II. HYDROMETEOROLOGY

A. OBSERVATIONS

With the Pacific Northwest's highly diverse hydrologic conditions, both areally and seasonally, information on weather, snow packs, and streamflows played a pivotal role in the effective operation of the dams and reservoirs to meet the needs of the region's people, industry, and natural resources. This chapter summarizes these conditions, first generally in describing the overall conditions throughout the year and then some unique conditions that had a pronounced effect on the region. The chapter concludes with summaries of forecasts and peak streamflow conditions.

1. Weather

The Pacific Northwest has the most diverse weather conditions of any region of the nation, varying from the arid conditions in the shadows of the Olympic and Cascade Mountains to very wet rainforest along the Pacific coast to dry areas that are subject to occasional cold outbreaks of winter continental weather in the Rocky Mountains along the Continental Divide. The normal seasonal variations are just as dramatic with the coastal areas and Cascade Mountains receiving their maximum precipitation in the winter months while the eastern basins, with more steppe and continental climates, have their maximum precipitation in early summer. To best consider all these seasonal and areal variations, the following weather discussion will reference departures of temperatures and precipitation from normals rather than observed values. Monthly sub-basin precipitation is shown in Table 1 and Table 2, basin temperature in Table 3, and Figure 6 is a map of the annual precipitation in the Columbia drainage. Figure 6 shows accumulated precipitation across the Columbia Basin during the October 2001 through the September 2002 water year. Figure 7 denotes the monthly accumulation of the Columbia Basin snowpack for Water Year 2002 expressed as a percent of normal peak snowpack. Figure 8 denotes the accumulated precipitation in inches for the Water 2002 at primary Columbia River basins. Figure 9 is a map of the Pacific Northwest monthly temperature departures from normal for the month of December 2001.

The month of October was cooler and wetter than normal. A dry weather pattern generally held across the Region early in the month. During the middle and latter part of October the jet stream sagged south of the United States, Canadian Border. This allowed a series of storm systems to impact the Region and pushed precipitation to above normal levels across much of the Region. The 31 Stations Temperature Index for the Pacific Northwest departed -0.4 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -3.1 to 2.0 degrees.

In November it was warmer and wetter than normal west of the Cascades, and warmer and drier than normal east of the Cascades. Early in the month a ridge of high pressure maintained drier than normal weather across southern tier basins. With only weak weather systems impacting the area, northern tier basins also experienced lighter than normal precipitation. Late in the month a stormier weather scenario developed across the Region. A series of storm systems bringing frequent periods of valley rain and mountain snow were sufficient to push precipitation totals to above normal levels west of the Cascades. East of the Cascades precipitation was not quite heavy enough to make up for deficits that built up earlier in the month. The 31 stations temperature index for the Pacific Northwest departed +3.6 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from 0.7 to 9.3 degrees.

In late November a stormy weather pattern developed across the Pacific Northwest and continued across the Region through the early and middle parts of December. A series of storm systems moved across the Region bringing frequent periods of valley rain and mountain snow to the Pacific Northwest, especially to areas west of the Cascades. A drier scenario set up late in the month as a ridge of high pressure developed, causing low-pressure systems to weaken as they approached the Western United States. The 31 Station Temperature Index for the Pacific Northwest departed +0.6 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -4.8 to 4.3 degrees. No new temperature records were established in December.

It was a wet January west of the Cascades and across Northern Idaho, and warmer than normal across all areas except the southwest basins. Frequent episodes of valley rain and mountain snow impacted west side basins and brought precipitation to above normal levels. Storm systems weakened and did not have as much moisture to work with as they moved east of the Cascades. Precipitation was below normal. From Eastern Washington and Oregon into Southern Idaho and Western Montana. The 31 Station Temperature Index for the Pacific Northwest departed +2.5 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -3.2 to 5.9 degrees.

The Pacific Northwest experienced a cooler and drier than normal February across most areas. During the beginning of the month a series of weak weather disturbances impacted the Region. Valley rain and mountain snow with these systems were generally light. Late in the month a stalled frontal system and copious moisture combined to produce heavy precipitation across British Columbia and Northwest Washington. This pushed divisional totals to near or slightly above normal levels across far northwest basins. The rest of the region maintained drier than normal conditions. The 31 Station Temperature Index for the Pacific Northwest departed -1.6 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -10.6 to 1.3 degrees.

March was cooler than normal across most areas. Precipitation transitioned from above normal across the north to below normal across the south in March. A trough of low pressure at upper levels of the atmosphere maintained a cool northwest flow across the Pacific Northwest through much of the month. Storm systems had their greatest impact across the north. Southern British Columbia, Northern Washington, Northern Idaho, and Northwest Montana reported above normal precipitation. Daily precipitation records, established in March, all occurred on the 20th. The 31 Station Temperature Index for the Pacific Northwest departed -5.2 degrees from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -9.5 to -2.3 degrees.

April had above normal precipitation across Northwest and Southeast Basins with near or below normal precipitation elsewhere across the Pacific Northwest. A ridge of high pressure off the Washington and Oregon coasts brought drier than normal conditions to the Region early and again very late in the month. Frequent periods of mostly light to moderate precipitation were common the rest of the month as a series of frontal systems pushed across the Region. The heaviest 24 hour precipitation amounts were reported on the 12th and 13th, when 1 to 2.5 inches and .5 to 1 inches were common a cross Northwest and Northeast Basins respectively.

A cool Northwest flow dominated through much of the month of May and kept temperatures at below normal levels across most areas. Upper level low pressure systems brought mainly light precipitation as they moved Southeast from the Gulf of Alaska into British Columbia and the Pacific Northwest. Above normal precipitation was mainly confined to parts of Southern British Columbia and Northwest Montana.

A series of storm systems tracking across northern tier basins pushed precipitation to above normal levels across Southern British Columbia, Washington, Northern Idaho and Western Montana for the month of June. South of the main storm track precipitation remained below normal across much of Oregon and Southern Idaho.

An area of high pressure positioned across the Western United States brought dry conditions to the Pacific

Northwest through much of the month of September. Brief breaks from dry weather occurred from the 15th to the 16th and from the 29th to the 30th when low pressure systems moved across the Region.

2. Snowpack

After a year of near record minimum snowpacks and streamflows in the Columbia Basin, the overall water year 2002 snowpack was as close to average as one can get.

The overall snowpack index at The Dalles was 102 percent of average for January 1, compared to 59 percent in water year 2001. The mainstem Columbia snowpack ranged from 85 percent in the Kettle Basin to 153 percent in the Deschutes Basin. The Snake Basin was also well ahead of 2001 with a composite snowpack of 100 percent of average.

The February 1 snowpack for the Columbia Basin above The Dalles was up 8 percent over January 1. The northern sub-basins generally gained snowpack, while southern sub-basins had generally declining percents of average. Things were certainly different than 2001.

The March 1 snowpack index for the Columbia Basin above The Dalles was down 2 percent from February 1. In general, basin snowpack percent of seasonal averages declined in the U.S., reflecting a dry second half of February. In summary, the March 1 Columbia Basin snowpack index above Castlegar was 119 percent of average, above Grand Coulee was 113 percent, the Snake was at 93 percent, and above The Dalles, it was 107 percent of average.

Overall, the snowpack index was 108 percent of average above The Dalles on April 1. However, the snowpack north of the Clearwater Basin increased dramatically, while the southern tier snowpack decreased about 5 percent on the average.

April snowfall was quite varied over the Basin. While measurements over most of the Upper Columbia snowpack indicated small increases, the Oregon snowpacks experienced considerable decreases, and the Washington Cascade snowpack increased as much as 14 percent of average. The May 1 composite snowpack measured above The Dalles was 110 percent of average.

For information about snowpack measurements including that needed to develop the Oregon Surface Water Supply Index or SWSI for Table 4, see the NRCS National Water & Climate Center web site at http://www.or.nrcs.usda.gov/snow/watersupply/swsi.html .

3. Surface Water Supply Index – SWSI

Category-score numerical methods have been developed to indicate the status of the overall surface water supply. The Surface Water Supply Index (SWSI) was developed by the NRCS and has been applied, with slight variations, in portions of the Pacific Northwest. Thus far, the SWSI has only been applied to basins in Oregon, Idaho, and Montana; but only the Oregon values are computed monthly. These indices include consideration of the status of the surface waters and reservoir contents of the basin, along with precipitation, snow, temperature, and other parameters. The index has a range of +4.1 (very ample supply of water) through 0.0 (normal supply), to -4.1 (very inadequate supply).

For monthly information about the Oregon SWSI for the years 1997 to 2002, see the web site at: http://www.or.nrcs.usda.gov/snow/watersupply/swsi.html. For pertinent information about the Idaho SWSI for water year 2002, see the web site at: http://www.id.nrcs.usda.gov/snow/watersupply . (The Klamath, Lake County, and Harney areas do not contribute to the Columbia drainage or have flood control reservoirs and therefore are not germane to this report).

The effects of the water supply on the regulation of the specific reservoir projects are discussed in Chapter

III, the effects on power generation, irrigation, recreation, fisheries, and other activities are discussed, by activity, in Chapter IV.

4. Streamflow

Streamflows in the Pacific Northwest were measured at approximately 900 gaging stations. To condense this information, data from 10 index gages, on both uncontrolled and controlled streams, were used to summarize the flows throughout the region. Data from all gages are reported with observed flows and are not adjusted for the amount of storage. Monthly mean discharges for each of these index stations, expressed as a percentage of their 1971-2000 normal discharges, are shown in Table 5. Flood peaks will be discussed in Section 5.

After experiencing record or near record low annual mean flows in WY 2001, most of the Columbia River Basin managed to post annual mean flows near or above normal for WY 2002. The notable exceptions of the index sites were the Snake River Basin sites, which ended the year with an annual mean of 66% of normal or less. The index station with the highest mean annual discharge, in percent of normal, was the Spokane River at Spokane, Washington with 121%, and the lowest was the Snake River at Weiser, Idaho with 56%.

The below normal flows at most index sites at the end of WY 2001 continued into the early part of WY 2002. Snowpack accumulation through the end of December was at or above normal for most of the Columbia River Basin except western Montana and parts of eastern Idaho, which recorded below normal snowpack. Streamflows remained below normal through December for most sites in the basin except for the Willamette Basin in Oregon, which received a boost from a wet November and December. The near normal snowpack trend and below normal stream flow trend continued through February. In April, melting low-level snowpack improved the monthly mean flows for most index sites into or above the normal range.

Late spring and summer precipitation were below normal for most of the Columbia River Basin. Streamflows improved or stayed near their normal range through the summer for a number of index sites. The John Day Basin in Oregon was the exception with its monthly mean flows eroding from 103% of normal in April to just 38% of normal by September.

Tables 6, 7, 8, 9, and 10 show additional comparisons of WY 2002 observed streamflows and runoff with historical flows. The Snake River at Anatone had a record low October mean observed streamflow for the period of record.

5. Flood Events

The flood evens for water year 2002 were mostly in the realm of minor flooding, with a few exceptions. Flooding began in the usual locations - northwest Washington in November. The Skagit, Snoqualmie, Tolt and Skokomish Rivers all had minor flood events. Issaquah Creek near Seattle also experienced som flooding.

a. WINTER FLOODS. A stretch from the middle of December to the end of January was the most active flood period during the winter. All Western Washington tributaries from the Puyallup River north experienced minor to moderate flooding. The Olympic Mountain tributaries and SW Washington were also hit with flooding during this time. The most serious flooding was on the Dungenous River on the Olympic Peninsula. The rain also worked its way south into Oregon where several Coastal range tributaries received minor flooding. See Table 11 for a description of these winter flood events.

b. SPRING FLOODS. Late winter and early spring rainfall coupled with low elevation snow melt brought some minor flooding to the Upper Palouse, Coeur D'Alene and St. Joe Rivers in northern Idaho and on the Fisher, Yaak and St. Regis Rivers in Montana. The upper Naches River in eastern Washington and the Grand Ronde River in northeast Oregon also had some minor flooding. Also, a few snow melt floods augmented by precipitation occurred. The basins affected were Fisher, Yaak, Thompson and St. Regis Rivers in Montana; the St.

Joe River in Northern Idaho; and The Okonagon River in northeastern Washington. See Table 12 for a description of these spring flood events.

B. FORECASTS

River forecasts are prepared primarily by the Northwest River Forecast Center (NWRFC) under an agreement between the NWRFC, the Corps, and Bonneville and are fully coordinated with the Bureau of Reclamation. Under this Columbia River Forecasting Service (CRFS) agreement all major projects are assumed to be operated based on coordinated forecasts. This minimizes unanticipated project operations due to the use of different flow forecasts. This agreement sets three main goals: (1) pool certain resources of the three participating agencies within the region; (2) avoid duplication of forecasts; and (3) increase the overall efficiency of operation. These forecasts are released monthly about the tenth of each month between January and June and are based on the basin hydrologic conditions on the first of each month plus normal weather assumed throughout the remainder of the forecast period.

In addition to these CRFS forecasts, the NWRFC also prepared forecasts that are distributed through the state NWS offices for public warning, for rivers in areas that were not affected by project regulations.

For forecast points located below flood control projects, outflow schedules are provided by the operating agency before the downstream flood warning is issued. The forecast area includes all of Oregon, Washington, Idaho, western Montana, western Wyoming, and the Columbia Basin portion of British Columbia. Distribution of all these forecasts was through CROHMS, by the Columbia Basin Telecommunications system (CBT), and the National Weather Service (NWS) web page (http://www.nws.noaa.gov/forecasts.html). The NWS AFOS system is used to transmit the forecasts to the state hydrologist offices in Seattle, Portland, Medford, Boise, Missoula, Pendleton, Pocatello, and Spokane for public release.

1. Runoff Volumes

Water supply volume forecasts issued on both January 1 and April 1, Table 13, indicated near normal runoff conditions could be expected from most sub-basins. Slightly above average runoff was forecast for streams draining from the Rocky Mountains into the upper Columbia River Basin, and below average runoff was forecast for the lower Snake River basin. Tables 14 displays the monthly forecasts at key sites and their verification.

On January 1st most forecasts were for near average flows. The exceptions were western Montana where the Natural Resource Conservation Service (NRCS) thought that dry soil would limit runoff and on the mainstem of the Snake River below Milner where the forecasts were near 75%. As the year developed, cool temperatures allowed snow accumulations to continue through May. Then, spring rainfall augmented runoff, especially on the Columbia and Kootenai Rivers in Canada and in western Montana. Consequently most volume forecasts increased from January 1st to April 1st. The exception was the upper and middle Snake River area where low snow accumulation, low spring precipitation and increased diversions reduced forecast volumes. January 1st forecast errors generally fell into the 5 to 25 percent range. By April 1st the forecast errors were mostly in the 1 to 15 percent range.

Table 15 shows the history of forecasts of the January-July runoff of the Columbia River at The Dalles for the period 1970-2002. These are the actual forecasts made each year and do not include the effects of improvements in forecast models or changes in the amount and quality of data used in models. WY-2000 adjusted runoff for the Dalles was 98.0 maf. A caveat for this table lists the actual historic forecasts that were made at the time and do not include corrections or adjustments for improvements in forecast models, changes in the quality of data, number of data stations used or their locations that have occurred in recent years.

For information about water supply streamflow products posted by NRCS, National Water & Climate Center, see the NRCS web site at http://www.wcc.nrcs.usda.gov/water/w_qnty.html. Products for this web site include streamflow color graphics maps and forecast probability charts.

2. Long-Range Peaks

Spring peak flow forecasts, expressed as a range of stages or flows, are a product of volume forecasts with model simulation of daily forecasts that provide adjustments to these long-range predictions. The forecast peak stage or flow are expressed so there was a probability that 16% of peak drainage may occur above the higher limit and a 16% probability of the peak occurring below the lower limit.

With near average runoff, no streams were forecast to exceed flood stage during the spring runoff period. Most snow melt crests fell within the April 1st expected ranges. No major streams exceeded flood stage but tributaries on the Kootenai, Coeur D'Alene, the lower Pend Oreille, Yakima and the Grand Ronde did experience some minor flooding. The regulated peak for the Portland-Vancouver harbor was below 12 ft. Table 16 provides a comparison of this years forecast and observed peaks for key sites.

3. Daily Streamflows

The forecasts of operational streamflow were prepared by the NWRFC. The three operating agencies, Bureau of Reclamation, Bonneville Power Administration, and the Corps, used these streamflow forecasts in their day-to-day reservoir project operation and energy production. Close and constant coordination was required between these agencies and the NWRFC because project operations were dependent upon forecasts and the forecasts must take into consideration the project operation. The results of water resource uses of these forecasts are described in the following two chapters of this report.