much cooler. The outlets at the storage dams generally are located in such a way that they draw water from the lower levels. As a result, water released from the reservoirs is a different temperature than in the open river. This water temperature difference can harm or benefit fish downstream of the dams.

To provide **temperature control** that benefits fish, the Corps has installed multilevel withdrawal gates at Libby and Dworshak Dams. The gates can be operated to supply water at any temperature available within the range of temperatures in the reservoirs.

G. Power Generation

Falling water is the "fuel" for power-generating turbines at the dams. Hydropower supplies approximately 75 percent of the electricity in the Northwest. It is also an important export product for BPA and the region's generating utilities, when it is surplus to their needs. The remainder of the region's electricity comes from thermal resources, primarily nuclear and coal-fired plants.

Hydropower operations are based on a determination of how much firm energy the system can generate. In most years, there is enough water in

the system to produce additional energy, called nonfirm or secondary energy.

Power production on the Columbia River system involves three primary considerations:

- Meeting the region's firm energy loads.
- Refilling all of the reservoirs each year.
- Maximizing nonfirm energy production.

Matching Runoff to Power Demand. Streamflows in the region do not follow the same pattern as electric energy use. Customers in the Northwest require more electricity in the winter than in summer. The Columbia River, however, is driven by snowmelt, with high runoff in the late spring and early summer. Natural flows are low in the fall and winter, when demand for power is high. This discrepancy between seasonal runoff and power demand is at least partially corrected through operation of the storage reservoirs.

Storage reservoirs are the key to matching the region's plentiful water resources with electricity use patterns. Energy—in the form of water—is held in reservoirs when natural streamflows exceed power generation requirements. Water is released for generation when it is needed to produce electricity.

Northwest Thermal Plants. In the Northwest, there are two operating nuclear plants: Portland General Electric's Trojan plant near Rainier, Oregon, and WNP-2 at Hanford, Washington, owned and operated by the Washington Public Power Supply System. The region's coal plants include PGE's Boardman plant at Boardman, Oregon, and the Centralia, Washington, plant operated by Pacific

Combustion Turbines: This type of generation uses some form of combustible fuel to power turbines, similar to aircraft engines, which in turn spin generators. Combustion turbines (or CTs, as they are commonly called) can burn either gas or oil, depending upon availability and cost of the supply. CTs are often used in the Northwest to meet peak winter heating loads because they can be switched on quickly and easily.

The Washington Public Power Supply System's WNP-2 plant, at Hanford, Washington, is one of the Northwest's large thermal generating plants. With the hydro system extensively developed, the region has turned to thermal generation to serve the growing load. It now supplies about 25 percent of the region's electricity.

Power & Light. There are also several natural gas and oil-fired **combustion turbines** in the region that are used periodically during high demand. Other thermal plants in and outside the region also provide power.

Hydroelectric generating plants can be quickly and easily ramped up and down to produce more or less electricity at any given time. As a result, these plants can follow ups and downs in demand very efficiently and are the key to meeting peak power loads. Large thermal plants are not so flexible and are not easily switched on and off. They are called baseload plants since they function best when meeting a constant, stable load, 24 hours a day, week in and week out.

Nuclear and coal-fired power plants and combustion turbines add to the Northwest's generating resources.

42-Month Critical Period

This graph illustrates the reservoir levels for a typical project if the lowest recorded runoff condition in the region were repeated. Under critical-period operation, a reservoir is operated to optimize power production while being drafted from full to empty over 42 months.

The worst water conditions in the basin occurred during the years of 1928 to 1932.

Reliability Standard: Just as there are reliability standards for electrical appliances, there are standards for entire electrical supply systems. The standards are set in a way that ensures electricity will be delivered reliably, or without interruption.

Critical Period Planning. On the Coordinated Columbia River System, a multilayered planning system has evolved, based on the possibility that the lowest historical streamflow conditions could recur in the future. System planners call this worst-case sequence of water years the "critical period."

Critical period planning is essentially a **reliability standard** that defines how much hydro system energy should be considered firm or guaranteed. It serves as a basis for determining how much non-hydro power is needed to meet expected energy load in the region. This power could come from thermal plants in the region or from power purchases.

The critical period is determined each year by analyzing a 50-year streamflow record and isolating the portion that would produce the least amount of energy, with all reservoirs drafted from full to empty. Reservoirs are assumed to be full at the beginning of the critical period and drawn down to empty at the end. (Empty in this case means drawn down to lowest operating levels.)

In recent years, the critical period has been based on the 42-month interval from September 1, 1928, through February 29, 1932. This is often referred to as the four-year critical period. In general, critical period planning and the resulting coordination allows for more power generation than

if operations were established on a 12-month cycle.

Rule Curves for Power Operation.

A set of rule curves is developed annually to guide reservoir operations for power production. These rule curves result from numerous studies of historical water conditions. In effect, the rule curves determine whether water in storage can be used for producing firm energy, for producing nonfirm energy, or should be held as storage to ensure the next year's refill of the reservoirs.

The planning and operating year for power production is August 1 through July 31. In the fixed drawdown period—from August through December—before the year's runoff forecast is available, reservoir operation is guided by three fixed rule curves. These are the critical rule curve, the assured refill curve, and the flood control rule curve. During the variable drawdown and refill periods—from January through July—when runoff forecasts are available, operation may be guided by one more rule curve called the variable energy content curve.

Critical Rule Curves. Critical rule curves define reservoir elevations that must be maintained to ensure that firm hydro energy requirements can be met under the worst historical streamflow conditions. In the planning process, a critical rule curve is derived for each of the four years in the critical period. These are called Critical Rule Curves 1, 2, 3, and 4.

If reservoirs in the system begin an operating year full, the rule curve used to guide actual drawdown that year is usually Critical Rule Curve 1. If reservoirs begin the operating year less than full, or if streamflows are lower than those in the critical period, then the second-, third-, or fourth-year critical rule curve will guide operations during the current year, depending on

how low the reservoirs and streamflows actually are. Operation with Critical Rule Curve 2, 3, or 4 is known as proportional draft.

Assured Refill Curve. The assured refill curve represents the level from which a reservoir could refill if the low runoff pattern of 1931, the third lowest volume in the 50-year water record, repeated itself. The assured refill curve gives operators reservoir draft limits below which reservoirs would not refill under very adverse water conditions. The assured refill curve is used to limit reservoir draft for nonfirm energy production in the fixed drawdown period before the year's runoff forecasts are known. Drafts below this curve are permitted to meet firm hydroelectric energy requirements.

Power operations are planned according to the worst water conditions.

Critical Rule Curves for a Typical Columbia River Reservoir

This graph separates the critical period rule curve into four operating years. Water levels on July 31 influence which of the rule curves operators will follow in drafting reservoirs over the coming year.

Critical Rule Curve

Assured Refill Curve

with Critical Rule Curve

The planning process yields rule curves to guide power operations.

The critical rule curve defines the reservoir elevations that must be maintained to ensure that firm hydro energy requirements can be met under the most adverse streamflows on record.

The assured refill curve is based on the Coordination Agreement Refill Test.

Flood Control Rule Curve: This curve is also called the upper rule curve. It sets the amount of storage space that must be maintained in a reservoir to reduce damaging flood conditions downriver.

Draft Limit: The lowest level to which a reservoir can be drawn down. The limit is based on rule curves that are calculated on both historic and current streamflow data.

Flood Control Rule Curve. The flood control rule curve defines the drawdown required to ensure adequate flood control space. See Section A. in this chapter for more details.

Energy Content Curve. The critical rule curve, the assured refill curve, and the flood control rule curve are combined to form another important rule curve known as the energy content curve. The energy content curve is the higher of the critical rule

curve or the assured refill curve and must be at or below the flood control rule curve. It represents the level to which reservoirs can be drawn down to produce nonfirm energy.

From January through the remainder of the operating year, when actual streamflow data and runoff forecasts are known, a new **draft limit** for nonfirm energy production is calculated regularly. This forms the variable energy content curve; it su-

Flood Control Rule Curve

with Critical Rule Curve and Assured Refill Curve

The flood control rule curve defines the drawdown required to assure adequate space is available in the reservoir to regulate the predicted runoff for the year without causing flooding downstream.

persedes the energy content curve when it is lower.

Variable Energy Content Curve.

The first runoff forecast is made in early January. This is the beginning of the variable drawdown period. It lasts through March, when the refill season begins. A new forecast is produced every month from January through June and is used to calculate a new variable energy content curve.

When it is lower than the energy

Variable Energy Content Curve

with Critical Rule Curve, Assured Refill Curve, and Flood Control Rule Curve

The variable energy content curve, which guides nonfirm energy generation, is usually the lowest of the four curves during the winter and early spring and is based on predicted runoff for the year.

content curve, the variable energy content curve is used to limit the draft on reservoirs to produce nonfirm energy. If it is lower than the energy content curve, it defines the minimum reservoir elevations that will ensure refill by the end of July within a 95 percent probability. Operators are permitted to draft below the variable energy content curve to meet firm hydroelectric energy requirements.

The variable energy content curve limits the amount of nonfirm energy that can be produced.

**Power sales
blend the
needs of
Federal power
customers with
the system's
ability to
produce
power.**

Power Sales Take Many Forms

Firm Sales

The Northwest's publicly owned utilities have first call on power produced at Federal hydro projects, a principle known as preference. BPA has long-term firm power sales contracts with over 120 utilities, including municipalities, public utility districts, and rural cooperatives. The agency also sells firm power directly to some Federal agencies and some of the region's largest industries, including aluminum smelters. These companies are called direct service industries, or DSI's.

Nonfirm Sales

Nonfirm energy is generally sold with no guarantee of continuous availability, and delivery can be terminated on very short notice. The DSI's have first call on BPA's nonfirm energy. The remainder is sold to utilities. Preference applies to nonfirm energy sales.

The alternating current (AC) and direct current (DC) transmission lines to California were built to allow excess power to be sold to California utilities. Because of the relatively high cost of operating oil- and gas-fired generating plants in California and the seasonal differences in the need for power between the Northwest and the Southwest, these nonfirm sales have been mutually advantageous to the two regions. Nonfirm energy sales allow California utilities to shut down their expensive thermal plants, reducing operating costs and pollution. Nonfirm sales bring in revenues to the Northwest and help keep electricity rates among the lowest in the United States.

DSI Sales

BPA has 15 DSI customers, eight aluminum companies and seven non-aluminum companies. Their 3,000 megawatt load is important to the region, as it is used to provide some of the reserves required by the Federal power system. Three-fourths of the load is served with firm energy. The remainder is served with either nonfirm energy or firm energy that is "borrowed" from the future. If neither nonfirm nor borrowed energy is available, BPA has the right to interrupt service to one quarter of the DSI load.

One form of borrowed energy is Advance Energy. Under an agreement with BPA, the Corps and Reclamation will at times draw reservoirs below the energy content curve to serve the nonfirm portion of DSI load in the fall and winter months. This drawdown is done with the provision that, if the probability of reservoir refill is too low in the spring, BPA may restrict sales to the DSI's to permit more water to stay in the reservoirs, therein protecting service to BPA's firm power customers. This is known as provisional delivery. The DSI's return the energy they bought from BPA by reducing their operations or buying replacement power elsewhere.

Storage Agreements

When utilities have inadequate space or otherwise cannot store water in their own reservoirs, they may make arrangements to use other utilities' storage. In 1988, seven California utilities stored Water Budget energy for BPA. Water released under the Water Budget was used to generate surplus power, which BPA delivered to the California utilities. The California utilities used the power to meet loads, turning off some of their generating projects. Later in the year, the California utilities generated power and sent it back to serve loads in the Northwest. Columbia River dams had to generate less power, and reservoir levels rose. This helped keep Northwest reservoirs higher in a drought year, while still providing spring flows for fish.

Out-of-Region Sales and Exchanges

Turbines at the dams currently give the Northwest power system about 2,000 megawatts of excess capacity—the ability to generate large amounts of power for short periods of time—to meet peak loads as long as the water is available.

A Northwest utility may provide capacity in an arrangement similar to a storage agreement. For example, BPA may provide peaking capacity to the Los Angeles Department of Water and Power. Water is released from the dams to generate power that is sent to Los Angeles on its hottest summer days to meet daytime peak power loads normally served by its highest cost resources. At night, when the southland cools off, Los Angeles sends back the energy associated with the capacity delivery, using energy from lower cost power plants. BPA uses this returned energy to meet its nighttime load so releases from Northwest reservoirs are reduced. BPA receives payment for capacity supplied or some amount of additional exchange energy that can serve Northwest loads over the year.

Power Purchases

Power purchases can help utilities cope with short-term power shortages and refill reservoirs. For example, in the dry year of 1988, BPA bought \$24 million worth of power from utilities in Canada and the United States. These purchases were used to meet electricity loads, allowing more water to remain in storage.

The Columbia River Treaty which led to the construction of Mica Dam, engendered coordination between river managers in the U.S. and Canada. The Treaty requires two operating plans be prepared annually—the Assured Operating Plan for the long-term and the Detailed Operating Plan for the next 12 months (current operating year).

***Planning allows
operators to
look at many
potential
reservoir and
runoff
conditions.***

VI. System Planning

A. The Annual Planning Process

There are two reasons to plan: first, to factor in all uses of the system to determine how much water will be available for power production, and second, to coordinate generation to increase the amount of power that can be generated. This section outlines the planning that takes place under the Columbia River Treaty and the Pacific Northwest Coordination Agreement.

The annual planning process starts each February. Planning gives the operating agencies the ability to look at a variety of potential reservoir and runoff conditions. Computer models simulate the system's ability to meet reservoir operating requirements and assess the impact on the system of various scenarios.

The Columbia River Treaty. The Columbia River Treaty requires the United States and Canada to prepare an Assured Operating Plan and a

Detailed Operating Plan each year. The operating plans are prepared by the Columbia River Treaty Operating Committee, made up of representatives of the Corps, BPA, and B.C. Hydro.

The Assured Operating Plan dictates how Treaty storage will be operated six years in advance. It is developed to meet the flood control and power objectives of the Treaty—the only recognized purposes for project operation when the Treaty was signed. The Detailed Operating Plan examines the upcoming four-year critical period and addresses operations over the next 12 months.

The Assured Operating Plan and the Detailed Operating Plan are the basis for the operating rule curves for the Treaty projects in Canada. These two plans are factored into the annual plan developed by parties to the Pacific Northwest Coordination Agreement since releases of water from the Canadian storage reservoirs are crucial for coordinated system planning in the United States.

Coordination allows utilities to plan routine maintenance at individual plants, such as Bonneville Dam, without disrupting their ability to serve load.

The Pacific Northwest Coordination Agreement. The contractual basis for coordinated system operation of most of the hydropower facilities in the Columbia Basin in the United States is the Pacific Northwest Coordination Agreement. Coordinating system operations through annual planning provides many advantages.

Coordination enables utilities to exchange power and to help each other when emergencies shut down transmission lines or turbines. Utilities can take advantage of their differences in streamflows, loads, generation, and maintenance schedules to share resources. Coordination also lets utilities operate hydro and thermal resources more efficiently.

The Single-Ownership Concept. An important point to understand about the Coordination Agreement is that the planning studies are made as if the total coordinated system had a single owner. If all projects in the system belonged to a single utility, the owner would synchronize operations

to maximize power production. Coordinated planning attempts to duplicate that hypothetical situation. The Coordination Agreement contains a number of provisions, some of which are described below, to make the single-ownership concept work on a day-to-day basis.

The Coordination Agreement studies are performed by the Northwest Power Pool Coordinating Group in Portland, Oregon. The parties to the Agreement provide study data and closely monitor the results. The products of the planning process are rule curves and estimates of the amount of firm energy that can be produced by each project for each month of the critical period.

By February 1 prior to each operating year, parties to the Coordination Agreement provide data to the Coordinating Group. Each reservoir owner submits multiple-use operating requirements that must be accommodated in the resulting plan. Utility parties also submit forecasts of their

**The
Coordination
Agreement
planning
studies
assume the
coordinated
system has a
single owner.**

Exchange Power: Utilities frequently swap power with one another to use their resources more efficiently. Rather than sell excess power, Utility A may loan it to Utility B. Utility A will take equivalent power back, for example, when it must shut a generator down for maintenance.

Northwest Power Pool Coordinating Group. This organization includes the staff of the Northwest Power Pool, headquartered in Portland, Oregon, as well as public and private utilities in the region and in western Canada. The Pool collects operating data from the utilities, completes regulation studies, and turns the results into the rule curves that guide power production.

Maintenance Outage: All generating plants, hydro and thermal, require routine maintenance. Utilities generally schedule maintenance outages during periods when energy demand is low or hydro supplies are high. For example, Portland General Electric refuels and performs routine maintenance on the Trojan Nuclear Plant beginning in April when spring runoff usually begins.

Regulation: A computer study that develops a set of rule curves that guide project operation under terms of the Coordination Agreement.

Streamflow Records: For over 100 years, water resource managers in the Northwest have maintained records on the seasonal volume and rate of flow in the Columbia River. These historical records are of profound importance to planning system operations each year.

***Coordinated
planning yields
rule curves and
specifies the
firm energy to
be produced at
each project.***

electricity loads, the output of their non-hydro generating resources, and planned **maintenance outages** for both hydro and thermal resources. The resources include any contracts a utility has for firm power purchases or exchanges.

Once the data are submitted, studies are conducted to identify the critical period. The length of the critical period may vary from year to year due to changes in forecasted energy load or installation dates of large thermal units. It has been computed to be 42 months in the past several years.

Firm Energy Load Carrying Capability. The next step in coordinated planning is determining Firm Energy Load Carrying Capability (FELCC) for the system as a whole and for each Coordination Agreement party. The firm energy capability of each plant, each individual utility system, and the coordinated system as a whole is the amount of energy each is capable of producing during the critical period. It is the amount of energy the system and individual parties could produce if streamflows were as low as they were in the critical period.

FELCC is also the amount of energy that the system may be called on to produce on a firm or guaranteed basis during actual operations. The system and individual parties' FELCC may or may not be sufficient to meet power loads in the region. If it is insufficient, utilities with a firm deficit must seek other sources of power.

The Preliminary Regulation. Once the critical period studies have been conducted, the utilities and other parties have their first estimates of the amount and distribution by month of their FELCC. This initial step is called the Preliminary Regulation.

Parties are given the chance to comment on the Preliminary Regulation and adjust their data submittals before a Modified Regulation is produced. The Modified Regulation is then fine-tuned to make sure the hydro system is used to its fullest potential. Part of this fine-tuning includes determining interchange energy obligations and shifting and shaping FELCC (see boxes).

After adjustments to FELCC have been made and reported to the Coordinating Group, the Final Regulation is published. It provides each party to the Coordination Agreement with critical rule curves and FELCC for each month in the critical period.

Coordination Agreement Refill Test. The final analysis made in developing the annual operating plan is the Coordination Agreement Refill Test conducted by the Corps. It simulates how the hydro system would operate under the runoff conditions in each of 50 years of **streamflow records**. This analysis has two purposes. First, it determines whether the energy content curves are constructed in a way that does not threaten the coordinated system's ability to generate its firm energy capability under historical streamflow conditions.

Interchange Energy

The concept of "interchange" is fundamental to the Coordination Agreement. Interchange energy assures all parties an equal ability to serve their firm loads.

Each party to the agreement is expected to use its own resources to supply its own firm energy load carrying capability (FELCC) over the critical period. However, if a party's ability to produce energy in a given month is determined to be less than its FELCC, that party has a right to request the deficiency from other parties with excess FELCC. Parties with more energy capability than they need to meet their FELCC are obligated to supply all or a part of that excess capability to parties that need it. Energy transferred in this way is called interchange energy.

Shifting and Shaping FELCC

In preparing the annual plan, some utilities can make changes to reservoir operations to match generation more closely with loads or to optimize sales of surplus FELCC. This process is referred to as shifting and shaping FELCC.

BPA, for example, had a surplus during the 1980's. Its firm energy producing capability was greater than its firm load. The agency generally chose to shape its FELCC to make more surplus energy sales in the fall, when energy is more valuable, banking on the fact that normal water conditions would prevail later in the operating year. This meant more generation occurred earlier and reservoirs were drafted deeper earlier in the operating year. Overall, BPA could sell more power.

Shifting and shaping FELCC may reduce the coordinated system's overall capabilities somewhat, but the energy is more valuable because it is produced at a time when natural streamflows are lower. These shifting and shaping changes are limited to those that do not threaten the basic concept of operating as a single system to meet a single load.

Second, the 50-year analysis determines the reservoir draft limit for nonfirm energy by developing rule curves with a 95 percent chance of refill. Because reservoirs sometimes have to be operated below these rule curves, the system is expected to actually refill three out of four years. The refill test results are used to calculate the next year's assured refill curve and the variable energy content curve.

Generating resources can be used most efficiently when utilities coordinate and cooperate with one another. Close coordination is essential between operators of dams adjacent to one another on a river reach.

B. Where Planning Meets Operations

Reservoir operators begin the operating year with rule curves that are based on historical streamflows. They are faced with numerous project and system requirements and with electricity loads to meet with a combination of hydro and other power plants. To mesh all of these requirements, the Actual Energy Regulation (AER) is produced at least twice a month throughout the operating year.

Actual Energy Regulation. The AER studies are conducted by the Power Pool Coordinating Group. One result of these studies is an energy content curve for each storage project that accounts for specific conditions in the current operating year. The AER combines each utility's FELCC with

***The Actual
Energy
Regulation
meshes all
requirements
throughout the
operating year.***

Operators work around the clock to meet load with the best combination of resources

In low water years, draft is distributed equally among all reservoirs.

Proportional Draft Points—PDPs are drawdown limits for reservoirs when water conditions require drafting below energy content curves to serve firm load.

actual and current estimates of streamflow and defines draft points to produce the FELCC and meet other system and project requirements.

In good water years, these studies—based on updated forecasts—refine the amount of nonfirm energy that can be produced. In low water years, when reservoirs must be drafted below their energy content curves to produce FELCC, the AER will set **proportional draft points**. The proportional draft points equitably distribute the draft among all reservoirs.

BPA Weekly Planning. BPA has its own planning process to determine the power generating requests it will make to the Corps and Reclamation and to guide operation of thermal resources and decisions on power purchases. Each week a new operating plan is prepared that looks a month ahead. These weekly operating plans are an important tool to make decisions about the availability of nonfirm energy for Northwest utility and industrial customers and for export from the region.

In-Lieu Energy. In-lieu energy is another key feature of day-to-day operations. In-lieu energy, established in the Coordination Agreement, is the means by which a downstream party to the Coordination Agreement can receive water stored in a reservoir upstream, if there is water in the reservoir above the energy content curve draft level.

A reservoir owner may manage its storage to conserve excess generating capability it does not need or that the coordinated system does not need. However, individual owners of projects downstream from that reservoir may need the water and are entitled to it under the Coordination Agreement. They can request the release of the water.

The reservoir owner is obligated either to release such water from storage or to supply energy *in lieu* of the release of water. If the downstream operator has received in-lieu energy for the water and water above the energy content curve is subsequently released, then the downstream operator must return the in-lieu energy to the upstream party.

Hourly Power Operation. Hydro-electric generating projects adjacent to one another are coordinated on at least an hourly basis to be efficient. BPA's main dispatch center at Vancouver, Washington, coordinates the hourly operation of the chain of eight projects on the lower Snake and lower Columbia Rivers, from Lower Granite to Bonneville Dam.

The seven projects on the middle Columbia River from Grand Coulee

through Priest Rapids are also in a continuum along the river. These projects, owned by several different utilities, are operated as a group under the Hourly Coordination Agreement and dispatched by Grant County PUD in Ephrata, Washington. Most of the hydro projects along other **river reaches** are under the control of a single utility or agency to assure coordinated operation.

River Reaches. A general term used to refer to lengths along the river from one point to another, as in the reach from the John Day Dam to the McNary Dam.

BPA dispatches power and directs transmission from a central facility called the Dittmer Control Center, located at the Ross Complex in Vancouver, Washington.

***Hydro projects
in the same
river reach are
coordinated on
an hourly basis.***

With its huge storage capability and five non-Federal mid Columbia dams downstream, operation at Grand Coulee Dam plays an integral role in the Coordination Agreement's in-lieu energy transactions.

While each operating year is different, lessons from the past can be valuable in guiding operations in the future.

**Operations
vary in
accordance
with water
conditions.
1985-86 was an
average year.**

C. System Operation: How It Works

While storage reservoirs follow a fairly similar pattern of operation each year, operation does vary in accordance with water conditions. This section describes actual operations for an average water year, 1985-86, and for a low water year, 1987-88. The information is based on the **Columbia River Water Management Group's Annual Report** for those years.

Operation of the system in an average water year, 1985-86.

Operations in 1985-86 illustrate how the system works when runoff is normal. The 1985-86 water year began with reservoir levels slightly below normal, as the system had filled to only about 92 percent of full by July 31, 1985.

Flood Control. Runoff forecasts, beginning January 1, 1986, indicated that below-normal spring runoff was expected. This caused operators to reduce the draft from reservoirs because little additional flood control space was needed and water could be conserved for refill.

But during late February, heavy rains fell. Major increases to flow on the lower Columbia came from the Snake River, mid-Columbia tributaries, and the Willamette River, along with the western Cascade streams. There was a potential for damaging floods in the Portland/Vancouver area.

To improve the situation, operators reduced outflow from the Arrow and Duncan projects in British Columbia to reduce flow into Grand Coulee. Even so, inflows to Grand Coulee were still greater than normal.

Columbia River Water Management Group's Annual Report: Each year the Columbia River Water Management Group publishes a report that summarizes all operations throughout the year. Annual reports were used to prepare this section, which contrasts operations in a year of average water conditions with a year of dry conditions.

In addition, water could not be stored in Lake Pend Oreille because of ice around the edge of the lake. The lake level could not be raised without damaging shoreline facilities, so water had to be released, not stored.

In the Snake River Basin, moderate flood damage occurred below the Owyhee project in Oregon, which stored water nearly a foot above normal levels to reduce flooding. Reduced outflows from Brownlee, Dworshak, and other Snake River projects helped reduce Snake River flows and river levels in the lower Columbia.

At Vancouver, Washington, Columbia River system operation reduced the peak winter **flood stage** by 4.5 feet. Levees prevented any actual flooding.

The February storms caused reservoirs in the Snake and Willamette River basins to fill rapidly. After this event, the Willamette reservoirs were drafted back to flood control rule curves. All major reservoirs refilled, and their water levels were near normal at the end of September 1986.

Electric Energy. Because the reservoir system failed to fill in the summer of 1985, the reservoirs were proportionally drafted in the fall and winter. Above normal rainfall in October filled the reservoirs nearly to their flood control curves. Small amounts of nonfirm energy were

offered to Northwest and Southwest utilities in November. December was cold and dry. The reservoirs returned to proportional drafting.

BPA's **direct service industry** (DSI) customers' first quartile (top fourth) load was met with advance energy from October through most of December and nonfirm energy through early August 1986. Advance energy is normally provided by drafting reservoirs in August through December; it is "loaned" to the DSI's. If BPA needs the power in the spring to meet its firm loads, it can interrupt up to 50 percent of DSI service.

BPA began marketing nonfirm energy to Northwest and Southwest utilities in mid-February. Warm wet weather caused streamflows to rise rapidly and, as described above, the Columbia River system began flood control operation.

Flood control operation continued until the Water Budget began in mid-April. From late February to mid-August, the system was in spill. After June 20, spill continued to be provided for fisheries through mid-August.

System reservoirs filled by July, and nonfirm energy continued to be marketed through early August. Receding streamflows in late August and September 1986 required proportional drafting of reservoirs.

Fish. In the Snake River Basin,

Flood Stage: The river at or above flood stage is capable of causing property damage. At various points on the river, flood stage is identified as a particular water level. At the Vancouver, Washington gage, 16 feet is the threshold above which there can be damaging floods in the lower Columbia.

Direct Service Industry: In the late 1930s, cheap and abundant hydroelectricity attracted industries that consume large amounts of electricity. These industries, which include aluminum smelters, take service directly from BPA, rather than through their local utility, and thus, they became known as the direct service industries, or DSI's.

Reduced outflows at projects on the Snake River helped reduce river levels on the lower Columbia during flood season, 1986.

Hungry Horse Dam is an important component of the region's power generation system, turning water into kilowatts of electricity.

**1988 was the
second
consecutive
drought year in
the Northwest.**

Kilowatt-hours: A measure of electric energy. One kilowatt-hour equals 1,000 watt hours. A 100-watt light bulb burning for ten hours is equal to one kilowatt-hour. Reservoir levels can be valued in kilowatt-hours.

runoff forecasts indicated that during the Water Budget period (mid-April through mid-June), flows expected at Lower Granite Dam would be inadequate to meet a discharge of 85,000 cfs. Approximately 400,000 acre-feet of water from Dworshak Reservoir was designated as Water Budget and was available to augment flows, if necessary. A wet April and early May, followed by unseasonably hot weather in late May and June, resulted in near normal flows at Lower Granite. The natural flows met and exceeded the Water Budget requirements without using the water from Dworshak.

Grand Coulee outflows were managed to meet the Water Budget at Priest Rapids from April 15 through May 29. From December through early April, special operation of Grand Coulee provided minimum flows of 65,000 cfs past Priest Rapids to protect spawning sites at Vernita Bar.

Operation of the system in a low water year-1987-88.

The 1988 water year was the second consecutive drought year in the Northwest; it was the third low water year in a four-year period. Winter precipitation was about 55 to 75 percent of normal, resulting in spring runoff at The Dalles that was approximately 67 percent of normal. Snake River runoff was even lower, at 53 percent of normal. The Columbia Basin snowpack was below to well below average throughout 1988. Because of the low runoff and the low reservoir elevations, most of the storage reservoirs did not refill, leaving the coordinated system at 84 percent of storage capacity by July 31, 1988.

The operating year began (August 1, 1987) with the coordinated river system officially filled to about 98.5 percent of capacity. Due to low streamflows in August and September, the system was proportionally drafted below energy content curves

to meet firm loads.

By October 1, system reservoirs were 3 billion **kilowatt-hours** below first-year critical rule curves and remained below them throughout the water year. As a result, BPA marketed nonfirm energy only in May and June, when the Water Budget produced excess water that could not be conserved through storage arrangements inside or outside the Northwest.

Limited amounts of surplus firm energy were marketed through January 8. After that date, BPA marketed surplus firm energy only to utilities with existing contracts. This was done to conserve as much energy in the Northwest as possible to be able to fulfill future energy needs if the drought continued.

The water supply forecast for the January through July period at The Dalles was a very low 79.2 million acre-feet, about 73 percent of normal. The outlook for complete refill of the reservoir system was therefore poor, with individual reservoirs expected to be 10 to 50 feet below full on July 31. Even so, the reservoirs continued to be drafted significantly throughout the winter for firm power loads.

Water supply forecasts continued to drop throughout the winter and spring. As a result, the reservoir system did not need to be operated on a daily basis for flood control at any time during 1988. The only significant rise in lower Columbia flows occurred during the Water Budget. Water Budget flows were released from Grand Coulee between May 9 and June 10.

There was virtually no flooding on the Columbia River during the spring runoff period. Minor winter floods in December and January required some local flood regulation by reservoirs located in the Cascade Mountains.

Total hydroelectric energy production was low because of the poor runoff and low reservoir elevations. Throughout the year, BPA

purchased energy from other utilities and sources outside the region, and made special agreements to reduce the draft on the Columbia system reservoirs.

BPA also developed **storage agreements** to enable utilities to conserve energy to meet future Northwest needs. These arrangements were for special storage (storing light-load hour energy to serve heavy-load hour needs); energy conservation storage (storing energy at one-half the normal charge for use later by the utility); and Water Budget storage (storing over generation from the Water Budget to meet future needs).

Continued low streamflows in August and September required the reservoirs to remain on proportional draft. BPA continued to limit its surplus firm sales to utilities with existing contracts. On September 1,

1987, BPA began purchasing limited amounts of nonfirm energy from Northwest and Southwest utilities to support its FELCC. BPA's system wide firm energy load exceeded planning levels throughout the 1988 water year.

Irrigation reservoirs were drafted deeply in 1988, and by the end of the water year, many were empty or had very little carryover for 1989. Recreational use of some of the region's reservoirs declined due to the low water levels caused by early drawdowns to provide irrigation water.

From December through early April, Grand Coulee was operated to provide minimum flows of 65,000 cfs past Priest Rapids to protect the spawning sites on Vernita Bar.

In the Snake River Basin, runoff forecasts indicated that during the Water Budget period, the flows

Storage Agreement: Utility A must release water—to make space for heavy runoff, for example—at a time when its customers don't need the power. Under a storage agreement, Utility B acquires the power and stores enough water in its reservoirs to return an equal amount of power when Utility A needs it.

Reservoirs were drafted below energy content curves in the fall of 1987 to meet firm loads.

Flow at The Dalles was 73 percent of normal in 1988, and no special operation for flood control was needed.

***In 1988,
there was
virtually no
flooding during
the spring
runoff.***

Fish Passage Center: The center, which controls the Water Budget, coordinates the release of up to 4.64 million acre-feet of water in the Columbia River system from April 15 through June 15. It is staffed by representatives from government fisheries agencies and Tribes. Releases are timed to augment flows to improve juvenile fish migration.

BPA purchased power from utilities outside the region in 1988 to keep reservoirs from being drafted too heavily when runoff forecasts were poor.

expected at Lower Granite Dam would not meet desired minimum flows of 85,000 cfs. Therefore, approximately 300,000 acre-feet of water were provided from Dworshak and 150,000 acre-feet from Brownlee to augment Water Budget flows. April and May precipitation was above normal, but streamflows continued well below normal at Lower Granite.

Even with releases up to 25,000 cfs from Dworshak and up to 25,000 cfs

from Brownlee, the flows at Lower Granite Dam never met the **Fish Passage Center's** 85,000 cfs Water Budget goal. The Priest Rapids Water Budget allotment was used to augment flow in the lower Columbia.

Overall, flows throughout the fish migration period were much lower than fishery minimums. Higher flows could not be provided for much of the spring migration because of the limited water available.

With runoff low in 1988, many reservoirs did not refill during the spring and summer.

***Flows
throughout the
fish migration
season were
below desired
levels.***

*The drought also hurt many water uses
including fish migration*

VII. Conclusion

***As uses of the
river multiply,
the system
will be
hard-pressed
to meet all
demands.***

Thanks to cooperation among all the river's users, the dams and reservoirs of the Columbia River now fulfill more uses and produce more electricity than was anticipated when they were built. As uses of the river multiply and the region's population grows, the system will continue to be hard-pressed to meet all the demands.

The Columbia River System Operation Review gives us a chance to step back and examine how each use of the river affects all other uses and to

consider what the consequences might be of changing the way the system now operates. Do we have the best balance among uses? Can we agree on future courses of action that will benefit more river users? This publication has tried to describe how the Columbia River system works today. The System Operation Review enables all of us in the Northwest to consider how it might work better tomorrow.

The Columbia River system provides countless benefits to the region in wet and dry years alike. River managers face the challenge of continually balancing the benefits among all users.

While electricity generation was an important stimulus for building many Federal projects, it is only one aspect of multiple purpose operations today.

***The System
Operation
Review gives
us a chance
to step
back and
examine river
management.***

Appendix A. Columbia Basin Hydro Projects

Upper Columbia

Aberfeldie
Albeni Falls
Ashley Lake
Black Lake
Boundary
Box Canyon
Brilliant
Cabinet Gorge
Como Lake
Corra Linn
Duncan
Erickson
East Fork Rock Creek
Georgetown Lake
Grand Coulee
Hayden Lake
Hubbart

Hugh Keenleyside
Hungry Horse
Kerr
Kicking Horse
Kootenay Canal
Libby
Little Bitterroot
Little Falls
Long Lake
Lower Bonnington
Lower Crow
Lower Jocko Lake
McDonald
Mica
Mission
Moyie Upper
Nevada Creek

Nine Mile
Ninepipes
Noxon Rapids
Pablo
Painted Rock Lake
Post Falls
Priest Lake
Revelstoke
Seven Mile
South Slocan
Sullivan Lake
Tabor
Thompson Falls
Twin Lake
Upper Bonnington
Waneta
Whatshan

Mid-Columbia

Bumping Lake
Chandler
Chelan Lake
Chief Joseph
Cle Elum
Clear Lake
Conconolly
Keechelus
Kachees
Leader Lake

Long Lake
Naches
Nile Valley
North Dam
O'Sullivan
Owhi
Pinto
Priest Rapids
Rock Island
Rocky Reach

Roza
Salmon Lake
Snow Lakes
Soda Lake
Spectacle Lake
Tieton
Wanapum
Wells Lake

Upper Snake

Agency Valley
American Falls
Anderson Ranch
Antelope
Arrowrock
Ashton
Black Canyon
Blackfoot
Bliss
Bully Creek
C. Ben Ross
C.J. Strike
Cascade
Cedar Creek
Chimney Creek
Crane Creek
Deadwood
Fish Creek
Grassy Lake
Grays Lake
Henrys Lake
Hubbard
Island Park
Jackson Lake

Lake Fork
Lake Lowell
Little Camas
Little Wood
Lost Valley
Lower Malad
Lower Salmon
Lucky Peak
Mackay
Magic
Mann Creek
Milner Lake
Minidoka
Mountain Home
Mountain View
Mud Lake
Murtaugh
Oakley
One Thousand Springs
Owyhee
Paddock Valley
Palisades
Payette
Pleasant Valley

Portneuf
Ririe
Sage Hen
Salmon Falls
Shoshone Falls
Silver Creek
Swan Falls
Twin Falls
Twin Lakes
Upper Malad
Upper Salmon A
Upper Salmon B
Warm Springs
Wild Horse
Willow Creek #3
Wilson Lake
Wilson River

Lower-Middle Snake

Brownlee
Brundage
Dworshak
Goose Lake
Hells Canyon

Ice Harbor
Lower Granite
Lower Monumental
Little Goose
Mason

Oxbow
Thief Valley
Unity
Wallowa Lake

Lower Columbia

Bonneville
Bull Run
Bull Run #1
Bull Run #2
Cold Springs
Condit
Crane Prairie
Crescent Lake
Haystack
John Day

Mayfield
McKay
McNary
Merwin
Mill Creek
Mossyrock
Ochoco
Packwood
Pelton
Prineville

Powerdale
Round Butte
Swift #1
Swift #2
The Dalles
Wasco
Wickiup
Willow Creek
Yale

Willamette Basin

Big Cliff
Blue River
Carmen
Cottage Grove
Cougar
Detroit
Dexter
Dorena
Fall Creek

Faraday
Fern Ridge
Foster
Green Peter
Hills Creek
Leaburg
Lookout Point
North Fork
Oakgrove

River Mill
Scoggins
Smith
Timothy Lake
Trail Bridge
T.W. Sullivan
Walterville

Puget Sound and Coastal

Agate
Alder
Applegate
Cedar Falls
Clearwater #1
Clearwater #2
Cushman #1
Cushman #2
Diablo
Electron
Emigrant Lake
Fish Creek
Fish Lake
Four Mile Lake
Galesville

George Culmback
Glines Canyon
Gorge
Green Springs
Howard A. Hanson
Howard Prairie
Hyatt
La Grande
Lake Chaplain
Lake Tapps
Lake Whatcom
Lemolo #1
Lemolo #2
Lost Creek
Lower Baker

Mud Mountain
Prospect #2
Prospect #3
Ross
Slide Creek
Snoqualmie #1
Snoqualmie #2
Soda Springs
Toketee
Tolt
Upper Baker
Wyannochee
Yelm

Appendix B.

Selected Agencies and Organizations With Interests in the Columbia Basin

The Forecasters and Data Collectors

Forecasts of weather and water conditions in the Columbia River Basin are essential to operating the coordinated system for maximum benefit. There are two general types of forecasts required: water supply forecasts, which define the volume of runoff expected; and rate-of-flow forecasts, which project streamflow conditions. Several organizations have a hand in collecting and analyzing information that goes into these forecasts.

The Columbia River Forecasting Service was created by interagency agreement among the National Weather Service, the Corps, and BPA. The agencies pool their resources to jointly prepare streamflow forecasts used to guide system operations, both short- and long-term.

The National Weather Service's

Northwest River Forecast Center provides forecasts of river stages and streamflow conditions for the Columbia River Basin, the coastal basins of Oregon and Washington, and the Great Basin in Oregon.

The U.S. Soil Conservation Service measures the snowpack throughout the Columbia River Basin. Some measurements are gathered by hand, while others are transmitted electronically from remote stations. These data are used to calculate the volume of runoff that can be expected in the region's streams and rivers. The U.S. Geological Survey is responsible for maintaining the streamflow gages and reporting measurements.

The interagency Columbia River Water Management Group (CRWMG), which includes all of the key state and Federal water resource agencies, coordinates issues relating to data collection, forecasting, and river operation. Through the CRWMG, an

automated database for water managers called The Columbia River Operational Hydromet Management System (CROHMS) has been developed.

CROHMS is the extensive data collection and processing system used in scheduling reservoir operations and forecasting streamflows in the Northwest. Development of the system began in 1970; in October 1978, the central computer facility for CROHMS went into operation.

The Northwest Power Pool is a voluntary organization formed during World War II to increase reliability of the electric system through cooperative operations. Today the Pool has a major role in preparing annual operating plans under the Pacific Northwest Coordination Agreement. The Pool's Operating Committee, with a member from each participating utility, meets regularly to handle power system operation matters.

The Regulators and Advisory Agencies

Several agencies that have no direct role in operating projects in the Columbia River Basin act in a regulatory or advisory capacity to the project operators.

The Federal Energy Regulatory Commission (FERC) is a five-member panel appointed by the President of the United States to regulate the interstate aspects of the electric power and natural gas industries. The Commission licenses and enforces licensing provisions for construction and

operation of non-Federal hydroelectric projects. These provisions can affect river operations in a number of ways. For example, under the conditions of its FERC license, Idaho Power provides the Corps with flood control storage at Brownlee Dam on the Snake River.

State water resource agencies, which enforce water rights laws, also play a role in operations. They control how much water is withdrawn from streams and reservoirs for irrigation, municipal and industrial water supply, and other beneficial purposes. In western States, the principle "first in time, first in right" generally applies to

water rights. Each rightholder must demonstrate to the State that beneficial use is being made of the water to which it holds rights. The Idaho Department of Water Resources, the Montana Department of Natural Resources and Conservation, the Oregon Department of Water Resources, and the Washington Department of Ecology oversee this function for their respective States.

Fish and Wildlife Interests. The National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service, and several state-level agencies have responsibility to protect fish and wildlife in the Columbia River Basin. NMFS, which is part of the U.S. Department of Commerce, provides management and research services for the protection, conservation, and use of marine resources. The agency also studies the impacts of natural and human activities—such as operation of dams—on marine life.

The U.S. Fish and Wildlife Service, part of the U.S. Department of the Interior, is the lead Federal agency in the conservation of the nation's migratory birds, certain mammals, and sport fish. Fish hatcheries, biological monitoring, and enforcement of several animal protection laws are part of the agency's mission.

The Idaho Fish and Game Department, Montana Department of Fish, Wildlife and Parks, Oregon Department of Fish and Wildlife, Washington Department of Fisheries, and the Washington Department of Wildlife are the State agencies that protect and manage fish and wildlife in their respective States.

Tribes and Coalitions. Indian Tribes have certain historic and treaty rights to take fish from the Columbia River and its tributaries. The Columbia River Inter-Tribal Fish Commission was formed in 1977 by the Yakima, Warm Springs, Umatilla, and Nez Perce Tribes to supply technical expertise and enforcement resources aimed at protecting those rights. The 19-member Northwest Indian Fisheries Commission operates in the Puget

Sound and Washington coastal areas as a counterpart to the Inter-Tribal Fish Commission.

The Upper Columbia United Tribes consists of the Spokane, Coeur d'Alene, Kootenai, and Kalispel tribes. The organization participates in various issues concerning the Northwest Power Act.

The Columbia Basin Fish and Wildlife Authority (CBFWA) represents fish and wildlife agencies from the four Northwest states, the National Marine Fisheries Service, and U.S. Fish and Wildlife Service, and 13 Indian Tribes in the Columbia Basin. CBFWA coordinates with BPA, the Corps, and the Council on behalf of its members to address fish and wildlife management issues.

The River Users

There are hundreds of individuals, agencies, organizations, and coalitions that use the river and its resources or have an interest in the way the river system is managed. Groups range from environmental advocates to industry associations, with members who purchase power generated at hydroelectric projects or harvest salmon commercially in the Columbia River Basin. Opinions on Columbia River water management issues are diverse.

Organizations that represent power users include the Pacific Northwest Utilities Conference Committee (PNUCC), the Public Power Council, and Direct Service Industries, Inc. The Pacific Northwest Waterways Association and port officials represent navigation interests. Irrigators participate in river management issues through the Northwest Irrigation Utilities. Oregon Trout dedicates itself to protecting wild fish runs.

The Natural Resources Defense Council and the Northwest Conservation Act Coalition are among the many groups that represent environmental interests. There are also organizations, such as the Puget Sound Anglers,

which speak for sports fishermen. Recreational interests, such as windsurfers and pleasure boating groups, also take an active interest in some issues that affect the Columbia Basin waterways, and they have formed groups to represent them. Local flood control districts and municipalities keep an eye on operations that could alter their shorelines.

All of these interests, individually and collectively, participate in forums that guide river management policies. Their representatives testify at public hearings, organize letter writing campaigns, and rally their members to be involved in decisions that affect the Columbia River system.

Glossary

Acre-foot: The volume of water that will cover an area of one acre to a depth of one foot.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch in freshwater, migrate to and mature in the ocean, and return to freshwater as adults to spawn.

Annual operating plan: A yearly plan for operating reservoirs on the Columbia River. Such a plan is specifically required by the Columbia River Treaty and by the Pacific Northwest Coordination Agreement.

Assured refill curve: A curve showing minimum elevations that must be maintained at each project to ensure refill even if the third lowest historical water year occurred; it sets limits on the production of energy.

Average megawatts (aMW): The average amount of energy (number of

megawatts) supplied or demanded over a specified period of time.

Baseload: In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.

Bypass system: Structure in a dam that provides a route for fish to move through or around the dam without going through the turbines.

Capacity: The maximum sustainable amount of power that can be produced by a generator or carried by a transmission facility at any instant.

Capacity/energy exchange: A transaction in which one utility provides another with capacity service in exchange for additional amounts of firm energy (exchange energy) or money, under specified conditions, usually during offpeak hours.

Critical period: The portion of the historical 50-year streamflow record that would produce the least amount of energy with all reservoirs drafted from full to empty.

Critical rule curves: A set of curves that define reservoir elevations that must be maintained to ensure that firm energy requirements can be met under the most adverse historical streamflow conditions. Critical rule curves are derived for all four years in the critical period. They are used to guide reservoir operation for power.

Cubic feet per second (cfs): A unit of measurement pertaining to flow or discharge of water. One cfs is equal to 449 gallons per minute.

Demand: The rate at which electric energy is used whether at a given instant, or averaged over any designated period of time.

Discharge: Volume of water flowing at a given time, usually expressed in cubic feet per second.

Displacement: The substitution of less-expensive energy generation for more-expensive energy generation (usually hydroelectric energy transmitted from the Pacific Northwest or Canada is substituted for more expensive coal and oil-fired generation in California). Such displacement usually means that a thermal plant can reduce or shut down its production, saving money and often reducing air pollution.

Draft: Release of water from a storage reservoir.

Drawdown: The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels.

Energy content curves: A set of curves that establishes limits on the amount of reservoir drawdown permitted for nonfirm energy production.

FELCC: Firm energy load carrying capability (FELCC) is the amount of energy the region's generating system, or an individual utility or project, can be called on to produce on a firm basis during actual operations. FELCC is made up of both hydro and non-hydro resources, including power purchases.

Firm energy: The amount of energy that can be generated given the region's worst historical water conditions. It is energy produced on a guaranteed basis.

Fish ladders: A series of ascending pools constructed to enable salmon or other fish to swim upstream around or over a dam.

Fish passage facilities: Features of a dam that enable fish to move around, through, or over without harm. Generally an upstream fish ladder or a downstream bypass system.

Flood control rule curve: A curve, or family of curves, indicating reservoir drawdown required to control floods. (Also called Mandatory Rule Curve or Upper Rule Curve.)

Flow: The volume of water passing a given point per unit of time.

Freshet: A rapid temporary rise in streamflow caused by heavy rains or rapid snowmelt.

Generation: Act or process of producing electric energy from other forms of energy. Also refers to the amount of electric energy so produced.

Hydraulic Head: The vertical distance between the surface of the reservoir and the surface of the river immediately downstream from the turbine and dam.

Hydroelectric: The production of electric power through use of the gravitational force of falling water.

Hydrology: The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Hydrometeorological observations: Data that combine snowpack measurements and climatic forecasts to predict runoff.

Intake: The entrance to a conduit through a dam or water facility.

Interchange energy: Electric energy received by one utility system usually in exchange for energy to be delivered to another system at another time or place. Interchange energy is different from a direct purchase or sale, although accumulated energy balances are sometimes settled in cash.

Interruptible: A supply of power which, by agreement, can be shut off on relatively short notice (from minutes to a few days).

Juvenile: The early stage in the life cycle of anadromous fish when they migrate downstream to the ocean.

Levee: An embankment constructed to prevent a river from overflowing.

Load: The amount of electric power or energy delivered or required at any specified point or points on a system. Load originates primarily at the energy-consuming equipment of customers.

Lock: A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move from one elevation to another along the waterway.

Mainstem: The principal river in a basin, as opposed to the tributary streams and smaller rivers that feed into it.

Megawatt (MW): A megawatt is one million watts, a measure of electrical power.

Mid-Columbia: The section of the Columbia River from the Canadian border to its junction with the Snake River.

Nitrogen supersaturation: A condition of water in which the concentration of dissolved nitrogen exceeds the saturation level of water. Excess nitrogen can harm the circulatory systems of fish.

Nonfirm energy: Energy available when water conditions are better than the worst historical pattern; generally such energy is sold on an interruptible (nonguaranteed) basis. Sometimes called secondary energy.

Non-power operating requirements: Operating requirements at hydroelectric projects that pertain to navigation, flood control, recreation, irrigation, and other non-power uses of the river.

Northwest Power Pool Coordinating Group: Made up of BPA, the Corps, Reclamation, and public and private utilities in the Northwest and British Columbia and Alberta. The group's primary functions are administering the Pacific Northwest Coordination Agreement and participating in Northwest Power Pool Committee activities.

Offpeak hours: Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).

Operating limits: Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see operating requirements, below.)

Operating requirements: Guidelines and limits that must be followed in the operation of a reservoir or generating project. These requirements may originate in authorizing legislation, physical plant limitations, or other sources.

Operating rule curve: A curve, or family of curves, indicating how a reservoir is to be operated under specific conditions and for specific purposes.

Operating year: The 12-month period from August 1 through July 31.

Outages: Periods, both planned and unexpected, during which the transmission of power stops or a particular power-producing facility ceases to provide generation.

Pacific Northwest Coordination Agreement: A binding agreement among BPA, the Corps, Reclamation, and the major generating utilities in the Pacific Northwest that stemmed from the Columbia River Treaty. The Agreement specifies a multitude of operating rules, criteria, and procedures for coordinating operation of the system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

Peak load: The maximum electrical demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.

Project outflow: The volume of water per unit of time discharged from a project.

Proportional draft: A condition in which all reservoirs are drafted in the same proportion to meet firm loads.

Refill: The point at which the hydro system is considered "full" from the seasonal snowmelt runoff. Also, refers to the annual process of filling a reservoir.

Reliability: For a power system, a measure of the degree of certainty that the system will continue to meet load for a specified period of time.

Reservoir draft rate: The rate at which water, released from storage behind a dam, reduces the elevation of the reservoir.

Reservoir elevations: The levels of the water stored behind dams.

Reservoir storage: The volume of water in a reservoir at a given time.

Resident fish: Fish species that reside in freshwater throughout their lives.

Rule curves: Water levels, represented graphically as curves, that guide reservoir operations.

Run-of-river dams: Hydroelectric generating plants that operate based only on available streamflow and some short-term storage (hourly, daily, or weekly).

Secondary energy: Hydroelectric energy in excess of firm energy, often used to displace thermal resources. Sometimes called nonfirm energy.

Shaping: The scheduling and operation of generating resources to meet changing load levels. Load shaping on a hydro system usually involves the adjustment of reservoir releases so that generation and load are continuously in balance.

Smolt: A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt its body from a freshwater to a saltwater environment.

Spawning: The releasing and fertilizing of eggs by fish.

Spill: Water passed over a spillway without going through turbines to produce electricity. Spill can be forced, when there is no storage capability and flows exceed turbine capacity, or planned, for example, when water is spilled to enhance juvenile fish passage.

Spillway: Overflow structure of a dam.

Storage reservoirs: Reservoirs that have space for retaining water from springtime snowmelts. Retained water is released as necessary for multiple uses—power production, fish passage, irrigation, and navigation.

Streamflow: The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

Surplus: Energy generated that is beyond the immediate needs of the producing system. This energy may be sold on an interruptible basis or as firm power.

Thermal power plant: Generating plant that converts heat energy into electrical energy. Coal, oil, and gas-fired power plants and nuclear power plants are common thermal resources.

Turbine: Machinery that converts kinetic energy of a moving fluid, such as falling water, to mechanical or electrical power.

Usable storage: Water occupying active storage capacity of a reservoir.

Usable storage capacity: The portion of the reservoir storage capacity in which water normally is stored or from which water is withdrawn for beneficial uses, in compliance with operating agreements.

Variable energy content curve (VECC): The January through July portion of the energy content curve. The VECC is based on the expected amount of spring runoff.

Water Budget: A part of the Northwest Power Planning Council's Fish and Wildlife Program calling for a volume of water to be reserved and released during the spring, if needed, to assist in the downstream migration of juvenile salmon and steelhead.

Water Rights: Priority claims to water. In western States, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over newer ones.

Acronyms and Abbreviations

AER	Actual Energy Regulation	MPC	Montana Power Company
aMW	average megawatts	MW	megawatts
BPA	Bonneville Power Administration	NEPA	National Environmental Policy Act
CBFWA	Columbia Basin Fish and Wildlife Authority	NMFS	National Marine Fisheries Service
cfs	cubic feet per second	NWPPC	Northwest Power Planning Council
Corps	U.S. Army Corps of Engineers	PGE	Portland General Electric
CROHMS	Columbia River Operational Hydromet Management System	PNUCC	Pacific Northwest Utilities Conference Committee
CRWMG	Columbia River Water Management Group	PP&L	Pacific Power and Light Company
CSPE	Columbia Storage Power Exchange	pud	public utility district
DSI's	Direct Service Industries	Reclamation	U.S. Bureau of Reclamation
FELCC	firm energy load carrying capability	SCL	Seattle City Light
FERC	Federal Energy Regulatory Commission	TCL	Tacoma City Light
IP	Idaho Power Company	USBR	U. S. Bureau of Reclamation
kcs	one thousand cubic feet per second	USCE	U.S. Army Corps of Engineers
kw	kilowatts	VECC	variable energy content curve
MAF	million acre-feet	WKP&L	West Kootenay Power & Light
		WWP	Washington Water Power Company

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All three System Operation Review agencies have extensive libraries and welcome public inquiries.

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