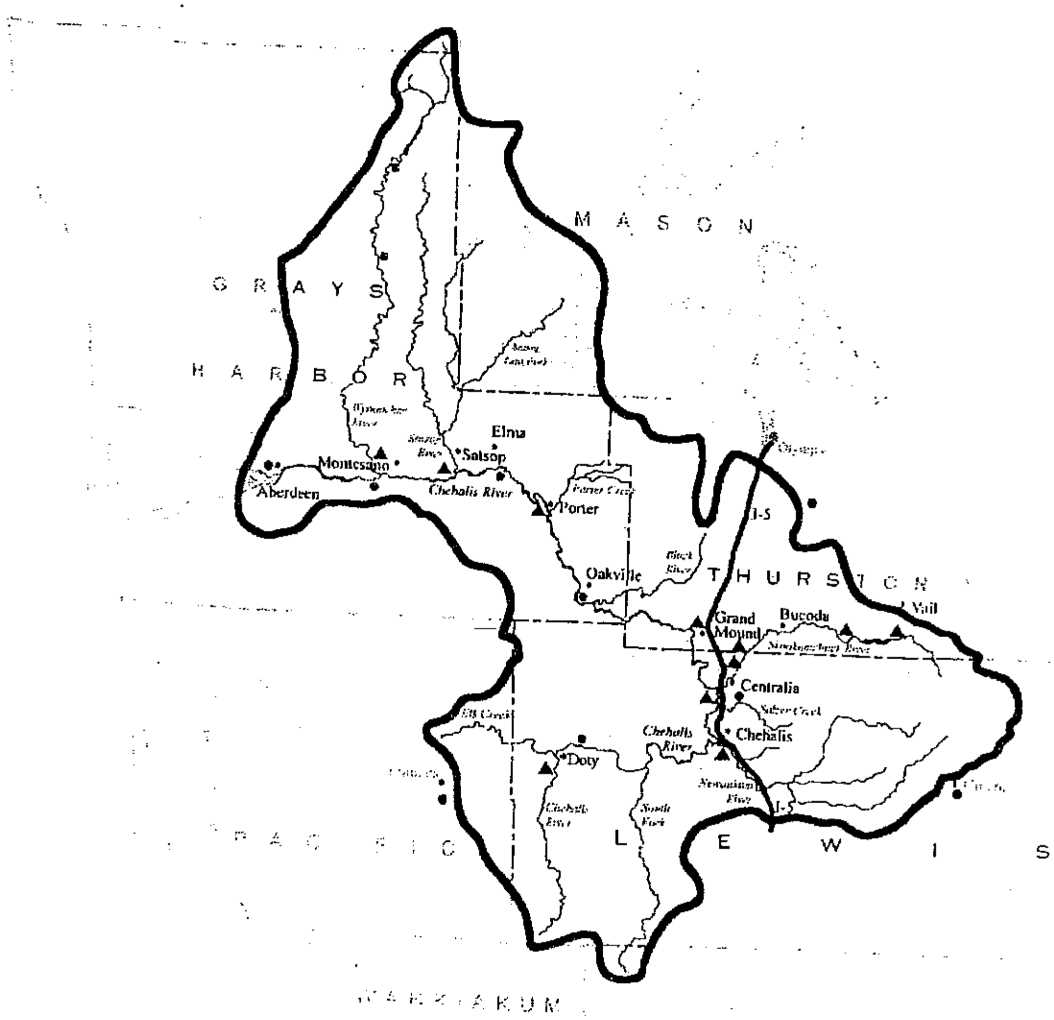
Prepared for

LEWIS COUNTY

Chehalis River Basin Flood Reduction Project

DRAFT Interim Report - December 1998



Prepared by

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Executive Summary

In recent years the chronic flooding that has historically plagued the businesses and residents of the Chehalis River floodplain in the vicinity of Chehalis and Centralia seems to have worsened. Several significant flood events often occur in one season. Eight major floods have occurred in the last ten years, including the first, second, third and sixth highest of record since accurate record keeping began in 1929. Recent statistical analysis established that the flood level experienced in 1996, the highest ever recorded, was a "100 year" flood (1% annual return frequency). The other devastating flood levels that have occurred in recent years will return much more frequently than previously expected.

Since 1931, many studies have investigated various proposed flood control projects only to find that no one project could be justified economically. Most of these studies were undertaken by the U.S. Army Corps of Engineers (USACE), which continues to work on small, local flood control projects, but has never implemented a basin-wide solution to the problem.

Spurred by the real, and obvious, economic impact that the chronic flooding had caused, local leaders began a broad-based initiative following the major 1996 flood to evaluate whether any realistic flood damage reduction options existed. By this time regional transportation problems had also become an issue. Interstate Highway 5 (I-5) was closed for several days during 1990 flooding and again in 1996. When the Washington State Department of Transportation (WSDOT) began planning to widen the I-5 corridor through the Chehalis-Centralia floodplain, they found that it would be necessary to raise the entire grade above flood stage in order to meet federal standards, in places up to 12 feet.

While the actions contemplated by WSDOT would address the flooding of I-5, they did nothing to address the flooding problem in the surrounding community. With support from several federal and state agencies including WSDOT, the local community instead proposed to investigate and develop a comprehensive flood hazard management project that would provide flood relief for communities across the basin as well as for I-5. A guiding principal of the community effort is that any project undertaken could not increase the potential for damage and harm to any part of the community.

In 1998 the Washington State Legislature appropriated $600,000 through WSDOT to Lewis County to support continuing community-based efforts to identify a comprehensive solution to flooding in the region. This Interim Report – December 1998 describes the work accomplished since that support became available in mid-1998.

An interlocal organization was created among Lewis County, Grays Harbor County, Thurston County, and the Cities of Chehalis and Centralia to oversee development of the community alternative. An Executive Committee comprised of one elected official and one senior staff person from each jurisdiction oversees the general direction of the project. Lewis County is designated as the lead agency and Lewis County Commisioner Richard Graham currently serves as the Project Manager. The Chehalis Confederated Tribe is considered an essential partner of the group, is informed of and consulted on all major actions and is welcome to participate on whatever level it deems appropriate.

Project consultants first developed a sophisticated computer model of the Chehalis River, calibrated to accurately emulate the flow during storm events that have caused flooding. This essential planning tool allows a thorough evaluation of any alternative or combination of alternatives to see if the reduction of flood level could be sufficient to meet the needs of the community and WSDOT.

After extensive evaluation of numerous options and potential components for reducing flood impacts, the consultants identified a strategy that included three components:

- Modifications of Skookumchuck Dam to hold back in time the contribution of Skookumchuck River flood flows to the Chehalis River flood peak.
- Enhancement of flood flow capacity through the Centralia-Chehalis reach of the Chehalis River.
- Elimination of a major flow constriction in the vicinity of the Mellen Street Bridge.

Two alternatives discussed in this report are based upon this strategy. Both alternatives enhance the flood flow capacity, one by modifications to the river floodway and the other to the river floodplain.

A comprehensive approach to the flooding issue provides tremendous opportunities to restore and enhance environmental functions in the Chehalis Basin, particularly fisheries resources along the river corridor.

A Technical Committee comprised of tribal, federal, state, and local agency representatives will provide input, guidance, and review as a preferred alternative is developed. An Alternatives Sub-Committee of the Technical Committee is charged with articulating other alternatives that will be thoroughly evaluated.

Alternatives discussed in this report are clearly promising. It appears feasible to reduce flood levels substantially and eliminate the need to raise the I-5 grade without increasing flood levels downstream. It appears that this can be done at a cost below the estimated incremental cost for simply raising I-5. An integrated project could reduce flood levels throughout the community and contribute to significant environmental restoration throughout the area.

1. Physical Characteristics

1.1. Watershed

1.1.1. Drainage Basin

The Chehalis River drainage basin covers approximately 2,114 square miles (see Figure 1-1). The Chehalis River is about 125 miles long, originating in the Willapa and Doty Hills southeast of Aberdeen and flowing northeast and then northwest before emptying into Grays Harbor at Aberdeen. The basin uplands include the Willapa Hills, the western flank of the Cascade Mountains, and the southern Olympic Mountains.

The Chehalis River originates in the extreme southwestern corner of the basin, and flows east for about 25 miles to its confluence with the Newaukum River at Chehalis. From Chehalis the river flows north for 8 miles, where it meets the Skookumchuck River at Centralia. The river then turns and flows generally north and west for about 50 miles to its mouth at Grays Harbor on the Washington coast.

The Chehalis River Valley, located in the southern end of the Puget Trough, is characterized by a broad, well-developed floodplain and low terraces surrounded by highly dissected uplands of low to moderate relief that have broad, rounded ridges. There are numerous perennial streams in the valley. The valley bottom is at an elevation of about 150 feet, and upland elevations average about 300 to 600 feet. Higher elevations in the basin range from about 1,000 feet in the lowland hills, to 2.658 feet at Capital Peak in the south Olympic Range, to 3.800 feet in the foothills of the Cascade Range east of Chehalis-Centralia, and 3,110 feet in the Boistfort Hills along the south basin.

1.1.2. Upper Chehalis River Basin

The slope of the upper Chehalis River from its source to Chehalis is steep, falling an average of 16 feet per mile. The slope flattens to about three feet per mile in the valley surrounding Centralia and Chehalis, where the Chehalis River has a meandering channel that occupies a fairly uniform floodplain averaging over one mile wide. Most of the valley is inundated during a severe flood such as the January 1990 and the February 1996 floods.

The Upper Chehalis River Basin includes three main drainages: the Skookumchuck River, the Newaukum River, and the upper Chehalis River. In addition there are several smaller subdrainages in the Centralia-Chehalis area including Coffee Creek, China Creek, Salzer Creek and Dillenbaugh Creek (see Fig. 1-2).

Skookumchuck River

The Skookumchuck River, one of the major Chehalis River tributaries, joins the Chehalis River at river mile (RM) 67, and is approximately 41 miles in length. It originates in the Mt. Baker-Snoqualmie National Forest northeast of Centralia, and empties into the Chehalis River at Centralia. The total drainage area for the Skookumchuck River is 181 square miles. Elevations within the basin range from 150 feet at the mouth to over 3,000 feet at the headwaters. The slope of the Skookumchuck River from its source to the town of Bucoda is steep, falling an average of 19 feet per mile. Below Bucoda, the slope flattens to about five feet per mile near Centralia. Except for the uppermost portion, the Skookumchuck River flows as a meandering channel in a floodplain, varying in width from a few hundred feet to 0.5 mile. The Skookumchuck River has several tributary creeks. The largest tributary, Hanaford Creek, has a drainage area of 58.4 square miles.

Three developments are notable within the Skookumchuck River system. The first is the City of Centralia, which occupies several square miles at the lower end of the basin. The second development is Skookumchuck Dam, located about 20 miles upstream from Centralia and operated by PacifiCorp. Skookumchuck Dam was completed in 1971 and has been considered several times for flood control use. The third development of note in the Skookumchuck Basin is the Centralia Steam Generating Plant on Hanaford Creek. Authority has been granted for this coal-fired facility to divert up to 54 cubic feet per second (cfs) of water from the Skookumchuck River.

Newaukum River

The Newaukum River joins the Chehalis River at RM 75 at the City of Chehalis. The Newaukum drains 175 square miles of lowland and foothills southeast of the City of Chehalis. Elevations in the basin range from approximately 180 feet at the confluence with the Chehalis River, to a little over 3,000 feet in the upper basin. The Newaukum River is the second major tributary to the Chehalis River in Lewis County.

The Newaukum River is made up of three forks: the north, middle, and south forks. Upstream sections on both the north and middle forks have slopes of 83 feet per mile; the south fork has a slope of 188 feet per mile above the town of Onalaska. The average channel slope for the entire drainage is 35 feet per mile.

Coffee Creek

Coffee Creek is a tributary of the Skookumchuck River. With headwaters in Thurston County, Coffee Creek flows south, through the Zenkner Valley, to the Skookumchuck River north of Centralia. The watershed encompasses 7.3 square miles of moderately sloping hills. Watershed elevations range from 186 feet at the confluence with the Skookumchuck River to 645 feet at the northern tip of the watershed. The stream gradient is low in the lower four miles of the watershed. Coffee Creek has been moved from its natural location to a periphery channel bordering the edge of adjacent hills and valley floor.

China Creek

China Creek is a relatively small, short stream that flows through the City of Centralia to the Chehalis River. The watershed extends about five miles east of the Chehalis River at Centralia. It encompasses approximately six square miles, ranging in elevation from 180 feet to 570 feet. Much of the land is moderately steep. Most of the channel consists of pipes and culverts through Centralia.

Salzer Creek

Salzer Creek flows into the Chehalis River from the east, just south of the Centralia city limits, and drains 24.5 square miles. Salzer Creek originates in the low-lying hills east of Centralia-Chehalis, and has a maximum elevation of about 800 feet. The stream gradient of Salzer Creek is relatively flat. Coal Creek, a major tributary of Salzer Creek, has a drainage area of 6.4 square miles, and has a steeper slope.

Dillenbaugh Creek

Dillenbaugh Creek flows into the Chehalis River from the east, at the City of Chehalis. It originates in the steep foothills southeast of Chehalis, and has a drainage area of approximately 15 square miles. The gradient of Dillenbaugh Creek in the upper reaches is approximately 70 feet per mile. After it flows out onto the Newaukum River floodplain, the gradient drops as Dillenbaugh Creek parallels the Newaukum and Chehalis Rivers for nearly three miles before finally flowing into the Chehalis River. Dillenbaugh Creek collects much of the storm drainage from the City of Chehalis in this lower reach.

Upper Chehalis River

The upper Chehalis River, above RM 86, drains an area of 434 square miles, and can be divided into two main drainages and several smaller subdrainages. The two main drainages are the South Fork Chehalis River and the mainstem of the Chehalis River. The South Fork Chehalis River joins the mainstem of the Chehalis River at RM 88, and drains 130 square miles. The mainstem of the Chehalis River above Doty drains 113 square miles at RM 101.8 (USGS Gage). The major subdrainages include Bunker Creek, Stearns Creek and Elk Creek, which drain 34, 34.3 and 46.7 square miles, respectively.

1.2. Geology and Soils

1.2.1. Geology

The bedrock geology of the Chehalis River Basin is composed primarily of igneous and sedimentary bedrocks of the Tertiary Period. Surficial deposits include the unconsolidated glacial sediments of the Pleistocene Epoch. Following formation of the bedrock (7-55 million years ago) the area underwent geologic uplift, raising the volcanic and sedimentary rocks above sea level. Deformation, in the form of faulting and folding, accompanied the uplift. Landslides, erosion, glaciation and glaciofluvial deposition, as well as recent volcanic activity, followed. The most recent 10,000 years have been a period of relatively stable climatic and geologic conditions with erosion being the dominant geologic process (ENSR, 1994).

From the City of Chehalis to the City of Montesano, the average width of the floodplain is about 1.5-2.0 miles. The sediments within this floodplain attain a maximum depth of approximately 100 feet. The floodplain shows very little relief either longitudinally or perpendicular to the direction of flow. This lack of relief has resulted in a very sinuous river course with numerous oxbow lakes and other abandoned channels.

Geologic evidence indicates that the Chehalis River has reworked its valley since the deposition of the glacial alpine outwash sand and gravel. This sand and gravel forms the older river terraces that line the valley margins. This time line would make the recent river deposits less than 7,000 to 10,000 years old. Canyon wall conditions imply a mature topographic landscape prior to river sedimentation. This type of landscape would contribute to the long term, slow aggradation by the river system with deposition of fine sand and some fine gravel, but a predominance of silt, clay and organic mud. Mapping of the Centralia-Chehalis area by the Soil Conservation Service confirms that at least 50% of the deposits in the upper 5 feet of the valley sediments are organic mud, silt and plastic clay. The longer term, more active stream channels contain the coarser grained sediments. Based on the recent site investigations performed by PIE's geotechnical subconsultant, the area contains two basic material types (HCI, 1998). Upstream of Centralia, soils are predominantly fine-grained sands, silts, and clays. Downstream of Centralia, substantial quantities of coarse sand and gravel mixtures were encountered.

1.2.2. Soils and Vegetation

The Soil Conservation Service published a soil survey of Lewis County in May, 1987. Much of the following information in this section is excerpted from that document (SCS, 1987). Soils in the floodplain tend to be a silty clay loam. These soils tend to be very deep and range from poorly drained to well drained. The native vegetation is wetland plants, deciduous plants, and conifers. The common wetland plants include bull thistle, cattail, peachleaf willow, reed canarygrass, and soft rush. The main woodland species are Douglas-fir and red alder. Among the trees of limited extent are black cottonwood, western red cedar and bigleaf maple. Among the common forest understory plants are western swordfern, vine maple, cascade Oregon-grape, red huckleberry, western brackenfern, Pacific trillium, and trailing blackberry.

Soils on plains, terraces and uplands tend to be very deep, and range from well drained gravelly sand to poorly drained silty clay. The main woodland species are Douglas-fir and red alder. Other trees found in limited extent are western hemlock, western red cedar and bigleaf maple. Among the common forest understory plants are cascade Oregon-grape, rose, red huckleberry, western brackenfern, violet, and salal.

Soils on uplands, mountains, and bigh terraces tend to be very deep, well drained silt loam. The main woodland species are Douglas-fir and red alder. Other trees found in limited extent are western hemlock, western red cedar and bigleaf maple. Among the common forest understory plants are cascade Oregon-grape, salmonberry, red huckleberry, western brackenfern, vine maple, and red elderberry.

All the soils in the basin fall predominately within AASHTO hydrologic group A. Soil permeability ranges from 0.6-2.0 inches per hour, to as high as 2.0-6.0 inches per hour.

1.3. Climate

The Centralia-Chehalis area has a predominately marine climate characterized by mild temperatures both summer and winter. Extreme temperatures are unusual for the area since prevailing westerly winds bring maritime air over the basin and provide a moderating influence throughout the year.

During the spring and summer, high-pressure centers predominate over the northeastern Pacific, sending a northwesterly flow of dry, warm air over the basin. The dry season extends from late spring to midsummer, with precipitation frequently limited to a few light showers. Average summer temperatures are in the 50's or 60's (°F), but occasionally hot, dry easterly winds cross the Cascade Mountains and raise daytime temperatures into the 90's. The Aleutian low-pressure center normally predominates during the winter, causing a counterclockwise circulation of cool, moist air over the basin and prevailing southwesterly winds.

The area from the Pacific Ocean to the crest of the Olympic Mountains, the western slopes of the Cascade Range, and the Black and Willapa Hills receives the full force of winter storms. Virtually every fall and winter (October through March), strong winds and heavy precipitation occur throughout the basin. Storms are frequent and may continue for several days. Successive secondary weather fronts with variable rainfall, wind, and temperatures may move onshore at daily intervals or less. Heavy orographic-type rainfall frequently is produced by these storm conditions when warm, maritime, saturated winds rise over the coastal range and west slopes of the Cascade Range. Occasional short cold periods are experienced when movement of arctic air into the Northwest interrupts the usual weather pattern.

The locations of the National Weather Service (NWS) climatological stations in the region are shown in Figure 1-1. A summary of pertinent data for these stations is shown in Table 1-1 below.

Table 1-1:
NWS Climatological Stations and Data Summary

Station Name	Station ID	Data Type	Elevation	Avg. Annual Precip. (in.)	Period of Record
Aberdeen	8	Daily	10	58.5	1931-Present
Aberdeen 20 NNE	13	Daily & Hourly	435	130.29	1948-Present
Centralia 1W	1277	Hourly	185	41.64	1931-Present
Chehalis	1330	Hourly	180	40.62	1948-1968
Cinebar 2E	1457	Hourly	1040	72.44	1948-Present
Doty 3E	2220	Daily	260	51.91	1978-Present
Elma	2531	Daily	69	66.83	1948-Present
Frances	2984	Hourly	231	71.91	1948-Present
Montesano 1S	5549	Hourly	25	76.79	1954-Present
Oakville	6011	Daily	80	56.06	1948-Present
Olympia AP	6114	Daily & Hourly	165	50.24	1948-Present

Source: National Weather Service

Precipitation in the basin is affected by distance from the Pacific Ocean, elevation, and seasonal conditions. Generally, the southern slopes of the Olympic Range and the more easterly, higher slopes along the Cascade Range receive the greatest precipitation. The Black Hills in the northeast portion of the basin and Willapa Hills between the coast and Centralia-Chehalis often receive moderate to heavy rainfall during the movement of oceanic storms through the basin.

The greatest amount of rainfall occurs between the months of October and March. The abundance of rainfall during this period is due to the frequent storm systems that pass over western Washington. In Centralia, monthly rainfall totals for this period typically range between five and eight inches. For the rest of the year, average monthly rainfall totals range only between 0.8 and 2 inches. The month with the highest average rainfall is November, with 7.77 inches. The month with the lowest average rainfall is July, with only 0.84 inches. Annual precipitation averages 41.64 inches, with annual records showing a range from as low as 28 inches to a high of 60 inches.

Snowfall in the region is not heavy, but the potential does exist for extremely large amounts on occasion. The average annual snowfall is approximately nine inches, with recorded extreme annual maximums at 45 inches. Most of the snowfall occurs in the month of January, with the monthly average at about 4.5 inches.

Winds in the region rarely exceed 30 mph; winds of this speed usually only occur during the fall and winter months in conjunction with rainstorms and/or thunderstorms that pass through the vicinity. Approximately 10 percent of the winds between the months of November and February have speeds between 15 and 30 mph. Only about two percent of the winds for the other months have speeds in this range (15 to 30 mph). The rest of the wind speeds typically range between 0 and 15 mph (about 90 percent of the time). Wind speeds have been measured in excess of 70 mph during the winter months. The majority of the highest wind speeds measured have originated from the south and southwest directions (southerly and southwesterly, respectively).

1.4. Environmental Setting

Environmental conditions in the Chehalis River Basin have been studied and described by a number of researchers. The descriptions of existing fisheries and wildlife habitats provided here are based upon previous studies conducted for USACE, Lewis County, the City of Centralia, and others. Site-specific and alternative-specific studies will need to be conducted in subsequent project phases to refine the understanding of existing environmental conditions, further define potential project impacts, and address regulatory and permitting issues.

1.4.1. Fisheries

Chehalis River

The Chehalis River supports chinook, coho, and chum salmon; steelhead, and sea-run cutthroat trout; as well as resident fish including bass, perch, crappie, bullhead, and sunfish. The mainstem of the Chehalis River provides a migration corridor for anadromous fish species, although spawning, incubation, and rearing habitats are limited. It is thought that salmon populations in the Chehalis River have been depressed by a combination of factors, including low streamflows, limited spawning habitat, elevated water temperatures, reduced dissolved oxygen levels, and habitat alteration (USACE, 1997a). However, with the exception of winter steelhead in the Skookumchuck and Newaukum Rivers, fish stocks in the Chehalis River system are considered healthy (CH2M-Hill, 1998).

Monitoring data indicate that water quality in the upper Chehalis River is generally good, with the reach between the headwaters and Rock Creek at RM 39 meeting Class AA (extraordinary) criteria. Downstream reaches generally meet Class A (excellent) criteria, although the Class A standards for temperature and dissolved oxygen are routinely not met during the summer months. A recent study by the Washington Department of Ecology indicates that problems with low dissolved oxygen levels and high temperatures are long-term and wide-spread (CH2M-Hill, 1998). Elevated water temperatures and/or low dissolved oxygen levels may cause the reach between Centralia and Chehalis to be impassible in late summer for adult chinook salmon attempting to migrate to upstream spawning grounds (USFWS, 1993).

Skookumchuck River

The Skookumchuck River provides transportation, spawning, incubation, and rearing habitats for numerous fish species. Fish inhabiting the portion of the river downstream of Skookumchuck Dam include fall and spring chinook salmon, coho salmon, resident and anadromous cutthroat trout, Olympic mudminnow, and largemouth bass. In comparison with historical populations, salmon populations in the Skookumchuck River are depleted. Chum salmon were historically found in the Skookumchuck, but the natural run is considered extirpated (USFWS, 1989). The winter steelhead run on the Skookumchuck is considered depressed by the Washington Department of Fish and Wildlife (WDFW) (CH2M-Hill, 1998).

Natural salmon spawning and rearing occurs in riffles between the mouth of the river and Skookumchuck Dam and in some 40 miles of tributary streams (ENSR, 1994, CH2M-Hill, 1997). WDFW operates a fish rearing facility, the Simpson Hatchery, approximately 0.5 miles downstream of Skookumchuck Dam. The Simpson Hatchery, which annually produces approximately two million coho smolts, contributes about 50 percent of the hatchery releases in the Chehalis River Basin.

Steelhead trout also utilize the Skookumchuck River for migration and rearing. WDFW traps the returning adult steelhead at a collection facility at the base of the dam, and transports them upstream, where the steelhead reproduce in the headwaters. About 50,000 steelhead smolts are planted annually to supplement the natural population.

Newaukum River

The Newaukum River watershed has four river reaches which provide important fish habitat. All of the mainstem of the Newaukum River, 17 miles of the North Fork, and all of the South Fork are utilized by coho and chinook salmon for migration, spawning, and rearing (ENSR 1994). Mainstem tributaries and tributaries to the north and south forks are also used for salmon production. Chum salmon have been located on the North Fork Newaukum River (ENSR, 1994). The winter steelhead run on the Newaukum River is considered depressed by WDFW.

1.4.2. Wildlife

The Chehalis River watershed provides habitat for numerous wildlife species including big game (black-tailed deer, Roosevelt elk, black bear, and cougar), game birds (primarily pheasant, grouse, and quail), fur-bearers (beaver, mink, muskrat, and other species), and waterfowl. The upper Chehalis River is on the Pacific Flyway for migratory birds.

Protected species of birds, including the bald eagle, osprey, and Northern spotted owl, inhabit the Chehalis River Basin. Recent studies indicate that bald eagles and ospreys use all of the major streams in Lewis County, particularly during winter months

(ENSR, 1994). Other protected wildlife species known to use habitats in the upper basin include the western pond turtle, giant Olympic salamander, and red-legged frog.

The wetland and riparian areas along the Chehalis River and its tributaries provide important habitat for a wide variety of wildlife. Wetlands and riparian areas generally support diverse vegetation and provide travel corridors and protected access to water. Wetlands and riparian areas are considered to be priority habitats in Washington State because they support high densities of mammals and birds. Wetland and riparian areas in the upper Chehalis River basin have been designated as sensitive areas by city and county jurisdictions. Migratory and resident waterfowl and passerine birds are particularly dependent upon these habitats; of the 53 bird species found in Lewis County, 42 (or 79 percent) are dependent upon wetlands and riparian areas (ENSR, 1994). As in many other areas of the country, riparian zones and wetlands within the basin have been adversely affected by agricultural and urban development.

1.5. Streamflow Characteristics

1.5.1. Streamgage Stations

Figure 1-2 shows the locations of the U.S. Geological Service (USGS) streamgage stations that are currently in operation in the Upper Chehalis River Basin. Table 1-2 summarizes pertinent data for these stations. In addition to the USGS streamgage stations, the National Weather Service (NWS) maintains wire weight stage gages at the Mellen St. Bridge and at the Pearl St. Bridge. The gages are used by the NWS for flood forecasting and warning.

1.5.2. Runoff

Streamflow generated within the Chehalis River Basin originates primarily from rainfall; although, snow melt occasionally augments runoff in the highest elevation reaches of the basin. The average annual runoff of the Chehalis River at its mouth (drainage area 2,114 square miles) and at the USGS streamgage near Grand Mound (drainage area 895 square miles), are estimated to be 6.4 million acre-feet and 2.0 million acre-feet, respectively.

The flow in the rivers and creeks of the Chehalis River Basin show seasonal variation characterized by sharp rises of relatively short duration from October to March, corresponding to the period of heaviest rainfall. After March, the flows tend to gradually decrease to a relatively stable base flow, which is maintained from July into October.

Major flooding occurs during the winter season, usually from November through February, as the result of heavy rainfall occasionally augmented by snow melt. Flooding may be either widespread throughout the Chehalis River Basin or localized in subbasins. Some storms may cover the entire basin and cause widespread flooding. Other storms may center over the Willapa Hills and cause flooding of the upper Chehalis River or center over the Black Hills and Cascade Foothills and result in flooding of the Skookumchuck River and Newaukum River.

Table 1-2:
USGS Streamgage Information

Station Name	Station ID	Drainage Area (Sq. Mi.)	River Mile	Record Period
Chehalis River near Doty	12020000	113	101.8	1939-Present
Elk Creek near Doty	12020500	46.7	2.5	1942-1970
S.F. Chehalis River near Boistfort	12020900	44.9	8.0	1965-1980
S.F. Chehalis River at Boistfort	12021000	48	6.0	1942-1965
Chehalis River near Chehalis	12023500	434	77.5	1929-1931
M.F. Newaukum River near Onalaska	12024000	42.4	8.0	1944-1971
N.F. Newaukum River near Forest	12024500	31.5	6.5	1960-1966
Newaukum River near Chehalis	12025000	155	4.1	1929-1931 1942-Present
Salzer Creek near Centralia	12025300	12.6	3.9	1968-1971
Skookumchuck River near Vail	12025700	40	28.8	1967-Present
Skookumchuck River near Centralia	12026000	61.7	21.0	1929-1969
Skookumchuck River below Bloody Run Creek	12026150	65.9	20.7	1969-Present
Skookumchuck River near Bucoda	12026400	112	6.4	1967-Present
Lincoln Creek near Rochester	12027000	19.3	9.0	1942-1950
Chehalis River near Grand Mound	12027500	895	59.9	1928-Present

Source: U.S. Geological Survey

1.5.3. Historical Floods

General

Precipitation totals at Centralia (Centralia 1W) for the ten largest one-day, two-day, and three-day storms of record are presented in Table 1-3 below. For comparison, from the NOAA Atlas 2, the estimated 100-year 24-hour rainfall varies in the basin from 4 inches in the Centralia area, to 8 inches in the higher elevation areas of the upper basin, and 12-13 inches in the headwaters of the Wynoochee drainage.

Table 1-3:

Precipitation Totals Ranked for 10 Largest Storms at Centralia 1W

One-Day Storm		Two-Day Storm		Three-Day Storm	
Month & Year	**Total Precip. (in.)**	**Month & Year**	**Total Precip. (in.)**	**Month & Year**	**Total Precip. (in.)**
Jan. 1990	4.13	Nov. 1986	6.09	Nov. 1986	6.49
Nov. 1990	3.96	Dec. 1933	5.10	Feb. 1996	6.40
Dec. 1933	3.95	Feb. 1996	5.02	Jan. 1990	5.87
Nov. 1986	3.22	Jan. 1990	4.96	Dec. 1933	5.49
Oct. 1942	3.22	Nov. 1990	4.82	Dec. 1937	5.41
Feb. 1996	3.34	Nov. 1932	4.02	Nov. 1990	5.25
Feb. 1951	3.15	Feb. 1951	3.84	Nov. 1932	4.47
Nov. 1932	3.07	Oct. 1942	3.59	Feb. 1951	4.22
Dec. 1937	2.10	Dec. 1937	3.58	Oct. 1942	4.20
Jan. 1972	1.95	Jan. 1972	3.13	Jan. 1972	3.64

Source: USACE, 1997b

The greatest flood discharge on the Chehalis River in the Centralia-Chehalis area during the last 70 years occurred in February 1996. Table 1-4 summarizes the largest floods of record in the basin.

Table 1-4:
Ten Largest Floods on the Chehalis, Skookumchuck and Newaukum Rivers (Since 1971)

Gage	Chehalis River near Grand Mound			Skookumchuck River near Bucoda			Newaukum River near Chehalis		
Year	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank
Feb. '96	20.04	74,900	1	17.87	9,370	1	13.34	13,800	1
Apr. '91	17.66	42,800	7	16.82	7,860	5	12.07	9,210	7
Nov. '90	18.12	48.00	5	17.23	8,400	3	12.73	10,300	4
Jan. '90	19.34	68,700	2	17.33	8,540	2	12.75	10,400	3
Nov. '86	18.41	51,600	3	15.01	5,770	10	12.76	10,700	2
Dec. '77	16.79	36,500	10	16.18	7,170	6	12.49	10,300	5
Dec. '75	17.73	44,800	6	15.42	6,110	8	10.85	8,020	10
Jan. '74	16.88	37,400	9	15.30	5,950	9	11.17	8,440	8
Jan. '72	18.21	49,200	4	16.82	8,190	4	12.12	9,770	6
Jan. '71	17.29	40,800	8	15.82	6,630	7	11.99	8,390	9

Source: USACE, 1997b

Brief descriptions of the three most recent, largest floods in the Centralia- Chehalis area (the, January 1990, November 1990, and February 1996 floods) are provided below. Descriptions for the two 1990 events came from USGS Open File Reports (Hubbard, 1991,1994), and the description for the 1996 event came from the USACE After Action Report (USACE, 1996a).

January 1990 Flood

The January 1990 flood was primarily the result of a series of back-to-back storms accompanied by heavy rainfall over the 8-day period January 3-10. The heaviest rainfall occurred on the seventh day of the storm, January 9, causing extreme flooding because the rain fell on soils that were saturated from the preceding rainstorms.

The storm system was quite complex and included high winds and strong surges of precipitation. The Centralia climatological station recorded 8 inches of rain during the eight-day period. This eight day total precipitation represents 19 percent of the total yearly precipitation that is recorded at the station on the average. The most intense precipitation in the basin occurred near the headwaters of the Skookumchuck and Newaukum rivers.

The surges in precipitation resulted in more than one flood peak in many of the rivers and creeks in the basin. The streams did not return to base flow between storm surges. The early precipitation saturated the soils in the basin and added greatly to the runoff potential when the heaviest rains arrived on January 9. Peaks of record, up to this event, were recorded at the following gaging stations: Chehalis River near Doty, Chehalis River near Grand Mound, and Chehalis River at Porter. These flood peaks were estimated at the time as the 100-year flood.

November 1990 Flood

Above average precipitation in October and early November resulted in saturated soils that contributed to the flooding potential when the major storm arrived during the period of November 21-25. During the period between a smaller storm in early November and the major storm, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000-foot elevation. The Cascade foothills averaged 6 inches at elevations of 1,000 to 2,000 feet; 12 inches at 2,000 to 3,000 feet; and 12-18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, November 21, snow changed to rain and temperatures rose. The warm front caused melting of snow up to elevations of 5,500 feet. Over the next 3 days, intense rain fell on drainages that were starting to swell from snow melt runoff; disastrous flooding resulted. A cold front moved in from the north on November 26, 1990, lowered freezing levels and diminished precipitation, finally ending the severe flooding.

February 1996 Flood

The February 1996 flood is the flood of record, to date, on all the major drainages in the Chehalis River Basin. Several of the main ingredients for a major storm flood were in place by February 5. The ground throughout the basin was at or near saturation from above average precipitation, which had fallen in the preceding weeks. In addition, snow had recently fallen as low as 500 feet above sea level during a cold snap. Third, warm, moist subtropical air was being transported from the Pacific Ocean into the Pacific Northwest. The freezing level in this subtropical air mass was well above 8,000 feet, which meant warm rains on the snow pack in the foothills.

Next, there was a strong polar jet stream with maximum wind speeds in its core in excess of 150 knots. These strong winds extended out into the central and western Pacific. Storms feed upon the stream and this powerful jet sustained and strengthened the storms as they moved in off the eastern Pacific. Also, the atmosphere was set up in a blocking pattern, which meant the major troughs and ridges around the Northern Hemisphere were stationary. The Pacific Northwest was situated between a major trough to the west and a major ridge to the east, ideal conditions for weather systems to be at maximum strength when they reached the area. The atmosphere remained in this general pattern for at least 96 hours during which copious amounts of rain fell and large quantities of water in the existing snow pack were released to flow into the rivers.

1.5.4. Flood Exceedance Frequency

USACE recently updated their flood frequency curves for the Chehalis River in the vicinity of Centralia (USACE, 1997b). USACE previously published flood frequency curves for the Chehalis River for a 1980 Federal Emergency Management Agency (FEMA) report (ENSR, 1994), and made revisions to the curves in 1989 (USACE, 1992). Since 1980, there have been three floods of record, and several other major floods on the Chehalis River. USACE incorporated the data since 1980 and recomputed the frequency curves. The recomputed frequency curves data, shown as years of recurrence interval, are shown below in Table 1-5. The recomputed frequency curves are significantly higher than those published in 1980 or 1989. Table 1-6 shows a comparison of estimated flood recurrence intervals for the Chehalis River at Grand Mound, using frequency numbers computed by the USACE and used by FEMA at various times.

Table 1-5:
Peak Discharge Frequency Data for Selected Locations

Location	2-Year Flow (cfs)	10-Year Flow (cfs)	25-Year Flow (cfs)	50-Year Flow (cfs)	100-Year Flow (cfs)
Chehalis near Grand Mound	25,000	43,800	55,000	64,300	74,300
Skookumchuck at Mouth	5,200	9,000	10,600	11,900	13,000
Skookumchuck at Pearl St.	4,800	8,450	10,100	11,300	12,500
Skookumchuck near Bucoda	3,900	6,900	8,300	9,300	10,400
Chehalis at Mellen St.	18,400	32,700	41,400	49,000	57,200
Chehalis above Salzer Creek	17,900	31,900	40,400	47,600	55,700
Newaukum near Chehalis	5,800	9,300	11,200	12,400	13,800

Source: USACE, 1997b

Table 1-6:
Comparison of Flood Recurrence Intervals at Grand Mound

Year	Date	Maximum Flow (cfs) at Grand Mound Gage	Flood Recurrence Interval (years)		
			USACE (1998 update)	USACE (1989 update)	FEMA (1980-present)
1996	Feb. 6	73,900	100	400	600
1990	Nov. 25	48,000	15	30	35
1990	Jan. 10	68,700	70	250	400
1986	Nov. 25	51,600	20	40	50
1972	Jan. 21	49,200	15	30	35

Figure 1-1:
Chehalis River Basin Watershed Boundary

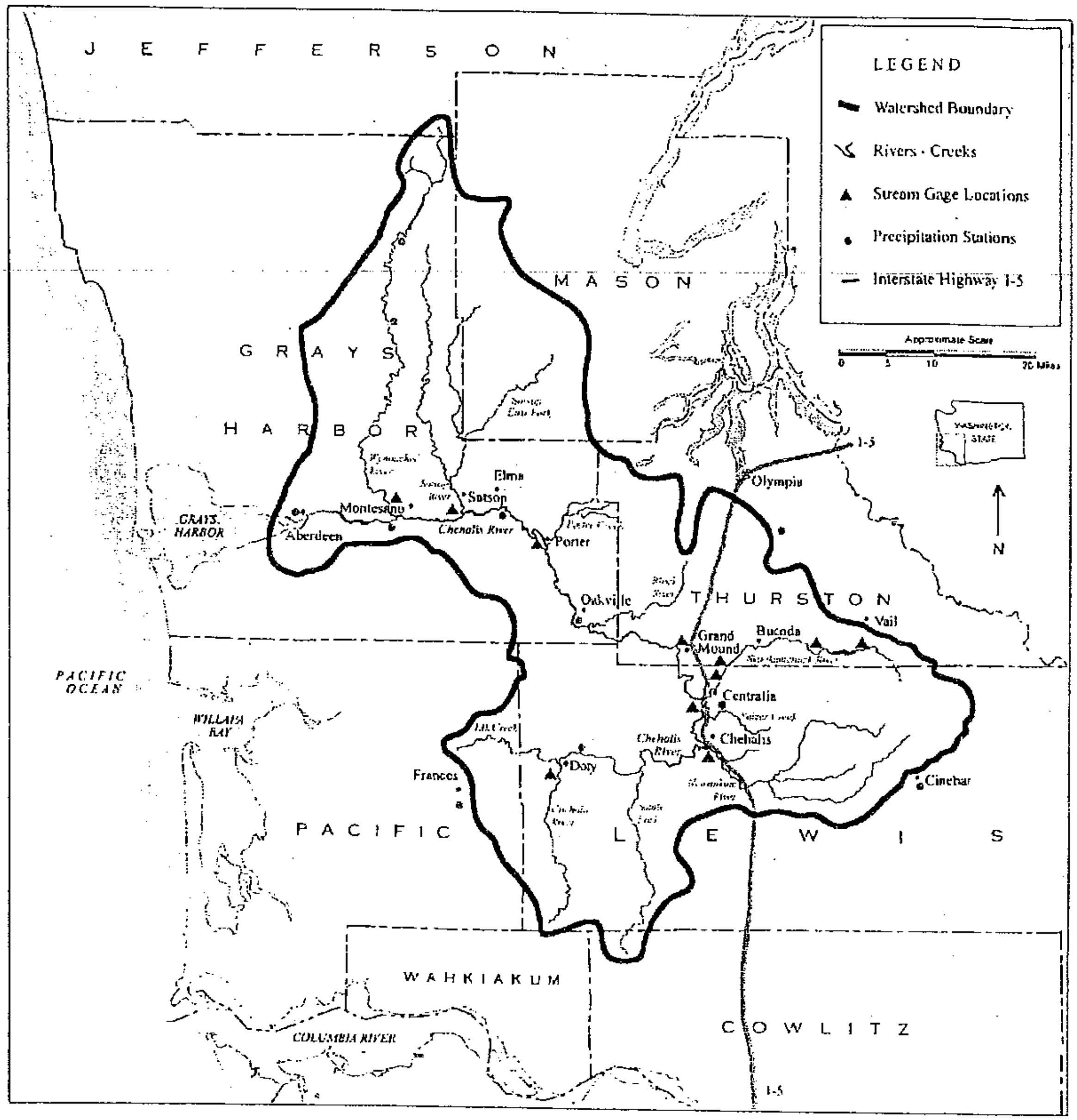
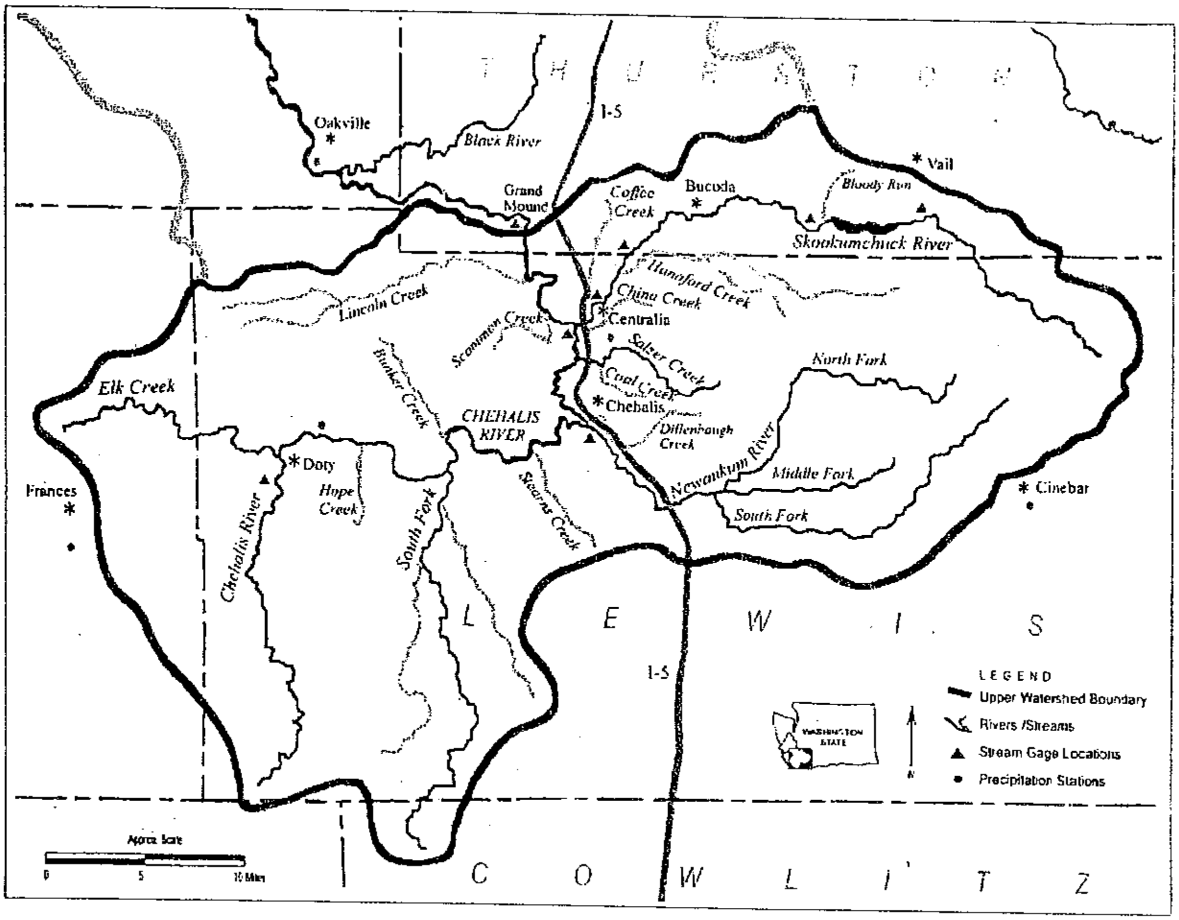


Figure 1-2:
Upper Chehalis River Basin Boundary



2. Baseline Flood Modeling

A baseline flood model (based on the UNET software) representing the existing conditions of the Upper Chehalis River Basin above the Grand Mound gage was developed during the previous pre-feasibility study and presented in the Pre-Feasibility Analysis of Alternatives Report (PIE, 1998a). This model was used to evaluate the potential effects of various flood control alternatives in this and the Pre-Feasibility Report for reducing flood stages and corresponding damages in the Centralia-Chehalis floodplain. This model can be used to evaluate other options or potential components of alternatives presented to or by the Alternatives Sub-Committee.

Development of the model was based on the February 1996 flood, which represents the new 100-year base flood in the mainstem of the Chehalis River. This flood event is the largest flood of record, and provides the most recent and complete observed flood stage data, allowing extensive calibration of the model. Upon calibration for the February 1996 flood, the model was verified during the pre-feasibility study against three other major flood events, the January and November 1990, and the January 1972 floods. The model was updated during this feasibility analysis with more recently surveyed river cross section data.

2.1. Methodology

The floodplain and floodway in the Centralia-Chehalis area present a complex flood hydraulic problem because of flat gradients, flow reversals, overland flow exchanges between subbasins, and local ponding created by existing dikes, levees, railroad embankments, bridge abutments, and I-5 fill in the floodplain. To adequately reproduce the historical flood flow and stage hydrographs in this area, the HEC-UNET (USACE, 1996b) software recently developed by Dr. Robert L. Barkau, for the USACE Hydrologic Engineering Center (HEC), was used to model the upper Chehalis River Basin.

UNET is a one-dimensional, unsteady flow flood routing model that can simulate flood flow in a complex network of open channels including off-channel storage and overbank storage areas, as well as the split of flow into two or more channels and the combining of flow. The channel cross-section data used in the HEC-2 (USACE, 1990) models previously developed by others (steady-state backwater model) can be readily adapted to the UNET input. Other input data includes flow and stage hydrographs, overflow spillways, bridges, culverts and levee systems. Because of its capability to include off-channel and overbank storage areas, UNET is a quasi two-dimensional model. and is considered to be the best tool available for modeling the upper Chehalis River Basin floods.

A schematic diagram of the currently updated UNET model for the Upper Chehalis River Basin, above the USGS streamgage at Grand Mound, is provided in Figure 2-1. Figure 2-2 shows how the subbasins were divided, and Table 2-1 tabulates the drainage areas for all subbasins used in the Upper Chehalis River Basin UNET model. There are a total of seven routing reaches of the UNET model and a total of 24 subbasins contributing flows to these routing reaches.

The UNET model requires input of flow hydrographs from all 24 drainage subbasins at various stream locations to account for total flood flow contribution in the upper Chehalis River stream network. Among these subbasins, three are gaged and 21 are ungaged. For the gaged subbasins, observed flow hydrographs were used as a direct input to the UNET model. For the ungaged subbasins, flood runoff hydrographs were simulated using USACE's HEC-1 computer program (Dodson, 1995).

The HEC-1 program is a single-event flood rainfall-runoff model which simulates flood runoff hydrographs from storm precipitation, taking into account antecedent ground conditions, loss rates, base flow, and snowmelt. The runoff hydrograph from each Chehalis River subbasin's response to a storm was derived by application of the Clark's unit hydrograph methodology to rainfall and snowmelt excesses.

A two-step approach was used in the HEC-1 modeling of the runoff from the upper Chehalis River subbasins. First, unit hydrograph and loss rate parameters were optimized to achieve a best-fit with respect to observed hydrographs for gaged subbasins. Secondly, these optimized parameters were used with appropriate adjustments for drainage area and hydrologic characteristics for the rainfall-runoff modeling of ungaged subbasins. Other HEC-1 input data included stream gage hydrographs, storm precipitation, and various meteorological and hydrological parameters.

Both UNET and HEC-1 use a large quantity of hydrologic data, including input and output data. The HEC-DSS program (USACE, 1995a) was used to provide a database system that enabled both UNET and HEC-1 to conveniently store and retrieve data from a central storage in a common format. The HEC-DSS database system used in this study includes observed hourly flow and stage hydrographs, hourly rainfall data, computed hourly flow, velocity and stage hydrographs, and computed maximum flow, velocity and stage profiles.

Five recent floods were selected for the Upper Chehalis River Basin HEC-1 and UNET modeling: the February 1996, January and November 1990, January 1972, and December 1994 floods. These events represent a spread of flood frequency between 5- and 100-year return intervals in the mainstem of the Chehalis River (see Table 1-6). The former four floods representing major events were selected for the modeling in the pre-feasibility study, based on criteria including availability and reliability of adequate observed meteorological and flood stage data, significant flooding in the Centralia-Chehalis area, and a representative spread of flood recurrence intervals. The latter flood (December 1994 event) representing a minor event was added in the current feasibility study due to downstream concerns of frequent flooding in the Thurston County and Chehalis Confederated Tribes floodplain. The computation steps for both HEC-1 and UNET were chosen to be on an hourly basis considering the drainage size and the modeling accuracy.

Further discussion of the HEC-1 and UNET model development for the upper Chehalis River Basin is provided in the following subsections.

Table 2-1:
Upper Chehalis River Subbasin Division Summary

Symbol (see Fig. 3-2)	Subbasin Stream Name	Drainage Area (Sq. Mi.)	UNET Routing Reach (See Fig. 3-1)
C1	Chehalis River Above Doty	113.0	1
C2	Elk Creek	46.7	1
C3	Hope Creek	6.3	1
C4	South Fork Chehalis River	130.2	1
C5	Bunker Creek	34.1	1
C6	Stearns Creek	34.9	1
C7	Chehalis River, RM 101.80 to RM 75.22	91.9	1
C8	Chehalis River, RM 75.08 to RM 70.20	5.4	3
C9	China Creek	4.4	5
C10	Chehalis River, RM 69.20 to RM 67.00	5.4	5
C11	Lincoln Creek	42.8	7
C12	Chehalis River, RM 66.90 to RM 59.93	10.8	7
N1	Newaukum River	155.0	2
N2	Newaukum River, RM 4.12 to RM 0.14	20.3	2
SA1	Salzer Creek	15.7	4
SA2	Coal Creek	5.4	4
S1	Skookumchuck River Above Skookumchuck Dam	61.4	6
S2	Bloody Run Creek	4.5	6
S3	Johnson and Thompson Creeks	24.3	6
S4	Skookumchuck River Tributary, RM 11.93	14.7	6
S5	Skookumchuck River Tributary, RM 6.64	8.4	6
S6	Hanaford Creek	49.3	6
S7	Coffee Creek	6.2	6
S8	Skookumchuck River, RM 3.71 to RM 0.01	6.2	6

2.2. Subbasin Rainfall-Runoff Modeling

The subbasin rainfall-runoff modeling by application of the HEC-1 program produced flow hydrographs required as input to the UNET flood routing model for ungaged subbasins. The HEC-1 modeling requires input of subbasin drainage geometric data, meteorological data, hydrological parameters including Clark's unit hydrograph parameters, precipitation losses and base flow estimates. To improve the accuracy of estimating ungaged subbasin flow hydrographs, hydrological parameters were optimized using observed hydrographs at gaged subbasins. The optimized hydrological parameters were then adjusted for application to the ungaged subbasins.

2.2.1. Subbasin Definition

All subbasin geometric data including drainage boundary, area, stream length and slope were delineated by utilizing the Watershed Modeling System (WMS) developed by the Engineering Graphics Laboratory of Brigham Young University (BYU) in cooperation with the USACE - Waterways Experiment Station (WES) (BYU, 1996). The digital terrain modeling functions of WMS were used to create terrain models using Triangulated Irregular Networks (TIN's) which automatically delineated watersheds, streams, subbasins and all required geometric data.

2.2.2. Meteorological Input

The network of meteorological stations used in the study consisted of the daily and hourly reporting climatological stations in and near the Chehalis River Basin. A total of 11 daily and hourly reporting precipitation stations were used. The stations and the type of data (either daily or hourly) for each station used in the HEC-1 modeling are listed in Table 1-1. Station locations are shown in Figure 1-1. The station records available for each storm period differ due to equipment or recording problems that result in data missing for some of the stations. To help fill gaps in the hourly precipitation records, daily reporting precipitation was converted to hourly precipitation based on the nearest hourly reporting precipitation patterns. The subbasin-average total and time distribution of storm precipitation were computed based on a composite weighted precipitation method.

2.2.3. Optimization of Hydrological Parameters for Gaged Subbasins

Modeling flood runoff with the HEC-1 program requires complete definition of unit hydrograph and precipitation loss rate criteria for each subbasin within the upper Chehalis drainage area. The controlling parameters can be estimated by correlating flood runoffs with the storm precipitation, using a suitable number of gaged subbasins. HEC-1 provides an optimization subroutine in which these variables are optimized by comparing the simulated flood (derived from rainfall volume) and its time distribution and drainage area, with the observed flood hydrograph. The "best" reconstitution is considered to be that which minimizes the weighted squared deviations between the observed hydrograph and a reconstituted hydrograph.

This optimization process for unit hydrograph parameters and ground loss rates was carried out for three upper Chehalis River subbasins having historical records of flood hydrographs and storm precipitation. These subbasins are the Chehalis River above Doty, Newaukum River, and Skookumchuck River above Vail.

The HEC-1 computer program derives unit hydrographs by the Clark Method. The Clark Method requires two parameters: time of concentration (Tc) and basin storage coefficient (R), both in hours. Loss rates were computed by the HEC exponential loss rate function which relates loss rates to the rainfall and to the accumulated losses. Both the loss rate parameters and unit hydrograph parameters were determined through the process of optimization. Each of these optimizations led to a reasonably consistent, though slightly different, set of values from event to event in the same subbasin. The optimization results of unit hydrograph parameters are summarized in Table 2-2.

The base flow quantities were also estimated through the optimization process. Base flow was determined by the exponential recession limb preceeding the storm runoff hydrograph. This base flow was added to the computed runoff hydrograph ordinates to obtain the total subbasin hydrograph. When the base flow is below a recession threshold flow, the program prevents it from receding faster by using the pre-flood base flow recession rate.

Table 2-2:
HEC-1 Optimization Results

Subbasin/ Flood Event	Clark's Unit Hydrograph Parameters (Hours)	
	Tc	R
Chehalis River above Doty		
Feb-96	5.21	8.88
Nov-90	5.70	9.70
Jan-90	4.33	7.37
Jan-72	5.36	9.13
Dec-94	6.61	11.25
Newaukum River basin		
Feb-96	10.45	17.80
Nov-90	12.41	21.12
Jan-90	12.30	20.95
Jan-72	12.76	21.73
Dec-94	10.25	17.46
Skookumchuck River above Vail		
Feb-96	4.57	6.85
Nov-90	6.26	9.39
Jan-90	4.35	6.52
Jan-72	7.36	11.04
Dec-94	5.02	8.55

2.2.4. Derivation of Hydrological Parameters for Ungaged Subbasins.

Upon optimization of hydrological parameters for gaged subbasins, a consistent relationship between the two Clark's unit hydrograph parameters, R and Tc, was established. A constant ratio of R/(Tc+R) = 0.63 was used for all subbasins and flood events.

The Tc parameter as optimized by HEC-1 was then compared with a computed Tc using the Kirpich Equation (Chow, 1964), resulting in an adjustment factor being applied to the computed Tc value for each gaged subbasin and flood event. Applying a similar adjustment Tc factor and the constant R/(Tc+R) ratio to a Tc value computed by the Kirpich Equation, final values for both Tc and R were derived and used as input to the HEC-1 rainfall-runoff model for each of the 21 ungaged subbasins under each of the five selected flood events.

Other hydrological parameters, including the precipitation losses and base flows for the ungaged subbasins, were estimated directly using the optimization results for the gaged subbasins without adjustments other than for a difference of drainage areas. These estimated losses and base flows were part of the HEC-1 input for flow hydrograph computations.

2.3. Flood Routing Modeling

As shown in Figure 2-1, the UNET model for the Upper Chehalis River Basin was developed to route flow hydrographs from headwater and intermediate sub-drainage areas along the floodplain routing reaches to the downstream end at the Grand Mound gage. Flow hydrographs input to the model include observed hydrographs for gaged subbasins, and computed hydrographs, as described in Section 2.2 for ungaged subbasins. Observed stage hydrographs at the Grand Mound gage were used as the downstream boundary conditions of the UNET model.

2.3.1. Development of the UNET Model

Development of the UNET model was based on expansion of USACE's 1997 UNET model which consists of one 21-mile reach of the Chehalis River between Adna (RM 81.14) and Grand Mound (RM 59.93). The expansion includes additions of a 20-mile reach above Adna to the Doty stream gage (RM 101.8), a 4-mile reach of the Newaukum River from its mouth to the Newaukum gage (RM 4.12), a 2.5-mile reach of lower Salzer Creek and a 22-mile reach of the Skookumchuck River from its mouth to the Skookumchuck Dam (RM 21.9). The model was developed during the pre-feasibility analysis (PIE, 1998a) and further updated during this feasibility study. The updated UNET model includes seven routing reaches above Grand Mound, and seventeen storage areas along the routing reaches. Characteristics of these routing reaches are provided in Table 2-3, which shows stream reach river mile range, number of cross-sections used, Manning's n, and contributing subbasins. Table 2-4 presents a description of the storage areas.

Most of the channel and bridge cross-section data for the Chehalis River reach between Grand Mound and Adna, for the Newaukum River reach and for the Skookumchuck River reach, were obtained from USACE. All these data were surveyed for USACE's earlier steady-state backwater analysis during the 1970's and the 1980's. There are 12 new cross-sections which were surveyed in 1997 for the pre-feasibility study by PIE's survey subconsultant within the 3-mile "hump" reach of the Chehalis River below the Skookumchuck River mouth. The currently updated UNET model includes 29 new cross-sections within the 8-mile reach of the Chehalis River between the Skookumchuck and the Newaukum River confluences, and 6 new cross-sections in the lower 2-mile reach of the Newaukum River, all surveyed in 1998 by PIE's survey subconsultant. All cross-section data in the Salzer Creek reach were based on available topographic maps at a 2-foot contour interval provided by the Cities of Chehalis and Centralia. The cross-section data between Adna and the Doty gage were based on the USGS 7.5-minute topographic maps. Additional topographic and bridge and culvert design data were obtained from various agencies including Lewis and Thurston Counties, Cities of Centralia and Chehalis, and WSDOT.

Table 2-3:
Characteristics of UNET Routing Reaches

UNET Reach (see Fig. 3-1)		River Mile Range (RM)	No. of Cross-sections	Range of Manning's n		Contributing Subbasins (see Fig. 3-2)
No.	Stream Name			Channel	Overbank	
1	Chehalis River	101.80 to 75.16	50	0.045 to 0.063	0.070 to 0.120	C1,C2,C3,C4, C5,C6,C7
2	Newaukum River	4.12 to 0.00	23	0.070	0.120	N1,N2
3	Chehalis River	75.15 to 69.16	34	0.045 to 0.070	0.080 to 0.180	C8
4	Salzer Creek	2.50 to 0.00	22	0.070	0.180	SA1, SA2
5	Chehalis River	69.14 to 66.92	17	0.048 to 0.065	0.090 to 0.120	C9, C10
6	Skookumchuck River	21.90 to 0.00	107	0.035 to 0.080	0.080 to 0.180	S1, S2, S3, S4, S5, S6, S7, S8
7	Chehalis River	66.91 to 59.93	32	0.032 to 0.060	0.065 to 0.130	C11, C12

Table 2-4:
Designation of UNET - Storage Areas

Storage Area (SA) No.	Description
SA #100, 101, 102	Ponding areas in floodplain S of Chehalis River RM 75.2 - 77.7
SA #300, 301, 302, 303, 304, 310	Ponding areas in the City of Chehalis floodplain along Dillenbaugh Creek
SA #2	Centralia - Chehalis Airport area
SA #3	Fairground area, N of Salzer Creek
SA #4	S of Salzer Creek and between Kresky Road and old US Hwy 99
SA #5	S of Alder St., E of I-5, W of Chehalis Western RR & N of Salzer Creek, including Trailer Park
SA #6	China Creek ponding area, E of I-5
SA #7	Coffee Creek ponding area, N of Reynolds Avenue
SA #8	Hanaford Creek mouth floodplain
SA #9	Lincoln Creek mouth floodplain

2.3.2. UNET Model Calibration and Verifications

The Upper Chehalis River Basin UNET model was originally calibrated during the pre-feasibility analysis, using observed stage and flow hydrographs at the Mellen St., Pearl St. and Bucoda gages for the February 1996 flood event. The calibration procedures involved primarily adjusting both channel and overbank Manning's n values, as well as the geometry (both elevation and width) of storage areas and overflow connections. Upon satisfactory calibration of the stage and flow hydrographs, further calibration was performed using the high water mark data provided by USACE, the Cities of Centralia and Chehalis, and WSDOT. The calibration results are presented in the Pre-Feasibility Analysis of Alternatives Report (PIE, 1998a), which show a good match between the observed and the computed stage and flow hydrographs at the Mellen St., Pearl St. and Bucoda gages. The updated UNET model was again calibrated against the February 1996 flood data in this feasibility study when more new river sections were included in the model.

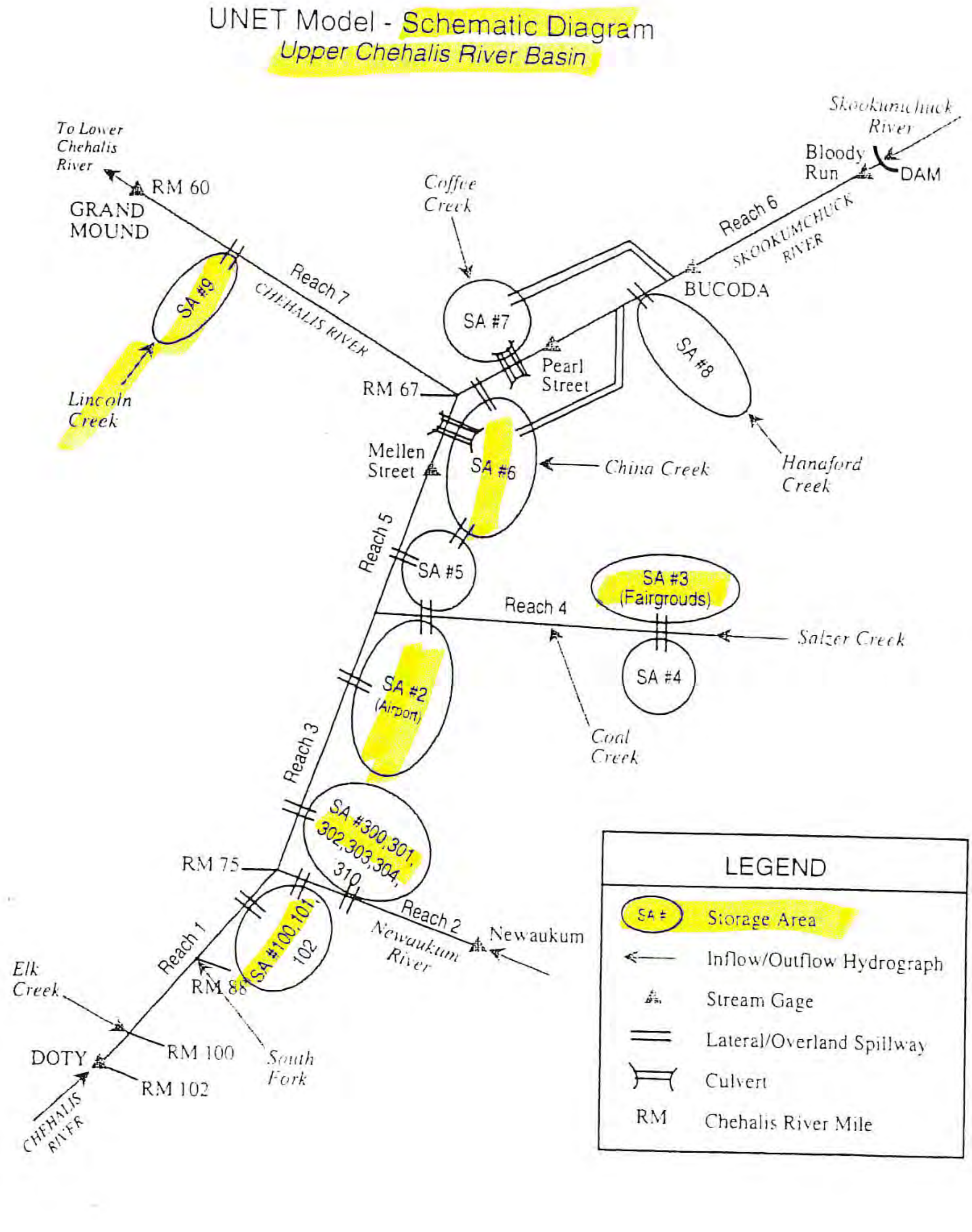
The Upper Chehalis River Basin UNET Model originally calibrated for the February 1996 event was verified against observed stage hydrographs at the Mellen St. and Pearl St. gages for the other three selected major flood events, the November and January 1990, and the January 1972 floods. The verification results are presented in the Pre-Feasibility Analysis of Alternatives Report (PIE, 1998a), which show satisfactory results of the UNET model in reproducing these flood stage hydrographs.

Also in the pre-feasibility study, the Upper Chehalis River Basin UNET model was expanded to include the Lower Chehalis River Basin from Grand Mound downstream to the river mouth in Grays Harbor. The expanded model includes the tidal stage hydrograph registered at Aberdeen as the downstream boundary conditions, and all downstream cross-section data obtained from USACE and surveyed by PIE's survey subconsultant in 1996 for the City of Montesano (PIE, 1996). This expanded UNET model for the entire Chehalis River Basin was calibrated using USACE's observed high water marks. A comparison of the results for both the Upper and the entire Chehalis River Basin UNET models indicates that insignificant differences exist between these two models above Grand Mound.

This comparison indicates that the Upper Chehalis River Basin UNET model is not significantly affected by the tailwater conditions downstream of Grand Mound, and that it is justified to end the model by using the Grand Mound stage hydrograph as the downstream boundary conditions.

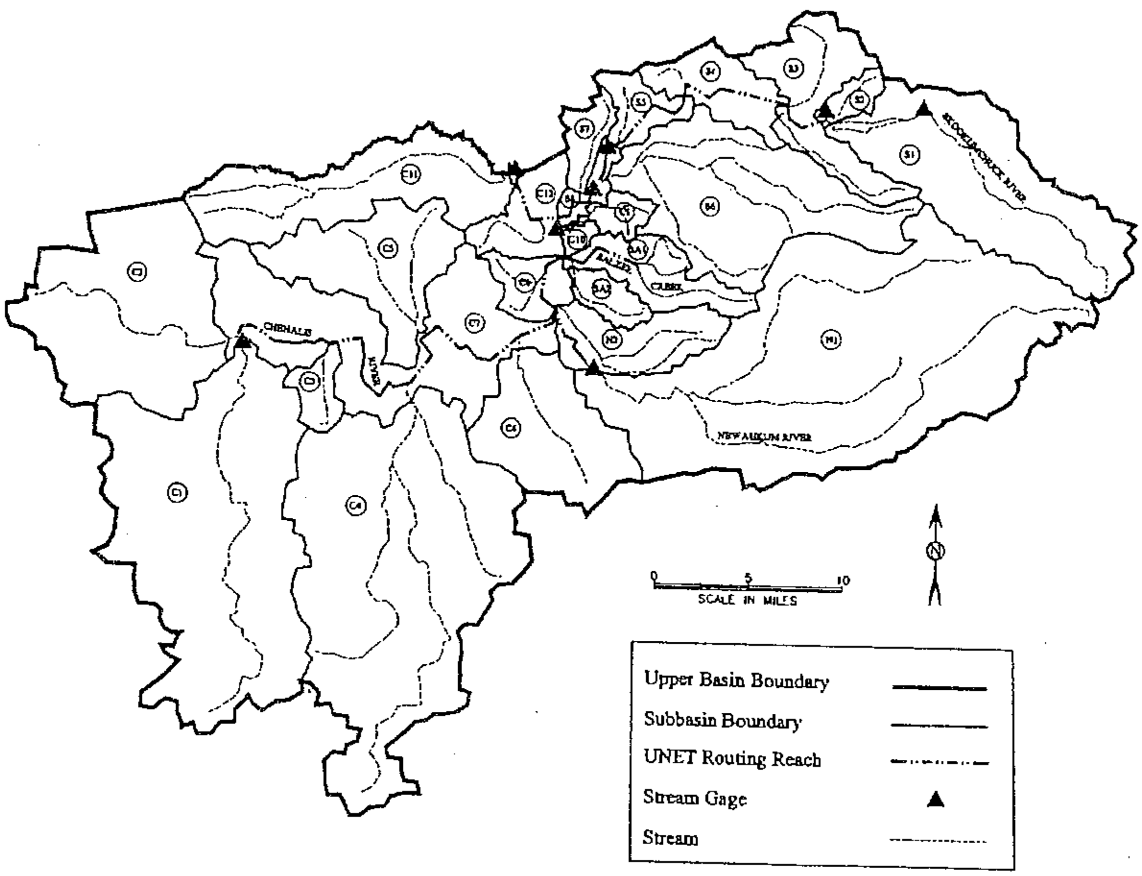
The expanded UNET model for the entire Chehalis River Basin was therefore split at the Grand Mound gage into the Upper and the Lower Chehalis River Basin UNET models. The Lower Basin model was later refined with the addition of 70 new river cross sections surveyed in 1998 by PIE's survey subconsultant, in a separate flood hydraulic analysis for five Lower Chehalis River bank erosion sites identified by Grays Harbor County (PIE, 1998b). The Lower Basin model was also used in this feasibility study to assist in evaluation of the flood conditions in the Thurston County and Chehalis Confederated Tribes floodplain.

Figure 2-1:



UNET Model - Schematic Diagram
Upper Chehalis River Basin
To Lower Chehalis River
RM 60
GRAND MOUND
Reach 7
CHEHALIS RIVER
SA #9
Lincoln Creek
Coffee Creek
SA #7
Skookumchuck River
Bloody Run
DAM
Reach 6
SKOOKUMCHUCK RIVER
BUCODA
SA #8
Pearl Street
RM 67
Mellen Street
SA #6
China Creek
Hanaford Creek
Reach 5
SA #5
SA #3 (Fairgrouds)
Reach 4
Salzer Creek
SA #4
SA #2 (Airport)
Coal Creek
Reach 3
SA #300,301, 302,303,304, 310
RM 75
SA #100,101, 102
Reach 2
Newaukum River
Newaukum
Reach 1
RM 88
Elk Creek
DOTY
RM 100
RM 102
South Fork
CHEHALIS RIVER
LEGEND
SA #
Storage Area
Inflow/Outflow Hydrograph
Stream Gage
Lateral/Overland Spillway
Culvert
RM
Chehalis River Mile

Figure 2-2:
Upper Chehalis River Subbasin Division Map



3. Options and Potential Components for Reducing Flood Impacts

USACE has studied flood control options on the Chehalis River since 1931. Initial study efforts (1931-1949) considered multipurpose storage projects, but none were found to be economically justified. Studies resumed in 1966 at the request of local governments following severe flooding in the basin. Through 1971, study efforts concentrated on identifying the significant flood problems in the basin and possible solutions. At that time, preliminary results indicated that large-multipurpose projects remained unjustified, but local protection projects for urban areas appeared to be economically justified.

Feasibility level studies for flood control in the Centralia-Chehalis area began in 1975. In 1980, USACE made a tentative recommendation for a levee system to protect 2,080 acres, primarily in the City of Centralia. Protection for the City of Chehalis and other nearby areas was not found to be economically justified. Centralia agreed to be the local sponsor for the USACE proposed project, but asked USACE to again review the possibility of modifying Skookumchuck Dam for flood control before proceeding with the levee project. In December 1982, USACE completed the Centralia Flood Damage Reduction Feasibility Report. The report reviewed the options that USACE had considered, and recommended modifications to Skookumchuck Dam to provide flood control storage.

USACE began pre-construction engineering and design in 1988. In 1990, USACE completed its revised flood damage appraisal, preliminary design, cost estimate and preliminary project evaluation. Even after several revisions to the design, USACE determined that the project could not be economically justified, and all feature design work was ceased. In 1992, USACE published a wrap-up report on the studies that had been performed to date.

The previous studies performed by USACE that proved the modifications to Skookumchuck Dam to be economically infeasible focused primarily on providing benefits to the Skookumchuck River Valley and the City of Centralia. Since USACE performed these studies, two major floods in the basin have caused the closure of I-5. With the inclusion of I-5 flooding impacts in the analysis, the potential benefits to reducing flooding in the Centralia-Chehalis floodplain could now prove to be substantially greater, raising the likelihood of an economically justified project.

As used in this report, an "option" for reducing flood impacts would reduce flood levels to a degree, but not enough to provide a comprehensive solution to the flooding problems of the communities and WSDOT either without impacts downstream or with economical justification. An "alternative" is a solution to the flooding problem that meets the needs of the communities and WSDOT without impacts downstream and with economical justification. With reevaluation, reconfiguration and additional analysis, many of the options described in this section could become components of an alternative solution to the flooding problem.

3.1. Non-Structural

The following are non-structural options for reducing flood damages in the Centralia-Chehalis area. Alone, they would not significantly reduce flood stages to benefit I-5 flooding impacts (ENSR, 1994). However, as a component of an alternative they remain viable. These options could also provide opportunities for environmental restoration and enhancement.

3.1.1. Watershed Management

This option involves the use of watershed management measures including reforestation, timber harvest control, and development control to reduce the amount of erosion and silting of streams, and to decrease the magnitude of peak runoff associated with flooding in the basin. Watershed management could have significant environmental benefits, including improvement in water quality and fish and wildlife habitats, but watershed management in the basin alone would have little effect on major floods in the Centralia-Chehalis area. This is due to the nature of flooding in the Chehalis River Basin. Major floods in the basin occur in the winter and are caused by intense rains falling on already saturated soils and snow. Watershed management would have little effect on the basin's hydrologic response to these flood events. Watershed management measures have been undertaken in the basin under the direction of the Natural Resource Conservation Service (NRCS) and the State of Washington. Lewis County has also developed and adopted a Comprehensive Flood Hazard Management Plan which emphasizes mostly non-structural measures to reduce flood hazards.

3.1.2. Flood-Proof Structures

This option would involve flood-proofing residential, commercial and industrial structures in the Centralia-Chehalis area that are currently subjected to flooding. Residential buildings would be raised so that the first floor would be above the 100-year flood level. Commercial buildings would be modified so that openings below the flood level are watertight. Existing floodplain zoning would continue, with no new buildings permitted in the floodplain. According to the December 1994 Comprehensive Flood Hazard Management Plan for Lewis County (ENSR, 1994), 1,300 residential and 130 commercial or industrial buildings would need flood-proofing in the Centralia area alone.

Flood damages to residential, commercial and industrial buildings could be largely eliminated. Flood damages to public streets and utilities would continue, as would disruption of road access, police, fire and ambulance services, and deposition of silt and debris. USACE decided that this option could not be economically justified. The Federal Emergency Management Agency (FEMA) recently provided funding to raise 55 houses, in the City of Centralia, above the February 1996 flood level.

3.1.3. Evacuation and Relocation

This option involves moving all residential, commercial and industrial buildings in the Centralia-Chehalis area out of the floodplain and relocating them to a flood-free site. Due to the tremendous amount of investment currently in the floodplain, this option is not considered politically or economically feasible. According to the December 1994 Comprehensive Flood Hazard Management Plan for Lewis County (ENSR, 1994), 2,390 residential and 315 commercial or industrial buildings would need relocation in the Centralia area alone, including much of Centralia's central business district.

3.2. Hydraulic Capacity Improvements

The following options all involve the flood reduction concept of river hydraulic capacity improvement. This means that flood stage is reduced by expanding flood flow carrying capacity, i.e. hydraulic conveyance, in or adjacent to the river channel. The concept of hydraulic capacity improvement could be implemented with channel clearing, dredging, floodway excavation, floodplain flow bypass, levee or combination of these. Specific options based on this concept are described below.

3.2.1. River Channel Excavation and Levee Improvements

The following hydraulic capacity improvement options were investigated by USACE (ENSR, 1994) and involve excavation directly in the river channel, or the construction of levees, or a combination of the two.

Channel Clearing

In this option, vegetation and debris would be cleared out of the main channel of the Chehalis River. Removal of the vegetation and debris would decrease flow resistance and provide an increase in flow capacity of the channel. This option would require annual maintenance to ensure continued effectiveness. USACE determined in its study (ENSR, 1994) that the increase in flow capacity provided by this option would be insignificant compared to the flood discharges, and would not benefit I-5 flooding.

Channel clearing would affect the quality of habitat for resident fish and could affect migration and rearing habitat for anadromous fish. Elements which provide habitat complexity (e.g., presence of varying water depths, woody debris, side channels) are not abundant in the Chehalis River, and the removal of vegetation and debris would further simplify fish habitat in the mainstem. Channel clearing would also reduce the availability of food and instream cover for juvenile fish, alter flow regimes, and potentially elevate water temperatures. Bank erosion would likely increase, and water quality in the project area and dowstream could be affected by the introduction of sediments. These impacts would be periodic and long-term because channel clearing would be conducted annually.

Channel Dredging

In this option, sections of the river where flow is constricted would be excavated and enlarged. USACE evaluated four variations of this option in their study (ENSR, 1994). Three of the four variations involved excavation in the mainstem of the Chehalis River and in the Skookumchuck River. All three variations included removal of a "hump" in the riverbed profile of the Chehalis River at RM 65 to RM 67. The estimated excavation quantities ranged from 480,000 to 2,000,000 cubic yards of material. The estimated water surface reduction ranged from 1.5 feet to 5 feet at Centralia. The fourth variation involved excavation of about 1,000,000 cubic yards of material from the Newaukum River. This was estimated to lower the 100-year flood stage by about 2 feet at the Labree Road Bridge upstream of Chehalis. USACE concluded that channel dredging was not an economically feasible option.

Channel dredging could result in potentially significant environmental impacts and would raise issues related to permitting feasibility. Although direct mortality of fish and spawning disturbance could be avoided by conducting the work within the seasonal work "window" approved by WDFW, water quality would be affected during construction as a result of sediment releases. Channel erosion could continue after construction, and affect aquatic resources both locally and downstream. Dredging of the river channel would result in long-term changes to fish habitat, including disturbance of spawning and rearing habitat for anadromous species. The options which considered dredging in the Skookumchuck and Newaukum Rivers and/or dredging in the Chehalis River near river mile 61 would impact known salmon spawning areas by disturbing or removing gravel substrates and eliminating the pools and riffles needed for rearing. Food resources for rearing juveniles could be diminished.

Depending on the level of stage reduction, the habitat available for fish could be reduced, particularly during low flows. Water temperatures could be increased. The U.S. Fish and Wildlife Service (USFWS) identified as a concern the accumulation of oxygen-demanding detrital matter in the excavated areas (USFWS 1975). If this were to occur, low dissolved oxygen levels could cause the excavated reaches to be impassible to fish. This condition, which is thought to occur presently in the Chehalis River between Chehalis and Centralia, could be magnified by channel dredging.

Channel Excavation with Levees

USACE considered dredging approximately 3,000,000 cubic yards of material over 9 miles of the mainstem of the Chehalis River in the Centralia area (ENSR, 1994). Some of the excavated material would be used to construct 20 miles of levee along the banks of the Chehalis River, Skookumchuck River and Salzer Creek to protect about 5,800 acres of land. USACE concluded that this option was not economically justified.

As with channel dredging, channel excavation and levee construction would raise significant concerns regarding environmental impacts and permitting feasibility. Channel excavation would affect fish migration, spawning, and rearing habitats. Because annual maintenance would be required to maintain channel capacity, these effects would be periodic and long-term.

The construction of levees would disturb a large area of wetland and riparian habitat. Removal of trees and shrubs from the streambanks would increase the potential for erosion, at least temporarily until vegetation could be established on levee slopes. Stream water temperatures, which are of concern under existing conditions, could be further elevated by the decrease in overwater shading. Removal of riparian vegetation would affect future recruitment of woody debris, simplify the aquatic habitat, and reduce its value for fish rearing and migration. These effects would be most significant on the Skookumchuck River and Salzer Creek.

Disturbance of wetland and riparian areas would also have potentially significant impacts on wildlife species dependent on these habitats. As proposed, the planting of vegetation on levee slopes would not replicate the existing vegetation community or structure. In addition to the direct disturbance, wetlands which are dependent upon overbank flows for recharge would most likely experience reductions in size and alteration in vegetation type. Wetlands of this type are extensive along Salzer Creek and occur in many locations along the Chehalis mainstem. Small mammals (including fur-bearers), resident waterfowl, and upland gamebirds would be particularly affected by the direct and indirect effects of levee construction.

There are several recorded archaeological sites located near the Chehalis River, and it is possible that there are other sites or artifacts that could be disturbed by levee construction.

Property owners in the area have expressed significant concern with the potential for trespassing, vandalism, loss of privacy, and aesthetic impacts posed by levee construction.

Urban Area Levees

USACE evaluated a number of locations in the cities of Centralia and Chehalis where levees could be built to protect urban areas (ENSR, 1994). In its 1982 report, USACE found that for some segments along the Chehalis and Skookumchuck Rivers and Salzer and China Creeks it might be economically justified to build levees. Currently, USACE is pursuing only one small levee project, the Long Road Dike Project in the Salzer Creek area. This project is described in the No-Action Alternative (Sections 4.1.1 and 4.1.2).

The construction of levees under this option would have environmental impacts similar to those described above, although the reduction in the number and length of the levee segments would reduce the magnitude of the impacts.

Levees with River Modification

USACE also considered an option to straighten and enlarge the Chehalis River between the confluence with the Newaukum River and the confluence with the Skookumchuck River (ENSR, 1994). In addition to the channel straightening and enlargement, levees would be built along both banks of the Chehalis and Skookumchuck Rivers. USACE concluded that this option was not economically justified.

Of the previously-studied flood impact reduction options, channel straightening and levee construction would incur the greatest environmental impact. Channel straightening would essentially eliminate fish spawning and rearing habitat in the Chehalis River reach between Chehalis and Centralia. Migration of anadromous fish could be affected by changes in stream hydraulics. As described above, straightening of the channel and construction of levees on the relocated banks would have significant detrimental impacts on wetland and riparian habitats and wildlife species.

3.2.2. Floodway and Floodplain Excavation

The concept of these hydraulic capacity improvement options is to increase high-flow hydraulic capacity of the Chehalis, Skookumchuck or Newaukum Rivers while maintaining the normal-flow channel hydraulic capacity. This increase in high-flow hydraulic capacity would be achieved by excavating areas of the floodway or floodplain. The options analyzed include the excavation of a bench in the floodway adjacent to the river channel, and excavation of a secondary flood overflow channel in the floodplain. Both floodway and floodplain excavation options for increasing high-flow capacity would also cause an increase of peak flood flow downstream. An examination of the two options is provided below.

Floodway Excavation

In this option, the floodway adjacent to the river channel would be excavated and terraced to provide additional flow area for higher flow events. The floodway terrace elevation would be set such that only during significant floods would the river flow into the enlarged area. As a result, the excavation could be done completely in the dry, thus reducing the costs and eliminating some of the environmental and permitting concerns posed by channel excavation. In addition, normal and low flows would be left unchanged, unlike in the river channel excavation options analyzed by USACE.

Floodway excavation was examined along portions of the Chehalis, Skookumchuck and Newaukum Rivers. Along the Chehalis River, floodway excavation was examined between RM 64.90 (2.5 miles downstream of the Mellen St. Bridge) and RM 75.08 (confluence with the Newaukum River). Floodway excavation was also examined in the lower two miles of both the Skookumchuck and Newaukum rivers. Maximum water surface and velocity profiles were plotted for the river reaches of interest. River reaches with constricted flow, and resulting high velocities and head losses, were targeted as areas that would provide the most benefit from floodway excavation. Based on the velocity profiles, the reaches with the highest velocities are between RM 64.90 and RM 67.44 (Mellen St Bridge), and the area around the SR6 Bridge (RM 74.60). Maximum velocities in the lower Skookumchuck and Newaukum rivers were typically much slower due to Chehalis River backwater effects during flood peaks. Therefore, floodway excavation in these reaches would not be as cost effective.

A number of different floodway excavation configurations were modeled to help determine the most cost effective and efficient layouts. In order to eliminate flooding of I-5 during a 100-year event equal in size to the 1996 flood, a water surface reduction of approximately 4 feet would be required at the north end of the airport (RM 70.6).

The significant environmental issues associated with floodway excavation would primarily involve disturbance of wetlands and riparian habitats. Other issues include a potential increase in erosion, stream sedimentation, and disposal of excavated materials. The degree of impact would be related to the total length of floodway excavated. There would be impacts to fisheries habitats, although properly designed bank excavation could provide a net habitat benefit by providing important backwater refuge for fish during high flows. For more detail on environmental issues associated with floodway excavation, refer to Section 4.2.4.

Secondary Flood Bypass Channel

Similar to the floodway excavation options, the secondary flood bypass channel options would increase the area of flow during high flow events. As the name implies, a secondary channel would be excavated to provide the additional flow area required. The channel would be excavated completely in the dry. The entrance elevation to the channel would be set such that flow entered the channel only during significant flood events. The remainder of the time the channel would remain dry. The channels would likely be grass lined and have a rock armored entrance and exit to prevent scour. Four different secondary channels were evaluated, with three of the channels off of the mainstem of the Chehalis River between RM 65.90-68.25. The remaining channel option would be off of the Skookumchuck River. The following sections briefly describe the options.

Mainstem Chehalis River

Three optional alignments were considered off of the mainstem of the Chehalis River. All three alignments cut across the large western bend in the Chehalis River due west of the City of Centralia. Alignment 'A' would start downstream of the Mellen St Bridge at about RM 67.3 and would end at about RM 66.5 This design would be the least expensive to construct; however, due to the wide channel widths required, there would be no advantage to a secondary channel compared to floodway excavation. Alignment

'B' would start upstream of the Mellen St. Bridge at about RM 67.6 and would end at about RM 66.3. This design would provide more benefit; however, it would require the purchase of a large number of private homes and commercial properties as well as the construction of two or three bridges. Alignment 'C' would start at about RM 68.0 and would end at the mouth of Scammon Creek at RM 65.9. This design would provide slightly more benefit than 'B' and would avoid some of the larger properties; however, it would require the construction of three bridges and would require excavating out lower Scammon Creek.

Construction of any of the optional secondary channels off the Chehalis mainstem would have less effect on wetlands than floodway excavation, but impacts to wetlands and riparian areas would not be completely avoided. Construction of a secondary channel along Alignment 'A' would require excavation through wetlands at the channel's downstream end. Construction along either Alignment 'B' or 'C' would also involve excavation through wetlands. The total area affected could be reduced through modification of the alignments. As with any of the options which modify flood stages, the recharge of wetlands through overbank flooding would be affected by construction of a secondary channel.

Construction of any of the secondary channels could alter channel and substrate conditions near RM 65.9, and affect potential fish spawning habitat at that location. The potential stranding of fish in the secondary channel following high flow events would be a concern. This potential would be more of a concern for a channel following Alignment 'C', because of its greater length-to-width ratio.

Scammon Creek, which likely provides valuable off-channel rearing habitat for fish, would be affected by channel construction along Alignment 'C'. Excavation would disturb the lower end of the creek, from the mouth to a point approximately one-half mile upstream. Although the creek channel could be reconstructed within the larger flood channel, the habitat quality would be significantly reduced. The periodic conveyance of flood flows through the channel would most likely prevent the reestablishment of valuable habitat elements in the excavated reach of Scammon Creek.

The impacts of secondary channel construction to the built environment would be substantial. Numerous residents and businesses could be displaced, and agricultural lands would be affected. A channel along Alignment 'B' would also require the relocation of medical facilities. Channel excavation along any of the alignments would require the construction of one or more bridges along existing roadways.

Skookumchuck River

This option would involve diverting a portion of the flow in the Skookumchuck River during flood events. This secondary overflow channel would start at approximately RM 1.5 of the Skookumchuck River. The channel would be routed under I-5, near the Reynolds Avenue underpass, and would connect up with some existing small lakes, and then a remnant channel of the Chehalis River. The channel would empty back into the Chehalis River at approximately RM 60.5, 6.5 miles downstream of the Skookumchuck's confluence with the Chehalis River. It was assumed that the channel would be designed to divert up to 5,000 cfs.

Construction of a secondary channel off the Skookumchuck River would affect fish habitat in the lower river, including spawning habitat for fall and spring chinook salmon. Of potential benefit would be a reduction in both streambed scouring and the destruction of salmonid redds; conversely, diversion of flood flows could negatively affect channel-forming and maintenance flows in the Chehalis River downstream of the confluence.

Because of the length of this alignment, scoured areas would form in the high flow channel and stranding of fish following flood events would be a concern.

The hydrologic recharge of wetlands and riparian areas in the lower 1.5 miles of the Skookumchuck River would most likely be affected by the reduction or elimination of overland flows. In the absence of periodic recharge, wetland and riparian vegetation communities would change to upland vegetation types. Negative impacts to wildlife dependent on wetlands and riparian areas would be expected.

Construction of a secondary channel along this alignment would have a large impact on the built environment, including residential, industrial, and commercial properties, farmlands, roads, and other public facilities.

3.3. Flood Control Dams

The concept of the following options is to reduce flood peak flows, and thus flood stages, by retaining flood flows through the use of flood control storage. Stored water would be gradually released once flood peak flows have passed downstream. Flood control dam options include the following: use of the existing Skookumchuck Dam for flood control, construction of new major upstream dams, construction of small headwater dams, and creation of temporal storage in the floodplain through the use of dikes.

3.3.1. Skookumchuck Dam Modifications

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The drainage area above the dam is nearly 62 square miles and the highest elevation in the basin is approximately 3,600 feet. The dam was constructed in 1970 to supply water for the Centralia steam generation plant. The dam, as it currently exists, is an earthfill structure approximately 190 feet high above bedrock with the top of the dam at elevation 497 feet. The project is essentially a fill and spill operation. The limited outlet capacity of the dam, which consists of two 24-inch Howell Bunger valves with a combined discharge of approximately 220 cubic feet per second (cfs), causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the 130-foot wide ungated spillway, which has a discharge capacity of 28,000 cfs at elevation 492 feet. Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 31,000 acre-feet.

USACE Studies

Preliminary investigations by USACE indicate that flood control storage could be feasible at Skookumchuck Dam without jeopardizing the steam plant water supply. Use of this project for flood control would require the addition of larger outlet works, and preferably, a spillway crest gate. USACE investigated several options for modifications, which are presented in detail in the USACE's December 1982 and February 1992 reports (USACE, 1982, 1992).

In their December 1982 report, USACE recommended a design that would have provided 17,000-28,500 acre-feet of flood control storage. The design consisted of a new 135-foot high multi-level intake tower and 12-foot diameter outlet tunnel with a design discharge of 3,000 cfs. In addition, the existing spillway would have been widened slightly, and 17-foot-high by 136-foot-wide steel bascule gates would have been installed on top of the spillway to provide control of reservoir pool elevations up to elevation 492 feet. For a 200-year flood event on the Skookumchuck River, the proposed design would have reduced water surface elevations along the Skookumchuck River by 2.5 to 4.0 feet. Downstream of the confluence with the Chehalis River, the proposed project would have reduced water surface elevations by 0.5 feet.

Preliminary design work on the USACE recommended Skookumchuck Dam Modification Project was halted in 1990 when preliminary economic analysis indicated that the project lacked economic justification. In the course of its preliminary design work, the USACE considered several optional arrangements. The steel bascule gate design was discarded due to its high cost and safety concerns surrounding the possibility that the gates could get stuck, or that they would not be operated properly during a major flood event. Options were evaluated which would modify the operation of the dam for flood control and provide additional outlet capacity, but would not increase the existing storage capacity. The primary arrangements considered were: addition of an intake tower and tunnel, modified spillway with gate in slot, modified spillway with sluice gate, and short spillway tunnel. The final two arrangements were estimated to be the least costly to construct. All of the optional designs would provide 11,900 acre-feet of storage. None of the options appeared to USACE to be economically justified, so all design work was suspended.

Rubber Weir Option

This option was developed as an alternative to the USACE's steel gate design. The option would include modifications to the existing spillway to allow for the placement of an approximately 15-foot high and 130-foot long inflatable rubber weir on the existing spillway crest. The spillway would also be modified to allow for two new 10-foot by 15-foot gated sluiceways. Preliminary estimates based on routing of the February 1996 flood event through the reservoir indicate that a potential flood storage capacity of approximately 20,000 acre-feet could be provided. This volume of storage would reduce the February 1996 flood stage on the Skookumchuck River by 1.4 to 4.4 feet, and on the Chehalis River by about 0.3 to 0.5 feet.

Environmental Issues

The significant environmental issues associated with modification of the Skookumchuck Dam involve maintenance of water quality within and downstream of the reservoir, maintenance of adequate instream flows and reservoir levels for fishery resources, and potential impacts to wildlife habitat as a result of changes in reservoir levels and downstream flows. For more detail on environmental issues related to dam modification, refer to Section 4.2.4.

3.3.2. Upstream Flood Control Dams

Upstream flood control dam projects could be constructed to reduce flooding impacts downstream. USACE investigated five potential locations for large multi-purpose storage dams in the Upper Chehalis River Basin in the course of its flood control studies (USACE, 1982). The five locations consisted of two sites on the Newaukum River, one site on the South Fork Chehalis River and two sites on the mainstem of the Chehalis River, upstream of the Newaukum River. All five options were determined to be economically infeasible.

As part of the Pre-Feasibility Analysis of Alternatives (PIE, 1998a), topographic and geologic maps of the Upper Chehalis River Basin were studied for potential single-purpose flood control dam sites. The five sites studied by USACE were reevaluated, along with three additional sites. The additional sites include two sites on the mainstem of the Chehalis River, upstream of the sites USACE investigated, and one site on Elk Creek. Construction of one or more of these dams would reduce the frequency and severity of flooding in the Centralia-Chehalis area.

Based on a preliminary review of available geologic information, site conditions appear to preclude large concrete structures. The relatively soft, deeply weathered foundation materials would likely require significant over-excavation to obtain sound bearing conditions. The most likely dam type suitable for these sites would be earthen embankment. The foundation and topographic requirements for earthfill dams are less stringent than for other types of dams. There appears to be sufficient suitable fill material nearby all of the sites.

For the purpose of developing pre-feasibility construction costs estimates, the typical construction layout for the dams was assumed to be very similar to that used for the existing Skookumchuck Dam. The dam would be designed as a non-overflow structure with a 2.5:1 (H:V) upstream face and a 2:1 (H:V) downstream face. Outlet works and a spillway would be provided on one of the abutments. The following sections briefly describe each of the sites.

Newaukum River Sites

The Newaukum River rises in the easternmost part of the Chehalis River Basin and flows westerly for about 30 miles, joining the Chehalis River at the City of Chehalis. The Newaukum drains an area of 155 square miles at the USGS gage (RM 4.1). The lower 13 miles of the basin are very broad (over 2 miles wide) and flat. From RM 13 to RM 28, the valley narrows somewhat to 0.5 mile wide, although it is still quite flat. This topography provides a great deal of natural overbank storage during flood events, which results in a significant attenuation of peak discharges. As a result, the downstream benefit of a flood control dam would probably be small relative to the cost involved

USACE evaluated two dam sites in the Newaukum River Basin (USACE, 1982). One site is located on the North Fork Newaukum River and had an estimated flood control storage of 9,000 acre-feet. The other site is located on the South Fork Newaukum River and had an estimated flood control storage of 15,000 acre-feet. The North Fork dam was estimated to reduce discharge of a 100-year flood at Grand Mound by 2,000 cfs, and the South Fork dam was estimated to reduce flows by 3,000 cfs. Either of these flow reductions would translate into flood stage reductions of approximately 0.3-0.4 feet at the Mellen St. Bridge. Neither dam was determined to be cost effective. The USACE estimated cost of construction of the dams in 1998 dollars would be approximately $90 million and $125 million, respectively, which would make them very expensive for the small benefit provided. Smaller scale single-purpose flood control dams at either of these sites would have less flood storage, yet would only be slightly less expensive to construct than the USACE's options. These sites were determined to be economically infeasible.

South Fork Chehalis River Site

The South Fork Chehalis River drains an area of 48 square miles at the old USGS gage site (RM 6). The lower portion of the basin up to RM 9 consists of a broad, flat valley with small creeks draining the hills on either side. Above RM 9 to RM 15, the valley narrows somewhat from 1.5 miles wide to 0.75 mile wide. There are no good flood control dam sites available below RM 15. Above RM 15, a suitable site could probably be found, but the contributing area would be too small to provide significant downstream benefit.

USACE investigated one site on the South Fork Chehalis River at approximately RM 10 (USACE, 1982). The dam at this site would have an estimated flood control storage of 16,000 acre-feet. The estimated discharge reduction of a 100-year flood at Grand Mound was 5,000 cfs, which would translate into a water surface reduction of approximately 0.7 feet at the Mellen St. Bridge. The USACE's estimated cost of construction of the dam in 1998 dollars would be approximately $120 million, which would make it very expensive for the small benefit provided. A smaller scale single-purpose flood control dam would cost only slightly less and would provide even less benefit. This site was determined to be economically infeasible.

Mainstem Chehalis River Sites

The Chehalis River above RM 77.5 (old USGS streamgage site) drains an area of 434 square miles (including the South Fork Chehalis River). Four potential single-purpose flood control dam sites were identified on the mainstem of the Chehalis River. Two of the sites were previously studied by USACE for large multipurpose dams. These four sites appeared to have more potential than the sites on the Newaukum, South Fork Chehalis River or Elk Creek, and were examined in greater detail.

Ceres Hill Dam Site

The first potential Upper Chehalis River Basin site is at approximately RM 86.6 of the Chehalis River in a canyon downstream of the confluence with the South Fork Chehalis River. Based on available geologic information, this site appears to have up to 20 feet of primarily sand and gravel alluvium in the valley bottom. This would require some form of foundation treatment, such as an augercast curtain wall, to prevent piping under the dam. This would add to the cost of construction. In addition, suitable finer grained materials for construction of the dam would have to come from farther away than at the other sites. This would add to the cost of hauling and would add to the overall construction cost.

With a spillway crest at elevation 240 feet, the resulting reservoir would cover an area of 3,300 acres and have a flood control storage volume of approximately 48,000 acre-feet. This storage volume would result in a flood stage reduction of approximately 1.8-1.9 feet at the Mellen St. Bridge for an event similar to the February 1996 flood event. The dam would be over 50 feet high and would cost approximately $164 million to construct, which equals $86 million per foot of stage reduction. Based on information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 130 buildings, 27,000 feet of highway SR-6 and an additional 63,000 feet of local roads and 37,500 feet of railroad track.

The USACE design scheme for this site (USACE named it Ruth Dam site) involved the construction of a much larger dam with flood control storage of 108,000 acre-feet. USACE estimated the potential reduction in discharge at Grand Mound of a 100-year flood to be 24,000 cfs. This would have resulted in a stage reduction of approximately 3.4 feet at the Mellen St. Bridge for the February 1996 flood event. The USACE estimated construction cost of the dam in 1998 dollars would be approximately $433 million, which equals $127 million per foot of stage reduction, assuming that cost sharing for other (non-flood control) purposes is insignificant.

Neither of these design schemes is cost-effective in comparison with other options evaluated as part of this study for the same magnitude of flood stage reduction.

Meskill Dam Site

The Meskill site is upstream of the confluence with the South Fork Chehalis River at approximately RM 93.4. The foundation appears to be highly fractured basalt over soft marine sandstone and siltstone with no alluvium mapped on the canyon floor. The juxtaposition of the hard rock over the top of the soft rock could result in significant differential settlement.

With a spillway crest at elevation 280 feet, the resulting reservoir would cover an area of 1,500 acres and have a flood control storage volume of approximately 30,000 acre-feet. This would result in a flood stage reduction of approximately 1.1-1.2 feet at the Mellen St. Bridge for an event similar to the February 1996 flood. The dam would be over 50 feet high and would cost approximately $267 million to construct, which equals $222 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 90 buildings, 27,000 feet of local roads, 19,000 feet of railroad track, and require the relocation of 12,000 feet of highway SR-6.

USACE considered this site as well (USACE, 1982), and evaluated a slightly larger structure with a flood storage capacity of 54,000 acre-feet. USACE estimated the potential reduction in discharge at Grand Mound of a 100-year flood to be 16,000 cfs with the construction of this dam. This would have resulted in a stage reduction of approximately 2.3 feet at the Mellen St. Bridge for the February 1996 flood event. The USACE estimated construction cost of the dam in 1998 dollars would be approximately $230 million, which equals $101 million per foot of stage reduction, assuming cost sharing for other (non-flood control) purposes is insignificant.

Neither of these design schemes is cost-effective in comparison with other options evaluated as part of this study for the same magnitude of flood stage reduction.

Doty Canyon Dam Site

The Doty Canyon dam site is located upstream of the town of Doty at RM 100.8. The foundation conditions at this site would be similar to those at the Meskill site. There appears to be moderately deep soil cover (approximately 10 feet) on the side slopes, and a similar depth of river channel deposits on the canyon floor.

With a spillway crest at elevation 385 feet, the resulting reservoir would cover an area of 1,700 acres and have a flood control storage volume of approximately 60,000 acre-feet. This would result in a flood stage reduction of approximately 2.4 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would be over 90 feet high and would cost approximately $283 million to construct, which equals $118 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 105 buildings, 20,000 feet of local roads, 22,000 feet of railroad track, and require the relocation of 25,000 feet of highway SR-6.

This design is not cost-effective in comparison with other options evaluated as part of this study for the same magnitude of flood stage reduction

Charlie's Hump Dam Site

The fourth site on the mainstem of the Chehalis River is located south of Pe Ell, above the valley floor in the area called Charlie's Hump. The site is founded on basic intrusive rock of gabbro, diabase or basalt. The rocks are fine grained and are likely to be moderately weathered and highly fractured with about 5 feet of soil cover.

With a spillway crest at elevation 600 feet, the resulting reservoir would cover an area of 700 acres and have a flood control storage volume of approximately 44,500 acre-feet. This would have resulted in a flood stage reduction of approximately 1.7-1.8 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would be over 180 feet high and would cost approximately $76 million to construct, which equals $42 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would not inundate any buildings, but it would inundate about 10,000 feet of existing local road.

This design is not cost-effective in comparison with other options evaluated as part of this study for the same magnitude of flood stage reduction.

Elk Creek Site

The final dam site evaluated is located approximately 3.5 miles west of the town of Doty at RM 2.8 of Elk Creek. The foundation consists of soft marine sandstone and siltstone.

With a spillway crest at elevation 440 feet, the resulting reservoir would cover an area of 1,300 acres and have a volume of approximately 32,000 acre-feet. This would have resulted in a flood stage reduction of approximately 1.1-1.2 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would over be 75 feet high and would cost approximately $82 million to construct, which equals $68 million per foot of stage reduction. From the USGS 7.5 minute quadrangle sheets, the reservoir would inundate only a few buildings, and 8,500 feet of local road.

This design is not cost-effective in comparison with other options evaluated as part of this study for the same magnitude of flood stage reduction.

3.3.3. Small Headwater Dams

In its studies, USACE also investigated the feasibility of building several small headwater dams for temporarily restraining flood flows (USACE, 1982). USACE evaluated twelve sites in the drainage above Centralia-Chehalis. The combined flood storage capacity of all twelve dams would be only 14,500 acre-feet, with an estimated reduction in flow at Grand Mound of 3,000 cfs for a 100-year flood event. The 3,000 cfs flow reduction would result in flood stage reduction of approximately 3 inches. In 1998 dollars, the USACE estimated cost to construct the twelve dams would be approximately $113 million, which would equate to approximately $350 million dollars per foot of flood stage reduction. Because of the poor benefit-to-cost ratio, this option was not investigated further.

3.3.4. Environmental Issues

The potential environmental impacts of the upstream flood control dam options can be divided into reservoir effects and downstream effects. Reservoir effects would occur as a result of the inundation and alteration of fish and wildlife habitats as well as inundation of structures, agricultural lands, roads and other public and private facilities. Dam construction at any of the sites would create a barrier to fish passage.

At each of the reservoir sites, wetlands and riparian areas are interspersed with upland habitats. At several of the potential reservoir sites, much of the riparian vegetation has been removed and the riparian zone is limited to a narrow (50 -100 ft) band adjacent to the stream. These areas would be inundated, with a resulting loss of wildlife feed, cover, nesting, and roosting areas, including habitat for threatened and endangered species such as bald eagles and spotted owls. It is expected that some of this habitat would be replaced by the establishment of riparian vegetation around the perimeter of the reservoir.

In-stream habitats, particularly transportation, spawning, incubation, and rearing habitats for anadromous fish, would be replaced by a lake environment. The miles of in-stream habitat lost would vary, depending upon the reservoir location. Particularly affected would be spawning habitat for spring and fall chinook salmon, coho salmon, and winter steelhead. Reservoir creation would provide lake habitat for resident fish, including rainbow and cutthroat trout.

The upstream flood control dam options would result in the inundation of a substantial number of structures and private property as well as roads, rail lines, and other facilities.

Potential downstream effects would include changes in the quality of water flowing out of the reservoir and changes in downstream water temperatures. Wetland and riparian areas that are dependent on overbank flows for recharge would most likely experience reductions in size and alteration in vegetation type. These changes could result in a long-term reduction of large, woody debris to the stream; reduction in shade cover; elevation of stream temperatures, and loss of instream cover for fish. Attenuation of minor flood flows would change channel substrates downstream. In terms of fish habitat, these changes could be positive or negative. Spawning areas which are currently subject to scouring could be spared; conversely, channel-forming and maintenance downstream of the dam could be negatively affected by flow alterations.

3.3.5. Flood Storage Dikes on the Floodplain

The concept of this option is to construct one or more flood storage areas in the floodplain. This would be accomplished by enclosing a large area with a dike. During floods, the floodwaters would overflow into the dike enclosed storage area. Stored floodwaters would then be released slowly through a downstream outlet. This type of flood storage operation would not be as efficient and effective as that provided by a flood control dam. Placing flood control storage in the floodplain is also not as effective as utilizing storage in the headwaters. In the floodplain, the flows are already rather attenuated and a much larger storage volume is required for an equivalent stage reduction.

Based on preliminary model runs, approximately 40,000 acre-feet of storage volume would be needed in the floodplain to achieve a 1-foot stage reduction at the Mellen St. Bridge. Assuming a ten-foot storage depth, this would require approximately 4,000 acres of land. In order to achieve more significant stage level reductions, a very large area would be required, which makes the option impractical. Preliminary cost estimates also indicate that this option is not cost effective on its own. The concept could prove to be cost effective at providing an additional incremental benefit if it were combined on a smaller scale with one of the excavation options. Material excavated from the floodway or floodplain, that would otherwise have to be disposed of, could be used to construct the enclosure dikes.

Because of the large land area required, environmental impacts of this option could be substantial. The elements of the environment that could be affected would not be defined until potential storage sites were located.

4. Alternative Flood Reduction Solutions

Based on the evaluation of options presented thus far, there is no single hydraulic capacity improvement or flood control storage option that could provide a cost-effective or acceptable solution to the flooding problems in the Centralia-Chehalis and I-5 corridor area without causing unacceptable downstream flooding or other issues. However, two alternatives that combine hydraulic capacity improvement concept components with flood control storage concept components would overcome the shortfalls of each if implemented separately, appear promising. These are the Floodway Modification Alternative and the Floodplain Modification Alternative. Both alternatives would include two common components, which are the Skookumchuck Dam modifications and the floodway modifications in the Mellen St. Bridge area. The only difference between these two alternatives would be the third component to reduce flood stages in the SR-6 Bridge vicinity within the City of Chehalis floodplain. The Floodway Modification Alternative would be based on the floodway excavation concept, one option of the hydraulic capacity improvement concept, to increase the river hydraulic capacity and the Floodplain Modification Alternative would use the floodplain flow bypass concept, another option of the hydraulic capacity improvement concept, to reduce peak flood discharges. A description of these two alternatives is presented below.

With further analysis and evaluation of specific configurations, many of the other options described in the above section could probably become components of an alternative. Many of the options could incorporate environmental enhancement and restoration features.

4.1. No-Action Alternative

4.1.1. Description of Alternative

It is assumed that if no project is undertaken to reduce the impacts of flooding currently affecting the Centralia-Chehalis area, flood damage will continue as documented for historical events. It is also assumed that one and possibly two projects addressing specific flood damage areas will be implemented. The two projects are: the USACE Long Road Dike Project and the WSDOT proposal to widen and raise the grade of I-5 in a 2.9 mile reach in the Centralia-Chehalis Area. Current scheduling for the Long Road

Dike Project suggests that it may be built prior to any decision regarding the flood damage reduction project discussed in this report, although the two project alternatives identified in this report would likely preclude the need for the Long Road Dike Project. The WSDOT I-5 Project is scheduled to go out to bid in 2004, but the portion of the project that involves raising I-5 could be eliminated if either of the two project alternatives identified herein is implemented.

Continuation of Existing Flood Damage Conditions

Since 1971, Lewis County has experienced 11 flood disasters which have significantly affected industrial, commercial, agricultural and residential areas in Lewis County (USACE, 1982 and Washington State Military Dept., 1995). The majority of the impact from these floods occurred in the urbanized and agricultural floodplain areas in the Centralia-Chehalis area near the confluence of the Chehalis and Skookumchuck Rivers and their tributaries, including China, Coffee, Newaukum, Salzer and Dillenbaugh Creeks. Under the No-Action Alternative, floodplain boundaries would be as shown in Figure 4-21. Existing average annual flood damage costs described in Section 4.1.3 would continue and most likely increase gradually.

USACE Long Road Dike Project

The Long Road Dike Project (LRDP) was designed by USACE under the authority of Section 205 of the 1948 Flood Control Act, as amended, in response to a request by the Lewis County Diking District Number 2. Lewis County requested federal assistance in providing protection to the Long Road District (LRD) from flooding caused by the Chehalis River backing up Salzer Creek. A Draft Environmental Assessment (DEA) was distributed for agency and public review by USACE on December 16, 1997 (USACE, 1997a). Review comments were due on January 15, 1998. The DEA shows construction scheduled for the summer of 1999. It is likely that this project will be built prior to any decision regarding the flood damage reduction project discussed in this report.

The LRD contains about one hundred acres, in the shape of a right triangle, located partially in the City of Centralia and partially in Lewis County. The sides of the triangle are formed by I-5 to the southwest, the Tacoma Eastern Railroad (TERR) to the east and

Mellen St. to the north. The south corner of the triangle, where the TERR begins to parallel I-5, is not completely closed off. The LRDP proposes to construct a dike across the low area at or near this portion of the triangle, where the existing non-federal embankments on the east and west sides of the triangle, combined with the new levee, could provide protection from up to a 45-year flood to the approximately 116 housing units, church and convalescent home in the LRD.

The proposed cross-levee would stretch about 2,200 feet between the railroad and I-5 embankments, using a "reverse L-shape" to avoid impacts to wetlands that run along the southern portion of the railroad embankment. The top of the levee is designed to be at elevation 177.0 feet (NGVD datum). This could provide complete protection from floods resulting from a 45-year event. Greater protection is not reasonable because flood waters resulting from larger events could overtop the low divide between China Creek and Salzer Creek backflooding the LRD.

According to the DEA, the total value of the improvements in the LRD is approximately $5,300,000. Based on 1996 prices and conditions, average annual flood damage within the LRD is estimated to be $84,800. The total construction cost of the proposed dike is estimated at $507,000. Average annual benefits resulting from prevention of flood damages totals $50,300. The average annual costs, evaluated at 7-3/8 percent interest rate over a 45-year economic analysis period, including allowances for operation and maintenance, amount to $43,500. Thus, the project has a net economic benefit of $6,800, resulting in a benefit-to-cost ratio of 1.2 to 1.0. The LRD would be responsible for operating and maintaining the project at an estimated average annual cost of $5,000.

WSDOT I-5 Project

WSDOT is proposing a project (the I-5 Toutle Park Road to Maytown Project) to widen and make various other improvements to I-5 to improve traffic flow and safety in the vicinity of Centralia-Chehalis. Implementation of this project will require that WSDOT and FHWA standards for minimum flood clearance be met. These standards state that the mainline pavement must not be flooded during the 50-year flood event (FHWA and WSDOT. 1997). FHWA manuals require that the interstate highway system be designed to be two feet above the 100 year flood boundary (WSDOT, 1997)

Based on recent recalculation of flood frequency curves for this area by USACE (USACE, 1997b), the minimum flood clearance requirements are not currently being met in a 2.9-mile section of I-5 between Chamber of Commerce Way Interchange in Chehalis and the Mellen St. (SR 507) Interchange in Centralia. Implementation of WSDOT's improvement project will require that I-5 be raised to meet the minimum flood clearance requirements in this section, unless other measures are taken to alter and reduce existing flood stage levels in the area.

Compared to widening without the grade change, widening of the roadway with the grade change would require additional fill, and construction of an expensive retaining wall. As discussed in Section 4.2.2 below, the additional fill and elevation of the embankment would incrementally add to the loss of floodplain storage in the area.

The construction cost of widening and raising I-5 from the existing grade to two feet above the 100-year flood elevation is estimated by WSDOT to be $321 million ($353 million if preliminary engineering by WSDOT is included) (WSDOT, 1998). The construction cost of widening I-5 without raising is estimated by WSDOT to be $223 million ($245 million including preliminary engineering), and the incremental cost associated with raising I-5 is $98 million ($108 million with preliminary engineering).

A Draft Environmental Impact Statement (DEIS) was issued for the I-5 Toutle Park Road (Exit 52) to Maytown (Exit 95) Project in January, 1997. Comments received on the DEIS indicate more information is needed regarding impacts of the project on flooding. USACE is in the process of finalizing a "Post Flood Study" report which provides updated flood information on the discharge and stage for the 50-year and 100-year floods on the Chehalis River in the vicinity of Centralia, and addresses the effects of potentially raising the road surface elevation of I-5 in the Centralia- Chehalis area. Based on conversations with WSDOT staff, the Final EIS for the I-5 Toutle Park Road to Maytown Project will be prepared as soon as the information from the USACE Post Flood Study report is available. The project is currently scheduled to go to bid in 2004.

4.1.2. Environmental Consequences of No-Action

USACE Long Road Dike Project

An analysis was conducted to determine the effect, if any, that construction of the LRDP would have on mainstem Chehalis River flood water surface profiles. The project would remove the LRD from the total overbank storage area currently available in the Centralia-Chehalis region for all floods up to the 45-year design event. However, the total volume associated with the area removed from storage is very small compared with the total amount of storage available in the Centralia-Chehalis region. The analysis determined that there would be no measurable change in Chehalis River flood water surface profiles for events when the LRDP would affect valley storage. In addition, the use of the area south of the levee alignment as a borrow site could replace some of the lost storage volume.

The LRDP would not require any relocation of buildings or facilities, nor is it expected to negatively affect any environmental resources. New or disturbed surfaces (including contractor staging and access areas) will be covered with topsoil and seeded with grass. Following construction of the levee, the borrow site could be developed as a wetland by the LRD, Lewis County or WSDOT.

WSDOT I-5 Project

A Draft Environmental Impact Statement was prepared by WSDOT and FHWA (FHWA and WSDOT, 1997) to describe the affects of the I-5 Toutle Park Road to Maytown Project (including raising I-5) on all aspects of the environment. In summary, the main concern with raising I-5 is the filling of wetlands on both sides of I-5. Because of this, compensatory mitigation for wetland losses is proposed at other locations within the project area. In addition, traffic circulation during construction will require additional efforts on the part of local police departments.

If implemented alone, the WSDOT project would protect I-5, but could negatively impact the rest of the region by exacerbating the damage caused by a normal flood event. The additional fill and elevation of the embankment would incrementally add to the loss of floodplain storage. Preliminary analyses by USACE suggest that raising I-5 to the 50- and 100-year flood levels will produce a

0.05 and 0.82 foot increase, respectively, in water surface elevation on the Chehalis River upstream of the Mellen St. Bridge.

4.1.3. Economic Consequences of No-Action

Estimated flood damages in Lewis County have exceeded \$60 million since 1990, not considering damages resulting from I-5 being closed for days. Flood hazards affecting economically significant areas within the Chehalis River floodplain fall into two general categories: 1) widespread inundation, which affects industrial, commercial and agricultural areas, and 2) localized bank erosion, which affects primarily agricultural lands.

The general order of magnitude of flood damages and the proportion of those damages which have an impact on the economically productive sectors of the economy can be seen from partial data available on the January 1990 flood. According to the USACE (1991), direct damages from the January 1990 flood event in the Chehalis River floodplain totaled \$19,189,000 in 1990 dollars. Estimates for the February 1996 flood, the highest of record, are still outstanding, but the cost of a four-day closure of I-5 alone has been estimated to exceed \$100 million (EMHCO and Associates, 1996).

If no action is taken to reduce flood stages in the area, flood damage will continue as documented for historical events, and WSDOT will spend approximately \$98 million (\$108 million with preliminary engineering) to raise I-5.

4.2. Floodway Modification Alternative

The Floodway Modification Alternative was identified in the Pre-Feasibility Analysis Report (PIE, 1998a) and would provide a promising solution to the flooding problem. This alternative would consist of three components. The first component is the Skookumchuck Dam modifications to provide flood control storage. The second component is floodway modifications between approximately RM 64.90 and RM 70.60, including modifications of the existing Mellen St. Bridge abutment. The third component is floodway modifications between approximately RM 74.55 and RM 75.08, including modifications of the existing SR-6 Bridge abutment.

The Skookumchuck Dam modifications alone could provide substantial flood control storage and could significantly reduce flood stages along the Skookumchuck River floodplain. A preliminary cost estimate indicates that this component would be the least costly option among all storage dam options evaluated for providing flood control storage of this magnitude. In addition, it would have the least environmental impacts of all storage dam options, as the dam already exists. However, the Skookumchuck Dam component alone would have very little effect on the Chehalis River flood stage (less than 0.5-foot flood stage reduction) and would not be economically feasible, as the benefit-to-cost ratio would be less than 1.0.

The floodway modifications in the Mellen St. Bridge and SR-6 areas could reduce a 100-year flood stage by more than 4 feet on the Chehalis River, enough to substantially reduce flood damages and sufficient for keeping I-5 above the 100-year flood level. Preliminary cost estimates indicate that the floodway modifications would be the least costly option for achieving the magnitude of flood stage reduction desired. However, the floodway modifications alone would result in peak flow increases downstream during floods and would not be acceptable to downstream floodplain communities.

A combined project including both the Skookumchuck Dam modifications and the floodway modifications in the Mellen St. Bridge and SR-6 areas would overcome the shortfalls that each would have if implemented separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck River peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway modifications. The substantial flood reduction benefits that can be achieved by the floodway modifications would be more than the total cost required to modify both Skookumchuck Dam and the floodway in the Mellen St. Bridge and SR-6 areas. The combined project would, therefore, become economically feasible and would also reduce the peak flood flow discharging downstream from the floodway modification areas.

The UNET model was used to evaluate the benefits and impacts of the combined components. The Skookumchuck Dam modifications and the Mellen St. Bridge area floodway modifications of this alternative were evaluated in detail in the pre-feasibility analysis (PIE, 1998a). However, due to insufficient river channel data at the time, the SR-6 Bridge area floodway modifications were only casually evaluated in the pre-feasibility analysis. Upon an update of the UNET model with the addition of new cross section data recently surveyed, further evaluation of the SR-6 Bridge area floodway modifications were performed in this feasibility analysis.

4.2.1. Components of the Floodway Modification Alternative

The Floodway Modification Alternative is the combination of modifications to Skookumchuck Dam with floodway modifications in the Mellen St. Bridge area to reduce the flooding in the City of Centralia floodplain, as well as floodway modifications in the SR-6 Bridge area to reduce the flooding in the City of Chehalis floodplain. A brief description of the components is provided below.

Skookumchuck Dam Modifications

The structural modifications to Skookumchuck Dam to permit flood control operation during winter months would involve modifications to the existing spillway to add 1) a 15-foot high inflatable crest weir at the top of the existing spillway, and 2) flood control outlet works including two gated (15-foot wide by 10-foot high) flood control outlet sluices.

These modifications would provide 20,000 acre-feet of reservoir storage between elevations 455 and 492 feet for winter flood control operation. This storage is sufficient to contain the peak flow of the February 1996 flood and would reduce the peak flood stage at the Pearl St. Bridge by 1.44 feet. This is equivalent to reducing the flood stage from a 70-year recurrence interval to a 10-year recurrence interval.

The flood control outlet works would be able to discharge approximately 3,000 cfs at the minimum flood control pool of elevation 455 feet in order to evacuate the reservoir within a maximum of 3 to 5 days following a major flood that fills the reservoir to the maximum pool of elevation 492 feet. This would allow the flood control storage to be evacuated in a timely manner to allow for the next flood event, which could potentially occur right after reservoir evacuation.

USACE developed a preliminary flood control operation rule curve as part of its studies (USACE, 1992). A rule curve similar to the USACE rule curve would provide flood control storage of 20,000 acre-feet from November 1 to February 1. After February 1, the reservoir would be allowed to refill. Drawdown of the reservoir would begin each year in early to mid September and would continue until the minimum flood control pool is reached, around the first of November.

The flood control operation rule curve must ensure releases in accordance with the existing fishery flow agreement. The agreement between PacifiCorp and WDFW provides a minimum instream flow of 140 cfs from September 10 to October 31 for salmon spawning. Incubation flows begin on November 1 or at the completion of spawning as determined by WDFW. A minimum of 95 cfs is supplied until March 31. From April 1 through August 31, rearing flows are set at a maximum of 95 cfs or natural river flow plus 50 cfs, whichever is less. Rearing flows may be adjusted downward as determined by WDFW to preserve water for use during the spawning period. The instream flow agreement also provides for instream water temperatures of 50° to 55° F. These temperatures must be maintained, to the maximum extent possible, depending on reservoir and climatic conditions.

USACE performed a water supply study of the Skookumchuck reservoir as part of its studies to determine if sufficient storage would be available to meet minimum instream flow requirements for fisheries and power diversion with the addition of flood control storage and water supply (USACE, 1992). USACE assumed that PacifiCorp would divert its entire 80 cfs water right, and determined that minimum instream flow and water supply requirements could be met in all years with the USACE proposed flood control operation rule curve. An update of the USACE water supply study was performed in this feasibility analysis and confirmed that minimum instream flow and water supply requirements could be met in all years with the above-described flood control operation rule curve.

The Skookumchuck Dam modifications, as described, include adding a 15-foot high weir above the existing spillway crest at elevation 477. This will provide approximately an additional 9,000 acre-feet of water storage behind the dam. This additional storage would be available to augment summer low flows downstream.

Mellen St. Bridge Vicinity Floodway Modifications

In the pre-feasibility analysis (PIE, 1998a), floodway modifications in the Mellen St. Bridge vicinity along the Chehalis River were evaluated in detail from approximately 2 miles downstream of its confluence with the Skookumchuck River (RM 64.90) to the north end of the Centralia-Chehalis Airport (RM 70.60), near its confluence with Salzer Creek. The modifications would involve terracing the floodway in areas where the flow is currently constricted in order to increase the high-flow hydraulic capacity of the Chehalis River during flood events. Floodway excavation was also evaluated further downstream to the Galvin Road Bridge (RM 64.08). Numerous variations of excavated width and excavation location were modeled. Cost estimates were then developed to help determine which arrangements appeared to be the most cost-effective.

Among all variations modeled with the developed UNET model, floodway modifications between RM 64.90 and the north end of the Chehalis-Centralia Airport (RM 70.60) appears to be the most efficient and cost-effective design. Two optional excavation schemes for this reach of the river were evaluated further in the pre-feasibility analysis (PIE, 1998a). The Option 1 excavation scheme would involve excavating approximately 2.8 million cubic yards of material between the hump location (RM 65.95) and one-half mile upstream of the Mellen St. Bridge (RM 68.02). UNET modeling of this scheme resulted in 4.49 feet of flood stage reduction near the mouth of Salzer Creek (RM 69.79) and 3.79 feet at the Mellen St. Bridge gage (RM 67.44) during the February 1996 event. The Option 2 excavation scheme would involve excavating approximately 7.2 million cubic yards of material between RM 64.90 and RM 70.60 (the north end of the airport). UNET modeling of this scheme resulted in 7.01 feet of flood stage reduction near the mouth of Salzer Creek and 7.27 feet at the Mellen St. Bridge gage during the February 1996 event. Either of these options would also provide an opportunity to create off channel rearing habitat to benefit anadromous fish, and opportunities for other habitat improvements.

The Mellen St. Bridge section of the Chehalis River is one of the most restrictive sections for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. It is envisioned that the right-bank (east-bank) would be excavated In conjunction with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway.

The existing wastewater treatment plant for the City of Centralia is located immediately downstream of the Mellen St. Bridge. Studies are currently underway to investigate the possibility of moving the treatment plant to a downstream location. The current site has very little room for expansion to meet the future needs of the area.

One of the major considerations for the floodway modifications is determining an appropriate location for disposal of excavated material. Several possibilities exist: constructing setback levees adjacent to the excavation, finding a downstream location in the floodplain, finding an upstream location in the floodplain, construction of setback levees between the Mellen St. Bridge and the south end of the airport to create additional flood storage areas, temporarily stockpiling material for use in the proposed I-5 widening project, construction of levees to help alleviate flooding on localized areas, or a large remote disposal site. Due to the large volumes of excavation being considered, it is likely that a combination of some of these possibilities would be required. More detailed design studies of the sites for final selection will be performed if this alternative is selected for project development.

Several sites downstream of the mouth of the Skookumchuck River have been considered as potential sites for a new wastewater treatment plant. It is possible that one or more of these sites could be used for disposal of excavated material. In addition, some fill could probably be utilized in any new treatment plant construction. The material could be used to either raise the treatment plant site, or help provide protection to the site from flood conditions. A downstream disposal site would be most economical for excavation downstream of the Mellen St. Bridge. Potential concerns of filling in the floodplain will be modeled and the impacts evaluated.

Upstream of the Mellen St. Bridge, fill could potentially be placed in areas along the west side of the valley, up against Scheuber Road. Upstream disposal areas would be most economical for floodway excavation upstream of the Mellen St. Bridge.

According to WSDOT, close to one million cubic yards of fill material would be required for construction of the proposed I-5 widening project between Chehalis and Centralia. Some of the floodway excavation material could be temporarily stockpiled to be used as fill in the widening project.

Between the Mellen St. Bridge and the SR-6 Bridge, levees could be constructed to enclose one or more areas to create additional storage during a flood event. During a flood, floodwaters would overflow the upstream bank at a predetermined flood stage and fill the enclosed area. The ponded water would then drain slowly through a downstream outlet.

Small levee projects similar in scale to the proposed Long Road Dike Project could be built with excavated floodway material to help with localized flooding problems. Small diking projects would likely only require a small percentage of the total volume of material being excavated.

A remote site (anything that is not in the immediate Centralia-Chehalis area) would be the least economically desirable of any of the possible disposal sites available. The costs of hauling excavated materials would escalate dramatically with increases in haul distances.

SR-6 Bridge Vicinity Floodway Modifications

The City of Chehalis experiences flooding between the 13th St. interchange and the Main St. (SR-6) interchange. Two railroads pass under I-5 between these two interchanges, creating openings in the I-5 embankment. During major flooding on the Newaukum River, floodwaters from the Newaukum River spill over into nearby Dillenbaugh Creek and flow through the railroad openings to the east side of I-5. The Mellen St. Bridge vicinity floodway modifications would not substantially reduce this flooding.

Several possibilities exist to reduce the flooding in this area. Flood stages on the Chehalis and Newaukum Rivers could be lowered by floodway modifications in the area of the SR-6 Bridge to the Newaukum River mouth. Another possibility would be to construct small levees between the Newaukum River and Dillenbaugh Creek to keep the two hydraulically separated during floods, or to construct small levees along portions of Dillenbaugh Creek to prevent floodwaters from inundating homes and businesses. Floodway modifications could also be combined with small levee construction.

Floodway modifications on the Chehalis River from shortly downstream of the SR-6 Bridge (RM 74.55) up to the mouth of the Newaukum River (Chehalis RM 75.15) were evaluated. The

SR-6 Bridge embankment constricts flood flows on the Chehalis River in much the same way as the Mellen St. Bridge downstream. This flow constriction is partially responsible for backing up Newaukum River flood flows. Floodway modifications involving modifications of SR-6 Bridge and excavation of approximately 800,000 cubic yards of material in this reach of the Chehalis River would result in approximately 1.5 feet of peak flood stage reduction on the lower Newaukum River (RM 1.0) for a flood event such as the February 1996 event. Floodway excavation in this area would be substantially extended downstream if further flood stage reduction is to be achieved.

4.2.2. Flood Stage and Peak Flow Reductions

Providing flood control storage at Skookumchuck Dam would substantially reduce flood stages and peak flows on the Skookumchuck River. Modifications of the Chehalis River floodway in the Mellen St. Bridge vicinity would achieve substantial flood stage reductions in the City of Centralia. However, modifications of the Chehalis River floodway in the SR-6 Bridge vicinity would achieve only moderate flood stage reductions in the City of Chehalis. The amounts of flood stage and peak flow reductions at various locations along the Skookumchuck and the Chehalis rivers were estimated by comparing the differences between pre-project and post-project conditions. The calibrated UNET model for the existing baseline (or pre-project) conditions was modified to incorporate the Skookumchuck Dam flood control operation and the Chehalis River floodway modifications.

Two floodway excavation options in the Mellen St. Bridge vicinity were incorporated into the UNET modeling. Option 1 would require a total excavation of approximately 2.8 million cubic yards of river bank material and would achieve a 100-year flood stage reduction of approximately 4 feet in the area upstream of the Mellen St. Bridge to the lower Salzer Creek floodplain east of I-5. Option 2 would require an excavation of approximately 7.2 million cubic yards and would reduce the 100-year flood stage by approximately 7 to 8 feet in this area. The existing I-5 low point (elevation 169) along the Centralia-Chehalis Airport stretch is five feet below the low point (elevation 174) of both the Tacoma Eastern Railroad embankment to the east and the Airport Road dike to the west. A four-foot flood stage reduction resulting from the Option 1 floodway excavation would keep I-5 from being flooded by a 100-year flood event. A seven- to eight-foot flood stage reduction resulting from the Option 2 floodway excavation would provide further flood damage reduction benefits to the floodplain communities, and additional freeboard to the railroad embankment and the Airport Road dike protecting I-5 from flooding.

Runs of the modified UNET model for the post-project conditions were executed, incorporating the Skookumchuck Dam flood control operation and the Chehalis River floodway modifications in the Mellen St. Bridge and SR-6 Bridge areas. Run results for either the Option 1 or Option 2 floodway excavation scheme indicates that overbank flows flooding the City of Centralia streets and buildings under the pre-project conditions would be almost completely eliminated upon implementation of this project alternative. The results also show that overtopping of the Airport Road dike and the Tacoma Eastern Railroad embankment, causing I-5 to be flooded, would be eliminated.

Upon implementation of the Floodway Modification Alternative with the Option 1 excavation scheme, the February 1996 flood stage (a 100-year event) at Mellen St. would be reduced to the 15-year flood level under existing conditions. If the Option 2 excavation scheme is implemented, the February 1996 flood stage at Mellen St. would be further reduced to the five-year flood level under existing conditions.

4.2.3. Cost Estimates

Pre-feasibility cost estimates were developed for the Floodway Modification Alternative, including both Option 1 and Option 2 floodway excavations in the Mellen St. Bridge area.

The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area Option 1 modification scheme, and the SR-6 Bridge area floodway modifications would be $50,684,529 and would have annual O&M costs of approximately $220,000. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area Option 2 modification scheme, and the SR-6 Bridge area floodway modifications would be $93,317,247 and would have annual O&M costs of approximately $270,000. The O&M costs consist of annual flood control operation of Skookumchuck Dam, as well as maintenance costs for clearing debris and excess vegetative growth from the floodway excavation.

An economic evaluation was performed in the pre-feasibility analysis for the Floodway Modification Alternative with the Mellen St. Bridge area Option 2 floodway excavation. The total average annual benefits were estimated at $9,498,000 and the total average annual costs estimated at $7,139,000, resulting in a benefit-to-cost ratio of 1.33. The benefit-to-cost ratio would be greater for the Floodway Modification Alternative with the Mellen St. Bridge area Option 1 floodway excavation.

Details of the cost estimates and the economic evaluation for the Floodway Modification Alternative are presented in the Pre-Feasibility Analysis of Alternatives Report (PIE, 1998a).

4.2.4. Environmental Issues

Skookumchuck Dam Modifications

Investigations conducted for the USACE Skookumchuck Dam Modification Project identified several potential environmental impacts relating to wildlife habitat and fishery resources, water supply, water quality, and dam safety. The following discussion is based upon those investigations and analyses; additional studies would be required to further define potential impacts that could occur if this alternative is to be implemented.

The existing reservoir drawdown zone provides approximately 65 acres of vegetated habitat that is important to wildlife (USFWS, 1989). This zone is used by waterfowl, deer, elk, and other wildlife. Changes in reservoir levels associated with a new flood control operation rule curve could induce changes in vegetation and loss of wildlife food and cover. Water dependent mammals like beavers and muskrats could be negatively affected by fluctuations in wintertime reservoir levels.

Downstream of the dam, wetlands and riparian habitat along the Skookumchuck River could be affected by a reduction in overbank flow.

Operational changes may affect resident fish inhabiting the reservoir, and under some conditions, could impair the outmigration of juvenile steelhead (USFWS 1989). Such changes, which could occur if the reservoir pool failed to refill prior to the beginning of March, could result in insufficient water to pass outmigrating fish over the spillway. Operational changes could also potentially affect the supply of water to the WDFW fish rearing facility downstream of the dam.

The existing maximum velocity on the Chehalis River is up to 12 fps downstream of the Mellen St. Bridge. This alternative would bring the maximum velocity in this area down to approximately 3 to 4 fps. Upstream of the Mellen St. Bridge, the existing maximum velocity would be increased from about 2 fps to 4 fps. The estimated changes in velocity would reduce both sedimentation above the bridge and erosion below the bridge.

With flood control storage at Skookumchuck Dam, peak velocities would decrease along the Skookumchuck River. This alternative would decrease the maximum velocities around Bucoda from about 2.5 to 8 fps to between 2 and 6.5 fps. Although the peak velocity would decrease, the time period during which the velocity is between 5 and 6 fps would increase. Whether or not effects of the increased duration of this range of velocity would result in scouring problems is currently unknown.

Other potential impacts to fish could occur as a result of changes in water temperatures, increases in reservoir turbidity, and the transport of sediments downstream. Increases in turbidity levels could result from erosion of exposed reservoir slopes during pool drawdown periods. Undefined at this time is the effect of flow changes on fishery resources. Beneficial effects could include a reduction in scouring of spawning beds; adverse impacts could result from rapidly changing river levels, especially during spawning and incubation periods. Due to the storage volume to be provided by the Skookumchuck Dam modifications, it is likely that seasonal streamflows could be augmented to enhance conditions for anadromous fish.

Measures considered by USACE to mitigate for wildlife impacts associated with its Skookumchuck Dam modification proposal included the transfer of 50 acres of forested land for incorporation into the Skookumchuck Habitat Management Area and construction of wood duck nesting boxes. The level of mitigation required if this alternative is implemented is not known at this time. Mitigation costs could be substantial and could include land acquisition as well as permitting, engineering, and construction costs.

Chehalis River Floodway Modifications

Floodway modifications would involve disturbance of wetlands and riparian habitats, and potentially could increase erosion and affect water quality. Although impacts to fish habitats would occur, floodway modifications would involve significantly less direct disturbance of instream habitats than channel excavation, and offers the potential to provide a net habitat benefit. Floodway modifications would also avoid the high level of impact to the built environment that would be associated with secondary channel construction.

Wetlands are interspersed with upland habitats along the entire proposed excavation length of the river. The area and magnitude of the potential impact to wetlands would depend on the ultimate floodway width and the reach or reaches selected for excavation. Wetlands are particularly extensive along RM 67, at the confluence with the Skookumchuck River, as well as in the areas between RM 69.5 and RM 70.5 (Salzer Creek mouth) and RM 71.5 and RM 75.08 (airport area to the Newaukum River); excavation in these areas would result in a relatively large area of wetland disturbance. Wetlands lying within the excavated floodway would be directly disturbed. Adjacent wetlands could also be indirectly affected by dewatering, either through interception of perched water tables or through reduction or elimination of periodic recharge by overbank flooding. The approximate locations of known wetlands have been mapped under the National Wetlands Inventory program. However, site specific surveys would be needed to evaluate specific wetland areas that might be directly or indirectly affected and to identify measures to avoid and minimize impacts to wetlands.

Removal of wetland and riparian vegetation across the floodway width would significantly reduce the wildlife habitat value of these areas. The removal of natural vegetative cover from the floodway could fragment remaining adjacent habitats by removing their connection to the river. It is possible that these effects could be partially offset by reestablishing vegetation on the excavated floodway and along the shoreline. However, because of the need to maintain channel capacity, a cover of woody overstory vegetation cannot be reestablished on the benches. A buffer of woody overstory vegetation could potentially be reestablished along some reaches of the shoreline without significantly affecting floodway hydraulics.

Floodway modifications would increase the potential for erosion at least temporarily, until vegetation could be reestablished along the streambank. Implementation of Best Management Practices during and following construction would be particularly important to avoid impacts to water quality at the project site and downstream.

The large volume of material that would be generated by the floodway excavation would require one or more sites for disposal. The specific environmental impacts associated with disposal of the excavated material would vary, depending on existing conditions at the site or sites selected for this purpose. Disposal of the material adjacent to the excavated area would most likely be the least environmentally desirable alternative, as it would significantly increase the area of wetland and riparian habitat disturbed. More desirable would be the beneficial use of the material in the construction of other projects. Such projects could include small levees to address localized flooding problems. The environmental effects of using the excavated material for the construction of small levees would be small, and would be dependent on site specific conditions.

Some of the excavated material could require special handling as a result of hazardous waste contamination. Because the Sewage Treatment Plant Landfill was used as an unregulated throw and burn site until the early 1970s, hazardous wastes may be present in soil and subsurface materials in this area (FHA and WSDOT, 1997).

A National Register-eligible archaeological site exists near the Mellen St. Bridge (FHA and WSDOT, 1997). Other recorded sites, including some that may be aboriginal townsites, occur in the project area. These and currently unrecorded cultural resources could be affected by project construction.

Excavation of the floodway would affect farmlands, but would have relatively little impact on existing structures and facilities. Facilities which would be affected include the Centralia Wastewater Treatment Plant and the Mellen St. Bridge. The existing wastewater treatment plant site is susceptible to flooding and provides insufficient space for plant expansion beyond the year 2025. Studies are underway to evaluate alternative sites for a new or modified wastewater treatment plant to meet the future wastewater service needs of the City of Centralia (CH2M-Hill, 1998).

Mitigation for unavoidable impacts to wetlands would be required under the provisions of the Clean Water Act and local critical areas ordinances; mitigation would also be required for impacts to fish and wildlife habitats. Mitigation costs could be substantial. Because the excavated floodway could be designed to bypass incised meanders, this alternative excavation provides opportunities to create valuable backwater refuge for fish at high flows. This type of mitigation action would be consistent with current efforts by tribal interests to create additional off-channel rearing habitat to benefit anadromous fish, and should be investigated further if the Floodway Modification Alternative is implemented.

4.3. Floodplain Modification Alternative

The Floodway Modification Alternative, which was identified in the Pre-Feasibility Analysis Report (PIE, 1998a) and discussed above, would provide a cost-effective solution to the flooding problems in the Centralia-Chehalis area and I-5 corridor. Further evaluation of that alternative, based on the updated UNET model described in Section 2.3, led to a new and improved alternative incorporating a concept of floodplain modifications in lieu of floodway modifications in the SR-6 Bridge vicinity. This new Floodplain Modification Alternative would provide substantial flood flow bypass and eliminate the need for any channel or bank excavation in the SR-6 Bridge vicinity for achieving significant flood stage reductions within the City of Chehalis floodplain.

The Floodplain Modification Alternative would consist of three components. The first component, common to the Floodway Modification Alternative, is modifications to Skookumchuck Dam to provide flood control storage. The second component, also common to the Floodway Modification Alternative, is floodway modifications in the vicinity of Mellen St. Bridge between River Mile (RM) 65.90 and RM 68.25, including modifications to the existing Mellen St. Bridge abutment. The third component is floodplain modifications in the vicinity of SR-6 to provide flood flow bypass and storage, and also to provide opportunities for habitat improvements.

The Floodplain Modification Alternative would be more cost-effective and environment-friendly than the Floodway Modification Alternative. The Floodplain Modification Alternative has been identified, so far, among all alternatives being evaluated as the most promising option in solving the flooding problems in the Centralia-Chehalis and I-5 corridor area. Therefore, details of this alternative are described in the following section which identifies the most promising solution to date.

This section describes the currently studied alternative that provides the most promising solution to the flooding problems in the Centralia-Chehalis and I-5 corridor area. Based on the evaluation of options presented in Section 3, the Floodplain Modification Alternative is the most promising alternative analyzed by PIE at this stage of project development and may be changed later if a better option is identified as the project development progresses and more alternatives are evaluated.

4.3.1. Components of the Floodplain Modification Alternative

The Floodplain Modification Alternative would consist of three components. The first component is modifications to Skookumchuck Dam to provide flood control storage. The second component is floodway modifications in the vicinity of Mellen St. Bridge between River Mile (RM) 65.90 and RM 68.25, including modifications to the existing Mellen St. Bridge abutment. The third component is floodplain modifications in the vicinity of SR-6 to provide flood flow bypass and storage.

The first and the second components are common to, while the third component differs from, the Floodway Modification Alternative described previously. The Floodplain Modification Alternative would provide substantial flood flow bypass and eliminate the need for any channel or bank excavation in the SR-6 Bridge vicinity for achieving significant flood stage reductions within the City of Chehalis floodplain. It would also provide opportunities for habitat improvements in the floodplain flow bypass area.

The Skookumchuck Dam modifications could provide flood control storage of 20,000 acre-feet, and could significantly reduce flood stages along the Skookumchuck River floodplain. A preliminary cost estimate indicates that this component would be the least costly of all storage dam options evaluated for providing flood control storage of this magnitude. In addition, this component would have the least environmental impact of all storage dam options, as the dam already exists. However, the Skookumchuck Dam component alone would have very little effect on Chehalis River flood stage reduction (less than 0.5-foot flood stage reduction) and would not be economically feasible alone, as the benefit-to-cost ratio would be less than 1.0.

The Mellen St. Bridge vicinity floodway modifications component alone could reduce a 100-year flood stage by more then 4 feet on the Chehalis River in the Mellen St. Bridge to Salzer Creek reach. This would be sufficient to substantially reduce flood damages and keep I-5 east of the Centralia - Chehalis Airport area above the 100-year flood level. Preliminary cost estimates indicate that this component would be the least costly of options, including new storage dams and channel dredging, for achieving the magnitude of flood stage reduction desired. However, the floodway modifications would result in peak flow increases downstream during floods and would not be acceptable to downstream floodplain communities.

The SR-6 vicinity floodplain modifications could substantially reduce the 100-year flood stage by approximately 2 to 3 feet within the City of Chehalis floodplain along the Chehalis River, the Newaukum River and Dillenbaugh Creek. Preliminary cost estimates indicate that this component would be the least costly among evaluated options, including new storage dams and channel or bank excavation, for achieving the magnitude of flood stage reduction desired in the City of Chehalis floodplain. However, the floodplain modifications alone could also result in flood peak flow increases downstream.

A combined project including the Skookumchuck Dam modifications, the Mellen St. vicinity floodway modifications and the SR-6 vicinity floodplain modifications, would overcome the shortfalls that each component would have if implemented separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck River peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway and the floodplain modifications. The substantial flood reduction benefits that can be achieved by the floodway and the floodplain modifications would be more than the total cost required to modify the floodway, the floodplain and the Skookumchuck Dam. The combined project would, therefore, become economically feasible and would also reduce the peak flood flow discharging downstream from the project.

The UNET model developed in the pre-feasibility analysis was updated as described in Section 2.3, and used to evaluate the flood stage reduction benefits and impacts of the combined components. The flood modeling evaluation was based on the February 1996 flood, which is the flood of record on the Chehalis River, representing the 100-year event. A brief description of the components is provided below.

Skookumchuck Dam Modifications

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The dam was constructed in 1970 to supply water for the Centralia steam generating plant. The dam is an earthfill structure approximately 190 feet high, above bedrock, with the top of the dam being at elevation 497 feet. Storage behind the dam is essentially a fill and spill operation. The limited outlet capacity of the dam, which consists of two 24-inch Howell Bunger valves with a combined discharge of approximately 220 cubic feet per second (cfs), causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the 130-foot wide ungated spillway, which has a discharge capacity of 28,000 cfs at the maximum pool elevation 492 feet. Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 31,000 acre-feet.

Preliminary investigations by USACE indicate that flood control storage at Skookumchuck Dam could be feasible without jeopardizing the steam plant water supply. USACE investigated several options for modifications, which are presented in detail in the USACE's December 1982 and February 1992 reports (USACE, 1982, 1992).

The first component of the Floodplain Modification Alternative is structural modifications to the existing Skookumchuck Dam to permit flood control operation during winter months. Modifications to the existing spillway would be made to add 1) flood control outlet works, including two gated flood control outlet sluices, and 2) an inflatable crest weir at the top of the existing spillway. The addition of the crest weir at the top of the existing spillway will also require modifications to the ogee crest and the spillway chute. A conceptual layout plan and sections of the modifications are shown in Figures 4-1 through 4-3. Figure 4-4 presents an artist's rendering of the modifications. Brief descriptions of the modifications are provided below, following the discussions on dam safety and reservoir regulation considerations.

Dam Safety Considerations

The proposed modifications to Skookumchuck Dam must enable the project to safely pass the Probable Maximum Flood (PMF) outflow of 28,000 cfs at a maximum design pool elevation of 492 feet. During the PMF, approximately 22,500 cfs would be discharged over the modified spillway, and 5,500 cfs would be discharged through the proposed flood control outlet.

The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while accounting for contingencies such as surcharge, wind wave runup, and embankment settlement. Five feet is considered adequate freeboard. The dam embankment currently has a top elevation of 497.0 feet. The maximum design pool level is at elevation 492.0 feet.

PacifiCorp (formerly Pacific Power & Light, the dam operator) had a dam safety and seismic stability analysis performed on the dam in 1988, which the USACE later reviewed. The USACE determined that, with the new operation for flood control, the embankment would suffer distress during the design earthquake, but would not fail and did not require any modification (USACE, 1992). More recently, PacifiCorp had a FERC (Federal Energy Regulatory Commission) Part 12 dam safety inspection performed in 1996. Stability analyses were performed for normal operating conditions, PMF, rapid drawdown, and seismic loading conditions. The embankment dam, spillway and all other structures were found to be safe for all cases investigated (Black & Veatch, 1996).

As a part of this feasibility analysis, Hart Crowser, PIE's geotechnical subconsultant, reviewed dam safety and stability taking into account the proposed changes to the reservoir operation for flood control. Conclusions of Hart Crowser's review are stated as follows (HCI, 1998):

- Additional static stability analyses for the 15-foot raised normal maximum headwater elevation at 492 feet had adequate factors of safety for steady state seepage and rapid drawdown conditions. This was consistent with other previous analyses of the dam.
- There have been significant advances in the estimation of static and seismic displacements of dams since the displacement calculations were conducted on the Skookumchuck Dam in 1990.
- The most recent seismic coefficients that have been

recommended for use at the Skookumchuck Dam have been 0.25 and 0.27 g. This is below what the USGS National Seismic Hazard Map recommends, which is 0.31 g for a 5% probability of exceedence in 50 years. However, the USGS recommendations are based on the probabilistic approach as opposed to the deterministic approach that has been used in the past.

As a result of this review, Hart Crowser recommends that seismic displacement based analyses of the Skookumchuck Dam, using a two-dimensional finite difference program (named FLAC), and an evaluation of the liquefaction potential at the site based on the field explorations be conducted.

Reservoir Regulation Considerations

USACE developed a preliminary flood control operation rule curve as part of its flood control operations investigation (USACE, 1992). The USACE rule curve provided flood control storage of 11,900 acre-feet between elevations 453 and 477 feet, from November 1 to February 1. After February 1, the reservoir would be allowed to refill until elevation 477 feet was reached on March 25. Drawdown of the reservoir would begin each year on September 10 and would continue until elevation 453 feet was reached around November 1.

PIE's proposed dam modifications would provide a flood control storage of 20,000 acre-feet between pool elevation 455 and 492 feet. This storage is sufficient to contain the peak flow of the February 1996 flood and would reduce the peak flood stage at the Pearl St. Bridge by 1.44 feet. This is equivalent to reducing the flood stage from a 70-year recurrence interval to a 10-year recurrence interval. A new reservoir operation rule curve, similar to the USACE rule curve, is shown in Figure 4-5 for the flood control operation.

The flood control operation rule curve must ensure releases in accordance with the existing fishery flow agreement. The agreement between PacifiCorp and Washington Department of Fish and Wildlife (WDFW) provides a minimum instream flow of 140 cfs from September 10 to October 31 for salmon spawning. Incubation flows begin on November 1, or at the completion of spawning, as determined by WDFW. A minimum of 95 cfs is supplied until March 31. From April 1 through August 31, rearing flows are set at a maximum of 95 cfs or natural river flow plus 50 cfs, whichever is less. Rearing flows may be adjusted downward as determined by WDFW to preserve water for use during the spawning period. The instream flow agreement also provides for instream water temperatures of 50° to 55° F.

The proposed flood control operation would be a significant change from the existing operation conditions since the reservoir, normally filled in December, would be refilled in February and March. The thermal characteristics of the reservoir and the downstream river will not be affected by the delayed refill of the reservoir, which will be delayed until March 25 under the proposed flood control operation conditions. Historically, average river water temperatures for January to March have been in the low to mid-40s (degree Fahrenheit). Water temperatures begin to warm slightly in April and continue warming significantly from May to July. Water stored during February and March will be sufficiently cold to provide adequate cool water for blending later in the summer when the reservoir becomes stratified. Therefore, since the reservoir will be full before it begins to stratify and since it will be filled with cold water, the proposed refill schedule will not impact the reservoir and river water temperature.

The dam modifications proposed by PIE include adding a 15-foot high inflatable weir above the existing spillway crest at elevation 477. This will provide an additional 9,000 acre-feet of storage, which would be available to augment summer low flows downstream. Since this additional storage will store cold water, summer releases of this water would improve downstream river water temperatures.

USACE performed a water supply study of the Skookumchuck reservoir as part of its investigation to determine if sufficient storage would be available to meet water supply and minimum instream flow requirements for fisheries and steam-plant cooling water diversion with the USACE proposed storage operation for flood control (USACE, 1992). USACE assumed that PacifiCorp would divert its entire 80 cfs water right, and determined that minimum instream flow and water supply requirements could be met in all years with the USACE proposed flood control operation rule curve.

A water budget model updating the USACE water supply study was performed in this feasibility analysis to determine the impacts of the PIE proposed flood control operation on water supply. The model determined reservoir storage and elevation on a daily basis for the period of record (59 years, 9 years longer than the USACE study). Flow data from the USGS gage—Skookumchuck near Centralia—were used as input prior to dam construction. Post-construction daily inflows were determined from reservoir records and from the USGU gage—Skookumchuck below Bloody Run. The flood control operation rule curve shown in Figure 4-5 was incorporated into the water supply analysis. Reservoir elevations for the six worst low-flow events are shown in Figure 4-6 for regulated conditions (with winter flood control) and in Figure 4-7 for non-regulated conditions (without winter flood control). As the two figures show, wintertime flood regulation would not lower the fall pool elevations during the worst fall droughts. Flow data for the 10 worst low-flow events are shown in Table 4-1. The lowest fall drawdown pool during the worst drough year of 1992 would reach elevation 428 feet (on 10/31/92) for regulated conditions, which is substantially above the reservoir minimum operation pool of elevation 400 feet. In comparison, the lowest pool would be elevation 420 feet, reached during three drought years (1929, 1952 and 1987) for non-regulated conditions. In summary, the updated water supply study, which is consistent with the USACE study, confirmed that minimum instream flow and water supply requirements could be met in all years with the PIE proposed flood control operation rule curve.

Also, USACE performed a preliminary hydropower analysis based on an HEC-5 continuous simulation model to determine the impacts of the USACE proposed flood control operation on electrical power generation at the Skookumchuck Dam 1-MW (megawatt) hydropower unit (USACE, 1992). Since on-line operation began in 1990, this unit has provided incidental power generation from dam releases made through the existing multilevel intake to supply water to the steam-plant and to meet instream flows for fish. USACE estimated that with the USACE proposed flood control operation rule curve, the average annual energy generated would decrease by 230 MWH (megawatt-hour), or 3% of the estimated average annual power generation for non-regulated conditions. A preliminary update of the USACE HEC-5 hydropower analysis was performed using the PIE proposed flood control operation rule curve. Results of the updated analysis indicates that due to the 15-foot increase in the summer pools with the PIE proposed flood control operation rule curve the average annual energy generation would increase by 120 MWH, or 2% of the estimated average annual power generation for non-regulated conditions.

Table 4-1:

Data for the Ten Worst Low-Flow Periods

Low Flow Period (Water Yrs)	Feb 1-Nov 30		Feb 1-Mar 31		Lowest 6 Months		Lowest Calc. Elev.*	
	Mean Flow (cfs)	Return Period (yrs)	Mean Flow (cfs)	Return Period (yrs)	Mean Flow (cfs)	Return Period (yrs)	Res. Elev. (ft)	Date
1929-1930	NA	NA	NA	NA	40	39	441	12/8/29
1930-1931	142	10	424	2	48	7	448	10/31/44
1941-1942	121	16	138	118	81	1.5	450	10/6/41
1944-1945	114	80	229	24	46	11	445	11/11/30
1952-1953	127	13	353	4	33	116	437	12/2/52
1965-1966	117	23	287	6	45	13	431	11/2/65
1976-1977	175	3	455	1.6	53	5	447	11/30/93
1987-1988	161	6	537	1.3	41	23	443	11/22/87
1992-1993	115	45	256	8	43	17	428	10/31/92
1993-1994	146	9	197	39	68	2	449	12/21/76

* Lowest calculated reservoir elevation with regular outflow (140 cfs 10 Sept - 31 Oct, 95 cfs 1 Nov - 9 Sept)

Flood Control Outlet Works

The proposed flood control outlet works would be located within the existing spillway and would consist of an approach channel and two gated sluiceways. The flood control outlet would be able to discharge approximately 3,000 cfs at the minimum flood control pool elevation of 455 feet. This would allow the flood control storage to be evacuated within a maximum of 3 to 5 days following a major flood that fills the reservoir to elevation 492 feet, providing capacity for the next flood event that could potentially occur right after evacuation.

A trapezoidal-shaped channel, approximately 250 feet long, would be excavated within the existing spillway approach channel. The existing spillway approach channel is excavated in rock to an invert elevation of 464 feet. The new sluiceway approach channel would have a bottom width of about 40 feet, an invert elevation of approximately 442 feet, and 1 horizontal (H) on 4 vertical (V) sloping sides. Approximately 10,500 cubic yards of rock would need to be excavated to construct the channel.

A section of the existing ogee spillway would be removed and a new spillway section containing two gated sluices would be constructed. The two sluice gates would each be approximately 15 feet wide and 10 feet high. Due to the large size of the gates, three gate arrangements were also considered. The final layout of the gates would have to be examined more closely in the next stage of design.

An emergency bulkhead would be supplied to allow for dewatering of the gates. Also, the bulkhead will be provided with a flared opening allowing fish to pass during extreme low-flow refill and fish outmigration periods in March, April and May when the reservoir level drops below elevation 464 feet, the bottom of the existing fishway sluice. Modeling of the reservoir operation shows that an event of this magnitude would occur only once in over 100 years. During such a severe drought, the bulkhead gate would be lowered into place. Fish would then pass through the bulkhead gate opening and plunge into a pool of water in the outlet conduit. For normal sluice gate dewatering and maintenance, the bulkhead gate opening would be closed with a cover plate.

Numerous other outlet works arrangements were considered, including all the arrangements considered by USACE. Several options were looked at for locating the outlets works on the right abutment. These schemes involved a freestanding tower intake and open channel tunnel through the right abutment. In all cases, the options proved to be very costly. In an effort to minimize costs, USACE developed a couple of other outlet works arrangements on the left abutment: Modified Spillway With Gate in Slot, and Short Spillway Tunnel. Both of these options were examined closely for this study. The first of these options involved cutting a 37-foot deep by 24-foot high slot in the existing spillway, and providing a gate in the slot. The second option would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. Flow would discharge through the tunnel into the existing spillway chute. Even with modifications from USCOE's arrangements in order to reduce cost, both of these options were estimated to cost significantly more than the currently favored arrangement, and both also had a number of concerns regarding hydraulics and operation.

Spillway Crest Weir and Chute

The discharge capacity of the existing uncontrolled spillway is 28,000 cfs at the maximum design pool elevation. But in a PMF discharge event of 28,000 cfs, the existing spillway crest will be submerged by water backing up from the spillway chute entrance. Modifications to the spillway would enable the use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and provide the PMF discharge capability. The modifications include adding a crest weir, modifying the ogee crest, and modifying a portion of the spillway chute.

A 15-foot high by 130-foot wide inflatable rubber weir would be added to the existing spillway crest. Inflatable rubber weirs have been used very successfully in North America, Europe, and Asia. The weir consists of a heavy-duty, reinforced rubber body that is anchored to a concrete foundation and inflated with air. The height of the weir can be varied by adjustments of the pressure within the tube. If necessary, the weir can be quickly deflated to allow for unrestricted flow of water over the spillway. Deflation of the weir is carried out automatically so that the weir is inherently safe under all conditions. Steel bascule and radial gate arrangements were also considered. In both cases, the estimated construction costs were significantly higher than for the rubber weir. There were also serious concerns regarding operational safety and reliability of the steel gates during flood events.

The existing spillway chute is located in a rock excavation on the left abutment. The chute bottom converges from a width of 40 feet to 25 feet and has 1H on 4V side slopes. The walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. During the PMF discharge, the water surface in the chute would overtop the concrete lined portion of the walls, but would still be contained within the excavated rock channel. This rock material has been identified as being highly fractured and susceptible to freeze-thaw damage. In order to protect the rock portion of the chute, the rock slopes would be lined with shotcrete up to the PMF water surface profile. The invert of the plunge pool below the spillway ogee crest would also be excavated out and lowered to make room for the new spillway sluices.

Mellen St. Bridge Vicinity Floodway Modifications

Floodway modifications along the Chehalis River in the Mellen St. Bridge vicinity, from approximately one mile downstream to one mile upstream of its confluence with the Skookumchuck River (RM 65.90 to RM 68.25), is the second component of the Floodplain Modification Alternative. The design of this component would involve terracing the floodway in areas where the flow is currently constricted in order to increase the high-flow hydraulic capacity of the Chehalis River during flood events. Floodway excavation was also evaluated between the Galvin Road Bridge (RM 64.08) and the Newaukum River mouth (RM 75.15). Between these two limits, numerous variations of excavated width and excavation location were modeled. Preliminary cost estimates were then developed to help determine which arrangements appeared to be the most cost-effective.

Excavation Reach

Among all variations modeled with the UNET model, floodway excavation between RM 65.90 and RM 68.25 appears to be the most efficient and cost-effective design. The recommended scheme would involve excavating approximately 3.2 million cubic yards (cy) of material between the hump location (RM 65.90) and three quarters mile upstream of the Mellen St. Bridge (RM 68.25). Based on the recent site investigations performed by PIE's geotechnical subconsultant, the excavation area contains two basic material types (HCI, 1998). Upstream of Centralia, soils are predominantly fine-grained sands, silts, and clays. Downstream of Centralia, substantial quantities of coarse sand and gravel mixtures were encountered. Excavated materials would be used for floodplain fill required for the SR-6 vicinity modification works described later in this report. UNET modeling of this scheme resulted in 4.44 feet of flood stage reduction at the mouth of Salzer Creek (RM 69.16) and 4.20 feet at the Mellen St. Bridge gage (RM 67.44) during the February 1996 event. The floodway excavation would also provide an opportunity to create off-channel rearing habitat to benefit anadromous fish, and opportunities for other habitat improvements. An overview plan of the Mellen St. Bridge area floodway excavation together with the SR-6 vicinity floodplain modifications is shown in Figure 4-8.

Excavation Elevation and Width

The floodway is designed to be excavated to a minimum elevation of 150 feet, which is above the normal flow stage so that construction activities would be above the water level. The estimated flow corresponding to this excavation elevation is 750 cfs at the Grand Mound gage. The floodway would have an average excavation width of about 600 feet. In the Mellen St. Bridge area, there is very limited room for an excavated bench because of the close proximity of Interstate 5. In this area, the excavated width would be limited to 300-400 feet. Maximum side slopes for permanent cuts were assumed to be 3H:1V for the finer grained soils, and 2H:1V for the more competent sands and gravels. For areas where scour may be of concern, shallower slopes and vegetative slope protection, or other methods of slope protection could be necessary. A schematic section view of the floodway excavation, not including the vegetation planting and habitat improvements plan that is expected to be required, is shown in Figure 4-9.

Mellen St. Bridge Modifications

The Mellen St. Bridge section of the Chehalis River is one of the most restrictive for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. Currently, it is envisioned that the right-bank (east-bank) would be excavated. In conjunction with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway. A schematic sectional view of the bridge is shown in Figure 4-10.

The existing City of Centralia wastewater treatment plant is located immediately downstream of the Mellen St. Bridge. Studies are currently underway to investigate the possibility of moving the treatment plant to a downstream location. The current site has very little room for expansion to meet the future needs of the area. The treatment plant would have to be relocated before this reach of the floodway could be modified. An option would be to excavate the west bank at the bridge, which would cost more than the east bank excavation.

SR-6 Vicinity Floodplain Modifications

The City of Chehalis experiences flooding between the 13th St. Interchange and the Main St. (SR-6) Interchange, along I-5. Two railroads pass under I-5 between these two interchanges, creating openings in the I-5 embankment. During major flooding on the Newaukum River, floodwaters from the Newaukum River spill over through Stan Hedwall Park and into nearby Dillenbaugh Creek and flow through the railroad openings to the east-side of I-5. The Mellen St. Bridge vicinity floodway excavation, presented above in Section 4.3.1 as the second part of the Floodplain Modification Alternative, would not substantially reduce this flooding.

Floodway excavation on the Chehalis River from shortly downstream of the SR-6 Bridge (RM 74.55) up to the mouth of the Newaukum River (Chehalis RM 75.15) was evaluated for the Floodway Modification Alternative as described in Section 4.2. The SR-6 Bridge embankment constricts flood flows on the Chehalis River in much the same way as the Mellen St. Bridge downstream. This flow constriction is partially responsible for backing up Newaukum River and Dillenbaugh Creek flood flows. Floodway excavation of approximately 800,000 cubic yards of material in this reach of the Chehalis River would result in approximately 1.5 feet of peak flood stage reduction on the lower 1.5-mile reach of the Newaukum River and Dillenbaugh Creek east of I-5, for a flood event such as the February 1996 event. Floodway excavation in this area would need to be substantially extended and increased downstream if further flood stage reduction is to be achieved.

In order to perform this floodway excavation, the existing SR-6 Bridge right bank approach would have to be removed and reconstructed. The existing bridge approach is elevated on a timber pile trestle system with a concrete deck for a total distance of about 745 feet. The necessary excavation would be approximately 350 feet wide and 14 feet deep. Since the timber pile support system is about 60 years old, it was assumed that the entire length of elevated bridge approach would be removed and replaced. This large scale structural work would add significantly to the cost of the excavation in this reach. Also of concern would be potential impacts to the large wetland area on the right bank upstream of the SR-6 Bridge.

More cost-effective and environmentally preferred than increasing the flood hydraulic capacity through floodway excavation is to reduce peak flood flows on the mainstem Chehalis River in the SR-6 Bridge area by modifying the floodplain to provide flood flow bypass. Several variations of the SR-6 vicinity floodplain modifications, including scheme, location and design dimensions, were evaluated with the UNET model. A combination of the following described modifications would provide substantial flood stage reductions in the City of Chehalis floodplain and comprise the third component of the Floodplain Modification Alternative. Figure 4-8 presents an overview plan of the floodplain modifications. Typical sections showing the floodplain modifications are presented in Figure 4-11.

SR-6 Flood Bypass Works

The 1.5-mile reach of the SR-6 roadway between the Scheuber Rd. intersection and the bridge crossing at RM 74.60 acts as a weir for limited overbank flows from the Chehalis River between RM 75.8 and RM 77.4. However, this reach of roadway is frequently overtopped by these flood flows. This roadway overtopping occurs when the flood exceeds the magnitude of approximately once in 5 to 7 years of recurrence interval. To prevent SR-6 from overtopping during floods up to the 100-year event and to provide a flood flow bypass to the floodplain east of Scheuber Rd., a section of the SR-6 roadway adjacent to an existing oxbow lake at RM 77 would be modified.

The proposed modifications would involve excavating approximately 250,000 cy of the existing ground level and elevating a 1,500-foot stretch of the SR-6 roadway to provide a 5-foot vertical clearance for bypassing overbank flows to the floodplain. Additionally, approximately 60,000 cy (up to a 4-foot excavation depth) of a 500-foot by 1000-foot overbank area west of the oxbow lake between the Chehalis River and the roadway would be excavated to provide more frequent overbank flow through this area. Flood bypass through the SR-6 opening to the floodplain would also occur more often as a result of this additional excavation. The floodplain along Scheuber Rd. would be bypassing and storing flood flows when the river flows on the Chehalis River at RM 77 exceed the annual flood magnitude.

Chehalis Floodplain Fill

A north-south oriented 1.5-mile long curving strip of the Chehalis floodplain north of SR-6, averaging 1000 feet wide, would be filled by the excavated material from the Mellen St. Bridge vicinity floodway modifications. This floodplain fill is intended to form a drainage divide for creating two separate hydraulic regimes between the floodplain bypass/storage area and a 3-mile reach of the mainstem Chehalis River downstream of the SR-6 Bridge (RM74.6 to RM 71.6).

Flood flows bypassing through the modified SR-6 overflow site to the floodplain would not return to the river until the flows reach the north end of the floodplain bypass/storage area. Returning flows discharge first through the existing Scheuber Drainage Ditch and then over the low lying overbank area between RM 71.6 and RM 72.4 of the Chehalis River.

Total fill quantity was estimated to be approximately 3,540,000 cy. The top of the fill would be at a maximum elevation of 185 feet, above the 100-year flood stage in the floodplain bypass area (estimated to be approximately at elevation 180 feet). The fill alignment generally follows the existing high ground dividing the low-lying floodplain to the west and the river channel (between RM 72.4 and RM 74.6) to the east. The fill would be constructed with mild finished side slopes (approximately 10 H to 1 V maximum slope). The floodplain bypass and storage area could also provide opportunities for environmental and habitat improvements as desired.

Several options were considered for hydraulic outlet to the floodplain storage area created with the fill. These include: a concrete outlet structure, an uncontrolled spillway section, a spillway section with an inflatable rubber weir, and an open outlet. All of the options were analyzed from the standpoint of cost and hydraulics. The open outlet was determined to be by far the most cost effective and environmentally preferred solution.

The proposed fill would create an additional flood storage area of approximately 1,000-acres in size, and could provide flood storage of up to 10,000 acre-feet. The increase in frequency of flooding bypass and storage could provide opportunities for wetland and habitat improvements on the floodplain. For these reasons, this plot of floodplain land was assumed to be purchased as part of the flood control project. The land is currently in agricultural use, with the predominant crop being hay. It is not known what the nature or extent of habitat improvements will be required as part of mitigation for the flood reduction project. However, it is possible that much of the floodplain land could continue to be used as pasture land.

RM-72 Left Bank Floodway Excavation

The Airport Rd. dike and the golf course clubhouse areas of the Chehalis River (located at RM 72.3) also have constricted flood flows. Floodway modification at this area would involve excavation of the left bank above the normal flow elevation of 150 feet, of a quantity of approximately 110,000 cy of material between RM 71.9 and 72.3. The excavated material would be used as part of the above-described floodplain fill to create the drainage divide just south of this floodway excavation site. Numerous variations of excavation reach, width, and depth were modeled in order to determine the most cost effective arrangement. Planting and habitat improvement features, as required, would be incorporated into the design and construction of this floodway excavation in a way similar to the Mellen St. Bridge floodway modifications previously discussed.

Newaukum Floodplain Fill

The drainage divide between the Newaukum River and Dillenbaugh Creek would be raised (up to 7 feet high) at the location between the City of Chehalis Stan Hedwall Park and WSDOT's planned wetland mitigation site just north of the park. Raising this divide would require a total fill of approximately 35,000 cy of material covering an area approximately 2,000 feet long by 180 feet wide. The top of the fill would be at elevation 184 feet, one foot above the reduced 100-year level flood upon implementation of the Floodplain Modification Alternative. The fill would tie to the existing high ground on both ends; to the east, the Rice Rd. off-ramp at the 13th St. Interchange and to the west, the Burlington Northern Railroad embankment. The proposed fill would prevent overbank flows from entering through the railroad underpass of I-5 onto the City's floodplain east of I-5. This overbank flow could occur either from the Newaukum River overtopping its banks and flooding the park or from upper Dillenbaugh Creek overtopping the low-lying section of Rice Rd. at the park.

The fill would be constructed within the WSDOT wetland mitigation site and would not impede any existing wetlands in the area, nor the Dillenbaugh Creek streambed or normal flow conditions. Fill material would be from the wetland site excavation. Coordination with WSDOT for design and construction of the wetland and the fill would be required.

4.3.2. Flood Stage and Peak Flow Reductions

Providing 20,000 acre-feet of flood control storage at Skookumchuck Dam would substantially reduce flood stages and peak flows on the Skookumchuck River. Modifications of the Mellen St. Bridge vicinity floodway and the SR-6 vicinity floodplain would achieve substantial flood stage reductions on the Chehalis River between Skookumchuck River and Newaukum River, including its tributary backwater areas. The amounts of flood stage and peak flow reductions at various locations along the Skookumchuck and the Chehalis rivers were estimated by comparing the differences between pre-project and post-project conditions. The UNET model, updated with the addition of recently surveyed cross-section data and calibrated for the February 1996 flood under the existing baseline (or pre-project) conditions as described in Section 2.3, was modified to incorporate the Skookumchuck Dam flood control operation and the Chehalis River floodway and floodplain modifications.

The Skookumchuck Dam modifications anticipate operation of the dam for flood control during flood events. The Skookumchuck Dam flood control operation would follow a release schedule which includes releases being maintained at a minimum outlet discharge of 95 cfs prior to passing of the flood peak, then being gradually increased at a rate of 500 cfs per hour after the flood peak is over, and finally being maintained at a maximum discharge of 3,000 cfs for up to three to five days to completely evacuate the stored flood water, making the 20,000 acre-foot flood control storage available for the next storm event.

The floodway modifications in the Mellen St. Bridge vicinity would achieve a 100-year flood stage reduction of over 4 feet in the area upstream of the Mellen St. Bridge to the lower Salzer Creek floodplain east of I-5. The existing I-5 low point (elevation 169) along the Centralia-Chehalis Airport stretch is five feet below the low point (elevation 174) of both the Tacoma Eastern Railroad embankment to the east and the Airport Road dike to the west. A four-foot flood stage reduction resulting from the floodway excavation would keep I-5 from being flooded by a 100-year flood event.

The floodplain modifications in the SR-6 vicinity would achieve a 100-year flood stage reduction of over 3 feet in the City of Chehalis floodplain on the lower reach of Dillenbaugh Creek, between the 13th St. Interchange and the Main St. (SR-6) Interchange on the east side of I-5. This flood stage reduction would keep I-5 between these two interchanges from being flooded by a 100-year flood event.

Runs of the modified UNET model for post-project conditions were executed, incorporating the Skookumchuck Dam flood control operation and the Chehalis River floodway and floodplain modifications. Run results for post-project conditions in comparison with modeling results for the pre-project conditions are shown in Table 4-2 through Table 4-4, and Figure 4-12 through Figure 4-20. Brief summaries of the results shown in the tables and figures are provided immediately below.

Figure 4-12 and Figure 4-13 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the Skookumchuck River for the February 1996 flood. A summary of flood stage reductions at various locations on the Skookumchuck River is presented in Table 4-2. Comparison of the flood stage and peak flow profiles indicates that overbank flows flooding the City of Centralia streets and buildings under pre-project conditions would be almost completely eliminated upon completion of the project.

Figure 4-14 and Figure 4-15 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the Chehalis River for the February 1996 flood. A summary of flood stage reduction at various locations along the Chehalis River between the Newaukum River confluence and the Mellen St. Bridge, including the lower Dillenbaugh and Salzer Creek areas, is presented in Table 4-3. Comparison of the profiles for the February 1996 flood indicates that overtopping of the Airport Road dike and the Tacoma Eastern Railroad embankment, causing I-5 to be flooded, would be eliminated as a result of implementation of the project. Also, both overtopping of SR-6 between the Scheuber Rd. intersection and the SR-6 Bridge at RM 74.6, and overtopping of the SR-603 Bridge south embankment at RM 77.6, would be eliminated.

Figure 4-16 and Figure 4-17 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the lower Newaukum River for the February 1996 flood. A summary of flood stage reduction at various locations along the Newaukum River between Devereese Rd. Bridge and Stan Hedwall Park is presented in Table 4-4. Comparison of the profiles for the February 1996 flood indicates that overtopping of I-5 north of the 13th St. Interchange would be eliminated as a result of implementation of the project.

Flood stage reductions based on the model runs for the other four selected smaller flood events are summarized in Table 4-5. These events are the December 1994, November and January 1990, and January 1972 floods. Together with the February 1996 flood, these events represent the wide spread of flood magnitudes that have historically occurred in the area. As indicated in this table, substantial reductions of flood stages in the Centralia - Chehalis floodplain could be achieved during all major floods upon implementation of the project.

Table 4-6 shows a comparison of pre-project flood frequency and post-project equivalent flood frequency based on the modeled flood stages and the associated flood frequency numbers revised by USACE in late 1997 (USACE, 1997b) for the existing basin conditions. This comparison is shown at the Mellen St., Pearl St., and Bucoda gage locations, as well as the lower tributary reaches within the Chehalis River backwater areas, for the selected five flood events. For example, the February 1996 flood stage at the Mellen St. location corresponds to the 100-year flood level under existing conditions. Upon completion of the project, the February 1996 flood stage at Mellen St. would be reduced to the 10-year flood level.

Figure 4-18 through Figure 4-20 show comparisons of pre-project and post-project flow hydrographs on the Chehalis River at the Grand Mound Gage (RM 60.0), Moon Road (RM 53.0) and Anderson Road (RM51.5) for the February 1996 flood event. These locations are all downstream of the project area. The flow comparison at these locations indicate that the post-project peak flow and time duration of flooding would be slightly reduced from the pre-project conditions. The peak flow reduction, though small (up to 2,870 cfs), would mean that the flood stage downstream of the project area would also be slightly reduced, though immeasurably (up to 0.2 feet). Based on the model runs for the December 1994 flood, a 5-year event at the Grand Mound gage, the peak flow and flooding time would all be slightly reduced in these downstream locations as a result of the project implementation.

Figure 4-21 shows a comparison of pre- and post-project approximate inundation areas for the 100-year flood (approximating the February 1996 flood). The post-project flood stage reduction includes the effects of modifications to Skookumchuck Dam, floodway excavation in the Mellen St. Bridge area, and floodplain modifications in the SR-6 vicinity. As this figure indicates, a substantial reduction of floodplain inundation area could be achieved as a result of the implementation of the Floodplain Modification Alternative. This map is preliminary only and will be refined in the next phase of work.

Table 4-2:

Comparison of Pre-Project and Post-Project Flood Stages on the Skookumchuck River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
10.86 (Upstream of Tono Rd. Bridge)	246.75	242.86	3.89
6.17 (Bucoda Gage)	210.78	207.21	3.57
4.53 (Upstream of SR-507 Bridge)	202.58	200.04	2.54
2.3 (Pearl St. Gage)	187.28	185.84	1.44
0.61 (Upstream of Harrison St. Bridge)	175.98	172.60	3.38

Table 4-3:
Comparison of Pre-Project and Post-Project Flood Stages on the Chehalis River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
75.15 (Newaukum River confluence)	182.11	179.86	2.25
74.63 (Upstream of SR6 Bridge)	180.95	178.65	2.30
72.70 (S. end of airport/River St.)	178.76	177.32	1.44
69.16 (Salzer Cr. confluence)	176.35	171.91	4.44
67.51 (Upstream of Mellen St. Bridge)	174.82	170.30	4.52
67.44 (Mellen St. Gage)	174.27	170.07	4.20
Dillenbaugh Cr. at Chehalis Ave./Third St., N.E. of I-5	182.72	179.66	3.06
Salzer Cr. at BNRR Bridge, E. of I-5	176.56	172.00	4.56

Table 4-4:
Comparison of Pre-Project and Post-Project Flood Stages on the Newaukum River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
1.88 (Stan Hedwall Park)	183.77	183.24	0.53
1.64 (Downstream of BNRR Bridge)	182.66	180. 90	1.76
0.57 (Upstream of Rail to Trail Bridge)	182.52	180.41	2.11
0.11 (Upstream of Devereese Rd. Bridge)	182.37	180.13	2.24

Table 4-5:

Post-Project Flood Stage Reductions during Four Other Smaller Flood Events

a) Skookumchuck River

Location RM (river mile)	Nov-90 Stage Reduction (ft)	Jan-90 Stage Reduction (ft)	Jan-72 Stage Reduction (ft)	Dec-94 Stage Reduction (ft)
10.86 (Upstream of Tono Rd. Bridge)	3.17	3.19	3.21	2.47
6.17 (Bucoda Gage)	2.93	2.73	2.96	2.35
4.53 (Upstream of SR-507 Bridge)	2.24	1.91	2.47	2.45
2.3 (Pearl St. Gage)	2.08	1.14	1.76	2.58
0.61 (Upstream of Harrison St. Bridge)	3.56	2.70	3.63	3.22

b) Chehalis River

Location RM (river mile)	Nov-90 Stage Reduction (ft)	Jan-90 Stage Reduction (ft)	Jan-72 Stage Reduction (ft)	Dec-94 Stage Reduction (ft)
75.15 (Newaukum River confluence)	2.87	2.45	2.93	0.77
74.63 (Upstream of SR6 Bridge)	2.58	2.39	2.65	0.59
72.70 (S. end of airport/River St.)	1.17	1.36	1.17	0.28
69.16 (Salzer Cr. confluence)	3.84	4.08	3.71	2.35
67.51 (Upstream of Mellen St. Bridge)	4.13	4.17	3.95	3.50
67.44 (Mellen St. Gage)	3.94	3.88	3.74	3.40
Dillenbaugh Cr. at Chehalis Ave./Third St., N.E. of I-5	3.84	3.26	3.62	1.21
Salzer Cr. at BNRR Bridge, E. of I-5	3.77	4.02	3.67	2.28

c) Newaukum River

Location RM (river mile)	Nov-90 Stage Reduction (ft)	Jan-90 Stage Reduction (ft)	Jan-72 Stage Reduction (ft)	Dec-94 Stage Reduction (ft)
1.88 (Stan Hedwall Park)	0.40	0.77	0.94	0.39
1.64 (Downstream of BNRR Bridge)	1.74	1.86	2.23	0.65
0.57 (Upstream of Rail to Trail Bridge)	2.44	2.27	2.73	0.76
0.11 (Upstream of Devereese Rd.Bridge)	2.72	2.44	2.88	0.78

Table 4-6:
Comparison of Pre-Project and Post-Project Flood Stage Recurrence Intervals (based on flood stages under existing flood conditions)

Stream & Location	Flood Event	Pre-Project Recurrence Interval (year)	Post-Project Recurrence Interval (year)
Chehalis River @ Mellen St.	Feb-96	100	10
	Jan-90	50	10
	Nov-90	20	6
	Jan-72	20	6
	Dec-94	7	2
Skookumchuck River @ Pearl St.	Feb-96	70	10
	Jan-90	60	10
	Nov-90	30	4
	Jan-72	25	3
	Dec-94	2	<2
Skookumchuck River @ Bucoda	Feb-96	180	5
	Jan-90	30	5
	Nov-90	25	4
	Jan-72	25	2
	Dec-94	2	<2
Lower Newaukum River, Dillenbaugh Creek and Salzer Creek (w/in Chehalis River backwater areas)	Feb-96	100	10
	Jan-90	50	10
	Nov-90	20	6
	Jan-72	20	6
	Dec-94	7	2

4.3.3. Cost Estimates

A preliminary cost estimate has been developed for the Floodplain Modification Alternative. All costs are presented in 1998 dollars and exclude interest during construction. The estimates include contractor's overhead and profit, sales tax, engineering and permitting, and a contingency appropriate to this phase of studies.

It should be noted that the estimated costs are preliminary only, and are contingent upon approval of the proposed design by resource agencies and other interested parties. The final project costs for the proposed design would also depend on final design details and price factors, and could vary from the estimates presented here.

Quantity estimates were made from work items and materials for the main components of the proposed design. Approximate unit prices were developed from previous cost estimates by USACE and WSDOT, bid prices from similar projects, and quotes from manufacturers and contractors.

The estimates are broken into three parts: Skookumchuck Dam modifications, floodway and floodplain modifications, and total overall project costs, including annual operation and maintenance (O&M) costs.

The estimated construction cost for the proposed modifications to Skookumchuck Dam is $9,534,314. A breakdown of this cost is shown in Table 4-7. The estimated construction cost for the Chehalis River floodway and floodplain modifications is $51,271,849. The cost breakdown is shown in Table 4-8. The major cost item for the floodway and floodplain modifications is the Mellen St. Bridge area floodway excavation between RM 65.90 and RM 68.25, and the related hauling and fill placement. Street legal haul vehicles were assumed to be used over existing roads Construction work was assumed to be limited to 8 hours a day, five days a week.

A summary of overall project costs and estimated annual O&M costs is included in Table 4-9. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area floodway and the SR-6 vicinity floodplain modifications, along with habitat improvements, would be $65,806,163, and would have annual O&M costs of approximately $300,000. The O&M costs consist of annual flood control operation of Skookumchuck Dam, maintenance for clearing debris and excess vegetative growth from the floodway excavation, and maintenance for habitat improvements. The level of mitigation, or the exact nature of habitat improvements required if this alternative is implemented, is not known at this time. As a result, the estimated costs for mitigation or habitat improvements and their associated annual maintence costs could change substantially. Mitigation costs could include additional land aquisition, as well as permitting, engineering, and construction costs.

Table 4-7:
Preliminary Cost Estimate
Skookumchuck Dam Modifications

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$400,000	$400,000
Diversion and Care of Water	1	LS	$25,000	$25,000
Cofferdam	1	LS	$50,000	$50,000
Approach Channel Excavation	10,500	CY	$50	$525,000
Approach Channel Rock Support	1,560	LF	$45	$70,200
Spillway Excavation	4,000	CY	$60	$240,000
Spillway Chute Concrete	750	CY	$600	$450,000
Concrete Demolition	750	CY	$150	$112,500
Spillway Concrete	3,450	CY	$450	$1,552,500
Grout Curtain	1	LS	$42,000	$42,000
Trashracks	2	EA	$100,000	$200,000
Slide Gates	2	EA	$175,000	$350,000
Bulkhead Gate	1	LS	$65,000	$65,000
Misc. Metals	1	LS	$50,000	$50,000
Rubber Weir	1	LS	$1,250,000	$1,250,000
Misc. Electrical	1	LS	$18,000	$18,000
Control House	1	LS	$40,000	$40,000
Monitoring & Communication System.	1	LS	$215,000	$215,000
Subtotal				**$5,655,200**
Contingency (@25%)				$1,413,800
Subtotal (w/contingency)				**$7,069,000**
Sales Tax (@7.9%)				$558,451
Direct Construction Cost				**$7,627,451**
Engineering and Permitting				$1,906,863
Total Cost (1998 Price Level)				**$9,534,314**

Table 4-8:
Preliminary Cost Estimate Floodway and Floodplain Modifications

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$1,300,000	$1,300,000
Erosion & Sediment Control	1	LS	$250,000	$250,000
Clearing and Grubbing	275	AC	$7,500	$1,725,000
Access Roads	1	LS	$400,000	$400,000
Removal of Existing Structures	1	LS	$500,000	$500,000
Excavation & Fill (65.9-68.3)	3,200,000	CY	$5	$16,000,000
Excavation & Fill (71.9-72.3)	110,000	CY	$3.50	$385,000
Replanting Disturbed Areas	230	AC	$5,000	$1,150,000
Mellen St. Bridge Modifications	1	LS	$3,000,000	$3,000,000
SR-6 Roadway Modifications	1	LS	$5,789,039	$5,789,039
Subtotal				**$30,499,039**
Contingency (@25%)				$7,624,760
Subtotal (w/contingency)				**$38,123,799**
Sales Tax (@7.9%)				$3,011,780
Direct Construction Cost				$41,135,579
Engineering and Permitting				$4,936,270
Land Acquisition				$5,200,000
Total Cost (1998 Price Level)				$51,271,849

Table 4-9:
Summary of Costs for Floodplain Modification Alternative

Item	Amount
Skookumchuck Dam Flood Control Storage	$9,534,314
Floodway & Floodplain Modifications	$51,271,849
Mitigation/Habitat Improvements	$5,000,000
Total Construction Cost	$65,806,163
Annual O&M Costs	$300,000

4.3.4. Economic Evaluation

USACE recently completed a pre-reconnaissance evaluation of flood damage reduction estimates for the Floodway Modification Alternative presented in the Pre-Feasibility Report (PIE, 1998a) for Lewis County. Based on 1998 prices and conditions, the average annual flood damage reduction benefits were estimated to be $1,137,000 and $415,000 in the Skookumchuck area and the Chehalis area, respectively (USACE. 1998). Average annual benefits resulting from prevention of flood damage totals

$1,552,000. This total does not include benefits resulting from prevention of flood damage in the Newaukum River and Dillenbaugh Creek floodplain within the City of Chehalis.

In addition to the benefits resulting from the prevention of flood damages, there is the added benefit that I-5 would not have to be elevated as part of WSDOT's I-5 widening project. According to WSDOT (1998), the incremental cost of raising the elevation of I-5 to two feet above the 100-year flood would be $107,953,555 including the cost of preliminary engineering. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area floodway excavation, and the SR-6 Bridge vicinity floodplain modifications is $65,806,163 with estimated annual O&M costs of approximately $300,000.

The project costs and all resulting benefits were evaluated at a 7-1/8 percent discount rate (the federal discount rate for water resource projects) over a 50-year economic analysis period. The total average annual benefits are estimated at $9,498,000 and the total average annual costs are estimated at $4,724,00 resulting in a benefit-to-cost ratio of 2.01 for this project alternative. Table 4-10 summarizes the potential project benefits and costs. The benefit-to-cost ratio would be greater for this alternative if benefits resulting from prevention of flood damage in Newaukum River and Dillenbaugh Creek floodplain within the City of Chehalis are included in the economical evaluation.

Table 4-10:
Benefit-Cost Evaluation – Floodplain Modification Alternative

Item	Average Annual Figures
Annual Benefits	
Skookumchuck Area	$1,137,000
I-5 Cost Savings	$7,946,000
Chehalis Area	$415,000
Total Annual Benefits	$9,498,000
Annual Project Costs	
Skookumchuck Dam Modifications	$884,000
Floodway and Floodplain Modifications	$3,840,000
Total Annual Costs	$4,724,000
Benefit-To-Cost Ratio	2.01

4.3.5. Environmental and Permitting Issues

Skookumchuck Dam Modifications

Investigations conducted for the USACE Skookumchuck Dam Modification Project identified several potential environmental impacts relating to wildlife habitat and fishery resources, water supply, water quality, and dam safety. The following discussion is based upon those investigations and analyses; additional studies would be required during the next project phase to further define potential impacts that could occur if this alternative is implemented.

The existing reservoir drawdown zone provides approximately 65 acres of vegetated habitat that is important to wildlife (USFWS, 1989). This zone is used by waterfowl, deer, elk, and other wildlife. Changes in reservoir levels associated with a new flood control operation rule curve could induce changes in vegetation and loss of wildlife food and cover. Water dependent mammals like beavers and muskrats could be negatively affected by fluctuations in wintertime reservoir levels.

Downstream of the dam, wetlands and riparian habitat along the Skookumchuck River could be affected by a reduction in overbank flow. The degree to which these wetlands are dependent on flood flows for recharge is not known at this time; to evaluate specific wetland areas that could be indirectly affected by flow modifications and to identify measures to avoid and minimize impacts to wetlands, surveys would be needed in the next study phase. Studies would also be required to assess the value of potentially affected wildlife habitats, both within and downstream of the reservoir area.

Operational changes may affect resident fish inhabiting the reservoir, and under some conditions could impair the outmigration of juvenile steelhead (USFWS 1989). Such changes, which could occur if the reservoir pool failed to refill prior to the beginning of March, could result in insufficient water to pass outmigrating fish over the spillway. Operational changes could also potentially affect the supply of water to the WDFW fish rearing facility downstream of the dam. An analysis of the reservoir flood control operation rule curve would be needed to assess the likelihood of such events.

The existing maximum velocity on the Chehalis River is up to 12 fps downstream of the Mellen St. Bridge. The Floodplain Modification Alternative would bring the maximum velocity in this area down to approximately 3 to 4 fps. Upstream of the Mellen St. Bridge, the existing maximum velocity would be increased from about 2 to 4 fps. The estimated changes in velocity would reduce both sedimentation above the bridge and erosion below the bridge.

With flood control storage at Skookumchuck Dam, peak velocities would decrease along the Skookumchuck River. The Floodplain Modification Alternative would decrease the maximum velocities around Bucoda from about 2.5 to 8 fps to between 2 and 6.5 fps. Although the peak velocity would decrease, the time-period during which the velocity is between 5 and 6 fps would increase. Whether or not effects of the increased duration of this range of velocity would result in scouring problems is currently unknown. Further analysis would be needed in the next phase of studies to determine the erodibility of the channel materials in various locations.

Other potential impacts to fish could occur as a result of changes in water temperatures, increases in reservoir turbidity, and the transport of sediments downstream. Increases in turbidity levels could result from erosion of exposed reservoir slopes during pool drawdown periods. Undefined at this time is the effect of flow changes on fishery resources. Beneficial effects could include a reduction in scouring of spawning beds; adverse impacts could result from rapidly changing river levels, especially during spawning and incubation periods. Due to the storage volume to be provided by the Skookumchuck Dam modifications, it is likely that seasonal streamflows could be augmented to enhance conditions for anadromous fish. An analysis of fish habitat under various flow regimes would be conducted to evaluate these opportunities.

Measures considered by USACE to mitigate for wildlife impacts associated with its Skookumchuck Dam modification proposal included the transfer of 50 acres of forested land for incorporation into the Skookumchuck Habitat Management Area and construction of wood duck nesting boxes. The level of mitigation required if the Floodplain Modification Alternative is implemented is not known at this time. Mitigation costs could be substantial and could include land acquisition as well as permitting, engineering, and construction costs.

Mellen St. Bridge Vicinity Floodway Excavation

Floodway excavation would involve disturbance of wetlands and riparian habitats, and potentially could increase erosion and affect water quality. Although impacts to fish habitats would occur, floodway excavation would involve significantly less direct disturbance of in-stream habitats than channel excavation, and offers the potential to provide a net habitat benefit. Floodway excavation would also avoid the high level of impact to the built environment that would be associated with secondary channel construction.

Wetlands are interspersed with upland habitats along the entire proposed excavation length of the river. The area and magnitude of the potential impact to wetlands would depend on the ultimate floodway width and the reach or reaches selected for excavation. Wetlands are particularly extensive along RM 67, at the confluence with the Skookumchuck River. Excavation in this reach would result in wetland disturbance. Wetlands lying within the excavated floodway would be directly disturbed. Adjacent wetlands could also be indirectly affected by dewatering, either through interception of perched water tables or through reduction or elimination of periodic recharge by overbank flooding. The approximate locations of known wetlands have been mapped under the National Wetlands Inventory program. However, in the next study phase, site specific surveys would be needed to evaluate specific wetland areas that might be directly or indirectly affected and to identify measures to avoid and minimize impacts to wetlands.

Removal of wetland and riparian vegetation across the floodway width would significantly reduce the wildlife habitat value of these areas. The removal of natural vegetative cover from the floodway could fragment remaining adjacent habitats by removing their connection to the river. It is possible that these effects could be partially offset by reestablishing vegetation on the excavated floodway and along the shoreline. However, because of the need to maintain channel capacity, a cover of woody overstory vegetation cannot be reestablished on the benches. A buffer of woody overstory vegetation could potentially be reestablished along some reaches of the shoreline without significantly affecting floodway hydraulics.

Floodway excavation would increase the potential for erosion at least temporarily, until vegetation could be reestablished along the streambank. Implementation of Best Management Practices during and following construction would be particularly important to avoid impacts to water quality at the project site and downstream.

Some of the excavated material could require special handling as a result of hazardous waste contamination. Because the Sewage Treatment Plant Landfill was used as an unregulated throw and burn site until the early 1970s, hazardous wastes may be present in soil and subsurface materials in this area (FHA and WSDOT, 1997). Investigations may be required during the next study phase to evaluate hazardous waste contamination in the project area.

A National Register-eligible archaeological site exists near the Mellen St. Bridge (FHA and WSDOT, 1997). Other recorded sites, including some that may be aboriginal townsites, occur in the project area. These and currently unrecorded cultural resources could be affected by project construction. An assessment would be needed in the next study phase to identify cultural resources that could be affected by project construction.

Excavation of the floodway would affect farmlands, but would have relatively little impact on existing structures and facilities. Facilities, which would be affected, include the Centralia Wastewater Treatment Plant and the Mellen St. Bridge. The existing wastewater treatment plant site is susceptible to flooding and provides insufficient space for plant expansion beyond the year 2025. Studies are underway to evaluate alternative sites for a new or modified wastewater treatment plant to meet the future wastewater service needs of the City of Centralia (CH2M-Hill, 1998).

Mitigation for unavoidable impacts to wetlands would be required under the provisions of the Clean Water Act and local critical areas ordinances; mitigation would also be required for impacts to fish and wildlife habitats. Mitigation costs could be substantial. Because the excavated floodway could be designed to bypass incised meanders, this alternative excavation provides opportunities to create valuable backwater refuge for fish at high flows. This type of mitigation action would be consistent with current efforts by tribal interests to create additional off-channel rearing habitat to benefit anadromous fish, and should be investigated further if the floodway excavation component is implemented.

been under the FERC jurisdiction since FERC issued a license exemption to the dam owners when a small hydropower facility was added in early 1990. The proposed modifications of the dam will require the submittal of a license exemption amendment application to FERC. FERC must approve the application before construction of any modifications is started.

Phase III - Skookumchuck Dam Modifications

In Spring 2000, and after the resolution of critical issues is achieved, project development would proceed with preliminary engineering design, permitting, and final design for the Phase III-Skookumchuck Dam modifications. Bids for construction could take place in Summer 2001 and construction could start in Fall 2001, taking advantage of low reservoir levels in the fall and winter months for all needed modification work. It is expected that the dam modifications construction can be completed by Summer 2002.

Phase IV - Chehalis River Floodway and Floodplain Modifications

The Phase IV work includes land acquisition, preliminary design, permitting, final design and construction for the Mellen St. Bridge area floodway modifications and the SR-6 area floodplain modifications, including construction of habitat features. This phase could proceed concurrently with the Phase III work described above. However, the Phase IV construction would most likely require 2 to 3 years. It is expected that the completion date for the project would be in early 2004.

4.4. Other Combinations

The Floodway Modification Alternative and the Floodplain Modification Alternative are both examples of how the options for reducing flood impacts described above in Section 3 can become components of an alternative solution. With reevaluation, reconfiguration and analysis for specific sitings, each option has the potential to contribute to the solution of the flooding problem. Many of the options can also be designed to incorporate environmental enhancement and restoration features. The preferred alternative will ultimately optimize the design and features that will provide the desired degree of flood reduction and environmental enhancement for the level of funding available.

Figure 4-1:
Skookumchuck Dam Spillway Modifications-Plan View

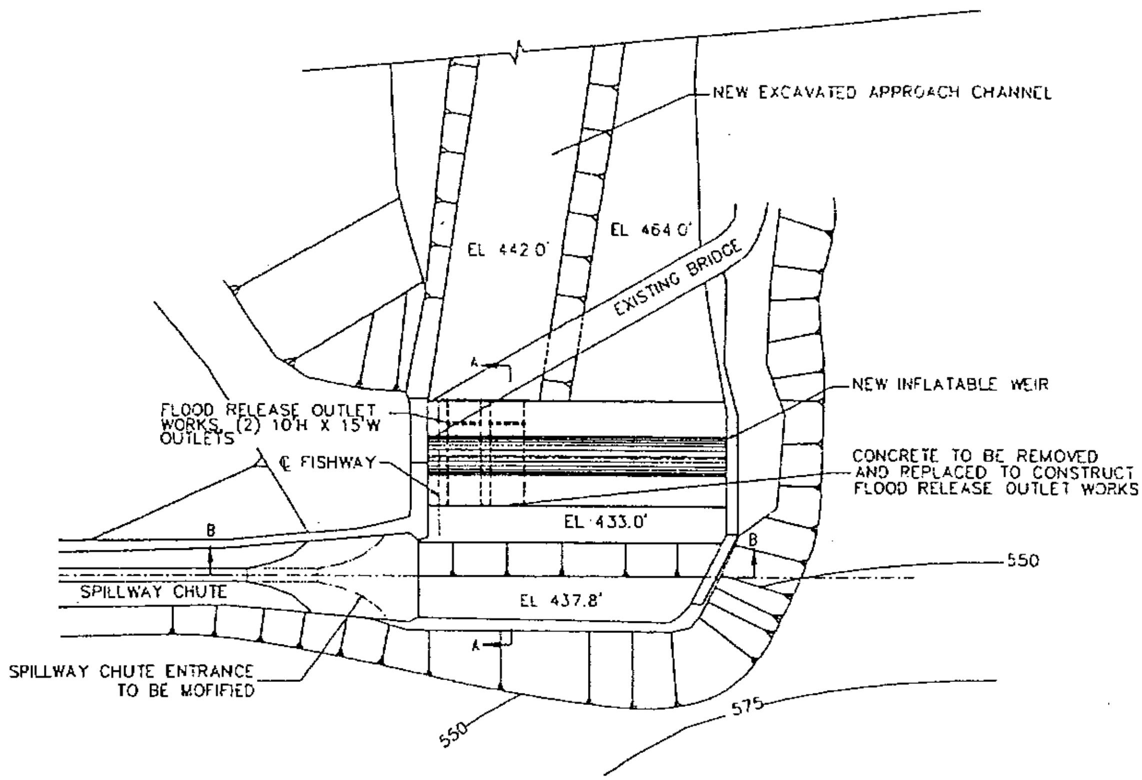


Figure 4-2:
Skookumchuck Dam Spillway Modifications-Downstream Elevation

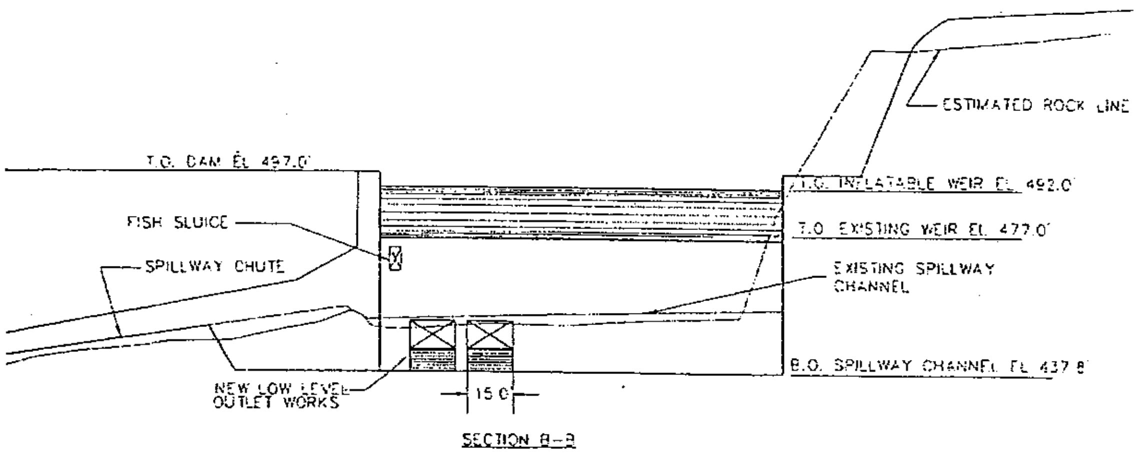


Figure 4-3:
Skookumchuck Dam Spillway Modifications-Sections

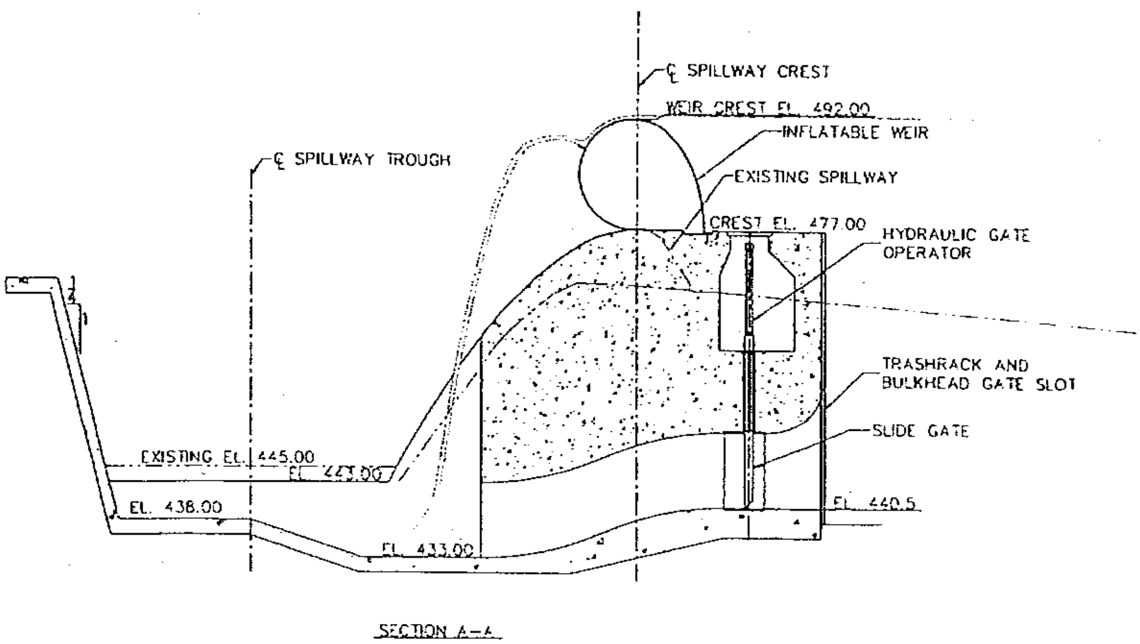
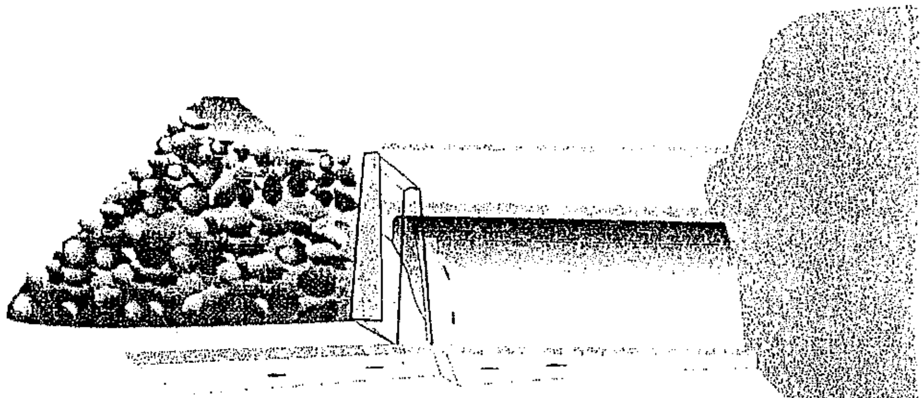
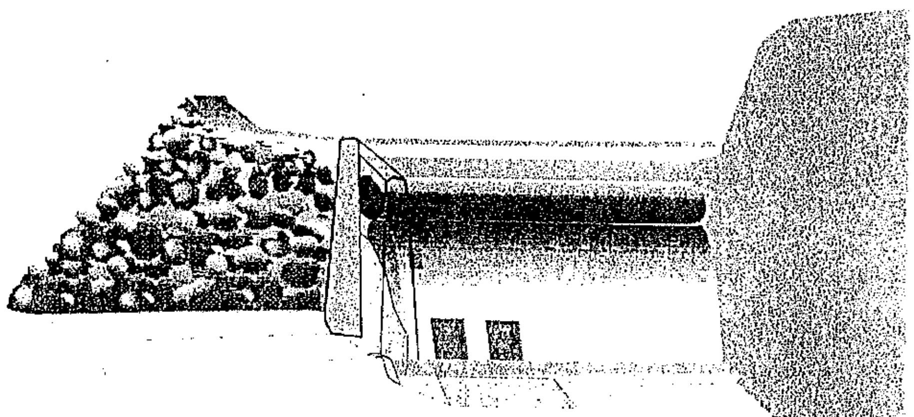


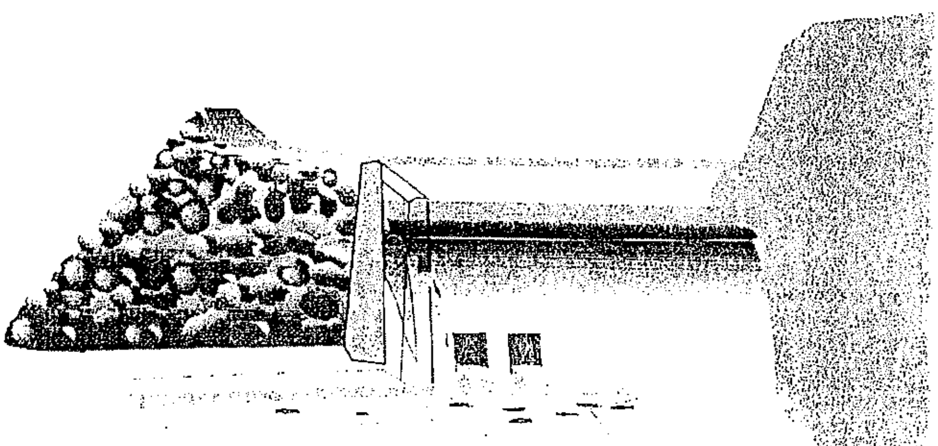
Figure 4-4:
Skookumchuck Dam Spillway Modifications, Section View, Artist Rendering



Existing Skookumchuck Dam Spillway



Modified Skookumchuck Dam Spillway with Rubber Weir Inflated



Modified Skookumchuck Dam Spillway with Rubber Weir Deflated

Figure 4-5:
Skookumchuck Dam Flood Control Rule Curve

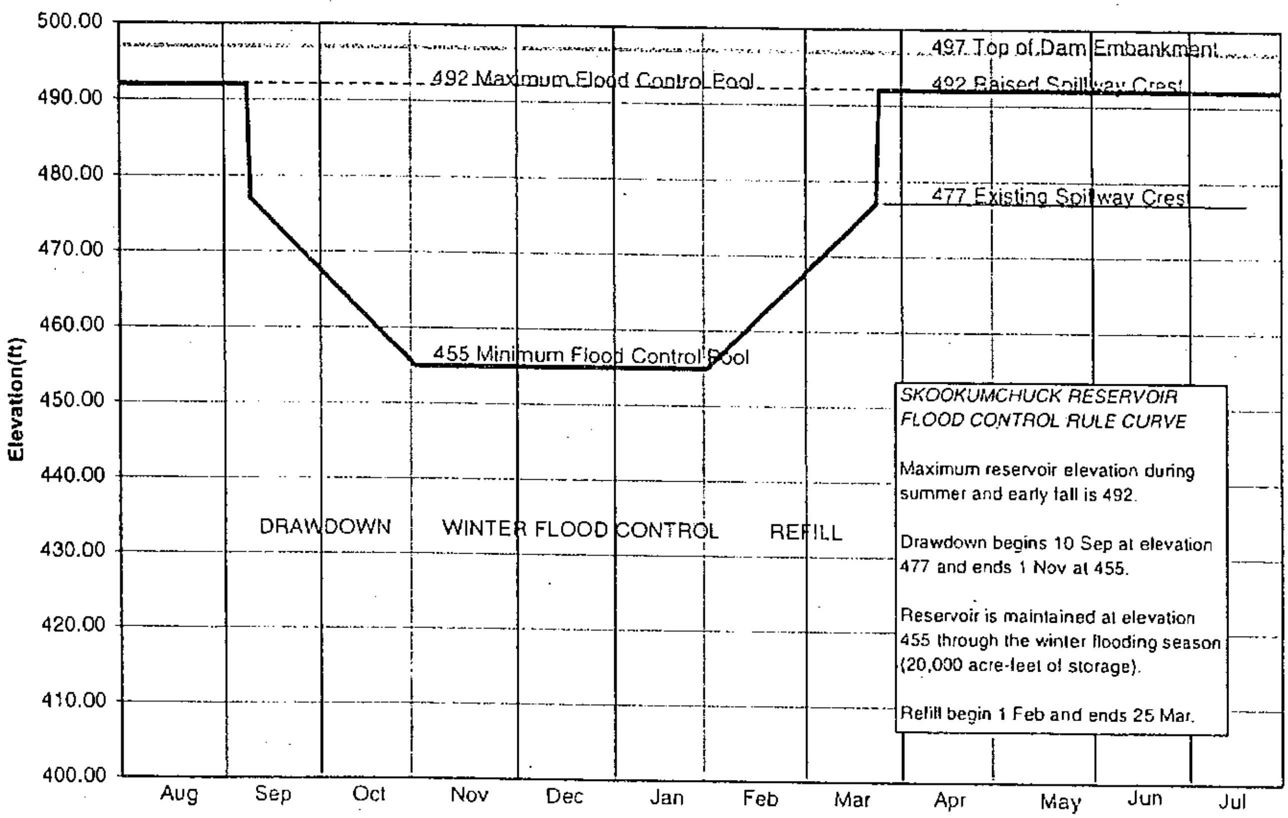


Figure 4-6:
Skookumchuck Reservoir Level with Flood Control Operation

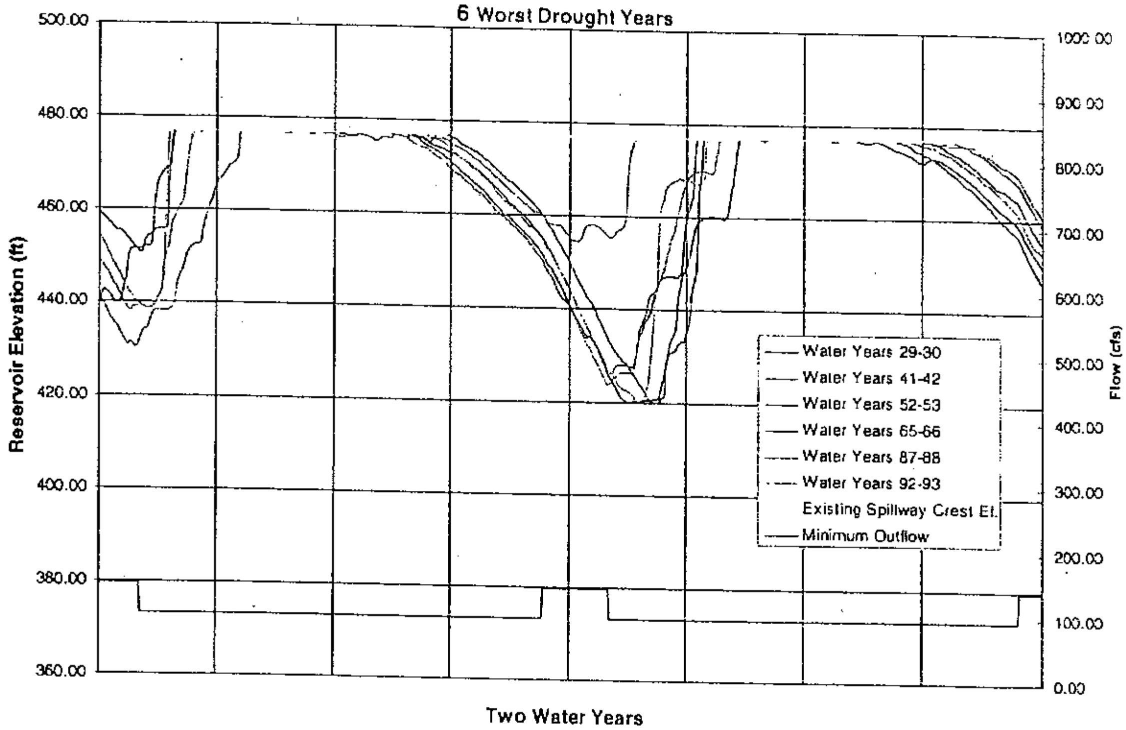
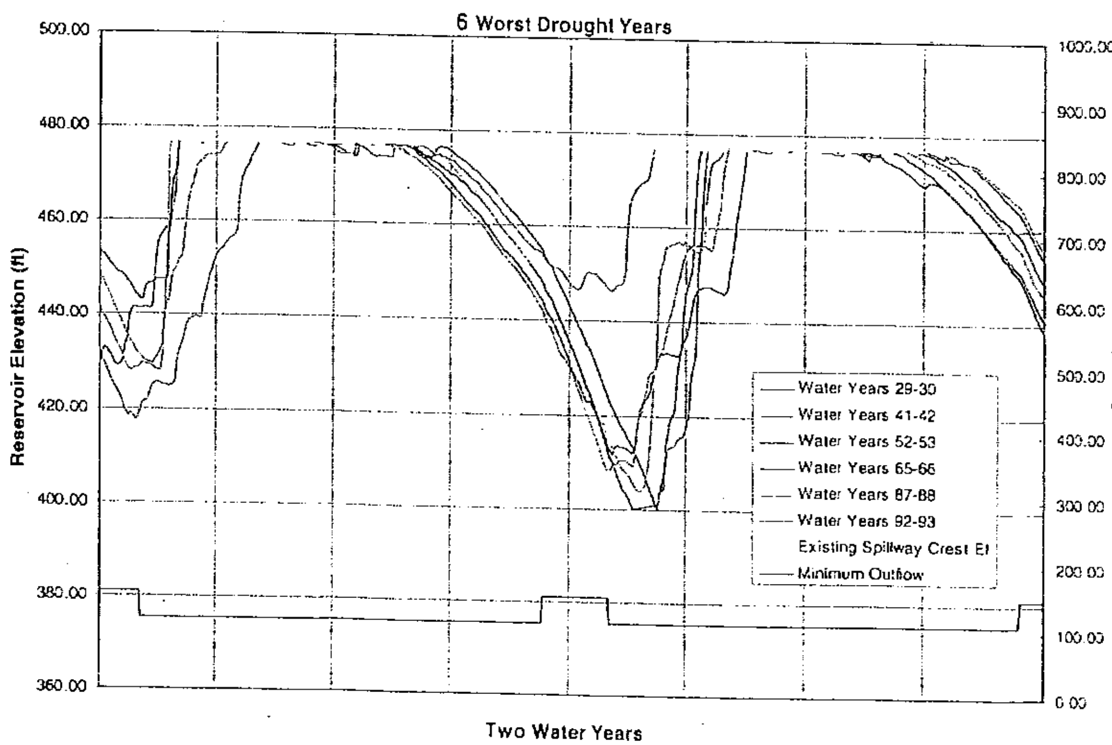


Figure 4-7:
Skookumchuck Reservoir Level with Flood Control Operation



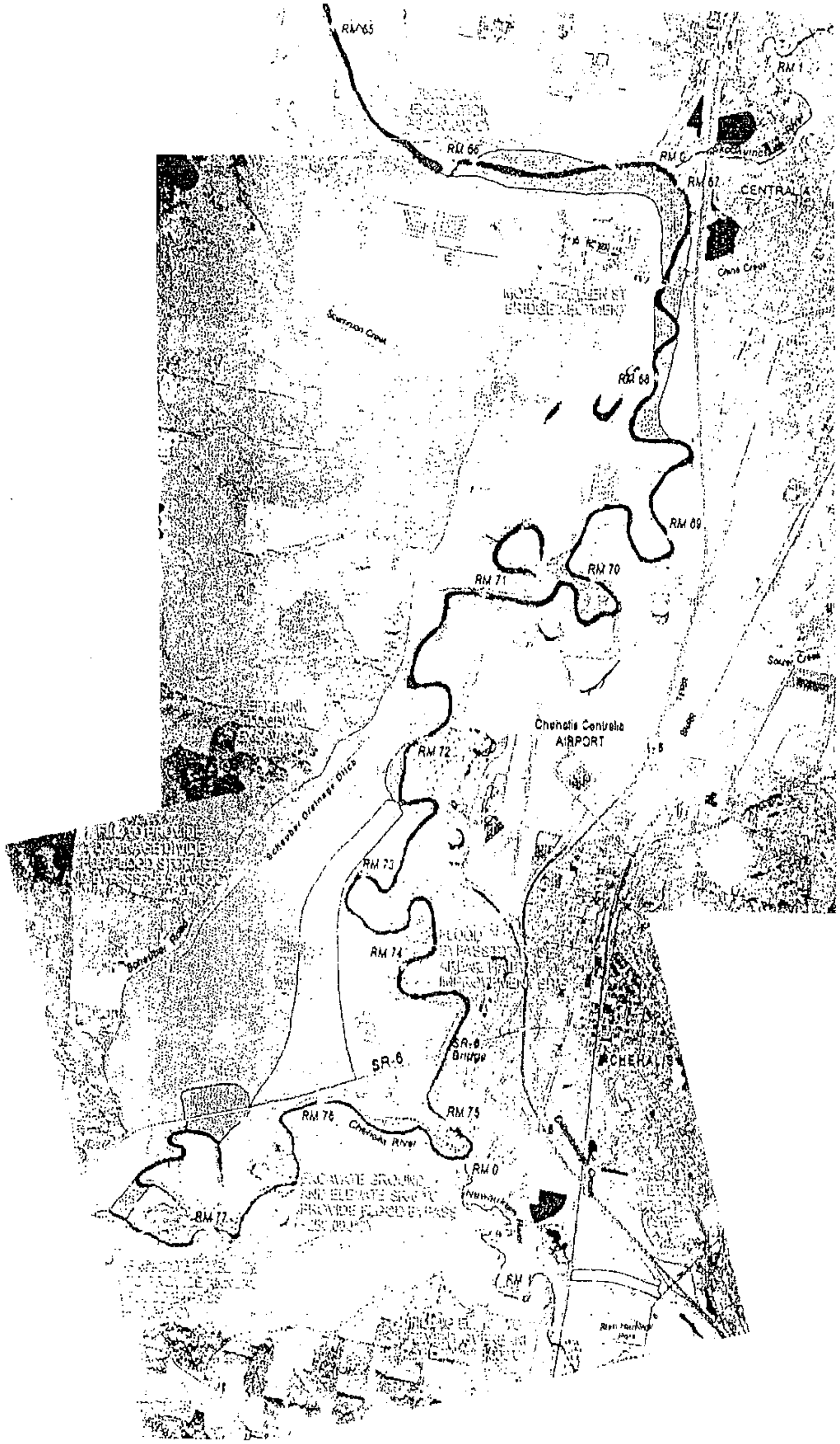
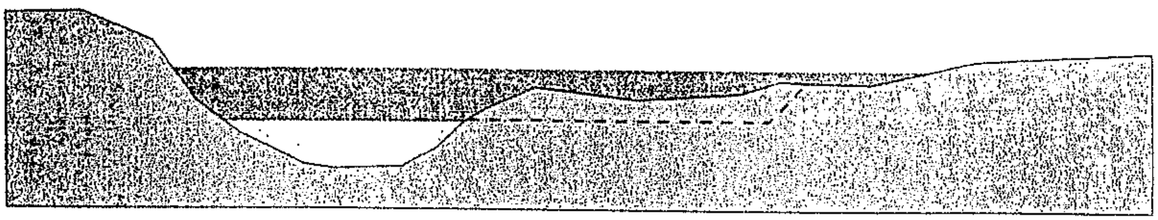


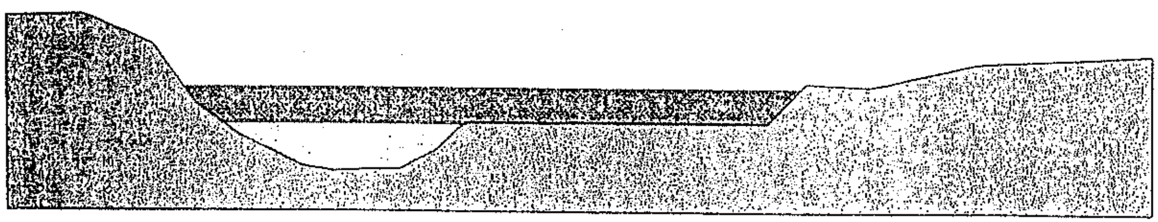
Figure 4-8:
Floodway and Floodplain Modification Plan

Figure 4-9:
Typical Floodway Excavation Section

Existing River Cross Section



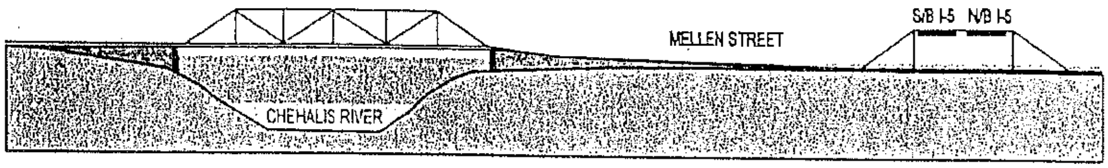
Modified River Cross Section



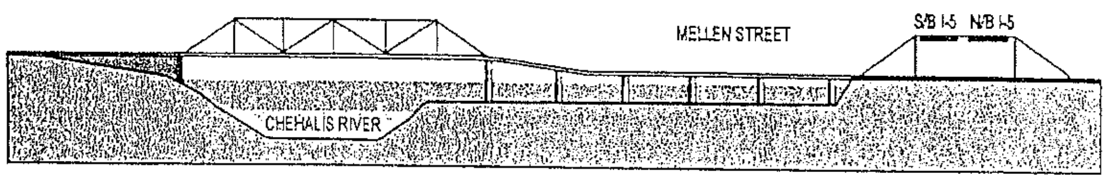
Normal River Stage   100 Year Flood Stage

Figure 4-10:
Mellen Street Bridge Modifications Modifications-Section View

Existing Mellen Street Bridge

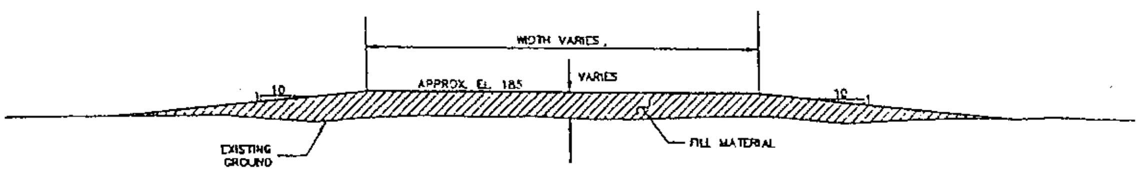


Modified Mellen Street Bridge

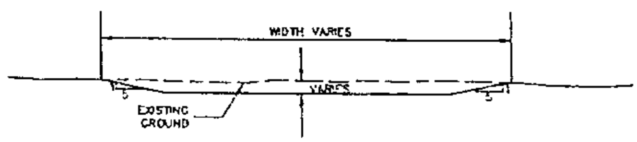


Normal River Flood Stage 100 Year Flood Stage

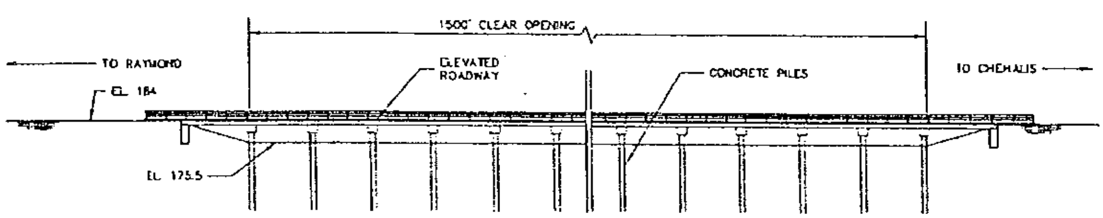
Figure 4-11:
Typical Floodway Modifications, Sections



TYPICAL FILL SECTION
N.T.S.



TYPICAL EXCAVATION SECTION
N.T.S.



SR-6 ROADWAY MODIFICATION - ELEVATION
N.T.S.

Figure 4-12:

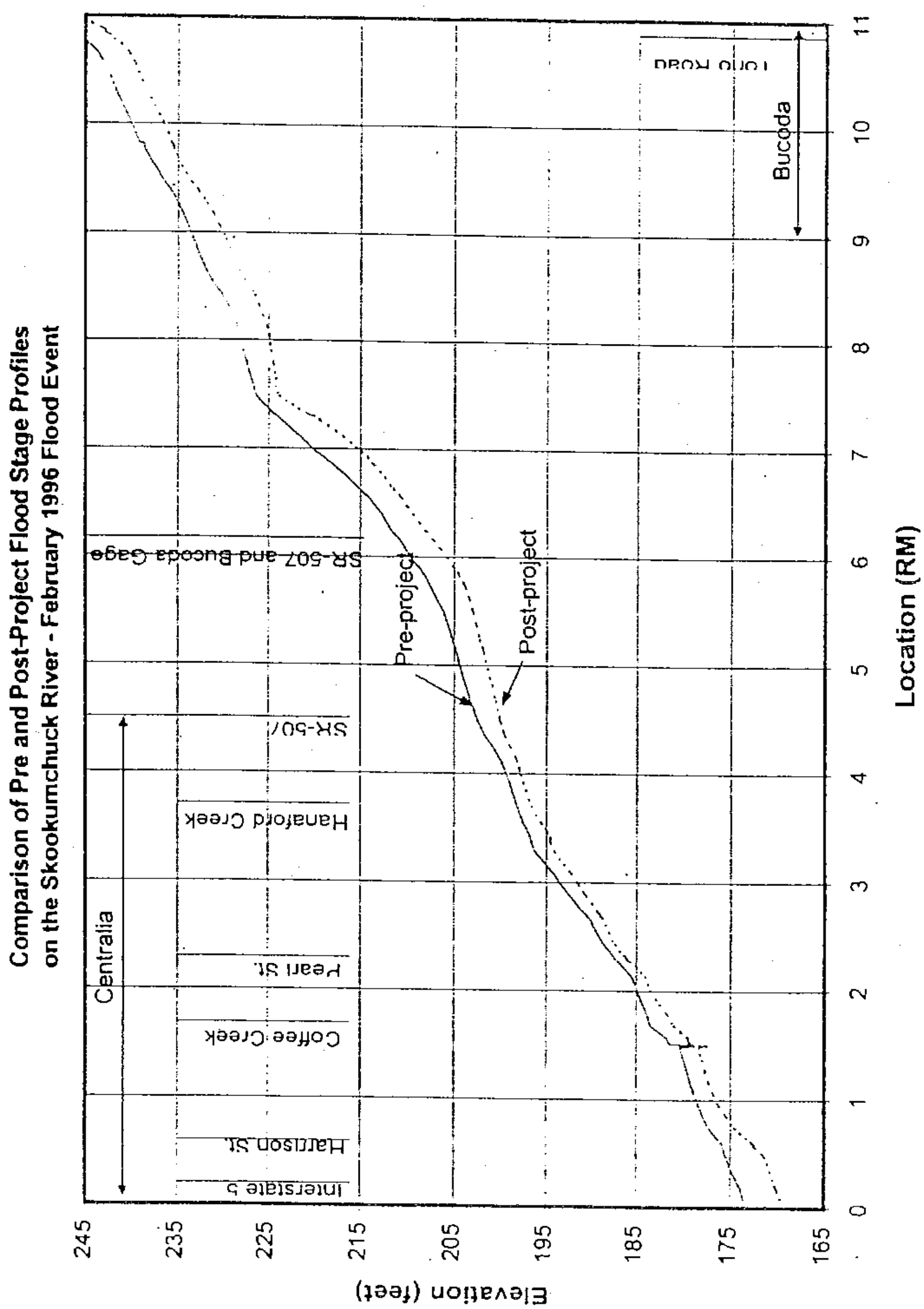

Comparison of Pre and Post-Project Flood Stage Profiles
on the Skookumchuck River - February 1996 Flood Event
Centralia
Bucoda
Interstate 5
Harrison St.
Coffee Creek
Pearl St.
Hanaford Creek
SR-507
SR-507 and Bucoda Gage
Tono Road
Pre-project
Post-project
Elevation (feet)
Location (RM)
245
235
225
215
205
195
185
175
165
0
1
2
3
4
5
6
7
8
9
10
11

Figure 4-13

Comparison of Pre- and Post-Project Peak Flow Profiles on the Skookumchuck River - February 1996 Flood Event

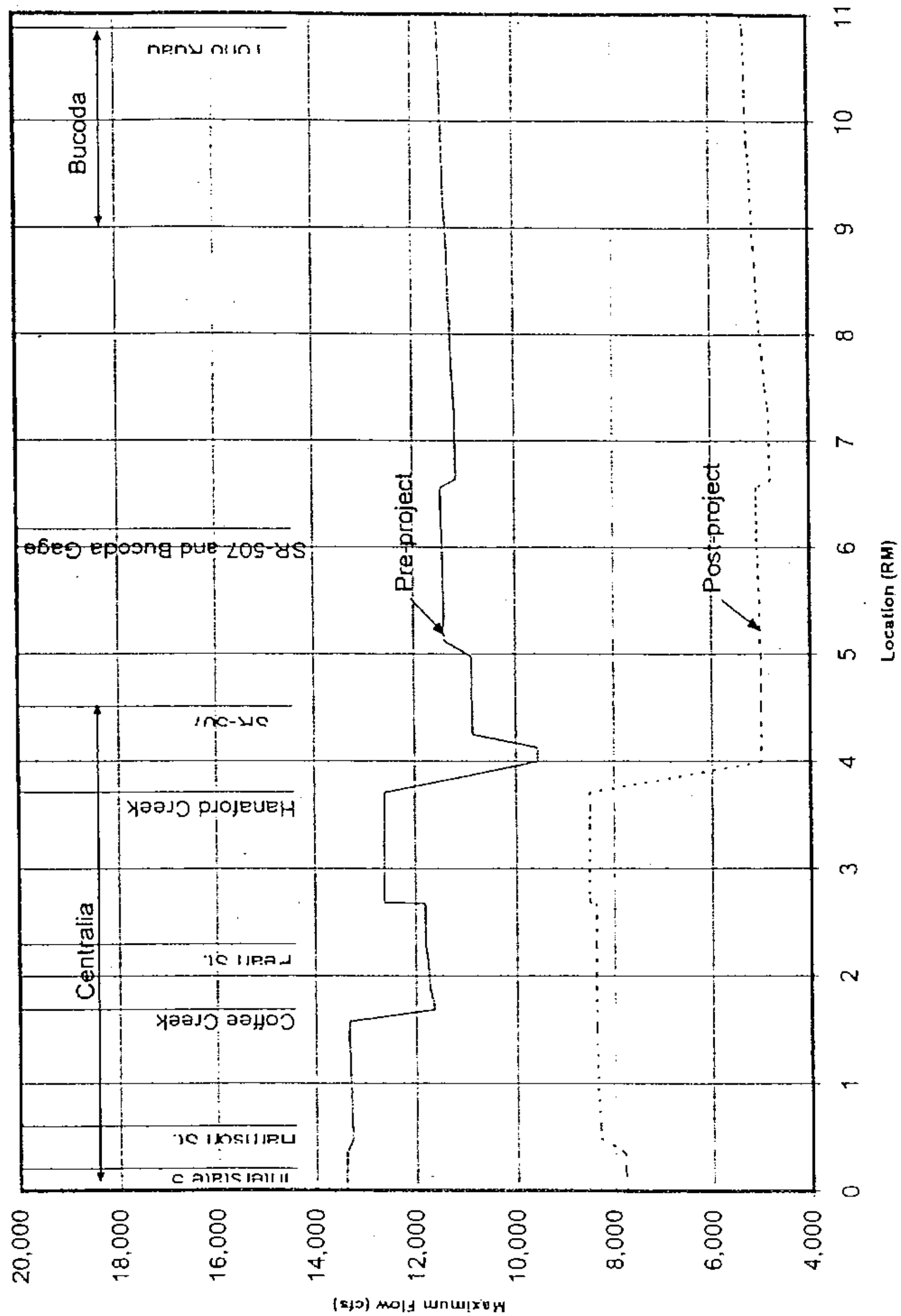
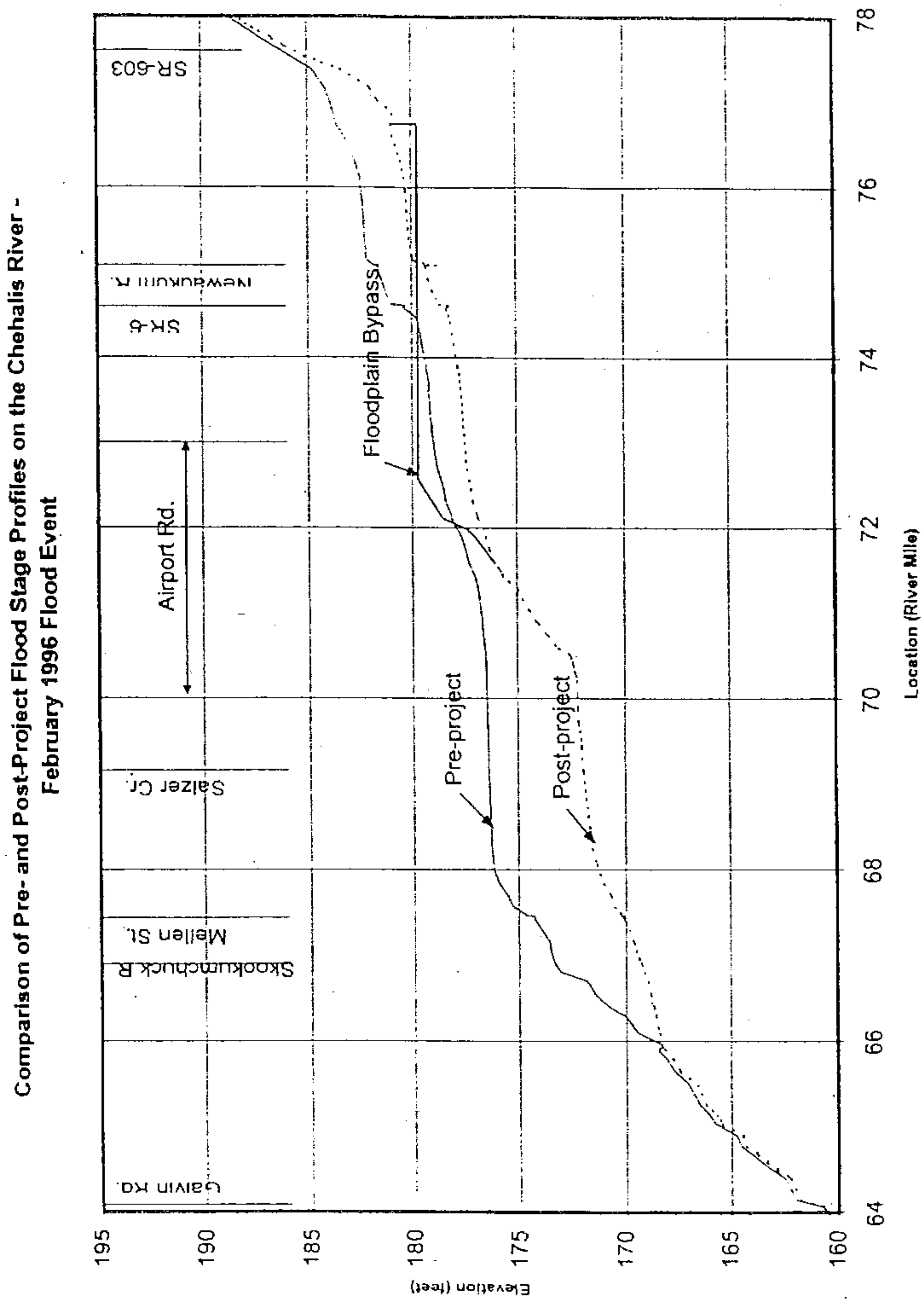


Figure 4-14



Comparison of Pre- and Post-Project Flood Stage Profiles on the Chehalis River -
February 1996 Flood Event
Elevation (feet)
Location (River Mile)
195
190
185
180
175
170
165
160
64
66
68
70
72
74
76
78
Gavin Rd.
Skookumchuck R.
Mellen St.
Salzer Cr.
Airport Rd.
SR-6
Newaukum R.
SR-603
Floodplain Bypass
Pre-project
Post-project

Figure 4-15

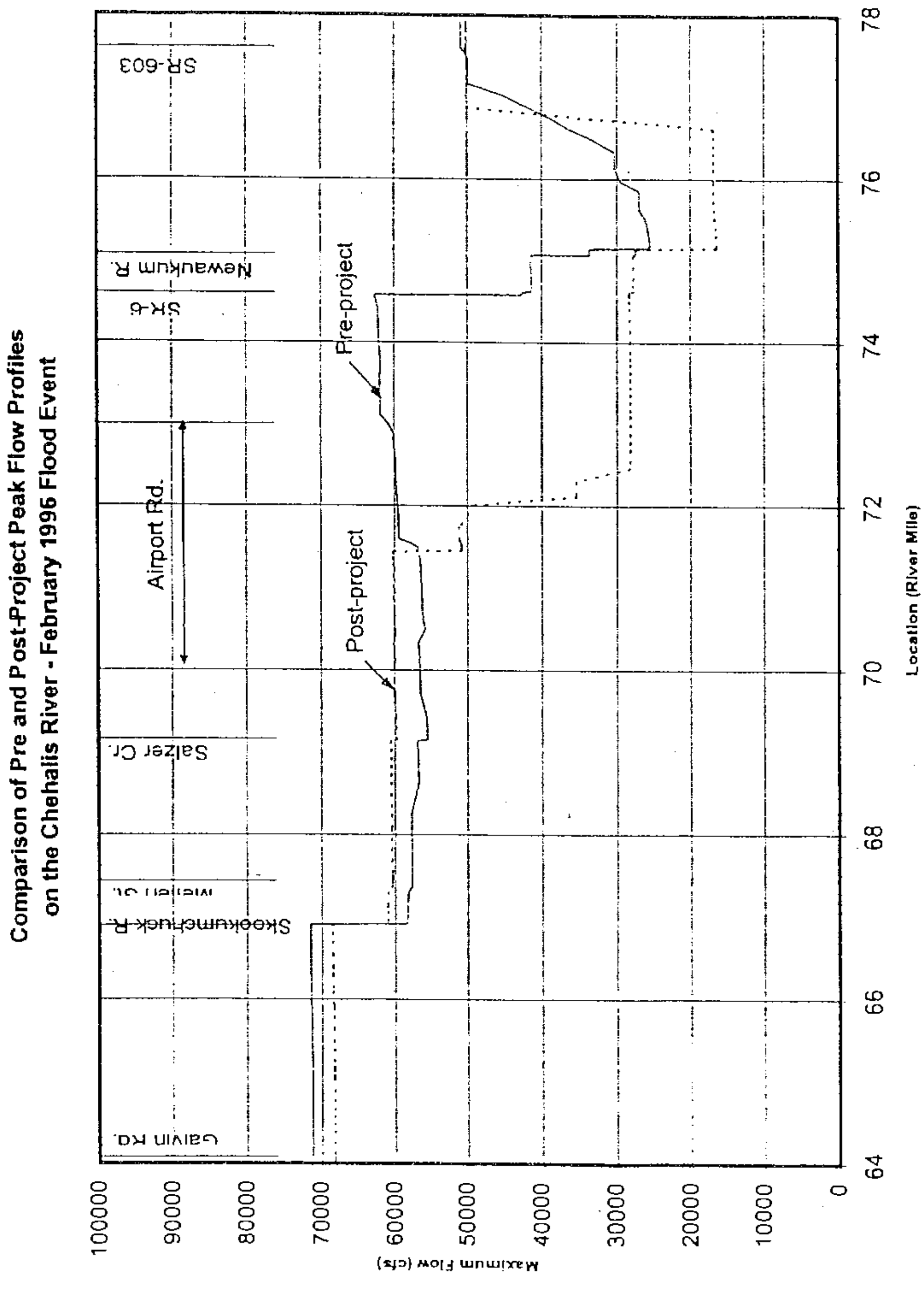
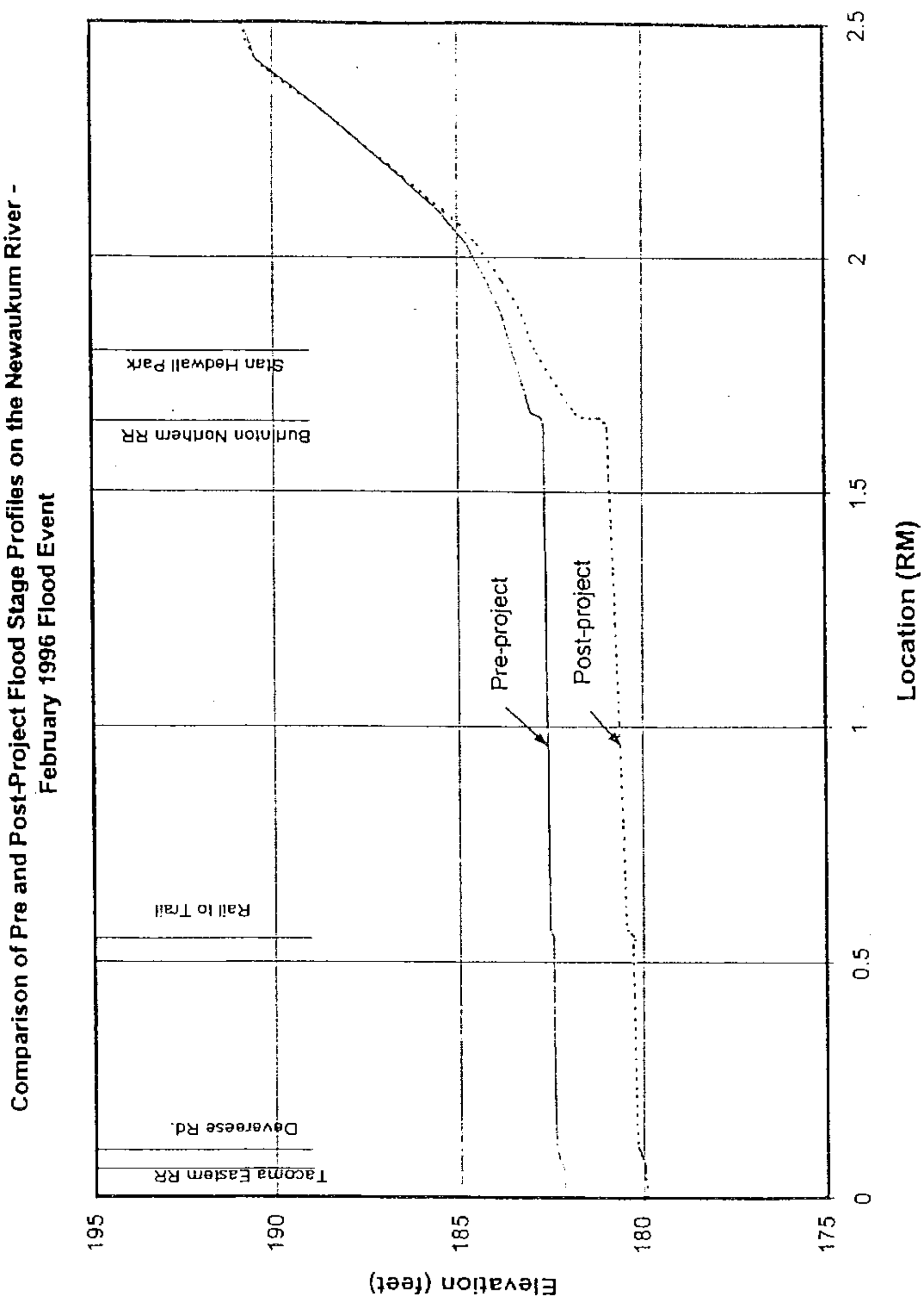
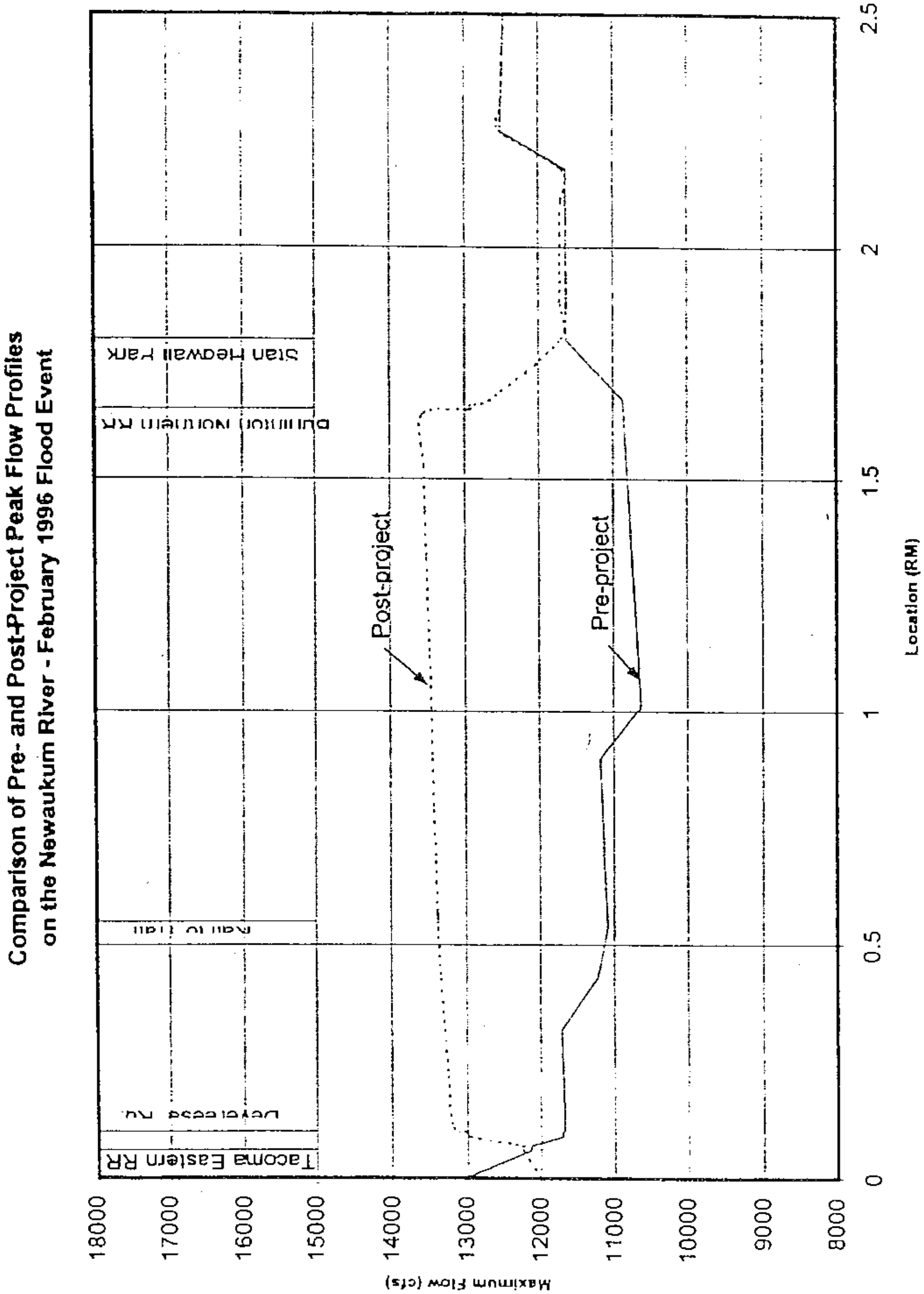

Comparison of Pre and Post-Project Peak Flow Profiles
on the Chehalis River - February 1996 Flood Event
Galvin Rd.
Skookumchuck R.
Mellen St.
Salzer Cr.
Airport Rd.
SR-6
Newaukum R.
SR-603
Pre-project
Post-project
Location (River Mile)
Maximum Flow (cfs)
64
66
68
70
72
74
76
78
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

Figure 4-16



Comparison of Pre and Post-Project Flood Stage Profiles on the Newaukum River - February 1996 Flood Event
Elevation (feet)
Location (RM)
195
190
185
180
175
0
0.5
1
1.5
2
2.5
Tacoma Eastern RR
Devereese Rd.
Rail to Trail
Burlinton Northern RR
Stan Hedwall Park
Pre-project
Post-project

Figure 4-17



Comparison of Pre- and Post-Project Peak Flow Profiles
on the Newaukum River - February 1996 Flood Event
Tacoma Eastern RR
Rail to Trail
Burlington Northern RR
Stan Hedwall Park
Post-project
Pre-project
Maximum Flow (cfs)
Location (RM)
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
0
0.5
1
1.5
2
2.5

Figure 4-18

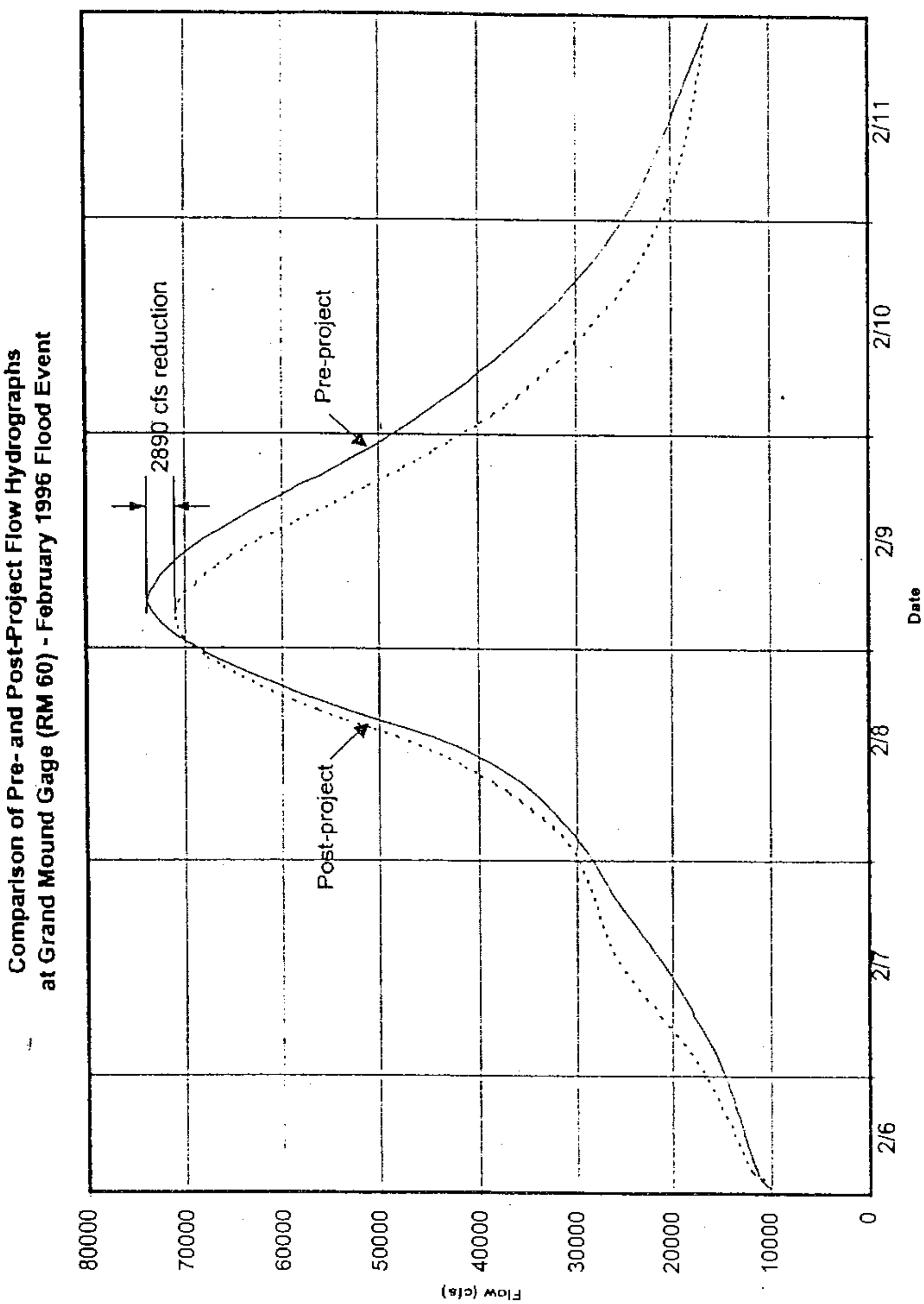
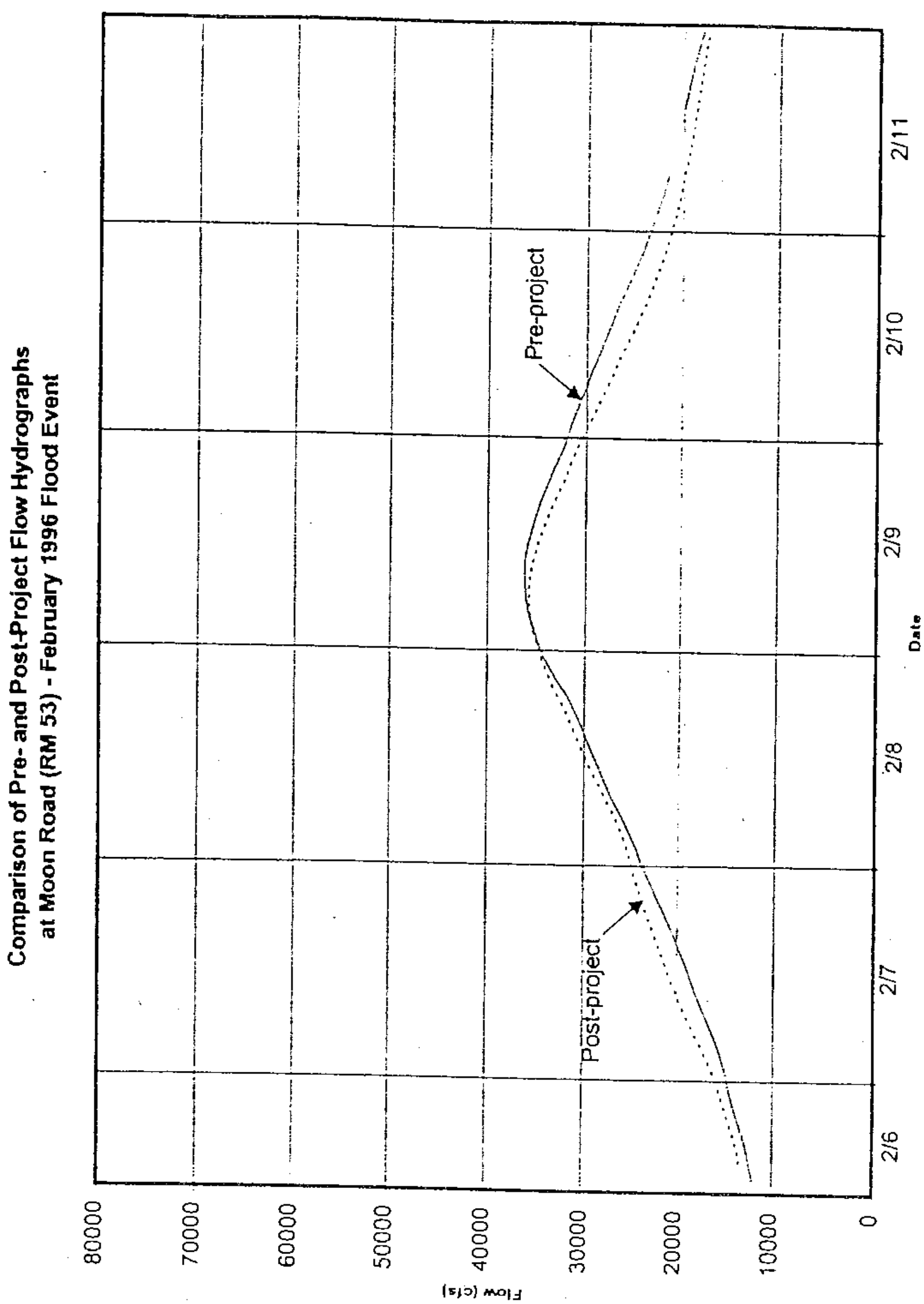

Comparison of Pre- and Post-Project Flow Hydrographs
at Grand Mound Gage (RM 60) - February 1996 Flood Event
2890 cfs reduction
Pre-project
Post-project
80000
70000
60000
50000
40000
30000
20000
10000
0
Flow (cfs)
2/6
2/7
2/8
2/9
2/10
2/11
Date

Figure 4-19



Comparison of Pre- and Post-Project Flow Hydrographs
at Moon Road (RM 53) - February 1996 Flood Event
Pre-project
Post-project
80000
70000
60000
50000
40000
30000
20000
10000
0
Flow (cfs)
2/6
2/7
2/8
2/9
2/10
2/11
Date

Figure 4-20

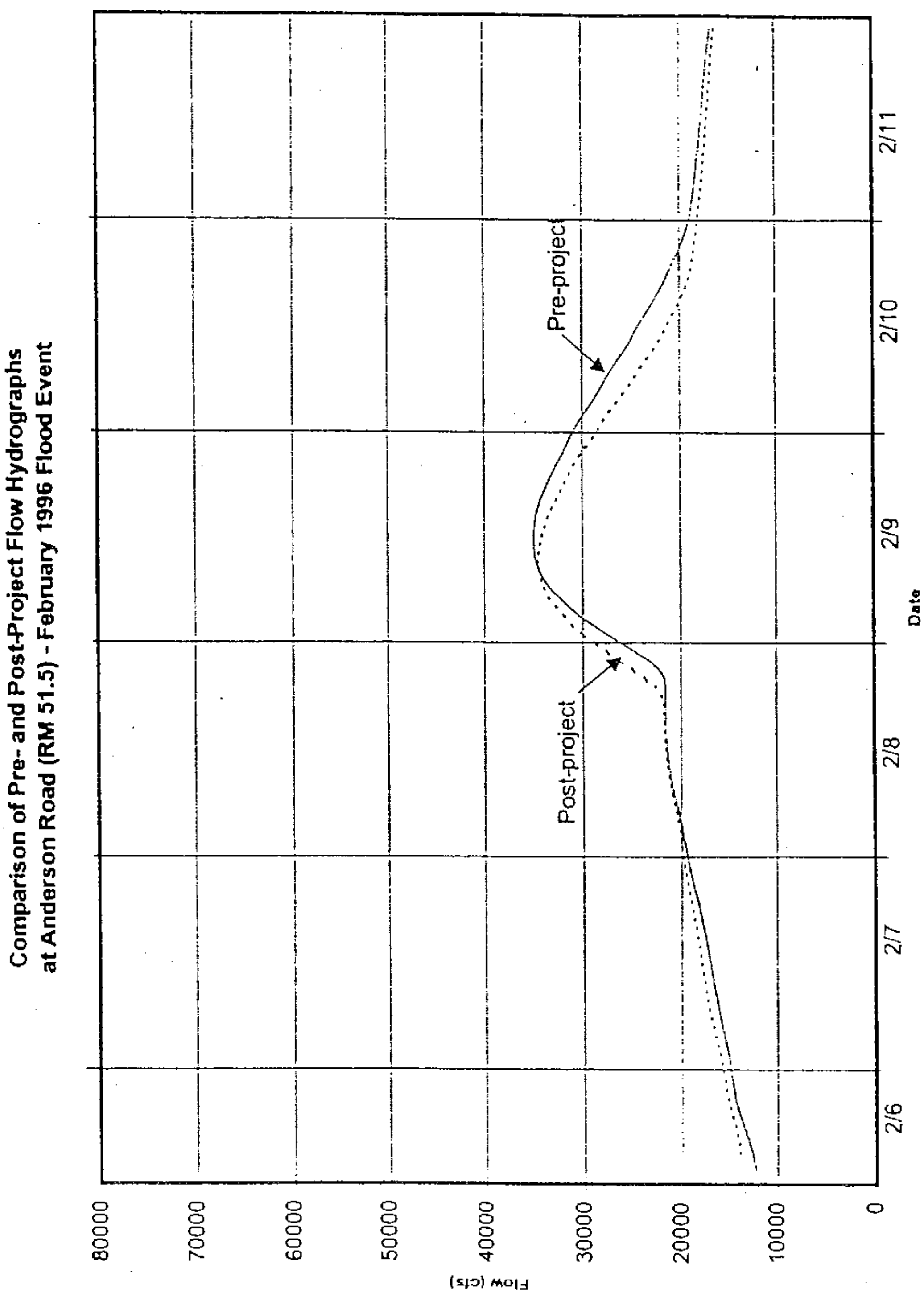
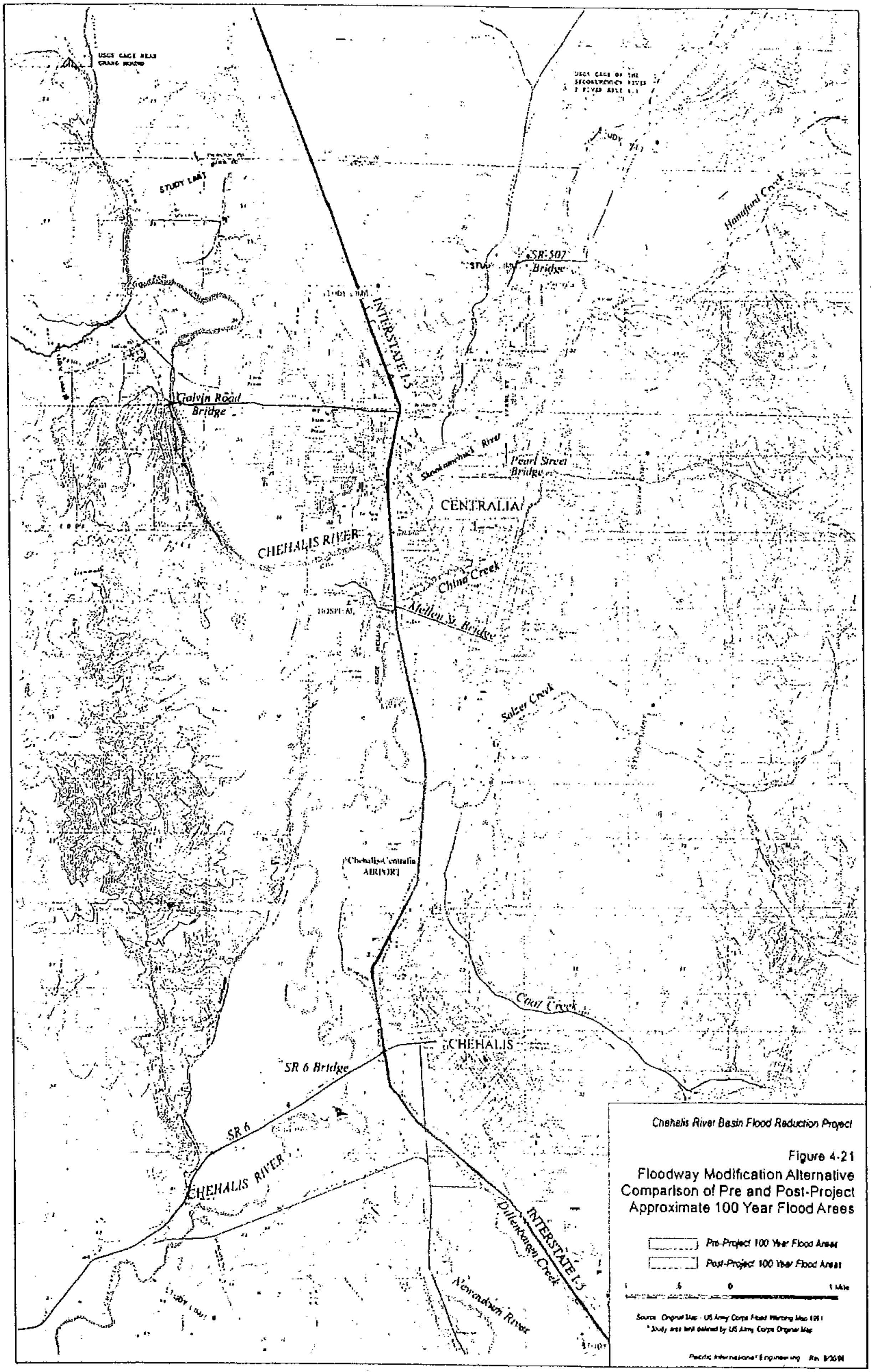
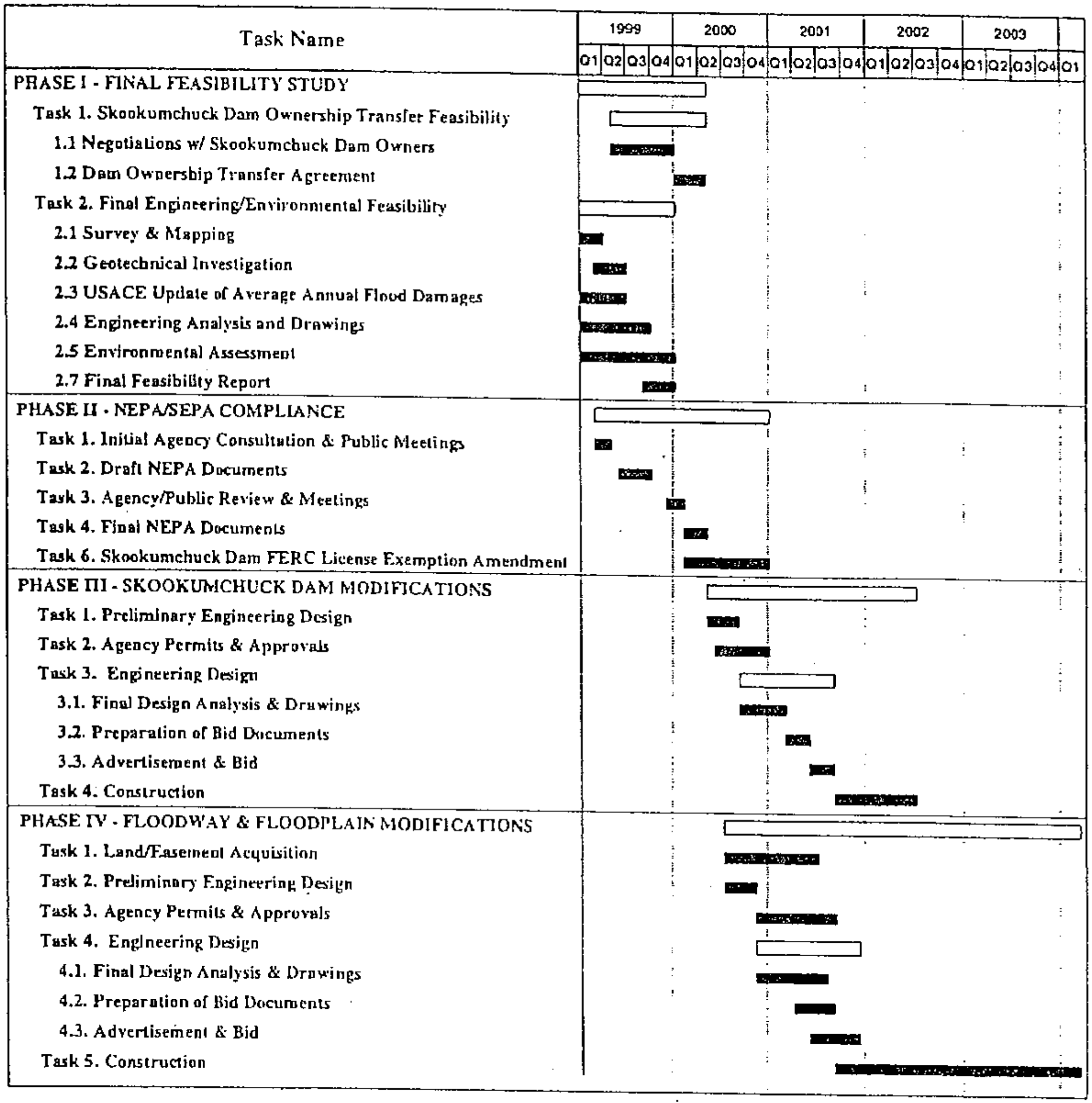

Comparison of Pre- and Post-Project Flow Hydrographs
at Anderson Road (RM 51.5) - February 1996 Flood Event
Pre-project
Post-project
80000
70000
60000
50000
40000
30000
20000
10000
0
Flow (cfs)
2/6
2/7
2/8
2/9
2/10
2/11
Date

Figure 4-21



INTERSTATE I-5
Hanaford Creek
SR 507 Bridge
Galvin Road Bridge
Skookumchuck River
Pearl Street Bridge
CENTRALIA
CHEHALIS RIVER
China Creek
Mellen St. Bridge
Salzer Creek
Chehalis-Centralia AIRPORT
Coal Creek
CHEHALIS
SR 6 Bridge
SR 6
CHEHALIS RIVER
Dillenbaugh Creek
INTERSTATE I-5
Newaukum River
Chehalis River Basin Flood Reduction Project
Figure 4-21
Floodway Modification Alternative
Comparison of Pre and Post-Project
Approximate 100 Year Flood Areas
Pre-Project 100 Year Flood Areas
Post-Project 100 Year Flood Areas
Pacific International Engineering

Figure 4-22:
Proposed Development Schedule



5. Conclusions and Recommendations

5.1. Conclusions

A baseline flood model representing the existing conditions of the Upper Chehalis River Basin was developed to evaluate the effects of various flood reduction options and potential components of alternative solutions, the results of which are included in this report. The model was used to evaluate flood control storage concept options such as headwater dams, like the existing Skookumchuck Dam, and possible new dams on mainstem and tributary streams for their potential in providing cost-effective flood control storage for retaining peak flows. The model was likewise used to evaluate hydraulic capacity improvement options such as floodway or floodplain modifications at various locations to improve floodway hydraulic capacity or floodplain flow bypass for flood stage reductions. This report also includes an evaluation of a No-Action Alternative and several alternatives previously developed by USACE.

The No-Action Alternative will likely result in construction of two projects which could be unnecessary if other measures are taken to reduce flooding in the area: 1) the Long Road Dike Project by USACE to protect the Long Road District from flooding and 2) raising of I-5 by WSDOT to protect it from flooding. Because these projects do not meet the needs of the greater Centralia-Chehalis area, and because the I-5 raising project is more expensive with fewer benefits than the two alternatives identified in this report, the No-Action Alternative was rejected.

Three stand-alone, nonstructural flood control options were evaluated by USACE. Watershed management measures would have little effect on the Basin's hydrologic response during flood events. Flood-proofing structures by raising them above the 100-year flood stage could not be economically justified. Finally, the evacuation and relocation of all residential, commercial and industrial buildings in the Centralia-Chehalis area was not considered economically or politically feasible because of the tremendous amount of investment currently in the floodplain. However, with reevaluation, reconfiguration and further analysis, the nonstructural options could still be potential components of promising alternatives.

River channel excavation and levee options were investigated previously by USACE. Channel clearing was rejected because the increased flow capacity provided by the removal of all vegetation and debris in the river channel would be insignificant compared to the flood discharge. Channel excavation to increase flow capacity in restricted areas of both the Chehalis River and the Newaukum River proved to be economically unfeasible. Both options also raised potentially significant environmental issues.

USACE also determined that channel excavation in conjunction with levee construction was not economically justified. Levees would disturb large areas of wetlands and archeological sites, increase erosion and increase stream temperatures. The construction of levees in an urban area would have fewer environmental impacts because of the reduction in the number and length of the levee segments. USACE found some urban segments economically justifiable and is pursuing the Long Road Dike Project.

Evaluated in this study was the option of modifying the Skookumchuck Dam to add flood control storage. Modifications would include the addition of high capacity outlet works and a spillway crest inflatable rubber weir. With these modifications, the dam could provide significant flood control storage and could significantly reduce flood stages along the Skookumchuck River floodplain. This option would be the least costly, with the fewest environmental impacts, of all other flood control dam alternatives because the dam already exists. However, this option would have little effect on the Chehalis River flood stage and would not be economically feasible alone.

Options providing for the construction of new upstream flood control dams to reduce flooding impacts downstream were also evaluated. Similar investigations performed by USACE were reviewed. All of the upstream flood control dams were determined to be extremely expensive and not cost effective in comparison with the other options evaluated as part of this study for the same magnitude of flood stage reduction. The environmental impacts of new upstream dams were also potentially substantial.

Evaluated in this study was the option of excavating the floodway adjacent to the river channel in the Mellen St. Bridge vicinity and modifying the floodplain in the SR-6 vicinity to provide additional flow capacity for higher flow events. The floodway excavation would be done in the dry to reduce costs and eliminate environmental concerns posed by channel excavation. A number of floodway excavation configurations were modeled to help determine the most cost effective and efficient layout. Excavation could reduce a 100-year flood stage substantially on the Chehalis River within the City of Centralia, thus, reducing the area flood damages and keeping I-5 dry from the 100-year flood level. The SR-6 area floodplain modifications would provide opportunities for habitat improvements and also reduce significantly flood stages in the City of Chehalis floodplain. Preliminary cost estimates indicate that this floodway and floodplain modification option would be the least costly option to achieve flood level protection of this magnitude. However, this option alone would result in peak flow increases downstream during floods. This would not be acceptable to downstream floodplain communities.

The study evaluated the excavation of a secondary overflow bypass channel along either the Chehalis River or the Skookumchuck River, at an elevation that would provide additional flow area only during high flow events. Three alignments off the mainstem of the Chehalis River were rejected because the first required too great of a channel width to provide any advantage over floodway excavation, the second affected too many homes and businesses and the third required the construction of bridges which rendered the project not cost-effective. A secondary channel on the Skookumchuck River was rejected for similar reasons.

No one flood control storage or hydraulic capacity improvement option alone proved to be cost effective and able to provide the protection desired without harming downstream residents. However, it appears that a promising solution would be the combination of three components, which includes both flood reduction concepts. The first component of the currently favored alternative is the Skookumchuck Dam modifications to provide flood control storage. The second component is the floodway excavation in the Mellen St. Bridge area including modifications to the bridge abutments to reduce flood stages in the Centralia floodplain and the third component is the floodplain modifications in the SR-6 vicinity to reduce flood stages in the Chehalis floodplain.

The combined project would overcome the shortfalls of these components evaluated separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway and floodplain modifications. The substantial flood reduction benefits that can be achieved by the floodway and floodplain modifications would be more than the total cost required to modify the floodway (including the bridge modifications) and the floodplain, and to modify the Skookumchuck Dam for the flood control provision. The combined project would, therefore, become economically feasible and would reduce the peak flood flow discharge downstream of the floodway and floodplain modification areas. The combined project would also provide more flood protection to the City of Chehalis while providing greater opportunities for fish and habitat recovery efforts.

5.2. Recommendations

It is tentatively recommended that the Skookumchuck Dam modifications be combined with the floodway modifications in the Mellen St. Bridge area and the floodplain modifications in the SR-6 area to create one project solution alternative for reducing flood damages in the general Centralia-Chehalis area. The following tasks are then recommended:

- An engineering and environmental final feasibility analysis should be performed to confirm selection of the currently favored alternative.

- A funding strategy should be developed to identify and obtain resources from benefited communities and agencies, including but not limited to USACE, FHWA, WSDOT, WSDOE, and any other federal, state, or local agencies benefited by the project.

- A NEPA/SEPA environmental compliance study should be performed when federal funds are made available.

- Efforts should be made to ensure that the alternative described herein is included in the Environmental Impact Statement of the WSDOT I-5 Toutle Park Road to Maytown Project and is selected as an alternative to raising the I-5 grade, and that the project is optimized to include as many beneficiaries as is cost-effective.

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MEMORANDUM

TO: Mike Zengel, Planning Manager

FROM: Pete Ringen, County Engineer

DATE: December 1, 1998

SUBJECT: Chehalis Basin Flood Reduction Study

Thank you for your presentation about the local Comprehensive Plan at the last meeting of the Technical Committee on Thursday, November 19, 1998. The Technical Committee was established as part of the 1998 State Supplemental proviso; and is made up of various local, tribal, state, and federal agencies that have critical knowledge related to flood hazard reduction projects within the Chehalis Basin. Your presentation was very informative and several agencies have voiced concern about ensuring that the Comprehensive Plan limit development and address impacts frequently flooded areas. In particular, the areas which are identified for future flood flow conveyance in the county consultant's work.

Therefore, as a follow up to your presentation, and in order that the critical areas section of the Comprehensive Plan take into consideration the proposed flood reduction alternative, I am enclosing a copy of the "Description of Floodplain Modification Alternative" report prepared by Pacific International Engineering in October 1998. This report expands on the three flood reduction elements identified in their work of May 1998; and also includes a flood bypass utilizing the agricultural floodplain north of SR6 and east of Scheuber Road.

I would also like to impart some of my own concerns on the issue of fill in the floodplain. Many individuals in speaking to me, have remarked on the visible floodplain development that is occurring in the areas of future flood flow conveyance and/or storage. Consequently, they have questioned the degree of local commitment to the Chehalis Basin Flood Reduction Study to meet our flood reduction goals. I believe it would be to our benefit to have the Comprehensive Plan ensure that development of frequently flooded areas be limited.

PR/SK:tlp

cc: Board of County Commissioners
Ray Miller, Director, Community Development Dept.
Stearns Woods, GIS/Transportation Planning Manager
Shirley Kook, Senior Engineer

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Chehalis River Basin Flood Control Project

Description of Floodplain Modification Alternative

Introduction

This report is in response to a request of the Technical Committee during the September 17, 1998, meeting at the Lewis County Public Works Department office. At that meeting, Pacific International Engineering PLLC (PIE) presented a new alternative incorporating a concept of floodplain modifications for solving the flooding problems in the Centralia-Chehalis/I-5 corridor area. Other alternatives including new dams, channel dredging, levees, floodway modifications and non-structural alternatives were evaluated and presented in the Pre-Feasibility Analysis of Alternatives Report (PIE, 1998). The Floodplain Modification Alternative would provide substantial flood flow bypass and eliminate the need for any channel or bank excavation in the SR-6 Bridge vicinity for achieving flood stage reductions within the City of Chehalis floodplain. Figure 1 presents a map of the Chehalis River Basin.

Components of the Floodplain Modification Alternative

The Floodplain Modification Alternative would consist of three components. The first component (common to the Floodway Modification Alternative presented in the pre-feasibility analysis report) is modifications to Skookumchuck Dam to provide flood control storage. The second component (also common to the Floodway Modification Alternative) is floodway modifications in the vicinity of Mellen St. Bridge between River Mile (RM) 65.90 and RM 68.25, including modifications to the existing Mellen St. Bridge abutment. The third component is floodplain modifications in the vicinity of SR-6 to provide flood flow bypass and storage.

The Skookumchuck Dam modifications could provide flood control storage of 20,000 acre-feet, and could significantly reduce flood stages along the Skookumchuck River floodplain. A preliminary cost estimate indicates that this component would be the least costly of all storage dam alternatives evaluated for providing flood control storage of this magnitude. In addition, this component would have the least environmental impact of all storage dam alternatives, as the dam already exists. However, the Skookumchuck Dam component alone would have very little effect on Chehalis River flood stage reduction (less than 0.5-foot flood stage reduction) and would not be economically feasible alone, as the benefit-to-cost ratio would be less than 1.0.

The Mellen St. Bridge vicinity floodway modifications component alone could reduce a 100-year flood stage by more then 4 feet on the Chehalis River in the Mellen St. Bridge to Salzer Creek reach. This would be sufficient to substantially reduce flood damages and keep I-5 east of the Centralia - Chehalis Airport area above the 100-year flood level. Preliminary cost estimates indicate that this component would be the least costly of options, including new storage dams and channel dredging, for achieving the magnitude of flood stage reduction desired. However, the floodway modifications would result in peak flow increases downstream during floods and would not be acceptable to downstream floodplain communities.

The SR-6 vicinity floodplain modifications could substantially reduce the 100-year flood stage by approximately 2 to 3 feet within the City of Chehalis floodplain along the Chehalis River, the Newaukum River and Dillenbaugh Creek. Preliminary cost estimates indicate that this component would be the least costly among evaluated options, including new storage dams and channel or bank excavation, for achieving the magnitude of flood stage reduction desired in the City of Chehalis floodplain. However, the floodplain modifications alone could also result in flood peak flow increases downstream.

A combined project including the Skookumchuck Dam modifications, the Mellen St. vicinity floodway modifications and the SR-6 vicinity floodplain modifications, would overcome the shortfalls that each component would have if implemented separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck River peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway and the floodplain modifications. The substantial flood reduction benefits that can be achieved by the floodway and the floodplain modifications would be more than the total cost required to modify the floodway, the floodplain and the Skookumchuck Dam. The combined project would, therefore, become economically feasible and would also reduce the peak flood flow discharging downstream from the project.

The UNET, an unsteady state flood model developed in the previous pre-feasibility analysis, was updated and used to evaluate the flood stage reduction benefits and impacts of the combined components. The flood modeling evaluation was based on the February 1996 flood, which is the flood of record on the Chehalis River representing the 100-year event. A brief description of the components is provided below.

Skookumchuck Dam Modifications

General

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The dam was constructed in 1970 to supply water for the Centralia steam generating plant. The dam is an earthfill structure approximately 190 feet high, above bedrock, with the top of the dam being at elevation 497 feet. Storage behind the dam is essentially a fill and spill operation. The limited outlet capacity of the dam, which consists of two 24-inch Howell Bunger valves with a combined discharge of approximately 220 cubic feet per second (cfs), causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the 130-foot wide ungated spillway, which has a discharge capacity of 28,000 cfs at elevation 492 feet. Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 31,000 acre-feet.

Preliminary investigations by USACE indicate that flood control storage at Skookumchuck Dam could be feasible without jeopardizing the steam plant water supply. USACE investigated several alternatives for modifications, which are presented in detail in the USACE's December 1982 and February 1992 reports (USACE, 1982, 1992).

The first component of the Floodplain Modification Alternative is structural modifications to the existing Skookumchuck Dam to permit flood control operation during winter months. Modifications to the existing spillway would be made to add 1) flood control outlet works, including two gated flood control outlet sluices, and 2) an inflatable crest weir at the top of the existing spillway. The addition of the crest weir at the top of the existing spillway will also require modifications to the ogee crest and the spillway chute. A conceptual layout plan and sections of the modifications are shown in Figures 2 through 4. Figure 5 presents an artist's rendering of the modifications. Brief descriptions of the modifications are provided below, following the discussions on dam safety and reservoir regulation considerations.

Dam Safety Considerations

The proposed modifications to Skookumchuck Dam must enable the project to safely pass the Probable Maximum Flood (PMF) outflow of 28,000 cfs at a maximum design pool elevation of 492 feet. During the PMF, approximately 22,500 cfs would be discharged over the modified spillway, and 5,500 cfs would be discharged through the proposed flood control outlet.

The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while accounting for contingencies such as surcharge, wind wave runup, and embankment settlement. Five feet is considered

adequate freeboard. The dam embankment currently has a top elevation of 497.0 feet. The maximum design pool level is at elevation 492.0 feet.

PacifiCorp (formerly Pacific Power & Light, the dam operator) had a dam safety and seismic stability analysis performed on the dam in 1988, which the USACE later reviewed. The USACE determined that, with the new operation for flood control, the embankment would suffer distress during the design earthquake, but would not fail and did not require any modification (USACE, 1992). More recently, PacifiCorp had a FERC (Federal Energy Regulatory Commission) Part 12 dam safety inspection performed in 1996. Stability analyses were performed for normal operating conditions, PMF, rapid drawdown, and seismic loading conditions. The embankment dam, spillway and all other structures were found to be safe for all cases investigated (Black & Veatch, 1996). Dam safety and stability is currently being reviewed by PIE's geotechnical subconsultant, Hart Crowser, taking into account the proposed changes to the reservoir operation for flood control.

Reservoir Regulation Considerations

USACE developed a preliminary flood control operation rule curve as part of its flood control operations investigation (USACE, 1992). The USACE rule curve provided flood control storage of 11,900 acre-feet between elevations 453 and 477 feet, from November 1 to February 1. After February 1, the reservoir would be allowed to refill. Drawdown of the reservoir would begin each year in early to mid September and would continue until elevation 453 feet was reached, around the first of November.

USACE performed a water supply study of the Skookumchuck reservoir as part of its investigation to determine if sufficient storage would be available to meet water supply and minimum instream flow requirements for fisheries and power diversion with storage operations for flood control (USACE, 1992). USACE assumed that PacifiCorp would divert its entire 80 cfs water right, and determined that minimum instream flow and water supply requirements could be met in all years with the USACE proposed flood control operation rule curve.

PIE's proposed dam modifications would provide a flood control storage of 20,000 acre-feet between pool elevation 455 and 492 feet. This storage is sufficient to contain the peak flow of the February 1996 flood and would reduce the peak flood stage at the Pearl St. Bridge by 1.44 feet. This is equivalent to reducing the flood stage from a 70-year recurrence interval to a 10-year recurrence interval. A new reservoir operation rule curve similar to the USACE rule curve, which would ensure water supply requirements, is being developed by PIE for the flood control operation.

The flood control operation rule curve must ensure releases in accordance with the existing fishery flow agreement. The agreement between

PacifiCorp and Washington Department of Fish and Wildlife (WDFW) provides a minimum instream flow of 140 cfs from September 10 to October 31 for salmon spawning. Incubation flows begin on November 1, or at the completion of spawning, as determined by WDFW. A minimum of 95 cfs is supplied until March 31. From April 1 through August 31, rearing flows are set at a maximum of 95 cfs or natural river flow plus 50 cfs, whichever is less. Rearing flows may be adjusted downward as determined by WDFW to preserve water for use during the spawning period. The instream flow agreement also provides for instream water temperatures of 50° to 55° F. These temperatures must be maintained, to the maximum extent possible, depending on reservoir and climatic conditions.

The dam modifications proposed by PIE include adding a 15-foot high inflatable weir above the existing spillway crest at elevation 477. This will provide, approximately, an additional 9,000 acre-feet of storage, which would potentially be available to augment summer low flows downstream.

Flood Control Outlet Works

The proposed flood control outlet works would be located within the existing spillway and would consist of an approach channel and two gated sluiceways. The flood control outlet would be able to discharge approximately 3,000 cfs at the minimum flood control pool elevation of 455 feet. This would allow the flood control storage to be evacuated within a maximum of 3 to 5 days following a major flood that fills the reservoir to elevation 492 feet, providing capacity for the next flood event that could potentially occur right after evacuation.

A trapezoidal-shaped channel, approximately 250 feet long, would be excavated within the existing spillway approach channel. The existing spillway approach channel is excavated in rock to an invert elevation of 464 feet. The new sluiceway approach channel would have a bottom width of about 40 feet, an invert elevation of approximately 442 feet, and 1 horizontal (H) on 4 vertical (V) sloping sides. Approximately 24,000 cubic yards of rock would need to be excavated to construct the channel.

A section of the existing ogee spillway would be removed and a new spillway section containing two gated sluices would be constructed. The two sluice gates would each be approximately 15 feet wide and 10 feet high. An emergency bulkhead would be supplied to allow for dewatering of the gates.

Spillway Crest Weir and Chute

The discharge capacity of the existing uncontrolled spillway is 28,000 cfs at the maximum design pool elevation. But in a PMF discharge event of 28,000 cfs, the existing spillway crest will be submerged by water backing up from the spillway chute entrance. Modifications to the spillway would

enable the use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and provide the PMF discharge capability. The modifications include adding a crest weir, modifying the ogee crest, and modifying a portion of the spillway chute.

A 15-foot high by 130-foot wide inflatable rubber weir would be added to the existing spillway crest. Inflatable rubber weirs have been used very successfully in North America, Europe, and Asia. The weir consists of a heavy-duty, reinforced rubber body that is anchored to a concrete foundation and inflated with air. The height of the weir can be varied by adjustments of the pressure within the tube. If necessary, the weir can be quickly deflated to allow for unrestricted flow of water over the spillway. Deflation of the weir is carried out automatically so that the weir is inherently safe under all conditions.

The existing spillway chute is located in a rock excavation on the left abutment. The chute bottom converges from a width of 40 feet to 25 feet and has 1H on 4V side slopes. The walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. During the PMF discharge, the water surface in the chute would overtop the concrete lined portion of the walls, but would still be contained within the excavated rock channel. This rock material has been identified as being highly fractured and susceptible to freeze-thaw damage. In order to protect the rock portion of the chute, the rock slopes would be lined with shotcrete up to the PMF water surface profile. The invert of the plunge pool below the spillway ogee crest would also be excavated out and lowered to make room for the new spillway sluices.

Mellen St. Bridge Vicinity Floodway Modifications

General

Floodway modifications along the Chehalis River in the Mellen St. Bridge vicinity, from approximately one mile downstream to one mile upstream of its confluence with the Skookumchuck River (RM 65.90 to RM 68.25), is the second component of the Floodplain Modification Alternative. The design of this component would involve terracing the floodway in areas where the flow is currently constricted in order to increase the high-flow hydraulic capacity of the Chehalis River during flood events. Floodway excavation was also evaluated between the Galvin Road Bridge (RM 64.08) and the Newaukum River mouth (RM 75.15). Between these two limits, numerous variations of excavated width and excavation location were modeled. Preliminary cost estimates were then developed to help determine which arrangements appeared to be the most cost-effective.

Excavation Reach

Among all variations modeled with the UNET model, floodway excavation between RM 65.90 and RM 68.25 appears to be the most efficient and cost-effective design. The recommended excavation scheme would involve excavating approximately 3.2 million cubic yards (cy) of material between the hump location (RM 65.90) and three quarters mile upstream of the Mellen St. Bridge (RM 68.25). The excavated material would be used for floodplain fill required for the SR-6 vicinity modification works described later in this report. UNET modeling of this scheme resulted in 4.51 feet of flood stage reduction at the mouth of Salzer Creek (RM 69.16) and 4.21 feet at the Mellen St. Bridge gage (RM 67.44) during the February 1996 event. The floodway excavation would also provide an opportunity to create off-channel rearing habitat to benefit anadromous fish, and opportunities for other habitat improvements. An overview plan of the Mellen St. Bridge area floodway excavation together with the SR-6 vicinity floodplain modifications is shown in Figure 6.

Excavation Elevation and Width

The floodway is designed to be excavated to an elevation above the summer normal flow stage so that construction activities would be above the water level. The floodway would have an average excavation width of about 600 feet. A schematic section view of the floodway excavation, not including the vegetation planting and habitat improvements plan that is expected to be required, is shown in Figure 7.

Mellen St. Bridge Modifications

The Mellen St. Bridge section of the Chehalis River is one of the most restrictive for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. Currently, it is

Scope of Work: Chehalis Basin Literature Review and GIS Data Acquisition

BACKGROUND

Northwest GIS Services, Inc. (NWGIS) was established in 1993 to meet the growing need for GIS services in relation to environmental studies and land use planning. Our business has grown steadily during the past five years and the majority of our work has come from repeat business and referrals. We believe this is largely due to the fact that we are able to deliver high-quality GIS products and services in a timely manner at a reasonable cost. We are especially noted for the excellence of our map products and have won awards on two occasions at the Northwest ARC/INFO User Conference. We take special care to ensure that every map we produce is attractive, readable, and clearly conveys the desired information.

NWGIS personnel have the technical skills and professional experience needed to translate environmental study objectives into GIS form. Collectively, we have more than 30 years of experience using GIS technology to address environmental issues. In addition, our chief GIS consultant has well-established professional credentials in the environmental field.

The application areas we have tended to specialize in most are watershed analysis, hydrology, and surface water planning and management. This typically involves the integration of many GIS data layers, including fish distribution, stream channel characteristics, riparian vegetation, roads, land use and land cover, geology, slope stability and erosion hazards, and layers derived from digital terrain models.

NWGIS provided GIS support for the *Snohomish River Basin Conditions and Issues Report*, a major water resource study carried out by Pentec Environmental, Inc., for the Snohomish Work Group, a consortium of local and tribal government agencies and surface water management organizations. We also provided GIS support on a total of ten watershed analysis projects in Washington and Oregon—following the Washington State standard methodology—carried out by three of the largest forest landowners in the Pacific Northwest.

Most recently, NWGIS has been conducting a study for the Washington State Department of Transportation (WSDOT), as a subcontractor to David Evans and Associates, Inc., called the *Snohomish Basin Literature Review and GIS Data Acquisition*. Under this contract, NWGIS screened more than 360 bibliographic citations and developed an annotated bibliography of more than 80 management plans, study reports and historical documents related to water resources in the Snohomish River Basin. Of particular interest were those containing site-specific recommendations for mitigation, restoration, or enhancement in relation to water quality, wetlands, fish passage, or habitat. As part of the annotation, documents were given a numerical rating as a source of either baseline geographic data or site-specific recommendations with values ranging from zero to three (0 = none, 1 = poor, 2 = fair, 3 = good). We are currently building a

GIS Database Design

Selected documents that meet the study criteria and also contain geographically oriented data will be further evaluated for inclusion in a GIS database. Map features or geographic references in the planning documents that describe recommendations or actions will be grouped into point, line, and polygon GIS data types. Passages or tables in the documents that characterize these recommendations or actions will be summarized in the GIS database along with other essential descriptive information. A common attribute schema will be developed for points, lines and polygons that is expected to include approximately 10-15 descriptive attributes. A key component of the attribute schema will be a citation tracking system that will link all spatial features and associated attributes back to the document they were extracted from. Within ArcView, links will be established between spatial features, attributes, and bibliographic citations that will allow relational queries between spatial and tabular data. The following are examples of database capabilities:

1. Select a location on a map and see all the plans, recommendations and actions associated with it.
2. Select a plan and see all recommendations, actions and map locations associated with it.
3. Select a certain type of recommendation or action (e.g., fish passage) and see all plans and map locations associated with it.

Database Implementation

After the client has approved the database design, any GIS data available from the source documents will be obtained and incorporated into the database. This will most likely involve some conversion and reformatting, such as importing non-ARC/INFO data into ARC/INFO, and re-projecting data from one earth coordinate system into another. The next step will be to convert geographic data extracted from these documents into GIS form. It is expected that these will primarily consist of text references, embedded maps and illustrations, and CAD drawings. Any diagrammatic or map-based information will be digitized as accurately as possible. Locational references contained in the text, such as place names, will be interpreted as well as possible into GIS representations. These representations are expected to take the form of points, lines, and polygons. Dynamic segmentation will be used to represent points along streams and stream reaches (this is the method used by state natural resource agencies). Passages or tables from these documents that characterize the recommendations or actions will be summarized and codified as described in the last section.

The emphasis in presenting the information contained in the database to the user community will be on interactive access rather than cartographic products. The ARC/INFO family of software includes a PC-based package called ArcView, which facilitates access to a GIS database. ArcView runs in the Windows environment and is designed to be intuitive and user-friendly while providing much of the data access, manipulation and display functionality of the parent ARC/INFO software. Complex queries can be constructed to select subsets of the data, and tabular attributes associated with map features can be related spatially. Ad hoc maps can be created by individual users that meet their needs. The GIS database will be delivered as a stand-

COST ESTIMATE

The following is a summary of anticipated time and costs required to complete the Upper Chehalis portion of the study (Phase I). Time and costs for Phase II, Lower Chehalis, are estimated to be about the same. Labor costs are based on a three-tiered rate structure that includes Research Assistant ($34.20/hour), GIS Technician ($54.15/hour), and GIS Analyst ($71.25/hour). These are "burdened" rates that include overhead and profit as indicated in Exhibit G-1. Project management time will be billed at the GIS analyst rate.

Task Description	Expense Category	Hours	Cost
Document Screening and Annotation	Reimbursable		300
Track down documents and screen	Research Assistant	120	4,104
Supervision, analysis, and write-up	GIS Analyst	40	2,850
GIS Database Design	Reimbursable		100
Interpret GIS data from documents	Research Assistant	20	684
Interpret GIS data from documents	GIS Technician	40	2,166
Supervision, database design, and write-up	GIS Analyst	48	3,420
Database Implementation	Reimbursable		318
Interpret GIS data from documents	Research Assistant	40	1,368
Digitize/convert data and populate database	GIS Technician	100	5,415
Supervision, database tuning, write-up	GIS Analyst	60	4,275
Total Estimated Costs			25,000

Reimbursable expenses include transportation costs in the Puget Sound area to track down GIS data and documents, and plotter supplies to create proof plots. This cost estimate represents a best guess of expected labor and material costs required to complete the work. It is based on information provided to date on the scope of the study and is subject to revision based on supplemental information. Reimbursable expenses and labor will be billed monthly on a time and materials basis.

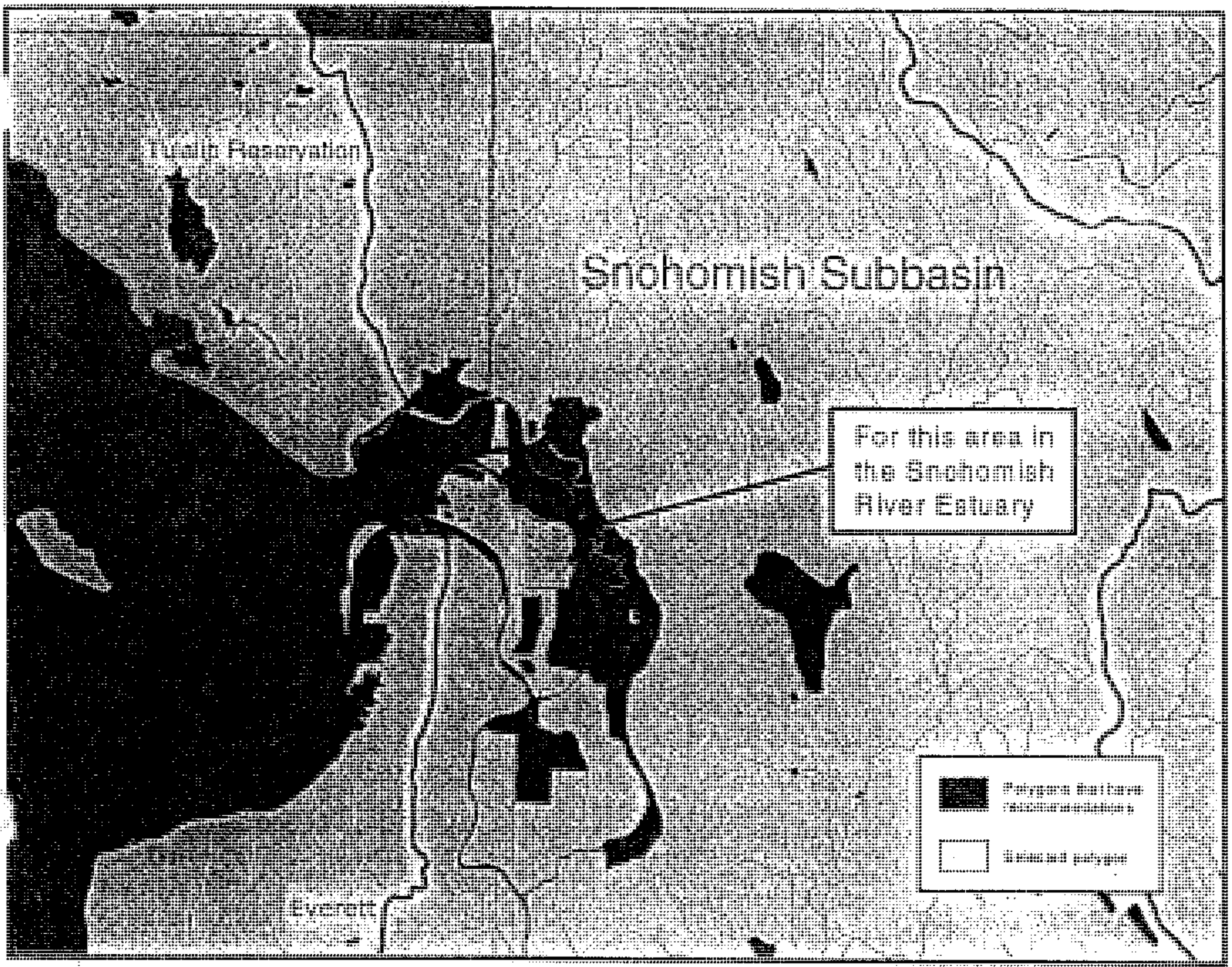
Note: This quotation is provided in confidence to Pacific International Engineering of Edmonds, Washington. It may be shared without prior notice with other agencies or individuals directly involved in the Upper Chehalis Flood Reduction Project and with the WSDOT Environmental Affairs Office.

Greg Konkel

Greg Konkel, President

9/8/98

Date



Doc no	Preserve	Mitigate	Enhance	Restore	Fishhab	Waterqual	Wetland	[illegible]
D003	X						X	Maintain existing signifigant areas of scrub-
D004			X				X	Build new dike from Ebey Slough to Steamboat
D004			X				X	Remove dike(s).
D004		X					X	Monitor for invasive species.
D005	X						X	Purchase for preservation with adjustments tc
D003				X			X	Excavate channels to pre-dike depths.
D003				X			X	Restore tidal emergent habitat.
D003				X			X	Restore to full tidal regime.
D003			X				X	Create islands out of remaining dike areas.
D003			X				X	Fill interior drainage ditches, leave larger
D003			X				X	Grade dike down to provide natural shelf trar
D003			X				X	Reconnect remnant tidal streams and sloughs.
D003			X				X	Removal of maximum area of dike.
D003			X	X			X	Restore and enhance 25 ft inland edge of buff
D004		X		X			X	Purchase as leverage for acquiring other site
D003				X			X	Restore tidal emergent habitat.
D003				X			X	Restore to partial tidal in order to protect
D003			X				X	Fill interior drainage ditches, leave larger
D003			X				X	Reconnect remnant tidal streams and sloughs.
D003			X	X			X	Restore and enhance 25 ft inland edge of buff

Pacific International Engineering
Pharos Corporation
Joint Venture Consultants

October 1, 1998

To: Distribution List

Fm: Albert Liou, P.E.

Re: Chehalis River Basin Flood Control Project Floodplain Modification Alternative

Enclosed for your review is a copy of the report entitled "Description of Floodplain Modification Alternative" for the Chehalis River Basin Flood Control Project.

The Report is being distributed in response to a request of the Technical Committee during it's September 17, 1998 meeting. At that meeting, Pacific International Engineering,PLLC verbally presented this new alternative, which involves a concept of bypassing flood flows through SR-6 and the floodplain east of Scheuber Rd. Further discussion of this alternative is expected during the Alternative Subcommittee Meeting scheduled for October 8, 1998.

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envisioned that the right-bank (east-bank) would be excavated. In conjunction with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway. A schematic sectional view of the bridge is shown in Figure 8.

The existing City of Centralia wastewater treatment plant is located immediately downstream of the Mellen St. Bridge. Studies are currently underway to investigate the possibility of moving the treatment plant to a downstream location. The current site has very little room for expansion to meet the future needs of the area.

SR-6 Vicinity Floodplain Modifications

General

The City of Chehalis experiences flooding between the 13th St. Interchange and the Main St. (SR-6) Interchange, along I-5. Two railroads pass under I-5 between these two interchanges, creating openings in the I-5 embankment. During major flooding on the Newaukum River, floodwaters from the Newaukum River spill over through Stan Hedwall Park and into nearby Dillenbaugh Creek and flow through the railroad openings to the east-side of I-5. The Mellen St. Bridge vicinity floodway excavation, presented in the previous section as the second part of the Floodplain Modification Alternative, would not substantially reduce this flooding.

Floodway excavation on the Chehalis River from shortly downstream of the SR-6 Bridge (RM 74.55) up to the mouth of the Newaukum River (Chehalis RM 75.15) was evaluated previously in the Pre-Feasibility Report (PIE, 1998). The SR-6 Bridge embankment constricts flood flows on the Chehalis River in much the same way as the Mellen St. Bridge downstream. This flow constriction is partially responsible for backing up Newaukum River and Dillenbaugh Creek flood flows. Floodway excavation of approximately 800,000 cubic yards of material in this reach of the Chehalis River would result in approximately 1.5 feet of peak flood stage reduction on the lower 1.5-mile reach of the Newaukum River and Dillenbaugh Creek east of I-5, for a flood event such as the February 1996 event. Floodway excavation in this area would need to be substantially extended and increased downstream if further flood stage reduction is required.

More cost-effective and environmentally preferred than increasing the flood hydraulic capacity through floodway excavation is reducing peak flood flows on the Chehalis River in the SR-6 Bridge area by modifying the floodplain. Several variations of the SR-6 vicinity floodplain modifications were evaluated with the UNET model. A combination of the following described modifications would provide substantial flood stage reductions in the City of Chehalis floodplain and comprise the third

component of the Floodplain Modification Alternative. Figure 6 presents an overview plan of the floodplain modifications. Typical sections showing the floodplain modifications are presented on Figure 9.

SR-6 Flood Bypass Works

The 1.5-mile reach of the SR-6 roadway between the Scheuber Rd. intersection and the bridge crossing at RM 74.60 acts as a weir for limited overbank flows from the Chehalis River between RM 75.8 and RM 77.4, but is frequently overtopped by these flood flows. This roadway overtopping occurs when the flood exceeds the magnitude of approximately once in 5 to 7 years of recurrence interval. To prevent SR-6 from overtopping during floods up to the 100-year event and to provide a flood flow bypass to the floodplain east of Scheuber Rd., a 1500-foot section of the SR-6 roadway adjacent to an existing oxbow lake at RM 77 would be modified. The proposed modifications would involve excavating approximately 250,000 cy of the existing ground level and elevating the SR-6 roadway to provide a 5-foot vertical clearance for bypassing overbank flows to the floodplain. Additionally, approximately 60,000 cy (up to a 4-foot excavation depth) of a 500-foot by 1000-foot overbank area west of the oxbow lake to the Chehalis River would be excavated to provide more frequent overbank flow through this area. Flood bypass through the SR-6 opening to the floodplain would also occur more often as a result of this additional excavation. The floodplain along Scheuber Rd., approximately an 1,000-acre area which could provide a flood storage of up to 10,000 acre-feet, would be bypassing and storing flood flows when the river flows on the Chehalis River at RM 77 exceed the annual flood magnitude. The increase in frequency of flooding bypass and storage would provide opportunities for wetland and habitat improvements on the floodplain.

Chehalis Floodplain Fill

A north-south oriented 1.5-mile long curving strip of the Chehalis floodplain north of SR-6, averaging 1000 feet wide, would be filled by the excavated material from the Mellen St. Bridge vicinity floodway excavation. This floodplain fill is intended to form a drainage divide for creating two separate hydraulic regimes between the floodplain bypass/storage area and a 3-mile reach of the mainstem Chehalis River downstream of the SR-6 Bridge (RM74.6 to RM 71.6).

Flood flows bypassing through the modified SR-6 overflow site to the floodplain would not return to the river until the flows reach the north end of the floodplain bypass/storage area. Returning flows discharge first through the existing Scheuber Drainage Ditch and then over the low lying overbank area between RM 71.6 and RM 72.4 of the Chehalis River.

Total fill quantity was estimated to be approximately 3,540,000 cy. Top of the fill would be at a maximum elevation of 185 feet, above the 100-

year flood stage in the floodplain bypass area (estimated to be approximately at elevation 180 feet). The fill alignment generally follows the existing high ground dividing the low-lying floodplain to the west and the river channel (between RM 72.4 and RM 74.6) to the east. The fill would be constructed with mild finished side slopes (approximately 10 H to 1 V maximum slope). The proposed fill would create an additional flood storage of approximately 10,000 acre-feet in the floodplain bypass area. The floodplain bypass and storage area could also provide opportunities for environmental and habitat improvements as desired.

RM-72 Left Bank Floodway Excavation

The Airport Rd. dike and the golf course clubhouse areas (located at RM 72.3) also have constricted flood flows on the Chehalis River. Floodway modification at this area would involve excavation of the left bank above the summer normal flow level for a quantity of approximately 110,000 cy of material between RM 71.9 and 72.3. The excavated material would be used as a part of the floodplain fill to create the drainage divide just south of the floodway excavation site. Planting and habitat improvement features, as required, would be incorporated into the design and construction of this floodway excavation in a way similar to the Mellen St. Bridge floodway modifications previously discussed.

Newaukum Floodplain Fill

The drainage divide between the Newaukum River and Dillenbaugh Creek would be raised (up to 7 feet high) at the location between the City of Chehalis Stan Hedwall Park and WSDOT's planned wetland mitigations site just north of the park. Raising this divide would require a total fill of approximately 35,000 cy of material covering an area approximately 2,000 feet long by 180 feet wide. The top of the fill would be at elevation 184 feet, one foot above the reduced 100-year level flood upon implementation of this alternative. The fill would tie to the existing high ground on both ends; to the east, the Rice Rd. off ramp at the 13th St. Interchange and to the west, the Burlington Northern Railroad embankment. The proposed fill would prevent overbank flows from entering through the railroad underpass of I-5 onto the City's floodplain east of I-5. This overbank flow could occur either from the Newaukum River overtopping its banks and flooding the park or from upper Dillenbaugh Creek overtopping the low-lying section of Rice Rd. at the park.

The fill would be constructed within the WSDOT wetland mitigation site and would not impede any existing wetlands in the area, nor the Dillenbaugh Creek streambed or normal flow conditions. Fill material would be from the wetland site excavation. Coordination with WSDOT for design and construction of the wetland and the fill would be required.

Flood Stage and Peak Flow Reductions

Providing 20,000 acre-feet of flood control storage at Skookumchuck Dam would substantially reduce flood stages and peak flows on the Skookumchuck River. Modifications of the Mellen St. Bridge vicinity floodway and the SR-6 vicinity floodplain would achieve substantial flood stage reductions on the Chehalis River between Skookumchuck River and Newaukum River, including its tributary backwater areas. The amounts of flood stage and peak flow reductions at various locations along the Skookumchuck and the Chehalis rivers were estimated by comparing the differences between pre-project and post-project conditions. The UNET model calibrated for the February 1996 flood under the existing baseline (or pre-project) conditions was modified to incorporate the Skookumchuck Dam flood control operation and the Chehalis River floodway and floodplain modifications.

The Skookumchuck Dam modifications anticipate operation of the dam for flood control during flood events. The Skookumchuck Dam flood control operation would follow a release schedule which includes releases being maintained at a minimum outlet discharge of 95 cfs prior to passing of the flood peak, then being gradually increased at a rate of 500 cfs per hour after the flood peak is over, and finally being maintained at a maximum discharge of 3,000 cfs for up to three to five days to completely evacuate the stored flood water, making the 20,000 acre-feet flood control storage available for the next storm event.

The floodway excavation in the Mellen St. Bridge vicinity would achieve a 100-year flood stage reduction of over 4 feet in the area upstream of the Mellen St. Bridge to the lower Salzer Creek floodplain east of I-5. The existing I-5 low point (elevation 169) along the Centralia-Chehalis Airport stretch is five feet below the low point (elevation 174) of both the Tacoma Eastern Railroad embankment to the east and the Airport Road dike to the west. A four-foot flood stage reduction resulting from the floodway excavation would keep I-5 from being flooded by a 100-year flood event.

Runs of the modified UNET model for post-project conditions were executed, incorporating the Skookumchuck Dam flood control operation and the Chehalis River floodway and floodplain modifications. Run results for post-project conditions in comparison with modeling results for the pre-project conditions are shown in Table 1 through Table 3, and Figure 10 through Figure 18. Brief summaries of the results shown in the tables and figures are provided immediately below.

Figure 10 and Figure 11 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the Skookumchuck River for the February 1996 flood. A summary of flood stage reductions at various locations on the Skookumchuck River is presented in Table 1. Comparison of the flood stage and peak flow profiles indicates that

overbank flows flooding the City of Centralia streets and buildings under the pre-project conditions would be almost completely eliminated upon completion of the project.

Figure 12 and Figure 13 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the Chehalis River for the February 1996 flood. A summary of flood stage reduction at various locations along the Chehalis River between the Newaukum River confluence and the Mellen St. Bridge, including the lower Dillenbaugh and Salzer Creek areas, is presented in Table 2. Comparison of the profiles for the February 1996 flood indicates that overtopping of the Airport Road dike and the Tacoma Eastern Railroad embankment, causing I-5 to be flooded, would be eliminated as a result of implementation of the project. Also, both overtopping of SR-6 between the Scheuber Rd. intersection and SR-6 Bridge at RM 74.6, and overtopping of the SR-603 Bridge south embankment at RM 77.6, would be eliminated.

Figure 14 and Figure 15 show comparisons of pre-project and post-project flood stage and peak flow profiles, respectively, on the lower Newaukum River for the February 1996 flood. A summary of flood stage reduction at various locations along the Newaukum River between Devereese Rd. Bridge and Stan Hedwall Park is presented in Table 3. Comparison of the profiles for the February 1996 flood indicates that overtopping of I-5 north of the 13th St. Interchange would be eliminated as a result of implementation of the project.

Table 4 shows a comparison of pre-project flood frequency and post-project equivalent flood frequency based on the modeled flood stages and the associated flood frequency numbers revised by USACE in late 1997 (USACE, 1997a) for the existing basin conditions. This comparison is shown at the Mellen St., Pearl St., and Bucoda gage locations, as well as the lower tributary reaches within the Chehalis River backwater areas, for the February 1996 flood event. For example, the February 1996 flood stage at the Mellen St. location corresponds to the 100-year flood level under existing conditions. Upon completion of the project, the February 1996 flood stage at Mellen St. would be reduced to the 10-year flood level.

Figure 16 through Figure 18 show comparisons of pre-project and post-project flow hydrographs on the Chehalis River at the Grand Mound Gage (RM 60.0), Moon Road (RM 53.0) and Anderson Road (RM51.5) for the February 1996 flood event. These locations are all downstream of the project area. The flow comparison at these locations indicate that the post-project peak flow and time duration of flooding would be slightly reduced from the pre-project conditions. The peak flow reduction, though small (up to 2,870 cfs), would mean that the flood stage downstream of the project area would also be slightly reduced, though immeasurably (up to 0.2 feet).

Figure 19 shows a comparison of pre- and post-project approximate inundation areas for the 100-year flood (approximating the February 1996 flood). The post-project flood stage reduction includes the effects of modifications to Skookumchuck Dam, floodway excavation in the Mellen St. Bridge area, and floodplain modifications in the SR-6 vicinity. As this figure indicates, a substantial reduction of floodplain inundation area could be achieved as a result of the implementation of the Floodplain Modification Alternative. This map is preliminary only and will be refined in the next phase of work.

Table 1: Comparison of Pre-Project and Post-Project Flood Stages on the Skookumchuck River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
10.86 (Upstream of Tono Rd. Bridge)	246.75	242.85	3.90
6.17 (Bucoda Gage)	210.78	207.21	3.57
4.53 (Upstream of SR-507 Bridge)	202.58	200.05	2.53
2.3 (Pearl St. Gage)	187.28	185.84	1.44
0.61 (Upstream of Harrison St. Bridge)	175.98	172.60	3.38

Table 2: Comparison of Pre-Project and Post-Project Flood Stages on the Chehalis River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
75.15 (Newaukum River confluence)	182.11	179.85	2.26
74.63 (Upstream of SR6 Bridge)	180.95	178.64	2.31
72.70 (S. end of airport/River St.)	178.76	177.31	1.45
69.16 (Salzer Cr. confluence)	176.35	171.84	4.51
67.51 (Upstream of Mellen St. Bridge)	174.82	170.19	4.63
67.44 (Mellen St. Gage)	174.27	170.06	4.21
Dillenbaugh Cr. at Chehalis Ave./Third St., N.E. of I-5	182.72	179.65	3.07
Salzer Cr. at BNRR Bridge, E. of I-5	176.56	171.93	4.63

Table 3: Comparison of Pre-Project and Post-Project Flood Stages on the Newaukum River during February 1996 Flood

Location	Pre-Project	Post-Project	
RM (river mile)	Max. WS El (ft)	Max. WS El (ft)	Stage Reduction (ft)
1.88 (Stan Hedwall Park)	183.77	183.24	0.53
1.64 (Downstream of BNRR Bridge)	182.66	180.89	1.77
0.57 (Upstream of Rail to Trail Bridge)	182.52	180.40	2.12
0.11 (Upstream of Devereese Rd. Bridge)	182.37	180.12	2.25

Table 4: Comparison of Pre-Project and Post-Project Feb-1996 Flood Stage Recurrence Intervals (based on flood stages under existing flood conditions)

Stream & Location	Pre-Project Recurrence Interval (year)	Post-Project Recurrence Interval (year)
Chehalis River @ Mellen St.	100	10
Skookumchuck River @ Pearl St.	70	10
Skookumchuck River @ Bucoda	180	5
Lower Newaukum River, Salzer Creek and Dillenbaugh Creek (within the Chehalis River backwater areas)	100	10

Cost Estimates

A preliminary cost estimate has been developed for the Floodplain Modification Alternative. All costs are presented in 1998 dollars and exclude interest during construction. The estimates include contractor's overhead and profit, sales tax, engineering and permitting, and a contingency appropriate to this phase of studies.

It should be noted that the estimated costs are preliminary only, and are contingent upon approval of the proposed design by resource agencies and other interested parties. The final project costs for the proposed design would also depend on final design details and price factors, and could vary from the estimates presented here.

Quantity estimates were made from work items and materials for the main components of the proposed design. Approximate unit prices were developed from previous cost estimates by USACE and WSDOT, bid prices from similar projects, and quotes from manufacturers and contractors.

The estimates are broken into three parts: Skookumchuck Dam modifications, floodway and floodplain modifications, and total overall project costs, including annual operation and maintenance (O&M) costs.

The estimated construction cost for the proposed modifications to Skookumchuck Dam is $10,834,745. A breakdown of this cost is shown in Table 5. The estimated construction cost for the Mellen St. Bridge area floodway and floodplain modifications is $51,271,849. The cost breakdown is shown in Table 6. The major cost item for the floodway and floodplain modifications is for the floodway excavation between RM 65.9-68.3, and the related hauling and fill placement. Street legal haul vehicles were assumed to be used over existing roads Construction work was assumed to be limited to 8 hours a day, five days a week.

A summary of overall project costs and estimated annual O&M costs is included in Table 7. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area floodway and the SR-6 vicinity floodplain modifications, along with habitat improvements would be $67,106,594, and would have annual O&M costs of approximately $300,000. The O&M costs consist of annual flood control operation of Skookumchuck Dam, maintenance for clearing debris and excess vegetative growth from the floodway excavation, and maintenance for habitat improvements. The level of mitigation, or the exact nature of habitat improvements required if this alternative is implemented is not known at this time. As a result, the estimated costs for mitigation or habitat improvements, and their associated annual maintence

costs could change substantially. Mitigation costs could include additional land aquisition, as well as permitting, engineering, and construction costs.

Table 5:
Preliminary Cost Estimate
Skookumchuck Dam Modifications

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$350000	$350,000
Diversion and Care of Water	1	LS	$25,000	$25,000
Cofferdam	1	LS	$50,000	$50,000
Excavation	24,250	CY	$50	$1,227,500
Rock Support	1	LS	$450,000	$450,000
Concrete Demolition	750	CY	$150	$112,500
Cast-in-place Concrete	3,450	CY	$450	$1,552,500
Trashracks	2	EA	$100,000	$200,000
Slide Gates	2	EA	$175,000	$350,000
Bulkhead Gate	1	LS	$60,000	$60,000
Misc. Metals	1	LS	$50,000	$50,000
Rubber Weir	1	LS	$1,250,000	$1,250,000
Misc. Electrical	1	LS	$18,000	$18,000
Control House	1	LS	$40,000	$40,000
Monitoring & Comm. Sys.	1	LS	$215,000	$215,000
Subtotal				**$5,950,500**
Contingency (@25%)				$2,082,675
Subtotal (w/contingency)				**$8,033,175**
Sales Tax (@7.9%)				$634621
Direct Construction Cost				**$8,667,796**
Engineering and Permitting				$2,166949
Total Cost (1998 Price Level)				**$10,834745**

Table 6:
Preliminary Cost Estimate
Floodway and Floodplain Modifications

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$1,300,000	$1,300,000
Erosion & Sediment Control	1	LS	$250,000	$250,000
Clearing and Grubbing	275	AC	$7,500	$1,725,000
Access Roads	1	LS	$400,000	$400,000
Removal of Existing Structures	1	LS	$500,000	$500,000
Excavation & Fill (65.9-68.3)	3,200,000	CY	$5	$16,000,000
Excavation & Fill (71.9-72.3)	110,000	CY	$3.50	$385,000
Replanting Disturbed Areas	230	AC	$5,000	$1,150,000
Mellen St. Bridge Modifications	1	LS	$3,000,000	$3,000,000
SR-6 Roadway Modifications	1	LS	$5,789,039	$5,789,039
	Subtotal			**$30,499,039**
	Contingency (@25%)			$7,624,760
	Subtotal (w/contingency)			**$38,123,799**
	Sales Tax (@7.9%)			$3,011,780
	Direct Construction Cost			**$41,135,579**
	Engineering and Permitting			$4,936,270
	Land Acquisition			$5,200,000
	Total Cost (1998 Price Level)			**$51,271,849**

Table 7:
Summary of Costs for Floodplain Modification Alternative

Item	Amount
Skookumchuck Dam Flood Control Storage	$10,834,745
Floodway & Floodplain Modifications	$51,271,849
Mitigation/Habitat Improvements	$5,000,000
Total Construction Cost	$67,106,594
Annual O&M Costs	$300,000

Economic Evaluation

USACE recently completed a pre-reconnaissance evaluation of flood damage reduction estimates for the combined Skookumchuck Dam modifications and the Mellen St. Bridge vicinity floodway excavation alternatives presented in the Pre-Feasibility Report (PIE, 1998) for Lewis County. Based on 1998 prices and conditions, the average annual flood damage reduction benefits were estimated to be $1,137,000 and $415,000 in the Skookumchuck area and the Chehalis area, respectively (USACE, 1998). Average annual benefits resulting from prevention of flood damage totals $1,552,000. This total does not include benefits resulting from prevention of flood damage in Newaukum River and Dillenbaugh Creek floodplain within the City of Chehalis.

In addition to the benefits resulting from the prevention of flood damages, there is the added benefit that I-5 would not have to be elevated as part of WSDOT's I-5 widening project. According to WSDOT (1998), the incremental cost of raising the elevation of I-5 to two feet above the 100-year flood would be $107,953,555 including the cost of preliminary engineering. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area floodway excavation, and the SR-6 Bridge vicinity floodplain modifications is $67,106,594 with estimated annual O&M costs of approximately $300,000.

The project costs and all resulting benefits were evaluated at a 7-1/8 percent discount rate (the federal discount rate for water resource projects) over a 50-year economic analysis period. The total average annual benefits are estimated at $9,498,000 and the total average annual costs are estimated at $4,811,00 resulting in a benefit-to-cost ratio of 1.97 for this project alternative. Table 8 summarizes the potential project benefits and costs. The benefit-to-cost ratio would be greater for this alternative if benefits resulting from prevention of flood damage in Newaukum River and Dillenbaugh Creek floodplain within the City of Chehalis are included in the economical evaluation.

Table 8:
Benefit-Cost Evaluation – Floodplain Modification Alternative

Item	Average Annual Figures
Annual Benefits	
Skookumchuck Area	$1,137,000
I-5 Cost Savings	$7,946,000
Chehalis Area	$415,000
Total Annual Benefits	**$9,498,000**
Annual Project Costs	
Skookumchuck Dam Modifications	$971,000
Floodway and Floodplain Modifications	$3,840,000
Total Annual Costs	**$4,811,000**
Benefit-To-Cost Ratio[1]	**1.97**

Environmental and Permitting Issues

Skookumchuck Dam Modifications

Investigations conducted for the USACE Skookumchuck Dam Modification Project identified several potential environmental impacts relating to wildlife habitat and fishery resources, water supply, water quality, and dam safety. The following discussion is based upon those investigations and analyses; additional studies would be required during the next project phase to further define potential impacts that could occur if this alternative is implemented.

The existing reservoir drawdown zone provides approximately 65 acres of vegetated habitat that is important to wildlife (USFWS, 1989). This zone is used by waterfowl, deer, elk, and other wildlife. Changes in reservoir levels associated with a new flood control operation rule curve could induce changes in vegetation and loss of wildlife food and cover. Water dependent mammals like beavers and muskrats could be negatively affected by fluctuations in wintertime reservoir levels.

Downstream of the dam, wetlands and riparian habitat along the Skookumchuck River could be affected by a reduction in overbank flow. The degree to which these wetlands are dependent on flood flows for recharge is not known at this time; to evaluate specific wetland areas that could be indirectly affected by flow modifications and to identify measures to avoid and minimize impacts to wetlands, surveys would be needed in the next study phase. Studies would also be required to assess the value of potentially affected wildlife habitats, both within and downstream of the reservoir area.

Operational changes may affect resident fish inhabiting the reservoir, and under some conditions could impair the outmigration of juvenile steelhead (USFWS 1989). Such changes, which could occur if the reservoir pool failed to refill prior to the beginning of March, could result in insufficient water to pass outmigrating fish over the spillway. Operational changes could also potentially affect the supply of water to the WDFW fish rearing facility downstream of the dam. An analysis of the reservoir flood control operation rule curve would be needed to assess the likelihood of such events.

The existing maximum velocity on the Chehalis River is up to 12 fps downstream of the Mellen St. Bridge. The recommended alternative would bring the maximum velocity in this area down to approximately 3-4 fps. Upstream of the Mellen St. Bridge, the existing maximum velocity would be increased from about 2 fps to 4 fps. The estimated changes in velocity would reduce both sedimentation above the bridge and erosion below the bridge.

With flood control storage at Skookumchuck Dam, peak velocities would decrease along the Skookumchuck River. The recommended alternative would decrease the maximum velocities around Bucoda from about 2.5-8 fps to between 2-6.5 fps. Although the peak velocity would decrease, the time-period during which the velocity is between 5 and 6 fps would increase. Whether or not effects of the increased duration of this range of velocity would result in scouring problems is currently unknown. Further analysis would be needed in the next phase of studies to determine the erodibility of the channel materials in various locations.

Other potential impacts to fish could occur as a result of changes in water temperatures, increases in reservoir turbidity, and the transport of sediments downstream. Increases in turbidity levels could result from erosion of exposed reservoir slopes during pool drawdown periods. Undefined at this time is the effect of flow changes on fishery resources. Beneficial effects could include a reduction in scouring of spawning beds; adverse impacts could result from rapidly changing river levels, especially during spawning and incubation periods. Due to the storage volume to be provided by the Skookumchuck Dam modifications, it is likely that seasonal streamflows could be augmented to enhance conditions for anadromous fish. An analysis of fish habitat under various flow regimes would be conducted to evaluate these opportunities.

Measures considered by USACE to mitigate for wildlife impacts associated with its Skookumchuck Dam modification proposal included the transfer of 50 acres of forested land for incorporation into the Skookumchuck Habitat Management Area and construction of wood duck nesting boxes. The level of mitigation required if the recommended alternative is implemented is not known at this time. Mitigation costs could be substantial and could include land acquisition as well as permitting, engineering, and construction costs.

Mellen St. Bridge Vicinity Floodway Excavation

Floodway excavation would involve disturbance of wetlands and riparian habitats, and potentially could increase erosion and affect water quality. Although impacts to fish habitats would occur, floodway excavation would involve significantly less direct disturbance of in-stream habitats than channel excavation, and offers the potential to provide a net habitat benefit. Floodway excavation would also avoid the high level of impact to the built environment that would be associated with secondary channel construction.

Wetlands are interspersed with upland habitats along the entire proposed excavation length of the river. The area and magnitude of the potential impact to wetlands would depend on the ultimate floodway width and the reach or reaches selected for excavation. Wetlands are particularly extensive along RM 67, at the confluence with the Skookumchuck River.

Excavation in this reach would result in wetland disturbance. Wetlands lying within the excavated floodway would be directly disturbed. Adjacent wetlands could also be indirectly affected by dewatering, either through interception of perched water tables or through reduction or elimination of periodic recharge by overbank flooding. The approximate locations of known wetlands have been mapped under the National Wetlands Inventory program. However, in the next study phase, site specific surveys would be needed to evaluate specific wetland areas that might be directly or indirectly affected and to identify measures to avoid and minimize impacts to wetlands.

Removal of wetland and riparian vegetation across the floodway width would significantly reduce the wildlife habitat value of these areas. The removal of natural vegetative cover from the floodway could fragment remaining adjacent habitats by removing their connection to the river. It is possible that these effects could be partially offset by reestablishing vegetation on the excavated floodway and along the shoreline. However, because of the need to maintain channel capacity, a cover of woody overstory vegetation cannot be reestablished on the benches. A buffer of woody overstory vegetation could potentially be reestablished along some reaches of the shoreline without significantly affecting floodway hydraulics.

Floodway excavation would increase the potential for erosion at least temporarily, until vegetation could be reestablished along the streambank. Implementation of Best Management Practices during and following construction would be particularly important to avoid impacts to water quality at the project site and downstream.

Some of the excavated material could require special handling as a result of hazardous waste contamination. Because the Sewage Treatment Plant Landfill was used as an unregulated throw and burn site until the early 1970s, hazardous wastes may be present in soil and subsurface materials in this area (FHA and WSDOT, 1997). Investigations may be required during the next study phase to evaluate hazardous waste contamination in the project area.

A National Register-eligible archaeological site exists near the Mellen St. Bridge (FHA and WSDOT, 1997). Other recorded sites, including some that may be aboriginal townsites, occur in the project area. These and currently unrecorded cultural resources could be affected by project construction. An assessment would be needed in the next study phase to identify cultural resources that could be affected by project construction.

Excavation of the floodway would affect farmlands, but would have relatively little impact on existing structures and facilities. Facilities, which would be affected, include the Centralia Wastewater Treatment Plant and the Mellen St. Bridge. The existing wastewater treatment plant site is susceptible to flooding and provides insufficient space for plant

expansion beyond the year 2025. Studies are underway to evaluate alternative sites for a new or modified wastewater treatment plant to meet the future wastewater service needs of the City of Centralia (CH2M-Hill, 1998).

Mitigation for unavoidable impacts to wetlands would be required under the provisions of the Clean Water Act and local critical areas ordinances; mitigation would also be required for impacts to fish and wildlife habitats. Mitigation costs could be substantial. Because the excavated floodway could be designed to bypass incised meanders, this alternative excavation provides opportunities to create valuable backwater refuge for fish at high flows. This type of mitigation action would be consistent with current efforts by tribal interests to create additional off-channel rearing habitat to benefit anadromous fish, and should be investigated further if the floodway excavation alternative is implemented.

SR-6 Vicinity Floodplain Modifications

The proposed floodplain modifications would have the potential to affect fish and wildlife habitats and wetlands, but would provide opportunity for significant habitat enhancement.

As described earlier, the SR-6 flood bypass would involve excavating an area between the Chehalis River and an existing oxbow lake. Construction of this flood bypass could directly affect a small area of wetland adjacent to the Chehalis River, although it may be possible to avoid this disturbance by siting the bypass outside existing wetland areas. Because this bypass is designed to carry flows from annual flood events, the hydrologic regime of the oxbow lake and its associated wetlands would likely be modified.

The Chehalis floodplain fill would affect farmed lands that provide habitat for upland game birds, waterfowl, and a variety of other wildlife. The fill would modify the visual appearance of the site, although this impact could be minimized through planting and establishment of an appropriate vegetation community. Use of the site for flood bypass and storage could affect existing farming operations. The level and significance of this impact would depend upon flooding frequency and other elements of final project design.

A variety of uses for the flood bypass and storage area, including significant habitat enhancement, can be accommodated through a process of design optimization. The types and acreages of habitat provided will depend upon the final design that results from this process, and specific design elements such as extent and duration of flooding. Opportunity exists to create a range of upland and aquatic habitats with a high degree of habitat diversity. In general, it is expected that the aquatic habitats that could be created would include wetlands with variable hydrologic regimes and off-channel habitats for anadromous fish.

The RM-72 left bank floodway excavation is not expected to affect existing wetland areas, although the excavation could involve the removal of some riparian vegetation.

As described earlier, the Newaukum floodplain fill is not expected to affect existing wetlands, nor Dillenbaugh Creek or normal flow conditions. The fill would have the potential to affect the design of the mitigation actions at the WSDOT wetland mitigation site, and coordination with WSDOT would be required in the design of both projects.

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Figure 1:
Chehalis River Basin Map

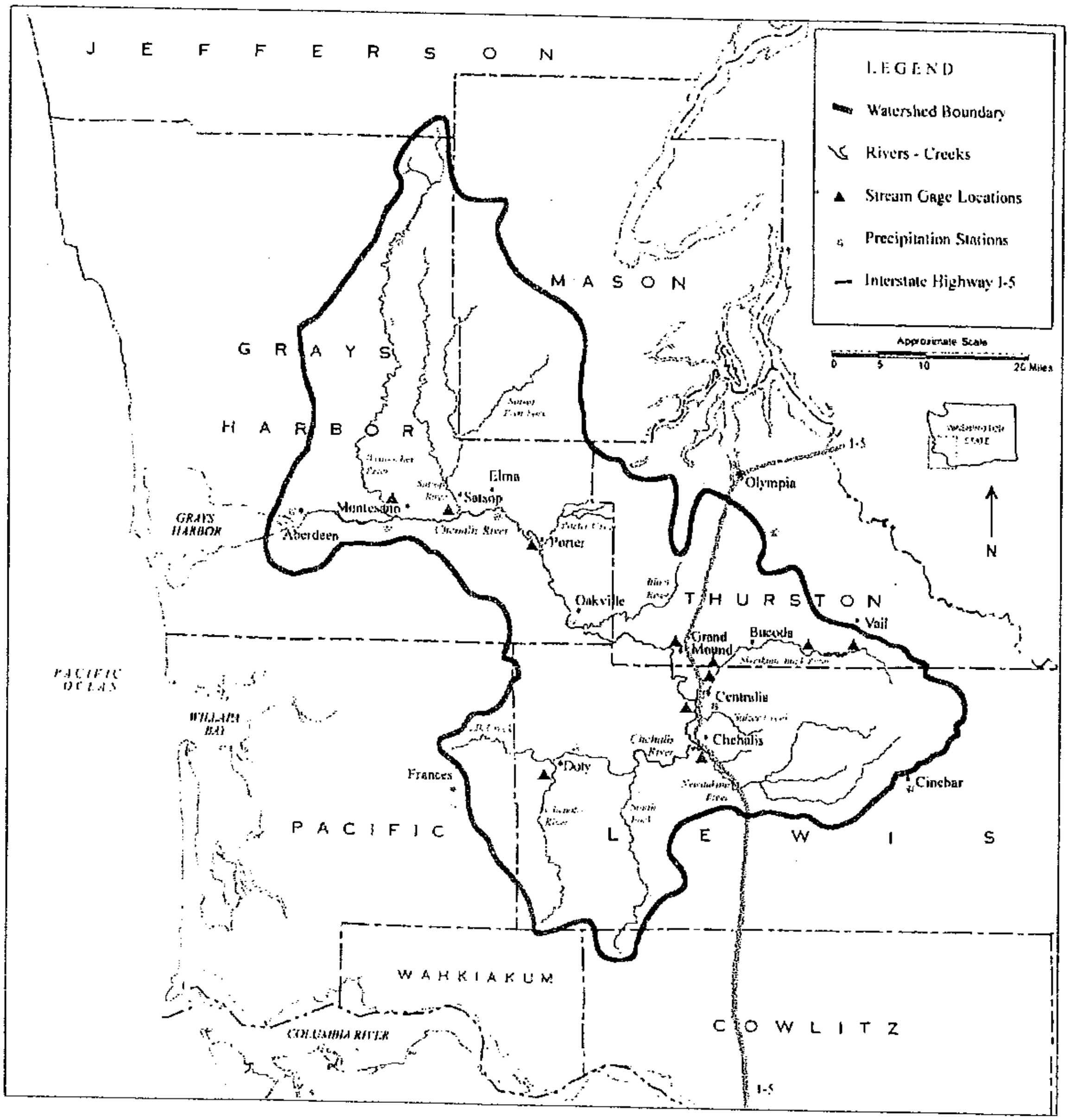


Figure 2:
Skookumchuck Dam Spillway Modifications – Plan View

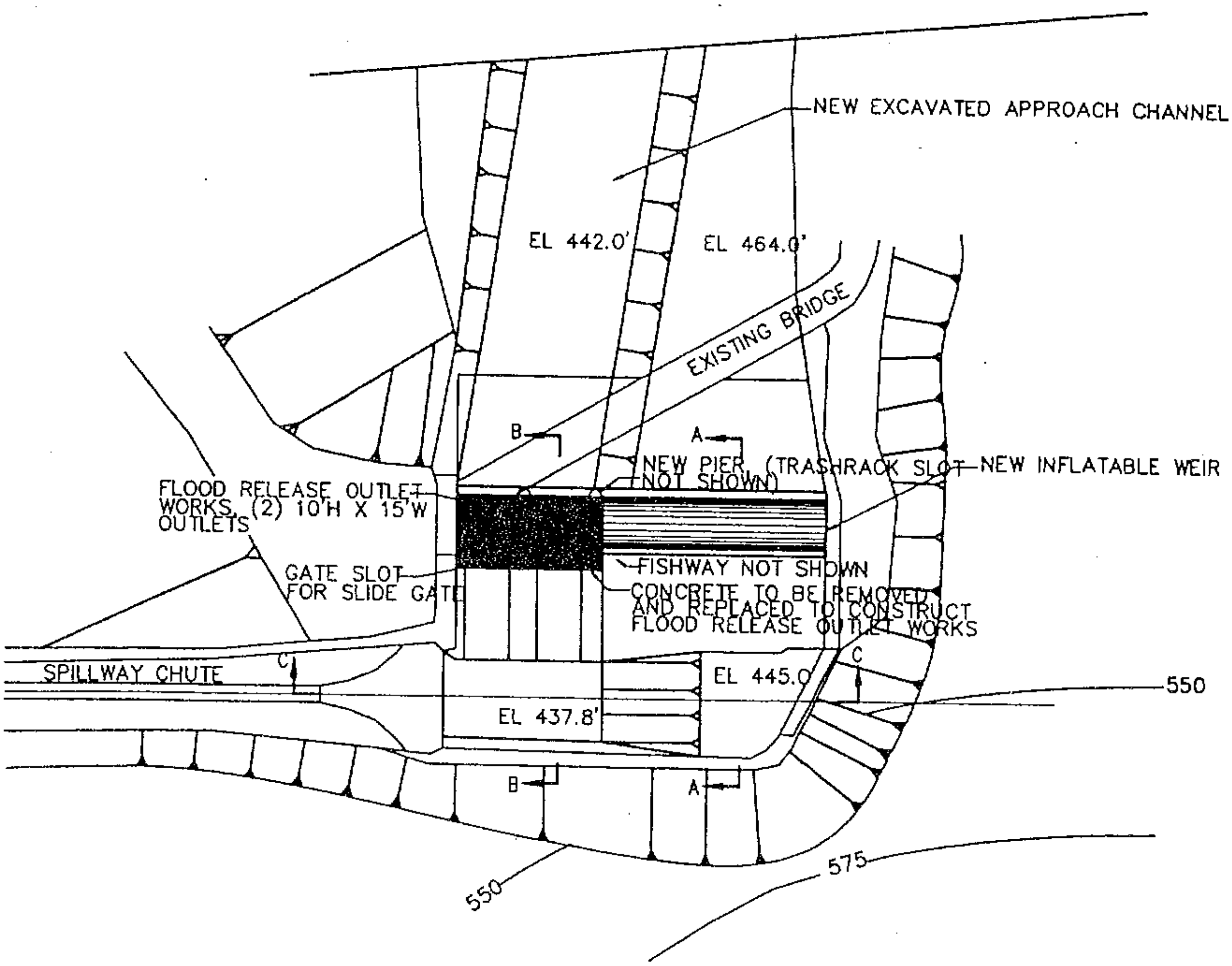


Figure 3:
Skookumchuck Dam Spillway Modifications – Downstream Elevation

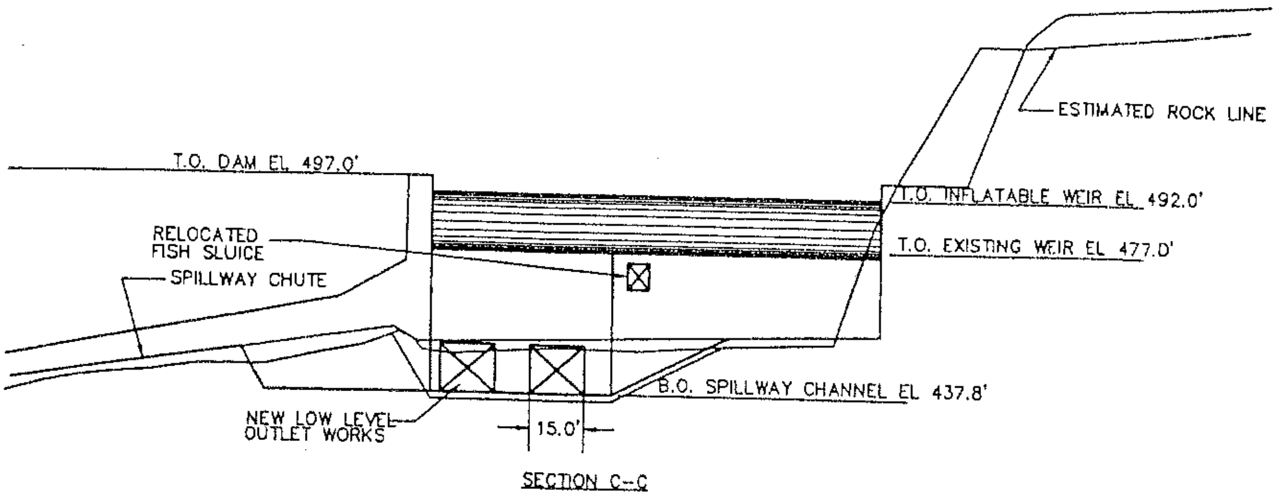
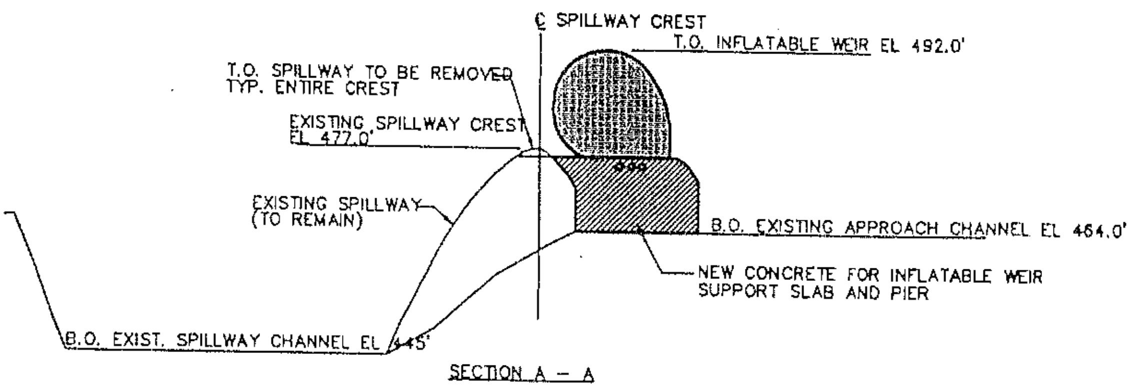


Figure 4:
Skookumchuck Dam Spillway Modifications – Sections



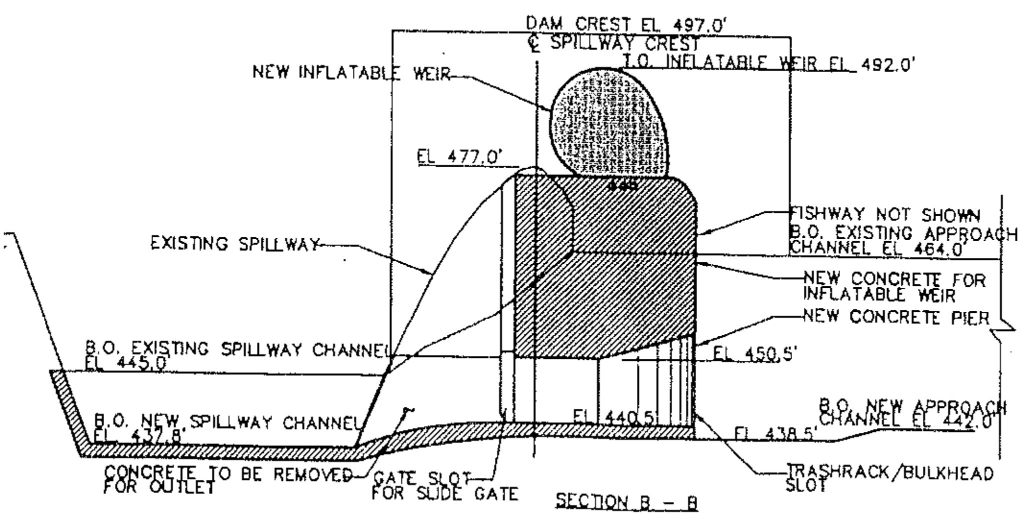
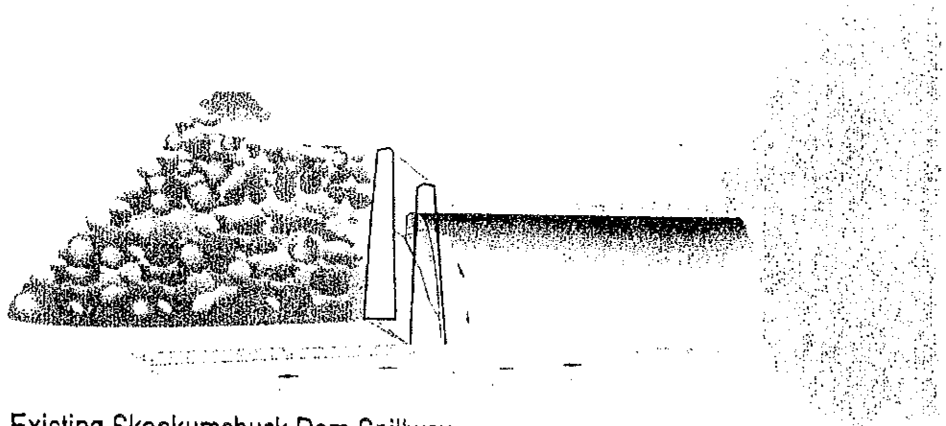
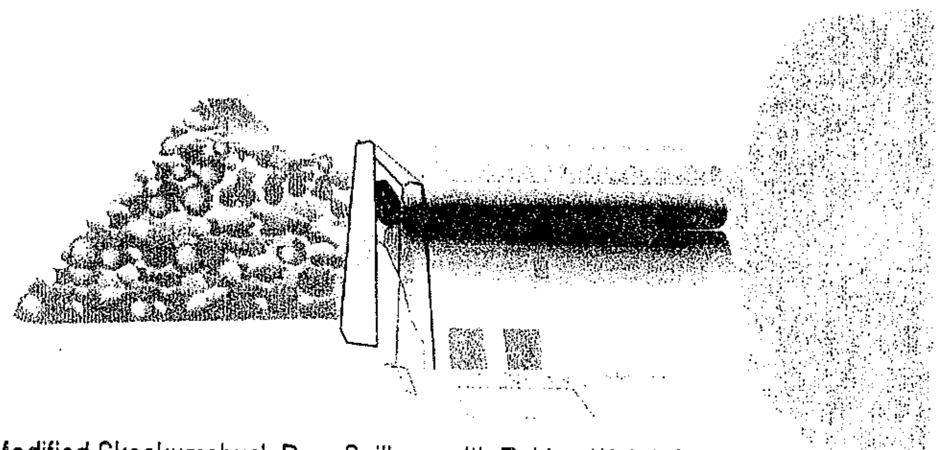


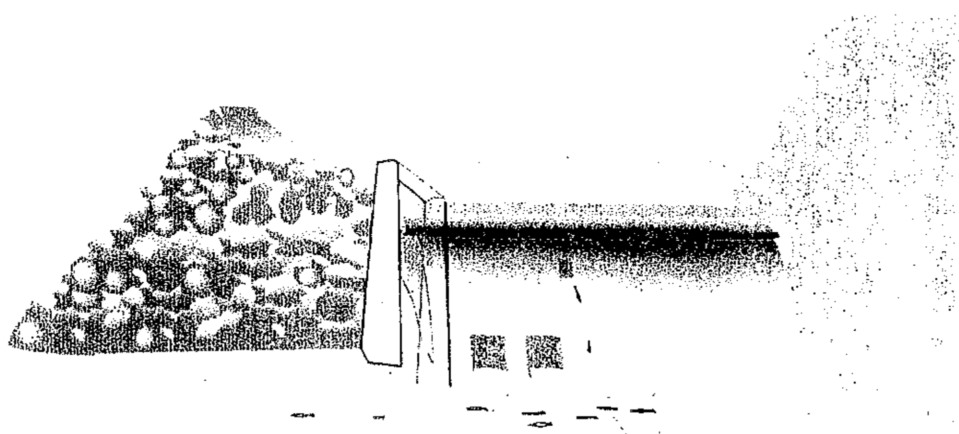
Figure 5:
Skookumchuck Dam Spillway Modifications, Section View, Artist Rendering



Existing Skookumchuck Dam Spillway



Modified Skookumchuck Dam Spillway with Rubber Weir Inflated



Modified Skookumchuck Dam Spillway with Rubber Weir Deflated

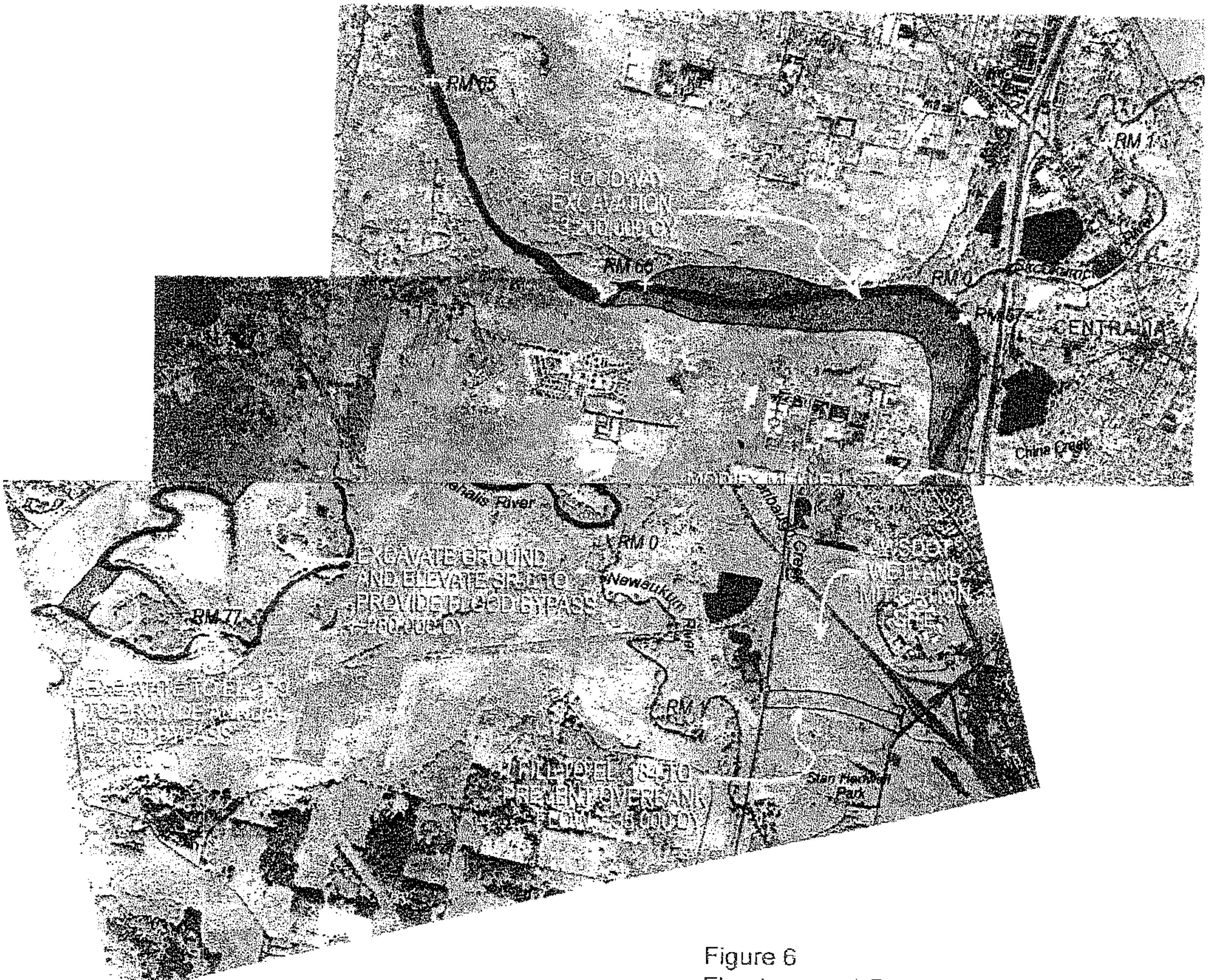
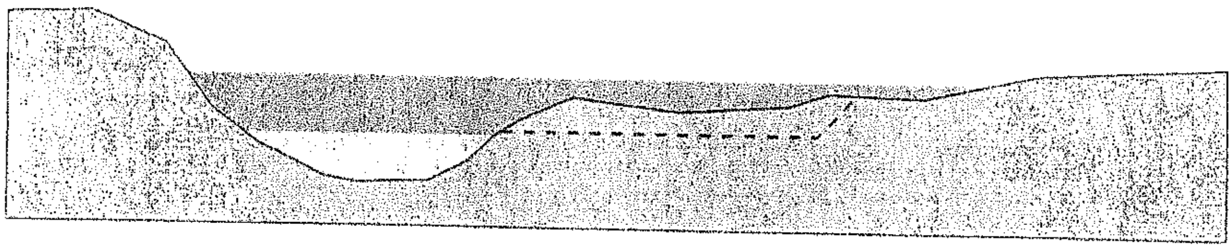


Figure 6
Floodway and Floodplain Modifications Plan

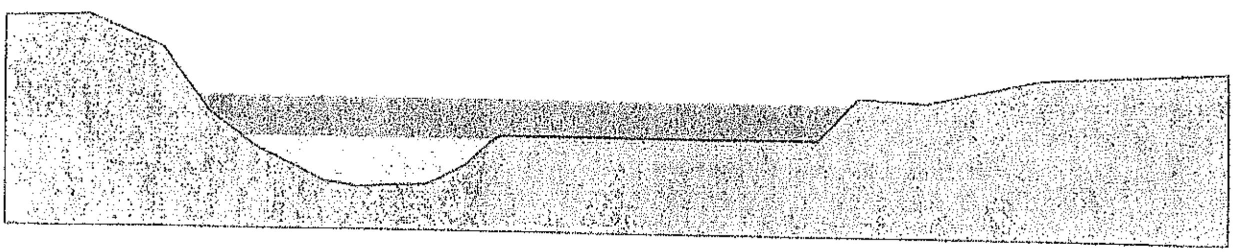
Figure 7:
Typical Floodway Excavation Section

Note: Plantings and habitat improvement plan not shown.

Existing River Cross Section



Modified River Cross Section



Normal River Stage 100 Year Flood Stage

Figure 8:
Mellen St. Bridge Modifications, Section View

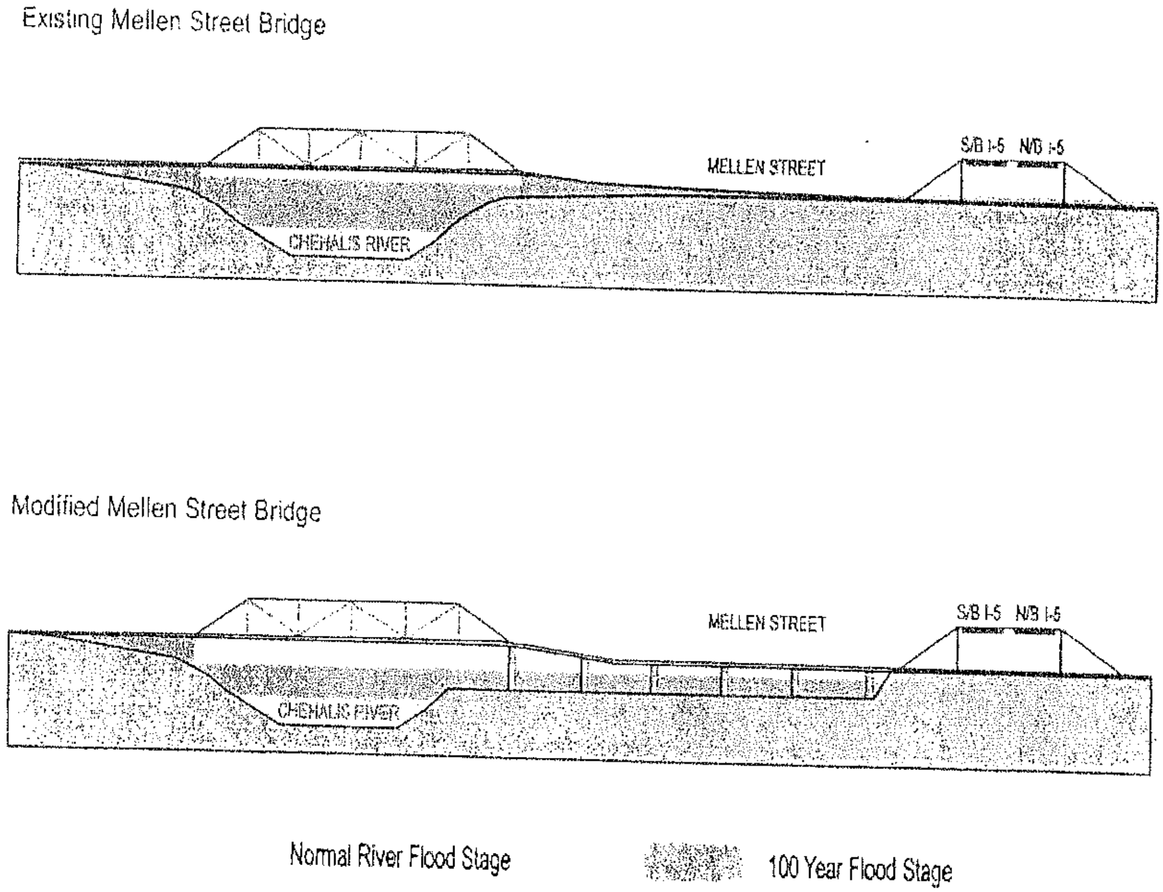
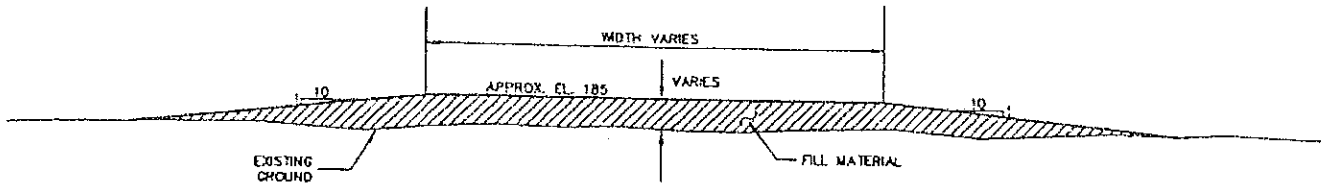
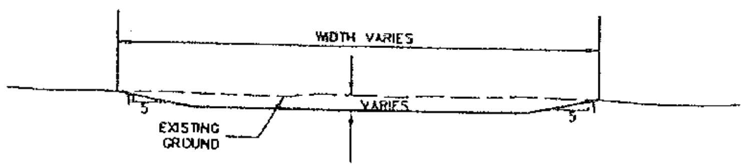


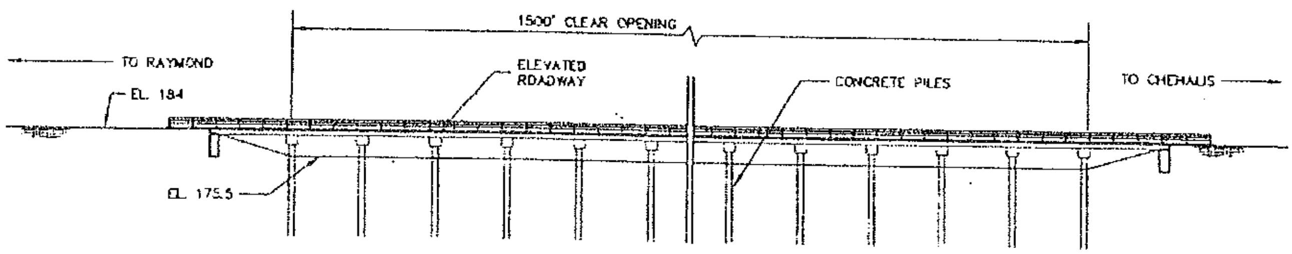
Figure 9:
Typical Floodplain Modifications - Sections



TYPICAL FILL SECTION
N.T.S.



TYPICAL EXCAVATION SECTION
N.T.S.



SR-6 ROADWAY MODIFICATION - ELEVATION
N.T.S.

Figure 10: Comparison of Pre- and Post-Project Flood Stage Profiles on the Skookumchuck River - February 1996 Flood Event

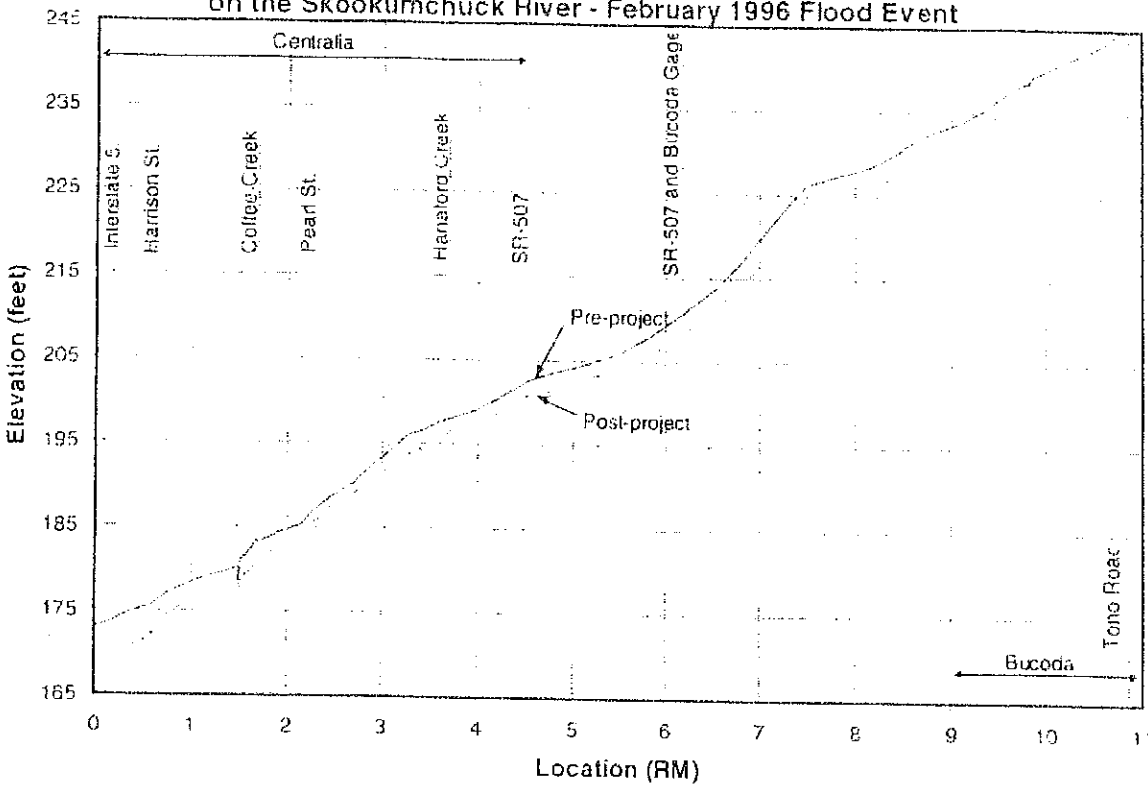


Figure 11: Comparison of Pre- and Post-Project Peak Flow Profiles on the Skookumchuck River - February 1996 Flood Event

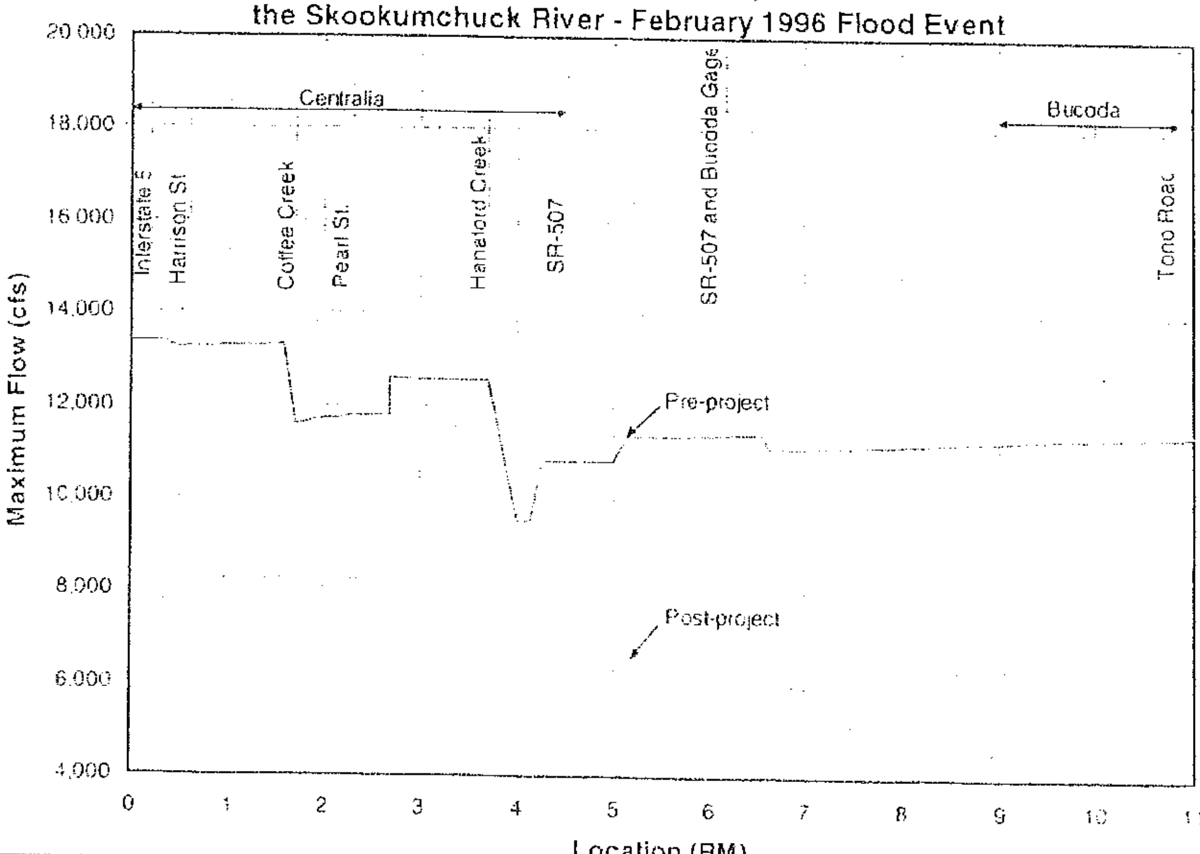


Figure 12: Comparison of Pre- and Post-Project Flood Stage Profiles on the Chehalis River - February 1996 Flood Event

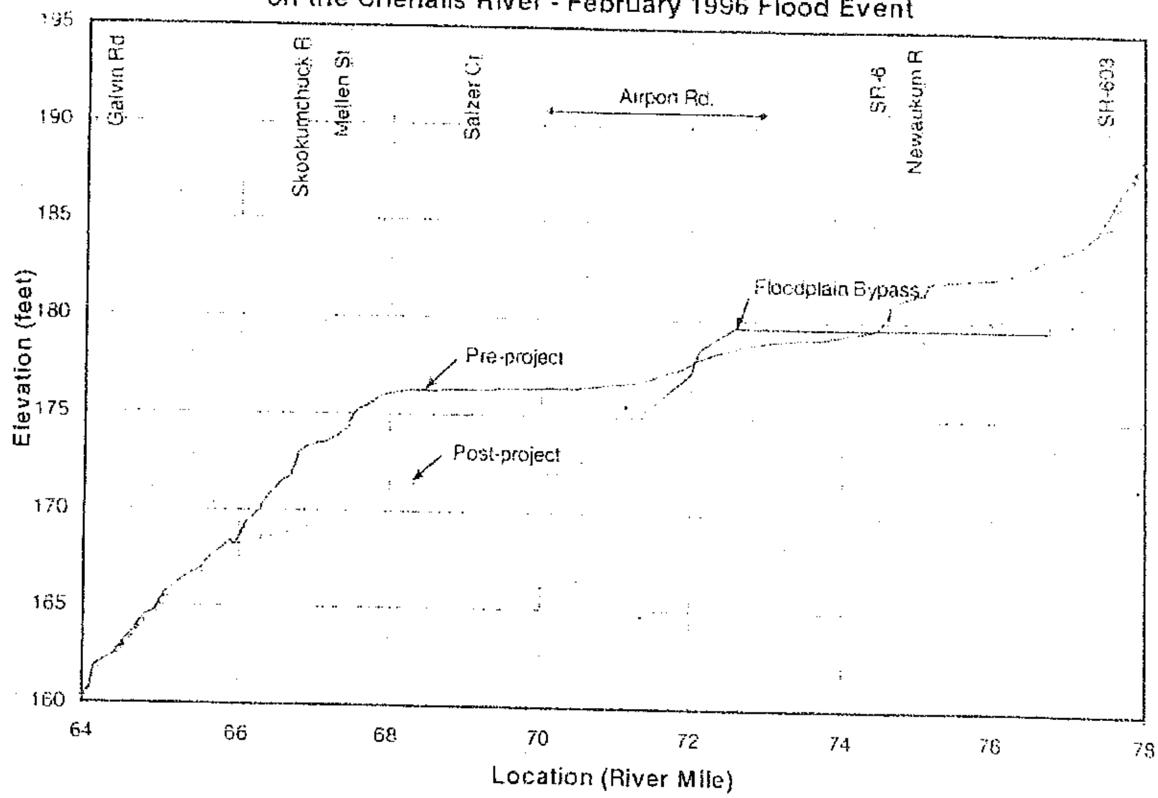


Figure 13: Comparison of Pre- and Post-Project Peak Flow Profiles on the Chehalis River - February 1996 Flood Event

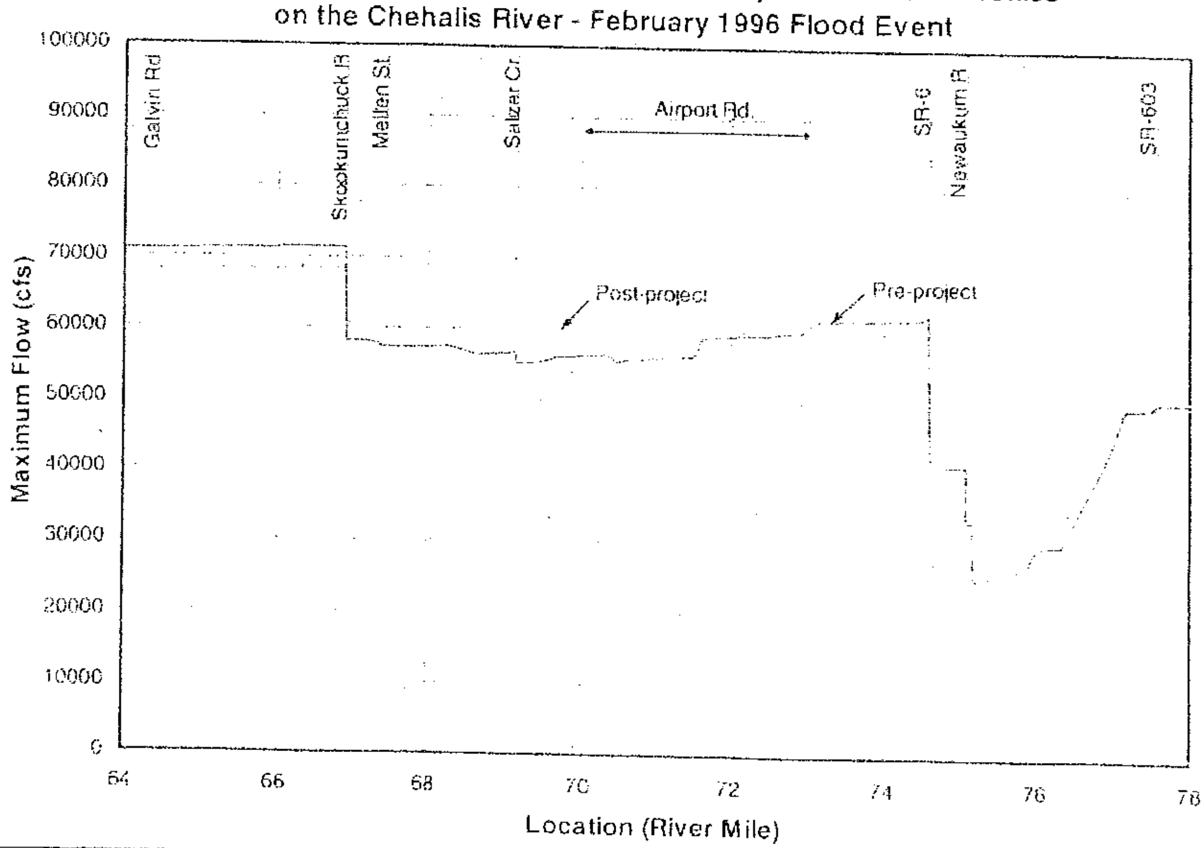


Figure 16: Comparison of Pre- and Post-Project Flow Hydrographs at Grand Mound Gage (RM 60) - February 1996 Flood Event

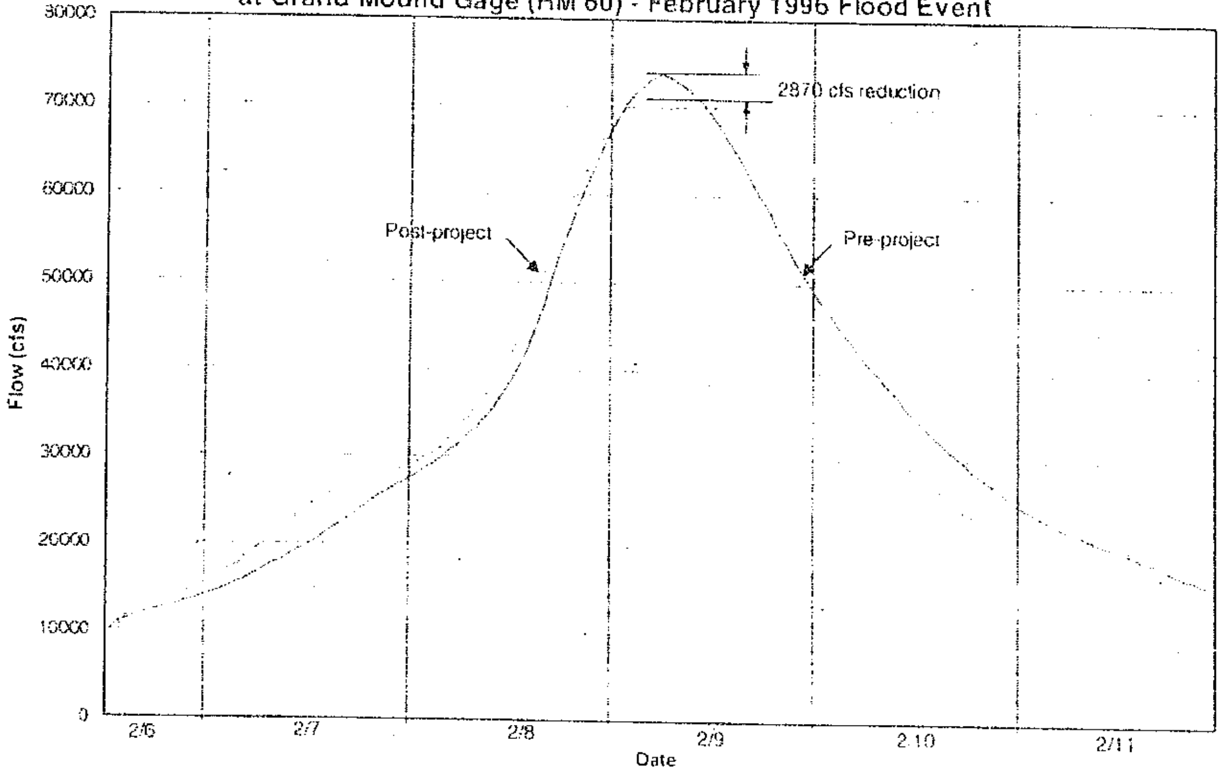


Figure 14: Comparison of Pre- and Post-Project Flood Stage Profiles on the Newaukum River - February 1996 Flood Event

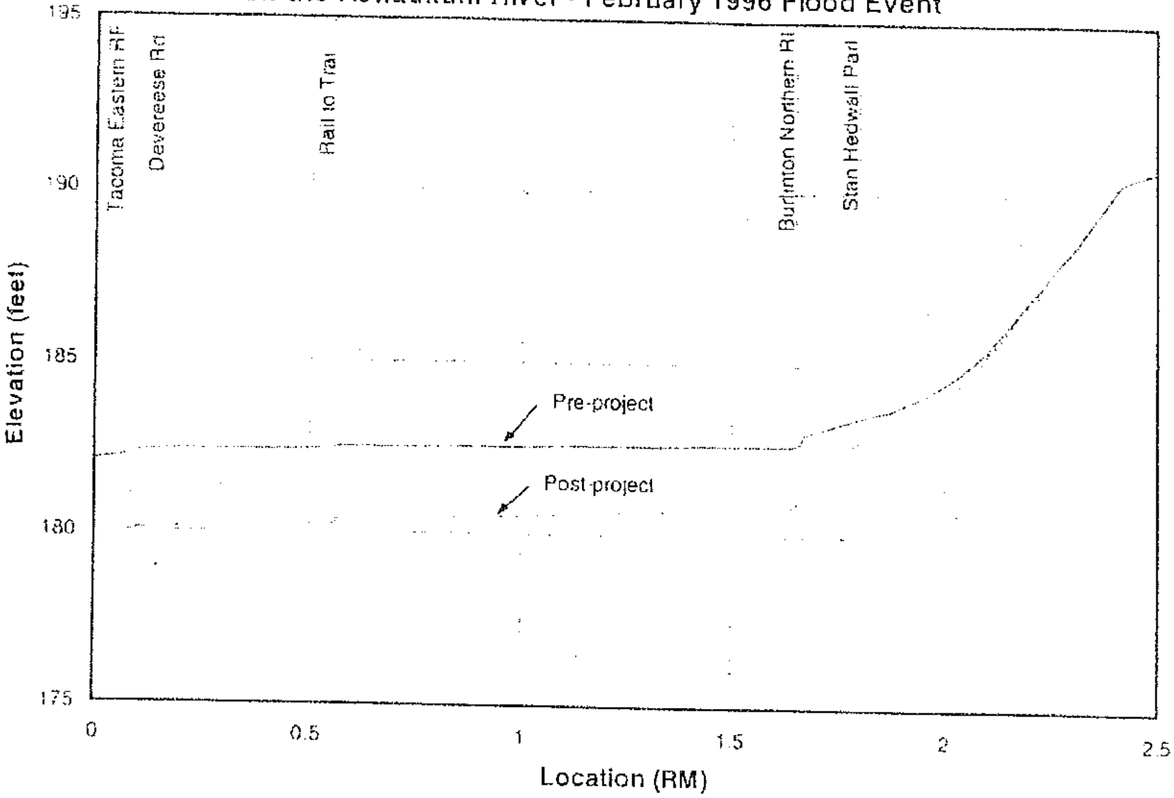


Figure 15: Comparison of Pre- and Post-Project Peak Flow Profiles on the Newaukum River - February 1996 Flood Event

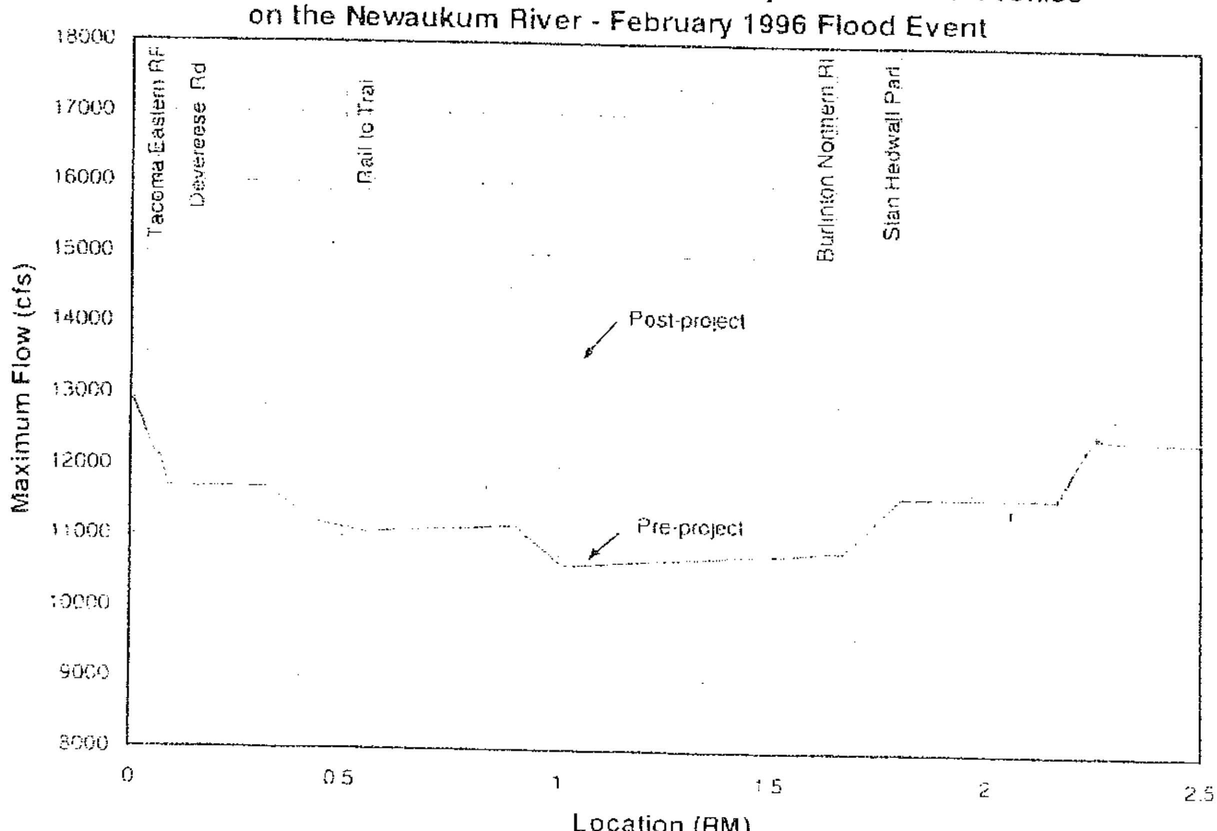


Figure 17: Comparison of Pre- and Post-Project Flow Hydrographs at Moon Road (RM 53) - February 1996 Flood Event

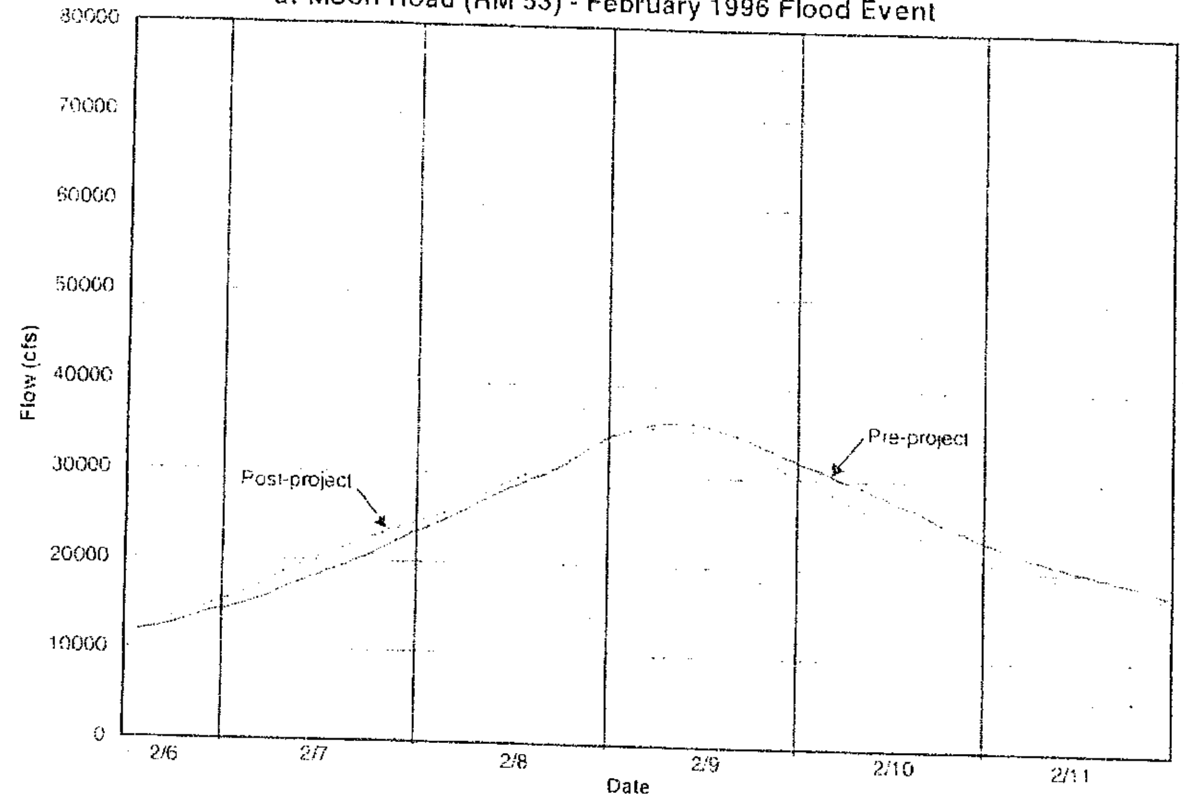
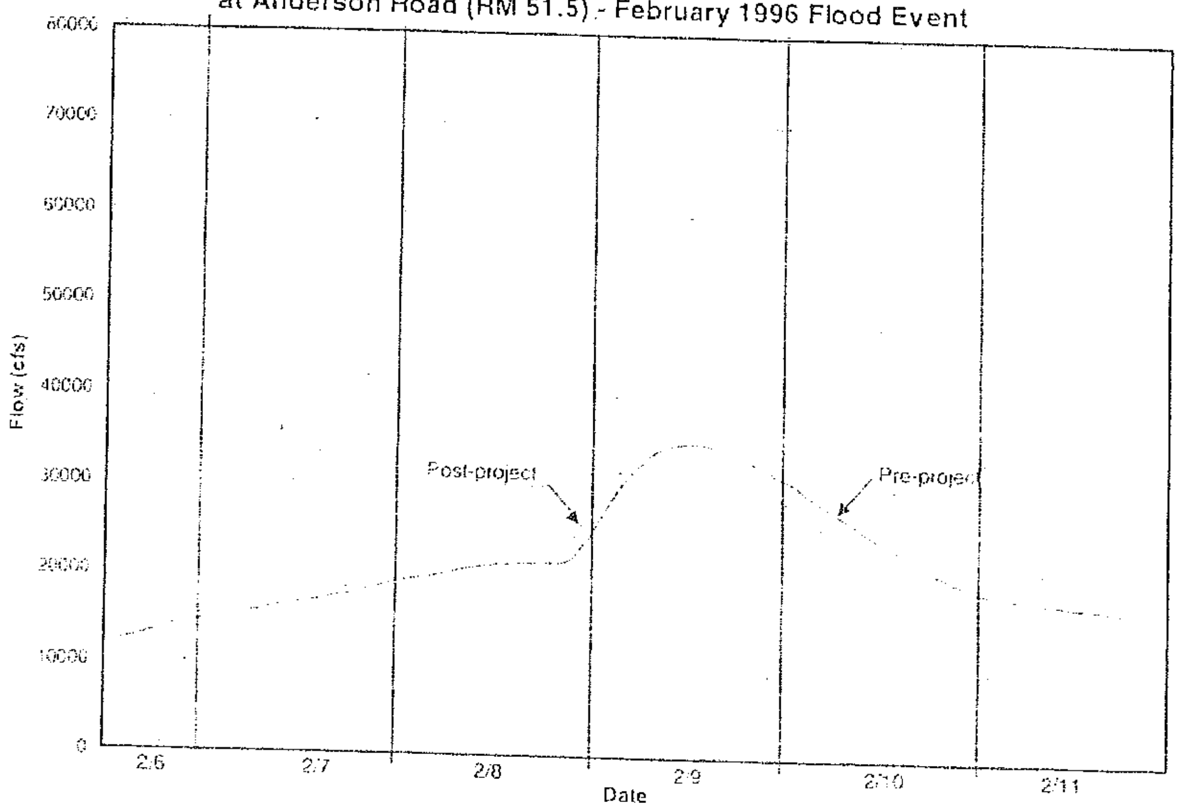
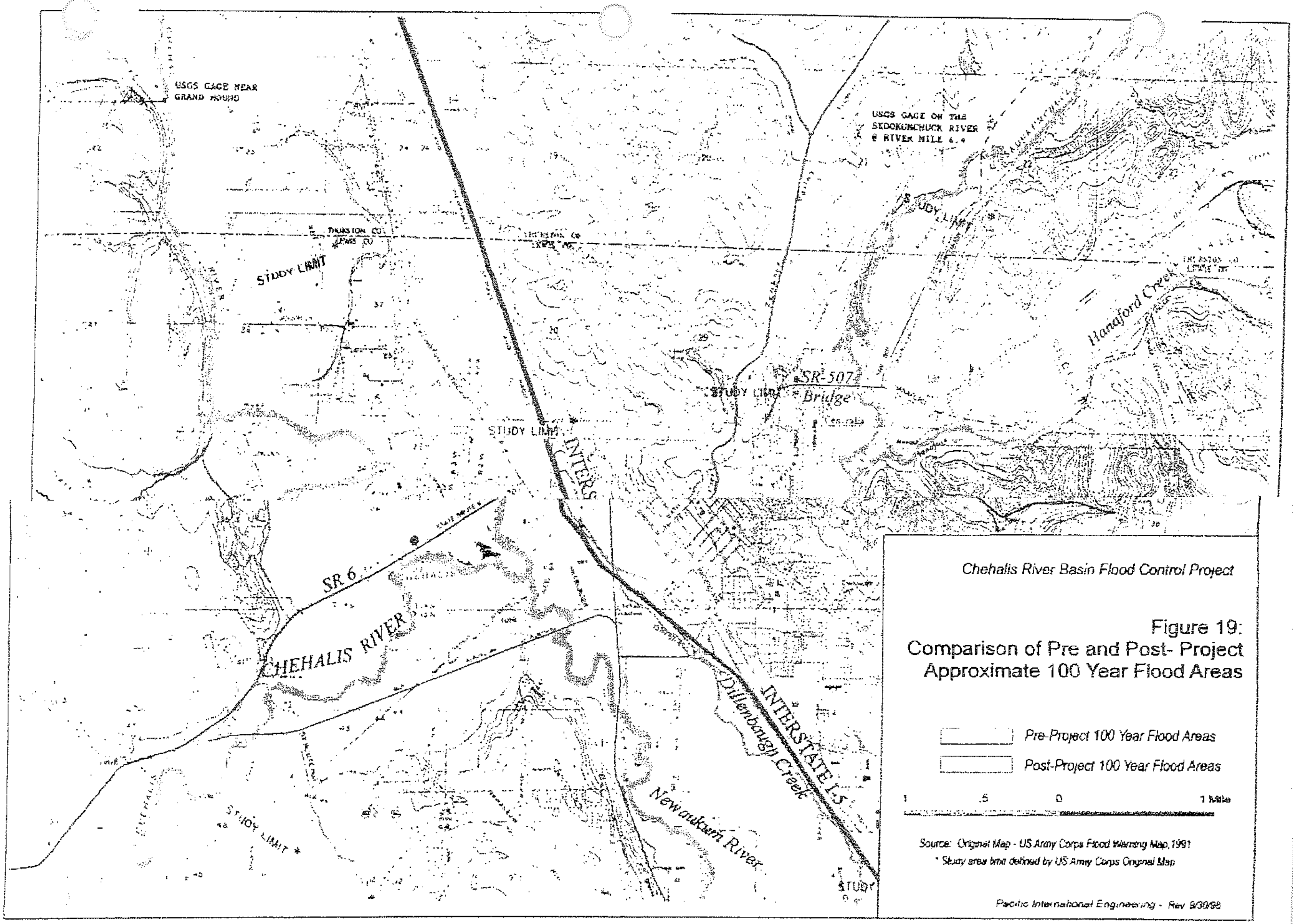


Figure 18: Comparison of Pre- and Post-Project Flow Hydrographs at Anderson Road (RM 51.5) - February 1996 Flood Event

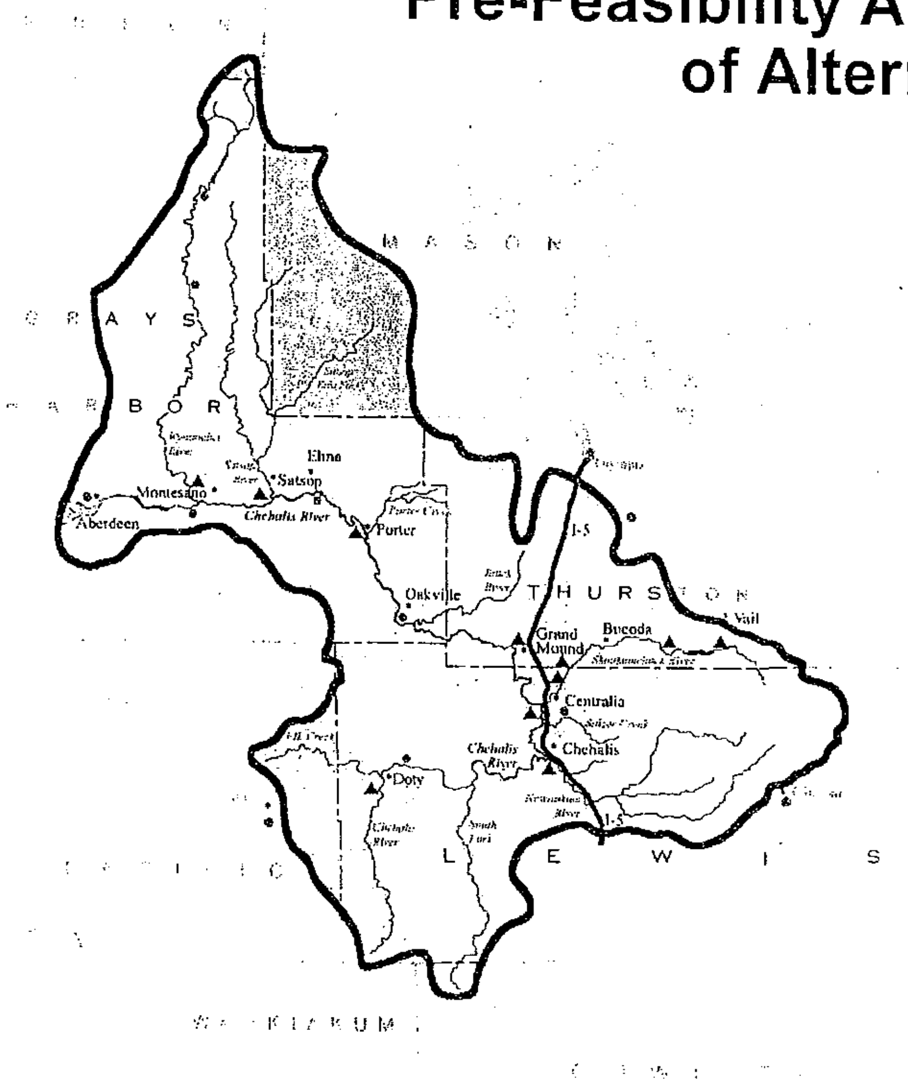



USGS GAGE NEAR GRAND MOUND
USGS GAGE ON THE SKOOKUMCHUCK RIVER @ RIVER MILE 6.4
STUDY LIMIT
THURSTON CO
LEWIS CO
Hanaford Creek
SR-507
Bridge
INTERS
SR 6
CHEHALIS RIVER
Dillenbaugh Creek
INTERSTATE I-5
Newaukum River
STUDY LIMIT *
Chehalis River Basin Flood Control Project
Figure 19:
Comparison of Pre and Post- Project Approximate 100 Year Flood Areas
Pre-Project 100 Year Flood Areas
Post-Project 100 Year Flood Areas
1 .5 0 1 Mile
Source: Original Map - US Army Corps Flood Warning Map, 1991
* Study area limit defined by US Army Corps Original Map
Pacific International Engineering - Rev 9/30/98

Submitted to

Chehalis River Basin Flood Control Project

Pre-Feasibility Analysis of Alternatives



Prepared by

Pacific International Engineering ■ Pharos Corporation

May 5, 1998

1. Introduction

1.1. Need for Project

Flooding has historically plagued the businesses and residents of the Cities of Centralia and Chehalis in the Chehalis River floodplain. Flooding in this area appears to be getting more severe. Often two significant flood events are experienced in one flood season. Eight major floods have occurred in the last twelve years, including the first, second, third and sixth highest of record since 1929.

These floods have caused immeasurable damage to the lives, businesses and property of the people living in the region, particularly those living in the urbanized areas of Centralia and Chehalis. Damages caused by the January 1990 flood alone, the second highest of record, were estimated by U.S. Army Corps of Engineers (USACE) to be over $19 million dollars. Total estimated flood damages in Lewis County since 1990 have exceeded $60 million, not considering damages resulting from the closure of Interstate Highway 5 (I-5) for four days in February 1996. The cost of this 4-day closure has been estimated to exceed $100 million.

USACE has studied various flood control projects within the Chehalis River Basin since 1931, only to find that no one project proves to be economically justified. USACE continues to work on small, local flood control projects, but has never implemented a basin-wide solution to the problem.

Floodwaters have overtopped I-5 twice, both times within the last 10 years. The flooding of I-5 is being addressed by Washington State Department of Transportation (WSDOT) as a secondary issue: required flood mitigation for a highway widening project. WSDOT's I-5 Toutle Park Road to Maytown Project proposes to widen I-5 and make various other improvements for traffic flow and safety in the vicinity of Centralia and Chehalis. Implementation of this project will require WSDOT to meet minimum federal and state flood clearance standards, which are not currently being met. WSDOT proposes to raise I-5 from the existing grade to two feet above the 100-year flood elevation (WSDOT, 1998) unless other measures are taken to alter and reduce existing flood stage levels.

Raising I-5 without adequately addressing the impacts of the elevated road surface on flooding in the basin could prove to be counterproductive for the communities in the basin. USACE is currently finalizing a report which addresses the effects of raising the road surface elevation of I-5. Accordingly, WSDOT will not publish the final environmental impact statement for the I-5 Toutle Park Road to Maytown Project without considering this information. However, there are currently no options available to WSDOT to address the flood issue, other than raising the surface elevation.

The project alternative recommended in this report is a result of the need for a flood control project in the Chehalis River Basin that has not been addressed. The recommended alternative is designed to lower the flood level significantly in the Centralia-Chehalis area, which will eliminate a big portion of the economic damage suffered with each event, and provide a better alternative to raising I-5. The recommended alternative will lower the flood level to a lesser degree in the lower Chehalis River Basin.

1.2. Summary of Study

To develop a flood control solution that meets the needs of all of the affected parties, a baseline flood model representing the existing conditions of the Upper Chehalis River Basin above the Grand Mound gage was developed. This model was calibrated on and verified against observed data from four major Chehalis River flood events with a wide spread of recurrence intervals, from 15 to 100 years.

Upon development of this accurate baseline flood model, various "what if" basin conditions reflecting potential flood control alternatives were evaluated by use of the model. The model was appropriately modified to represent each alternative and used to evaluate the potential changes in the basin flood conditions. The alternatives evaluated by the "what if" model include headwater dams such as the existing Skookumchuck Dam and potential new dams at mainstem and tributary streams to provide flood control storage for retaining peak flows. Alternative floodway excavations at various locations to improve floodway hydraulic capacity for flood stage reductions were also evaluated with the model. Previous USACE flood control project alternatives were also reviewed in conjunction with the new alternatives described above.

Through use of the flood model for all potential "what if" conditions, a combination of modifying Skookumchuck Dam for flood control storage operation and excavating the floodway in the Mellen St. Bridge vicinity has been identified as the best alternative to significantly reduce flood stages in the Centralia-Chehalis floodplain. The study has also identified alternatives to reduce local flooding in the City of Chehalis floodplain, east of I-5 between the 13th St. and SR-6 (Main St.) interchanges.

2. Physical Characteristics

2.1. Physiography

2.1.1. General

The Chehalis River drainage basin covers approximately 2,114 square miles (see Figure 2-1). The Chehalis River is about 125 miles long, originating in the Willapa and Doty Hills southeast of Aberdeen and flowing northeast and then northwest before emptying into Grays Harbor at Aberdeen. The basin uplands include the Willapa Hills, the western flank of the Cascade Mountains, and the southern Olympic Mountains.

The Chehalis River originates in the extreme southwestern corner of the basin, and flows east for about 25 miles to its confluence with the Newaukum River at Chehalis. From Chehalis the river flows north for 8 miles, where it meets the Skookumchuck River at Centralia. The river then turns and flows generally north and west for about 50 miles to its mouth at Grays Harbor on the Washington coast.

The Chehalis River Valley, located in the southern end of the Puget Trough, is characterized by a broad, well-developed floodplain and low terraces surrounded by highly dissected uplands of low to moderate relief that have broad, rounded ridges. There are numerous perennial streams in the valley. The valley bottom is at an elevation of about 150 feet, and upland elevations average about 300 to 600 feet. Higher elevations in the basin range from about 1,000 feet in the lowland hills, to 2,658 feet at Capital Peak in the south Olympic Range, to 3,800 feet in the foothills of the Cascade Range east of Chehalis-Centralia, and 3,110 feet in the Boistfort Hills along the south basin.

2.1.2. Upper Chehalis River Basin

The slope of the upper Chehalis River from its source to Chehalis is steep, falling an average of 16 feet per mile. The slope flattens to about three feet per mile in the valley surrounding Centralia and Chehalis, where the Chehalis River has a meandering channel that occupies a fairly uniform floodplain averaging over one mile wide. Most of the valley is inundated during a severe flood such as the January 1990 and the February 1996 floods.

The Upper Chehalis River Basin includes three main drainages: the Skookumchuck River, the Newaukum River, and the upper Chehalis River. In addition there are several smaller subdrainages in the Centralia-Chehalis area including Coffee Creek, China Creek, Salzer Creek and Dillenbaugh Creek (see Fig. 2-2).

Skookumchuck River

The Skookumchuck River, one of the major Chehalis River tributaries, joins the Chehalis River at river mile (RM) 67, and is approximately 41 miles in length. It originates in the Mt. Baker-Snoqualmie National Forest northeast of Centralia, and empties into the Chehalis River at Centralia. The total drainage area for the Skookumchuck River is 181 square miles. Elevations within the basin range from 150 feet at the mouth to over 3,000 feet at the headwaters. The slope of the Skookumchuck River from its source to the town of Bucoda is steep, falling an average of 19 feet per mile. Below Bucoda, the slope flattens to about five feet per mile near Centralia. Except for the uppermost portion, the Skookumchuck River flows as a meandering channel in a floodplain, varying in width from a few hundred feet to 0.5 mile. The Skookumchuck River has several tributary creeks.. The largest tributary, Hanaford Creek, has a drainage area of 58.4 square miles.

Three developments are notable within the Skookumchuck River system. The first is the City of Centralia, which occupies several square miles at the lower end of the basin. The second development is Skookumchuck Dam, located about 20 miles upstream from Centralia and operated by PacifiCorp. Skookumchuck Dam was completed in 1971 and has been considered several times for flood control use. The third development of note in the Skookumchuck Basin is the Centralia Steam Generating Plant on Hanaford Creek. Authority has been granted for this coal-fired facility to divert up to 54 cubic feet per second (cfs) of water from the Skookumchuck River.

Newaukum River

The Newaukum River joins the Chehalis River at RM 75 at the City of Chehalis. The Newaukum drains 175 square miles of lowland and foot-hills southeast of the City of Chehalis. Elevations in the basin range from approximately 180 feet at the confluence with the Chehalis River, to a little over 3,000 feet in the upper basin. The Newaukum River is the second major tributary to the Chehalis River in Lewis County.

The Newaukum River is made up of three forks: the north, middle, and south forks. Upstream sections on both the north and middle forks have slopes of 83 feet per mile; the south fork has a slope of 188 feet per mile above the town of Onalaska. The average channel slope for the entire drainage is 35 feet per mile.

Coffee Creek

Coffee Creek is a tributary of the Skookumchuck River. With headwaters in Thurston County, Coffee Creek flows south, through the Zenkner Valley, to the Skookumchuck River north of Centralia. The watershed encompasses 7.3 square miles of moderately sloping hills. Watershed elevations range from 186 feet at the confluence with the Skookumchuck

River to 645 feet at the northern tip of the watershed. The stream gradient is low in the lower four miles of the watershed. Coffee Creek has been moved from its natural location to a periphery channel bordering the edge of adjacent hills and valley floor.

China Creek

China Creek is a relatively small, short stream that flows through the City of Centralia to the Chehalis River. The watershed extends about five miles east of the Chehalis River at Centralia. It encompasses approximately six square miles, ranging in elevation from 180 feet to 570 feet. Much of the land is moderately steep. Most of the channel consists of pipes and culverts through Centralia.

Salzer Creek

Salzer Creek flows into the Chehalis River from the east, just south of the Centralia city limits, and drains 24.5 square miles. Salzer Creek originates in the low-lying hills east of Centralia-Chehalis, and has a maximum elevation of about 800 feet. The stream gradient of Salzer Creek is relatively flat. Coal Creek, a major tributary of Salzer Creek, has a drainage area of 6.4 square miles, and has a steeper slope.

Dillenbaugh Creek

Dillenbaugh Creek flows into the Chehalis River from the east, at the City of Chehalis. It originates in the steep foothills southeast of Chehalis, and has a drainage area of approximately 15 square miles. The gradient of Dillenbaugh Creek in the upper reaches is approximately 70 feet per mile. After it flows out onto the Newaukum River floodplain, the gradient drops as Dillenbaugh Creek parallels the Newaukum and Chehalis Rivers for nearly three miles before finally flowing into the Chehalis River. Dillenbaugh Creek collects much of the storm drainage from the City of Chehalis in this lower reach.

Upper Chehalis River

The upper Chehalis River, above RM 86, drains an area of 434 square miles, and can be divided into two main drainages and several smaller subdrainages. The two main drainages are the South Fork Chehalis River and the mainstem of the Chehalis River. The South Fork Chehalis River joins the mainstem of the Chehalis River at RM 88, and drains 130 square miles. The mainstem of the Chehalis River above Doty drains 113 square miles at RM 101.8 (USGS Gage). The major subdrainages include Bunker Creek, Stearns Creek and Elk Creek, which drain 34, 34.3 and 46.7 square miles, respectively.

2.2. Soils and Vegetation

2.2.1. Geology

The bedrock geology of the Chehalis River Basin is composed primarily of igneous and sedimentary bedrocks of the Tertiary Period. Surficial deposits include the unconsolidated glacial sediments of the Pleistocene Epoch. Following formation of the bedrock (7-55 million years ago) the area underwent geologic uplift, raising the volcanic and sedimentary rocks above sea level. Deformation, in the form of faulting and folding, accompanied the uplift. Landslides, erosion, glaciation and glaciofluvial deposition, as well as recent volcanic activity, followed. The most recent 10,000 years have been a period of relatively stable climatic and geologic conditions with erosion being the dominant geologic process (ENSR, 1994).

From the City of Chehalis to the City of Montesano, the average width of the floodplain is about 1.5-2.0 miles. The sediments within this floodplain attain a maximum depth of approximately 100 feet. The floodplain shows very little relief either longitudinally or perpendicular to the direction of flow. This lack of relief has resulted in a very sinuous river course with numerous oxbow lakes and other abandoned channels.

Geologic evidence indicates that the Chehalis River has reworked its valley since the deposition of the glacial alpine outwash sand and gravel. This sand and gravel forms the older river terraces that line the valley margins. This time line would make the recent river deposits less than 7,000 to 10,000 years old. Canyon wall conditions imply a mature topographic landscape prior to river sedimentation. This type of landscape would contribute to the long term, slow aggradation by the river system with deposition of fine sand and some fine gravel, but a predominance of silt, clay and organic mud. Mapping of the Centralia-Chehalis area by the Soil Conservation Service confirms that at least 50% of the deposits in the upper 5 feet of the valley sediments are organic mud, silt and plastic clay. The longer term, more active stream channels contain the coarser grained sediments.

2.2.2. Soils

The Soil Conservation Service published a soil survey of Lewis County in May, 1987. Much of the following information in this section is excerpted from that document (SCS, 1987). Soils in the floodplain tend to be a silty clay loam. These soils tend to be very deep and range from poorly drained to well drained. The native vegetation is wetland plants, deciduous plants, and conifers. The common wetland plants include bull thistle, cattail, peachleaf willow, reed canarygrass, and soft rush . The main woodland species are Douglas-fir and red alder. Among the trees of limited extent are black cottonwood, western red cedar and bigleaf maple. Among the common forest understory plants are western swordfern, vine maple, cascade Oregon-grape, red huckleberry, western brackenfern, Pacific trillium, and trailing blackberry.

Soils on plains, terraces and uplands tend to be very deep, and range from well drained gravelly sand to poorly drained silty clay. The main woodland species are Douglas-fir and red alder. Other trees found in limited extent are western hemlock, western red cedar and bigleaf maple. Among the common forest understory plants are cascade Oregon-grape, rose, red huckleberry, western brackenfern, violet, and salal.

Soils on uplands, mountains, and high terraces tend to be very deep, well drained silt loam. The main woodland species are Douglas-fir and red alder. Other trees found in limited extent are western hemlock, western red cedar and bigleaf maple. Among the common forest understory plants are cascade Oregon-grape, salmonberry, red huckleberry, western brackenfern, vine maple, and red elderberry.

All the soils in the basin fall predominately within AASHTO hydrologic group A. Soil permeability ranges from 0.6-2.0 inches per hour, to as high as 2.0-6.0 inches per hour.

2.3. Climate

The Centralia-Chehalis area has a predominately marine climate characterized by mild temperatures both summer and winter. Extreme temperatures are unusual for the area since prevailing westerly winds bring maritime air over the basin and provide a moderating influence throughout the year.

During the spring and summer, high-pressure centers predominate over the northeastern Pacific, sending a northwesterly flow of dry, warm air over the basin. The dry season extends from late spring to midsummer, with precipitation frequently limited to a few light showers. Average summer temperatures are in the 50's or 60's (°F), but occasionally hot, dry easterly winds cross the Cascade Mountains and raise daytime temperatures into the 90's. The Aleutian low-pressure center normally predominates during the winter, causing a counterclockwise circulation of cool, moist air over the basin and prevailing southwesterly winds.

The area from the Pacific Ocean to the crest of the Olympic Mountains, the western slopes of the Cascade Range, and the Black and Willapa Hills receives the full force of winter storms. Virtually every fall and winter (October through March), strong winds and heavy precipitation occur throughout the basin. Storms are frequent and may continue for several days. Successive secondary weather fronts with variable rainfall, wind, and temperatures may move onshore at daily intervals or less. Heavy orographic-type rainfall frequently is produced by these storm conditions when warm, maritime, saturated winds rise over the coastal range and west slopes of the Cascade Range. Occasional short cold periods are experienced when movement of arctic air into the Northwest interrupts the usual weather pattern.

The locations of the National Weather Service (NWS) climatological stations in the region are shown in Figure 2-1. A summary of pertinent data for these stations is shown in Table 2-1 below.

Table 2-1:
NWS Climatological Stations and Data Summary

Station Name	Station ID	Data Type	Elevation	Avg. Annual Precip. (in.)	Period of Record
Aberdeen	8	Daily	10	58.5	1931-Present
Aberdeen 20 NNE	13	Daily & Hourly	435	130.29	1948-Present
Centralia 1W	1277	Hourly	185	41.64	1931-Present
Chehalis	1330	Hourly	180	40.62	1948-1968
Cinebar 2E	1457	Hourly	1040	72.44	1948-Present
Doty 3E	2220	Daily	260	51.91	1978-Present
Elma	2531	Daily	69	66.83	1948-Present
Frances	2984	Hourly	231	71.91	1948-Present
Montesano 1S	5549	Hourly	25	76.79	1954-Present
Oakville	6011	Daily	80	56.06	1948-Present
Olympia AP	6114	Daily & Hourly	165	50.24	1948-Present

Source: National Weather Service

Precipitation in the basin is affected by distance from the Pacific Ocean, elevation, and seasonal conditions. Generally, the southern slopes of the Olympic Range and the more easterly, higher slopes along the Cascade Range receive the greatest precipitation. The Black Hills in the noreheast portion of the basin and Willapa Hills between the coast and Centralia-Chehalis often receive moderate to heavy rainfall during the movement of oceanic storms through the basin.

The greatest amount of rainfall occurs between the months of October and March. The abundance of rainfall during this period is due to the frequent storm systems that pass over western Washington. In Centralia, monthly rainfall totals for this period typically range between five and eight inches. For the rest of the year, average monthly rainfall totals range only between 0.8 and 2 inches. The month with the highest average rainfall is November, with 7.77 inches. The month with the lowest average rainfall is July, with only 0.84 inches. Annual precipitation averages 41.64 inches, with annual records showing a range from as low as 28 inches to a high of 60 inches.

Snowfall in the region is not heavy, but the potential does exist for extremely large amounts on occasion. The average annual snowfall is approximately nine inches, with recorded extreme annual maximums at 45 inches. Most of the snowfall occurs in the month of January, with the monthly average at about 4.5 inches.

Winds in the region rarely exceed 30 mph; winds of this speed usually only occur during the fall and winter months in conjunction with rainstorms and/or thunderstorms that pass through the vicinity. Approximately 10 percent of the winds between the months of November and February have speeds between 15 and 30 mph. Only about two percent of the winds for the other months have speeds in this range (15 to 30 mph). The rest of the wind speeds typically range between 0 and 15 mph (about 90 percent of the time). Wind speeds have been measured in excess of 70 mph during the winter months. The majority of the highest wind speeds measured have originated from the south and southwest directions (southerly and southwesterly, respectively).

2.4. Environmental Setting

Environmental conditions in the Chehalis River Basin have been studied and described by a number of researchers. The descriptions of existing fisheries and wildlife habitats provided here are based upon previous studies conducted for USACE, Lewis County, the City of Centralia, and others. Site-specific and alternative-specific studies will need to be conducted in subsequent project phases to refine the understanding of existing environmental conditions, further define potential project impacts, and address regulatory and permitting issues.

2.4.1. Fisheries

Chehalis River

The Chehalis River supports chinook, coho, and chum salmon; steelhead, and sea-run cutthroat trout; as well as resident fish including bass, perch, crappie, bullhead, and sunfish. The mainstem of the Chehalis River provides a migration corridor for anadromous fish species, although spawning, incubation, and rearing habitats are limited. It is thought that salmon populations in the Chehalis River have been depressed by a combination of factors, including low streamflows, limited spawning habitat, elevated water temperatures, reduced dissolved oxygen levels, and habitat alteration (USACE, 1997). However, with the exception of winter steelhead in the Skookumchuck and Newaukum Rivers, fish stocks in the Chehalis River system are considered healthy (CH2M-Hill, 1998).

Monitoring data indicate that water quality in the upper Chehalis River is generally good, with the reach between the headwaters and Rock Creek at RM 39 meeting Class AA (extraordinary) criteria. Downstream reaches generally meet Class A (excellent) criteria, although the Class A standards for temperature and dissolved oxygen are routinely not met during the summer months. A recent study by the Washington Department of Ecology indicates that problems with low dissolved oxygen levels and high temperatures are long-term and wide-spread (CH2M-Hill, 1998). Elevated water temperatures and/or low dissolved oxygen levels may cause the reach between Centralia and Chehalis to be impassible in late summer for adult chinook salmon attempting to migrate to upstream spawning grounds (USFWS, 1993).

Skookumchuck River

The Skookumchuck River provides transportation, spawning, incubation, and rearing habitats for numerous fish species. Fish inhabiting the portion of the river downstream of Skookumchuck Dam include fall and spring chinook salmon, coho salmon, resident and anadromous cutthroat trout, Olympic mudminnow, and largemouth bass. In comparison with historical populations, salmon populations in the Skookumchuck River are depleted. Chum salmon were historically found in the Skookumchuck, but the natural run is considered extirpated (USFWS, 1989). The winter steelhead run on the Skookumchuck is considered depressed by the Washington Department of Fish and Wildlife (WDFW) (CH2M-Hill, 1998).

Natural salmon spawning and rearing occurs in riffles between the mouth of the river and Skookumchuck Dam and in some 40 miles of tributary streams (ENSR, 1994, CH2M-Hill, 1997). WDFW operates a fish rearing facility, the Simpson Hatchery, approximately 0.5 miles downstream of Skookumchuck Dam. The Simpson Hatchery, which annually produces approximately two million coho smolts, contributes about 50 percent of the hatchery releases in the Chehalis River Basin.

Steelhead trout also utilize the Skookumchuck River for migration and rearing. WDFW traps the returning adult steelhead at a collection facility at the base of the dam, and transports them upstream, where the steelhead reproduce in the headwaters. About 50,000 steelhead smolts are planted annually to supplement the natural population.

Newaukum River

The Newaukum River watershed has four river reaches which provide important fish habitat. All of the mainstem of the Newaukum River, 17 miles of the North Fork, and all of the South Fork are utilized by coho and chinook salmon for migration, spawning, and rearing (ENSR 1994). Mainstem tributaries and tributaries to the north and south forks are also used for salmon production. Chum salmon have been located on the North Fork Newaukum River (ENSR, 1994). The winter steelhead run on the Newaukum River is considered depressed by WDFW.

2.4.2. Wildlife

The Chehalis River watershed provides habitat for numerous wildlife species including big game (black-tailed deer, Roosevelt elk, black bear, and cougar), game birds (primarily pheasant, grouse, and quail), fur-bearers (beaver, mink, muskrat, and other species), and waterfowl. The upper Chehalis River is on the Pacific Flyway for migratory birds.

Protected species of birds, including the bald eagle, osprey, and Northern spotted owl, inhabit the Chehalis River Basin. Recent studies indicate that bald eagles and ospreys use all of the major streams in Lewis County, particularly during winter months (ENSR 1994). Other protected wildlife species known to use habitats in the upper basin include the western pond turtle, giant Olympic salamander, and red-legged frog.

The wetland and riparian areas along the Chehalis River and its tributaries provide important habitat for a wide variety of wildlife. Wetlands and riparian areas generally support diverse vegetation and provide travel corridors and protected access to water. Wetlands and riparian areas are considered to be priority habitats in Washington State because they support high densities of mammals and birds. Wetland and riparian areas in the upper Chehalis River basin have been designated as sensitive areas by city and county jurisdictions. Migratory and resident waterfowl and passerine birds are particularly dependent upon these habitats; of the 53 bird species found in Lewis County, 42 (or 79 percent) are dependent upon wetlands and riparian areas (ENSR 1994). As in many other areas of the country, riparian zones and wetlands within the basin have been adversely affected by agricultural and urban development.

2.5. Hydrology

2.5.1. Streamgage Stations

Figure 2-2 shows the locations of the U.S. Geological Service (USGS) streamgage stations that are currently in operation in the Upper Chehalis River Basin. Table 2-2 summarizes pertinent data for these stations. In addition to the USGS streamgage stations, the National Weather Service (NWS) maintains wire weight stage gages at the Mellen St. Bridge and at the Pearl St. Bridge. The gages are used by the NWS for flood forecasting and warning.

2.5.2. Runoff

Streamflow generated within the Chehalis River Basin originates primarily from rainfall; although, snow melt occasionally augments runoff in the highest elevation reaches of the basin. The average annual runoff of the Chehalis River at its mouth (drainage area 2,114 square miles) and at the USGS streamgage near Grand Mound (drainage area 895 square miles), are estimated to be 6.4 million acre-feet and 2.0 million acre-feet, respectively.

The flow in the rivers and creeks of the Chehalis River Basin show seasonal variation characterized by sharp rises of relatively short duration from October to March, corresponding to the period of heaviest rainfall. After March, the flows tend to gradually decrease to a relatively stable base flow, which is maintained from July into October.

Major flooding occurs during the winter season, usually from November through February, as the result of heavy rainfall occasionally augmented by snow melt. Flooding may be either widespread throughout the Chehalis River Basin or localized in subbasins. Some storms may cover the entire basin and cause widespread flooding. Other storms may center over the Willapa Hills and cause flooding of the upper Chehalis River or center over the Black Hills and Cascade Foothills and result in flooding of the Skookumchuck River and Newaukum River.

Table 2-2: USGS Streamgage Information

Station Name	Station ID	Drainage Area (Sq. Mi.)	River Mile	Record Period
Chehalis River near Doty	12020000	113	101.8	1939-Present
Elk Creek near Doty	12020500	46.7	2.5	1942-1970
S.F. Chehalis River near Boistfort	12020900	44.9	8.0	1965-1980
S.F. Chehalis River at Boistfort	12021000	48	6.0	1942-1965
Chehalis River near Chehalis	12023500	434	77.5	1929-1931
M.F. Newaukum River near Onalaska	12024000	42.4	8.0	1944-1971
N.F. Newaukum River near Forest	12024500	31.5	6.5	1960-1966
Newaukum River near Chehalis	12025000	155	4.1	1929-1931 1942-Present
Salzer Creek near Centralia	12025300	12.6	3.9	1968-1971
Skookumchuck River near Vail	12025700	40	28.8	1967-Present
Skookumchuck River near Centralia	12026000	61.7	21.0	1929-1969
Skookumchuck River below Bloody Run Creek	12026150	65.9	20.7	1969-Present
Skookumchuck River near Bucoda	12026400	112	6.4	1967-Present
Lincoln Creek near Rochester	12027000	19.3	9.0	1942-1950
Chehalis River near Grand Mound	12027500	895	59.9	1928-Present

Source: U.S. Geological Survey

2.5.3. Historical Floods

General

Precipitation totals at Centralia (Centralia 1W) for the ten largest one-day, two-day, and three-day storms of record are presented in Table 2-3 below. For comparison, from the NOAA Atlas 2, the estimated 100-year 24-hour rainfall varies in the basin from 4 inches in the Centralia area, to 8 inches in the higher elevation areas of the upper basin, and 12-13 inches in the headwaters of the Wynoochee drainage.

Table 2-3: Precipitation Totals Ranked for 10 Largest Storms at Centralia 1W

One-Day Storm		Two-Day Storm		Three-Day Storm	
Month & Year	Total Precip. (in.)	Month & Year	Total Precip. (in.)	Month & Year	Total Precip. (in.)
Jan. 1990	4.13	Nov. 1986	6.09	Nov. 1986	6.49
Nov. 1990	3.96	Dec. 1933	5.10	Feb. 1996	6.40
Dec. 1933	3.95	Feb. 1996	5.02	Jan. 1990	5.87
Nov. 1986	3.22	Jan. 1990	4.96	Dec. 1933	5.49
Oct. 1942	3.22	Nov. 1990	4.82	Dec. 1937	5.41
Feb. 1996	3.34	Nov. 1932	4.02	Nov. 1990	5.25
Feb. 1951	3.15	Feb. 1951	3.84	Nov. 1932	4.47
Nov. 1932	3.07	Oct. 1942	3.59	Feb. 1951	4.22
Dec. 1937	2.10	Dec. 1937	3.58	Oct. 1942	4.20
Jan. 1972	1.95	Jan. 1972	3.13	Jan. 1972	3.64

Source: USACE, 1997a

The greatest flood discharge on the Chehalis River in the Centralia-Chehalis area during the last 70 years occurred in February 1996. Table 2-4 summarizes the largest floods of record in the basin.

Table 2-4: Ten Largest Floods on the Chehalis, Skookumchuck and Newaukum Rivers (Since 1971)

Gage	Chehalis River near Grand Mound			Skookumchuck River near Bucoda			Newaukum River near Chehalis		
Year	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank	Stage (ft.)	Disch. (cfs)	Rank
Feb. '96	20.04	74,900	1	17.87	9,370	1	13.34	13,800	1
Apr. '91	17.66	42,800	7	16.82	7,860	5	12.07	9,210	7
Nov. '90	18.12	48,00	5	17.23	8,400	3	12.73	10,300	4
Jan. '90	19.34	68,700	2	17.33	8,540	2	12.75	10,400	3
Nov. '86	18.41	51,600	3	15.01	5,770	10	12.76	10,700	2
Dec. '77	16.79	36,500	10	16.18	7,170	6	12.49	10,300	5
Dec. '75	17.73	44,800	6	15.42	6,110	8	10.85	8,020	10
Jan. '74	16.88	37,400	9	15.30	5,950	9	11.17	8,440	8
Jan. '72	18.21	49,200	4	16.82	8,190	4	12.12	9,770	6
Jan. '71	17.29	40,800	8	15.82	6,630	7	11.99	8,390	9

Source: USACE, 1997a

Brief descriptions of the three most recent, largest floods in the Centralia-Chehalis area (the, January 1990, November 1990, and February 1996 floods) are provided below. Descriptions for the two 1990 events came from USGS Open File Reports (Hubbard, 1991,1994), and the description for the 1996 event came from the USACE After Action Report (USACE, 1996).

January 1990 Flood

The January 1990 flood was primarily the result of a series of back-to-back storms accompanied by heavy rainfall over the 8-day period January 3-10. The heaviest rainfall occurred on the seventh day of the storm, January 9, causing extreme flooding because the rain fell on soils that were saturated from the preceding rainstorms.

The storm system was quite complex and included high winds and strong surges of precipitation. The Centralia climatological station recorded 8 inches of rain during the eight-day period. This eight day total precipitation represents 19 percent of the total yearly precipitation that is recorded at the station on the average. The most intense precipitation in the basin occurred near the headwaters of the Skookumchuck and Newaukum rivers.

The surges in precipitation resulted in more than one flood peak in many of the rivers and creeks in the basin. The streams did not return to base flow between storm surges. The early precipitation saturated the soils in the basin and added greatly to the runoff potential when the heaviest rains arrived on January 9. Peaks of record, up to this event, were recorded at the following gaging stations: Chehalis River near Doty, Chehalis River near Grand Mound, and Chehalis River at Porter. These flood peaks were estimated at the time as the 100-year flood.

November 1990 Flood

Above average precipitation in October and early November resulted in saturated soils that contributed to the flooding potential when the major storm arrived during the period of November 21-25. During the period between a smaller storm in early November and the major storm, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000-foot elevation. The Cascade foothills averaged 6 inches at elevations of 1,000 to 2,000 feet; 12 inches at 2,000 to 3,000 feet; and 12-18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, November 21, snow changed to rain and temperatures rose. The warm front caused melting of snow up to elevations of 5,500 feet. Over the next 3 days, intense rain fell on drainages that were starting to swell from snow melt runoff; disastrous flooding resulted. A cold front moved in from the north on November 26, 1990, lowered freezing levels and diminished precipitation, finally ending the severe flooding.

February 1996 Flood

The February 1996 flood is the flood of record, to date, on all the major drainages in the Chehalis River Basin. Several of the main ingredients for a major storm flood were in place by February 5. The ground throughout the basin was at or near saturation from above average precipitation, which had fallen in the preceding weeks. In addition, snow had recently fallen as low as 500 feet above sea level during a cold snap. Third, warm, moist subtropical air was being transported from the Pacific Ocean into the Pacific Northwest. The freezing level in this subtropical air mass was well above 8,000 feet, which meant warm rains on the snow pack in the foothills.

Next, there was a strong polar jet stream with maximum wind speeds in its core in excess of 150 knots. These strong winds extended out into the central and western Pacific. Storms feed upon the stream and this powerful jet sustained and strengthened the storms as they moved in off the eastern Pacific. Also, the atmosphere was set up in a blocking pattern, which meant the major troughs and ridges around the Northern Hemisphere were stationary. The Pacific Northwest was situated between a major trough to the west and a major ridge to the east, ideal conditions for weather systems to be at maximum strength when they reached the area. The atmosphere remained in this general pattern for at least 96 hours during which copious amounts of rain fell and large quantities of water in the existing snow pack were released to flow into the rivers.

2.5.4. Flood Exceedance Frequency

USACE recently updated their flood frequency curves for the Chehalis River in the vicinity of Centralia (USACE, 1997a). USACE previously published flood frequency curves for the Chehalis River for a 1980 Federal Emergency Management Agency (FEMA) report (ENSR, 1994), and made revisions to the curves in 1989 (USACE, 1992). Since 1980, there have been three floods of record, and several other major floods on the Chehalis River. USACE incorporated the data since 1980 and recomputed the frequency curves. The recomputed frequency curves data, shown as years of recurrence interval, are shown below in Table 2-5. The recomputed frequency curves are significantly higher than those published in 1980 or 1989. Table 2-6 shows a comparison of estimated flood recurrence intervals for the Chehalis River at Grand Mound, using frequency numbers computed by the USACE and used by FEMA at various times.

Table 2-5:
Peak Discharge Frequency Data for Selected Locations

Location	2-Year Flow (cfs)	10-Year Flow (cfs)	25-Year Flow (cfs)	50-Year Flow (cfs)	100-Year Flow (cfs)
Chehalis near Grand Mound	25,000	43,800	55,000	64,300	74,300
Skookumchuck at Mouth	5,200	9,000	10,600	11,900	13,000
Skookumchuck at Pearl St.	4,800	8,450	10,100	11,300	12,500
Skookumchuck near Bucoda	3,900	6,900	8,300	9,300	10,400
Chehalis at Mellen St.	18,400	32,700	41,400	49,000	57,200
Chehalis above Salzer Creek	17,900	31,900	40,400	47,600	55,700
Newaukum near Chehalis	5,800	9,300	11,200	12,400	13,800

Source: USACE, 1997a

Table 2-6:
Comparison of Flood Recurrence Intervals at Grand Mound

Year	Date	Maximum Flow (cfs) at Grand Mound Gage	Flood Recurrence Interval (years)		
			USACE (1998 update)	USACE (1989 update)	FEMA (1980-present)
1996	Feb. 6	73,900	100	400	600
1990	Nov. 25	48,000	15	30	35
1990	Jan. 10	68,700	70	250	400
1986	Nov. 25	51,600	20	40	50
1972	Jan. 21	49,200	15	30	35

Figure 2-1:
Chehalis River Basin Watershed Boundary

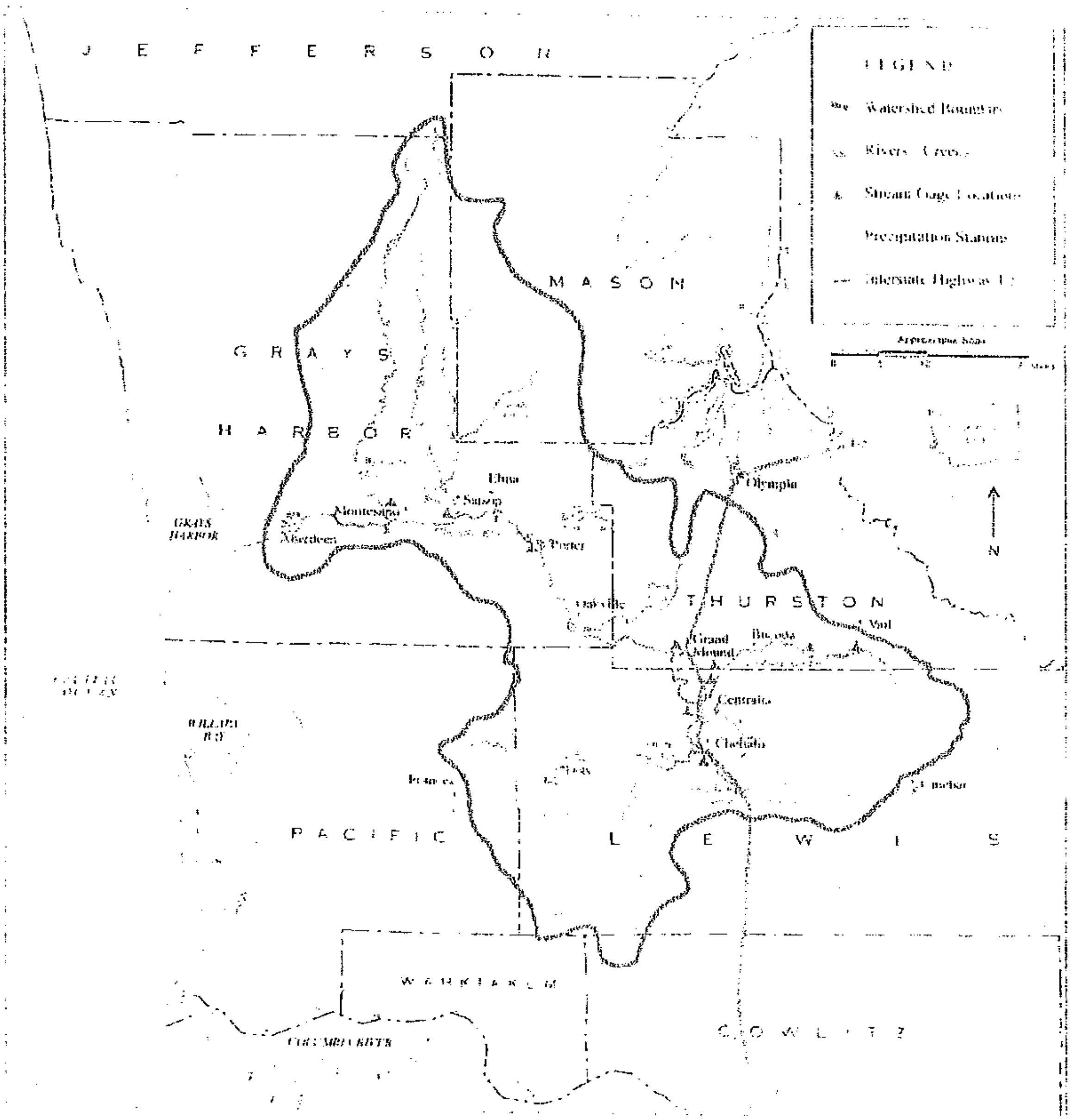
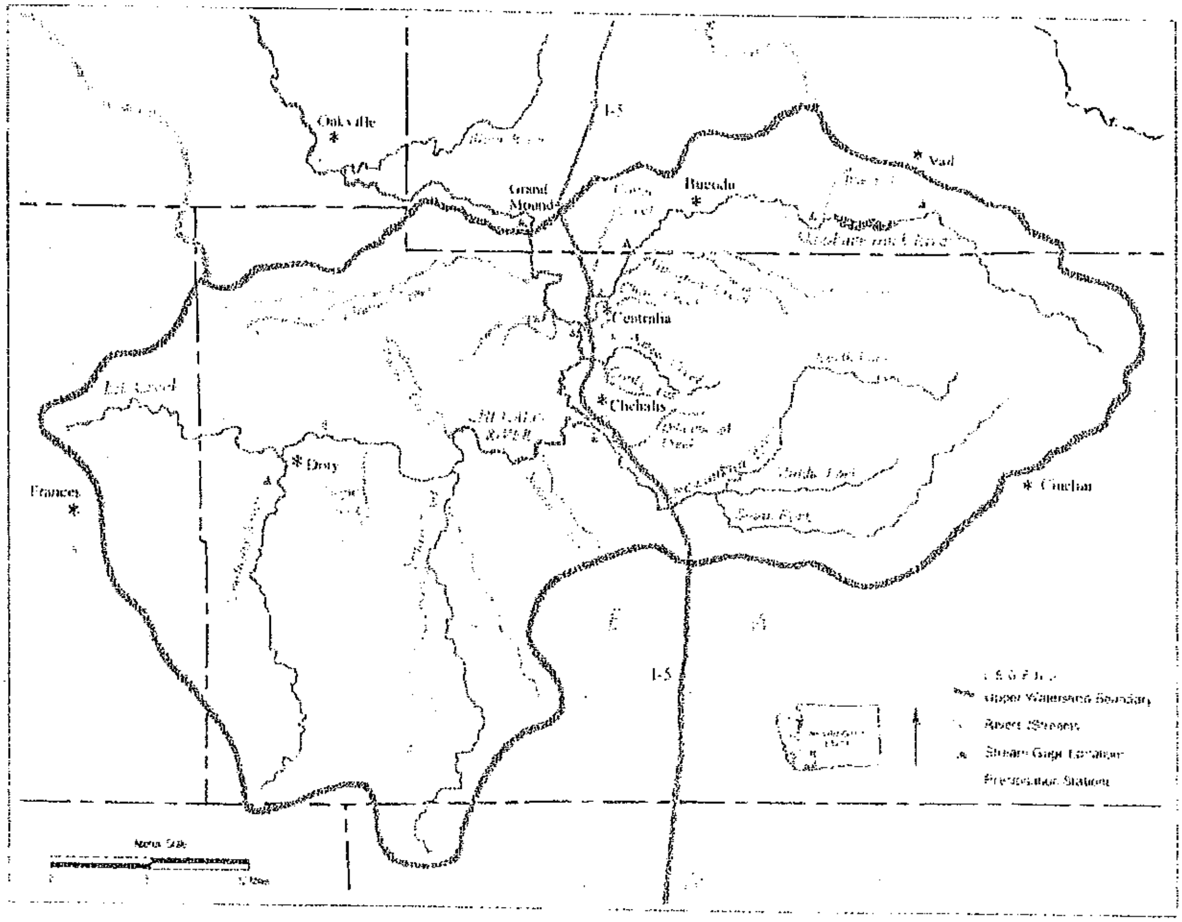


Figure 2-2:
Upper Chehalis River Basin Boundary



3. Baseline Flood Modeling

3.1. Introduction

To evaluate the potential effects of various flood control alternatives in reducing flood stages and corresponding damages in the Centralia-Chehalis floodplain, a baseline flood model representing the existing conditions of the Upper Chehalis River Basin above the Grand Mound gage was developed. Development of the model was based on the February 1996 flood, which represents the new 100-year base flood in the mainstem of the Chehalis River. This flood event is the largest flood of record, and provides the most recent and complete observed flood stage data, allowing extensive calibration of the model. Upon calibration for the February 1996 flood, the model was verified against three other major flood events, the January and November 1990, and the January 1972 floods.

3.2. Methodology

The floodplain and floodway in the Centralia-Chehalis area present a complex flood hydraulic problem because of flat gradients, flow reversals, overland flow exchanges between subbasins, and local ponding created by existing dikes, levees, railroad embankments, bridge abutments, and I-5 fill in the floodplain. To adequately reproduce the historical flood flow and stage hydrographs in this area, the HEC-UNET (USACE, 1996) software recently developed by Dr. Robert L. Barkau, for the USACE Hydrologic Engineering Center (HEC), was used to model the upper Chehalis River Basin.

UNET is a one-dimensional, unsteady flow flood routing model that can simulate flood flow in a complex network of open channels including off-channel storage and overbank storage areas, as well as the split of flow into two or more channels and the combining of flow. The channel cross-section data used in the HEC-2 (USACE, 1990) models previously developed by others (steady-state backwater model) can be readily adapted to the UNET input. Other input data includes flow and stage hydrographs, overflow spillways, bridges, culverts and levee systems. Because of its capability to include off-channel and overbank storage areas, UNET is a quasi two-dimensional model, and is considered to be the best tool available for modeling the upper Chehalis River Basin floods.

A schematic diagram of the UNET model for the Upper Chehalis River Basin, above the USGS streamgage at Grand Mound, is provided in Figure 3-1. Figure 3-2 shows how the subbasins were divided, and Table 3-1 tabulates the drainage areas for all subbasins used in the Upper Chehalis River Basin UNET model. There are a total of seven routing reaches of the UNET model and a total of 24 subbasins contributing flows to these

Further discussion of the HEC-1 and UNET model development for the upper Chehalis River Basin is provided in the following subsections.

Table 3-1:
Upper Chehalis River Subbasin Division Summary

Symbol (see Fig. 3-2)	Subbasin Stream Name	Drainage Area (Sq. Mi.)	UNET Routing Reach (See Fig. 3-1)
C1	Chehalis River Above Doty	113.0	1
C2	Elk Creek	46.7	1
C3	Hope Creek	6.3	1
C4	South Fork Chehalis River	130.2	1
C5	Bunker Creek	34.1	1
C6	Stearns Creek	34.9	1
C7	Chehalis River, RM 101.80 to RM 75.22	91.9	1
C8	Chehalis River, RM 75.08 to RM 70.20	5.4	3
C9	China Creek	4.4	5
C10	Chehalis River, RM 69.20 to RM 67.00	5.4	5
C11	Lincoln Creek	42.8	7
C12	Chehalis River, RM 66.90 to RM 59.93	10.8	7
N1	Newaukum River	155.0	2
N2	Newaukum River, RM 4.12 to RM 0.14	20.3	2
SA1	Salzer Creek	15.7	4
SA2	Coal Creek	5.4	4
S1	Skookumchuck River Above Skookumchuck Dam	61.4	6
S2	Bloody Run Creek	4.5	6
S3	Johnson and Thompson Creeks	24.3	6
S4	Skookumchuck River Tributary, RM 11.93	14.7	6
S5	Skookumchuck River Tributary, RM 6.64	8.4	6
S6	Hanaford Creek	49.3	6
S7	Coffee Creek	6.2	6
S8	Skookumchuck River, RM 3.71 to RM 0.01	6.2	6

3.3. Subbasin Rainfall-Runoff Modeling

3.3.1. General

The subbasin rainfall-runoff modeling by application of the HEC-1 program produced flow hydrographs required as input to the UNET flood routing model for ungaged subbasins. The HEC-1 modeling requires input of subbasin drainage geometric data, meteorological data, hydrological parameters including Clark's unit hydrograph parameters, precipitation losses and base flow estimates. To improve the accuracy of estimating ungaged subbasin flow hydrographs, hydrological parameters were optimized using observed hydrographs at gaged subbasins. The optimized

subbasins are the Chehalis River above Doty, Newaukum River, and Skookumchuck River above Vail.

The HEC-1 computer program derives unit hydrographs by the Clark Method. The Clark Method requires two parameters: time of concentration (Tc) and basin storage coefficient (R), both in hours. Loss rates were computed by the HEC exponential loss rate function which relates loss rates to the rainfall and to the accumulated losses. Both the loss rate parameters and unit hydrograph parameters were determined through the process of optimization. Each of these optimizations led to a reasonably consistent, though slightly different, set of values from event to event in the same subbasin. The optimization results of unit hydrograph parameters are summarized in Table 3-2.

The base flow quantities were also estimated through the optimization process. Base flow was determined by the exponential recession limb preceeding the storm runoff hydrograph. This base flow was added to the computed runoff hydrograph ordinates to obtain the total subbasin hydrograph. When the base flow is below a recession threshold flow, the program prevents it from receding faster by using the pre-flood base flow recession rate.

The reproduced and observed flow hydrographs for the selected four flood events at Doty, Newaukum, and Vail subbasins are shown in Figures 3-4 through 3-7, and indicate reasonable results of the optimization.

Table 3-2:
HEC-1 Optimization Results

Subbasin/ Flood Event	Clark's Unit Hydrograph Parameters (Hours)	
	Tc	R
Chehalis River above Doty		
Feb-96	5.21	8.88
Nov-90	5.70	9.70
Jan-90	4.33	7.37
Jan-72	5.36	9.13
Newaukum River basin		
Feb-96	10.45	17.80
Nov-90	12.41	21.12
Jan-90	12.30	20.95
Jan-72	12.76	21.73
Skookumchuck River above Vail		
Feb-96	4.57	6.85
Nov-90	6.26	9.39
Jan-90	4.35	6.52
Jan-72	7.36	11.04

sections used, Manning's n, and contributing subbasins. Table 3-4 presents a description of the storage areas.

Table 3-3: Characteristics of UNET Routing Reaches

UNET Reach (see Fig. 3-1) No.	Stream Name	River Mile Range (RM)	No. of Cross-sections	Range of Manning's n Channel	Overbank	Contributing Subbasins (see Fig. 3-2)
1	Chehalis River	101.80 to 75.22	49	0.035 to 0.063	0.046 to 0.120	C1,C2,C3,C4 C5,C6,C7
2	Newaukum River	4.12 to 0.00	13	0.031 to 0.048	0.045 to 0.080	N1,N2
3	Chehalis River	75.22 to 69.21	13	0.040 to 0.055	0.070 to 0.090	C8
4	Salzer Creek	2.50 to 0.00	22	0.070	0.180	SA1, SA2
5	Chehalis River	69.21 to 67.00	11	0.040 to 0.055	0.070 to 0.130	C9, C10
6	Skookumchuck River	21.90 to 0.00	107	0.035 to 0.080	0.080 to 0.180	S1, S2, S3, S4, S5, S6, S7, S8
7	Chehalis River	67.00 to 59.33	32	0.032 to 0.060	0.065 to 0.130	C11, C12

Table 3-4: Designation of UNET - Storage Areas

Storage Area (SA) No.	Description
SA #1	NE of I-5 & S of SR-6, in the City of Chehalis along Dillenbaugh Creek
SA #2	Centralia - Chehalis Airport area
SA #3	Fairground area, N of Salzer Creek
SA #4	S of Salzer Creek and between Kresky Road and old US Hwy 99
SA #5	S of Alder St., E of I-5, W of Chehalis Western RR & N of Salzer Creek, including Trailer Park
SA #6	China Creek ponding area, E of I-5
SA #7	Coffee Creek ponding area, N of Reynolds Avenue
SA #8	Hanaford Creek mouth floodplain
SA #9	Lincoln Creek mouth floodplain

Most of the channel and bridge cross-section data for the Chehalis River reach between Grand Mound and Adna, for the Newaukum River reach and for the Skookumchuck River reach, were obtained from USACE. All these data were surveyed for USACE's earlier steady-state backwater analysis during the 1970's and the 1980's. The developed UNET model includes 12 new cross-sections surveyed in 1997 by PIE's survey

through Figure 3-14 show a comparison of the computed and observed hydrographs at these two gages. The comparison presents satisfactory results of the UNET model in reproducing these flood stage hydrographs.

3.4.5. UNET Model Results

The results of the Upper Chehalis River Basin UNET modeling are presented in the following figures.

Figure 3-15 through Figure 3-18 show computed flow hydrographs at various locations along the Chehalis River for the four selected flood events. Peak flows during major flood events tend to be reduced as they reach the Centralia-Chehalis floodplain below the Newaukum River and above the Mellen St. Bridge.

Figure 3-19 and Figure 3-20 show computed peak flow and maximum stage profiles on the Chehalis River and the Skookumchuck River, respectively, for the four floods modeled. Peak flow is reduced at locations where overflow enters into overland storage areas, such as overtopping the Airport Road dike and the Skookumchuck River banks in the SR-507 Bridge and the Pearl St. Bridge vicinity. Overtopping of the Airport Road dike resulted in flooding of the airport and of I-5. Overtopping of the Skookumchuck River banks resulted in flooding of streets and buildings in the City of Centralia.

Figure 3-1:
Upper Chehalis River Basin UNET Model - Schematic Diagram

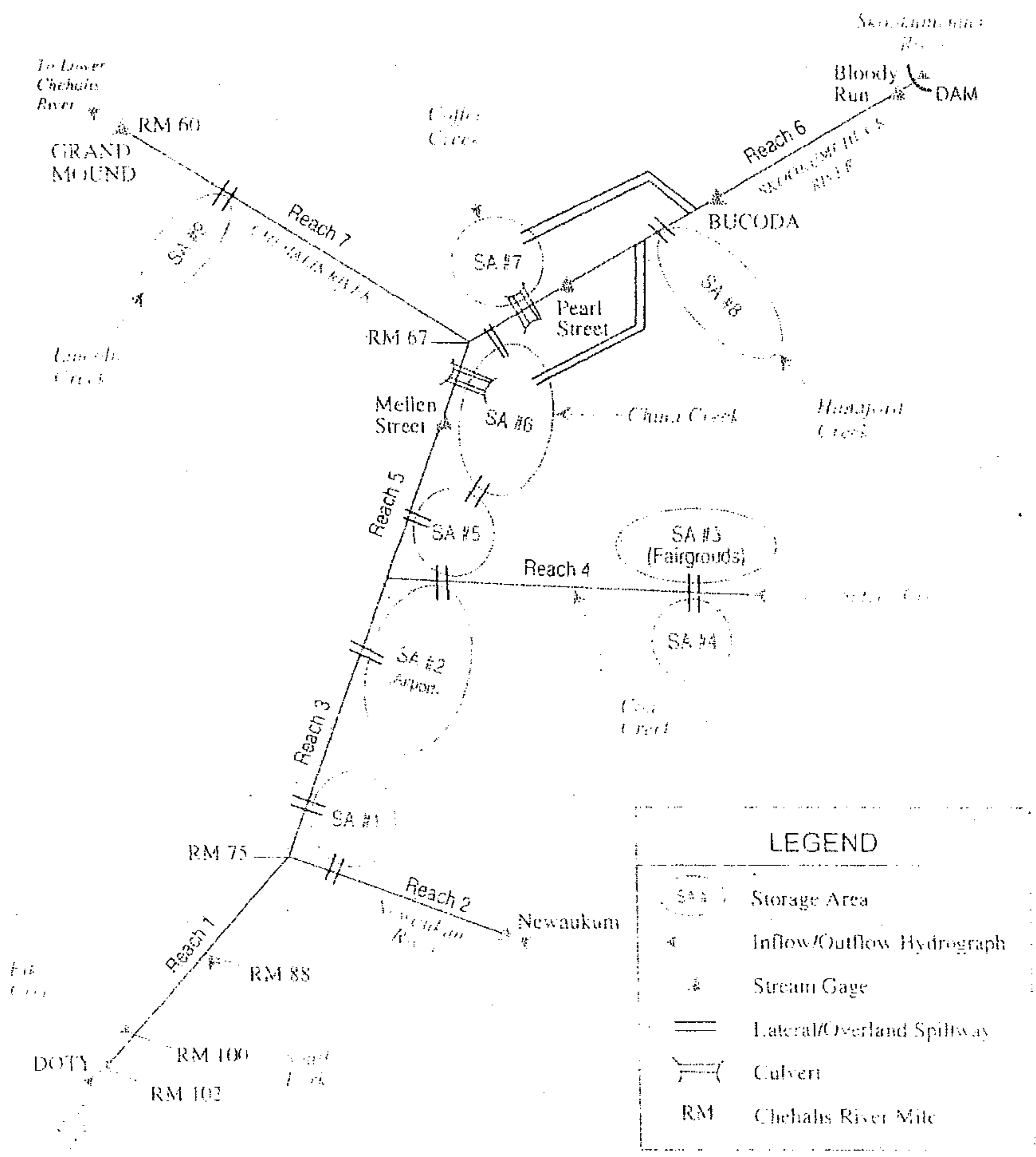


Figure 3-2:
Upper Chehalis River Subbasin Division Map

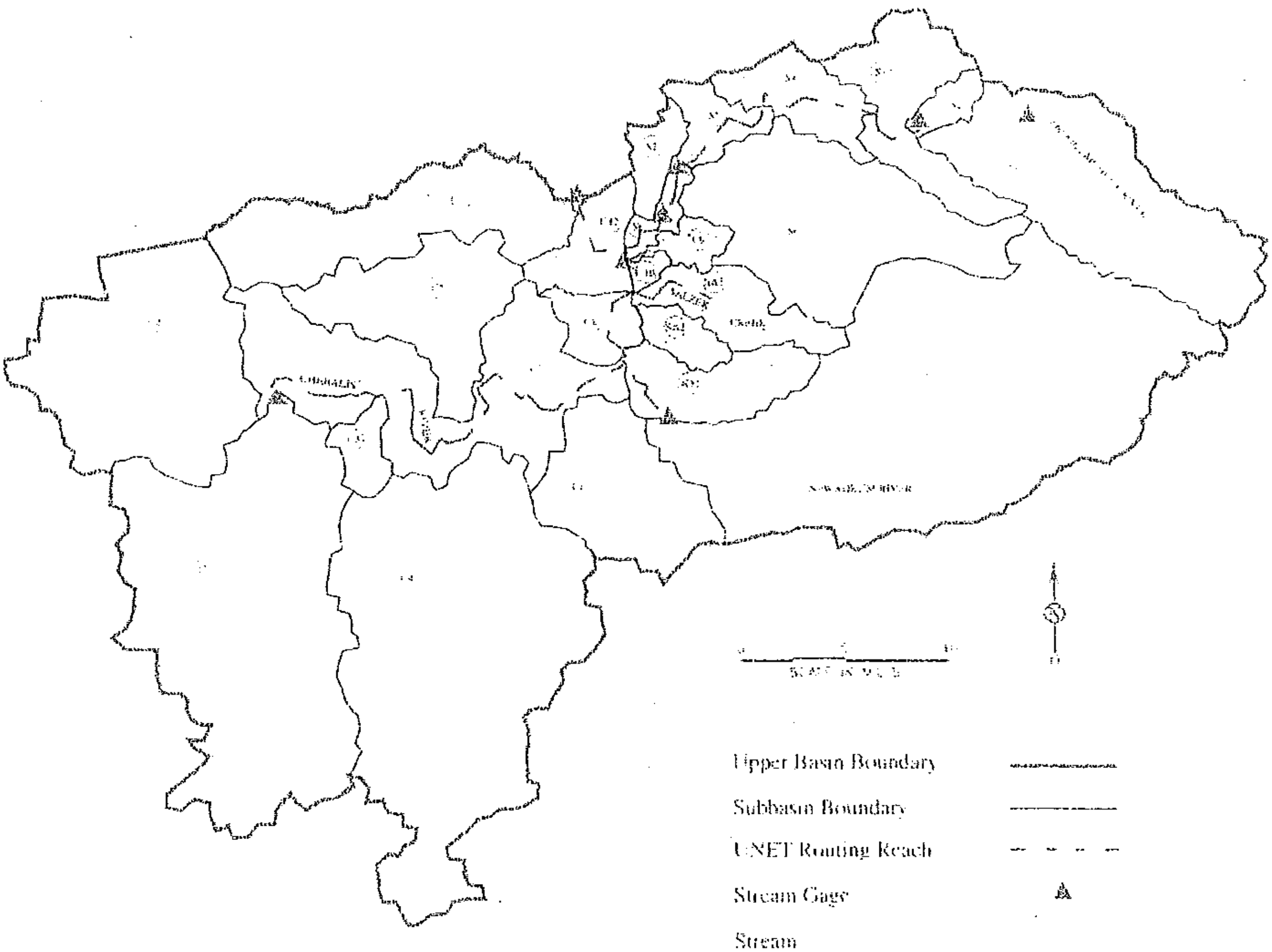
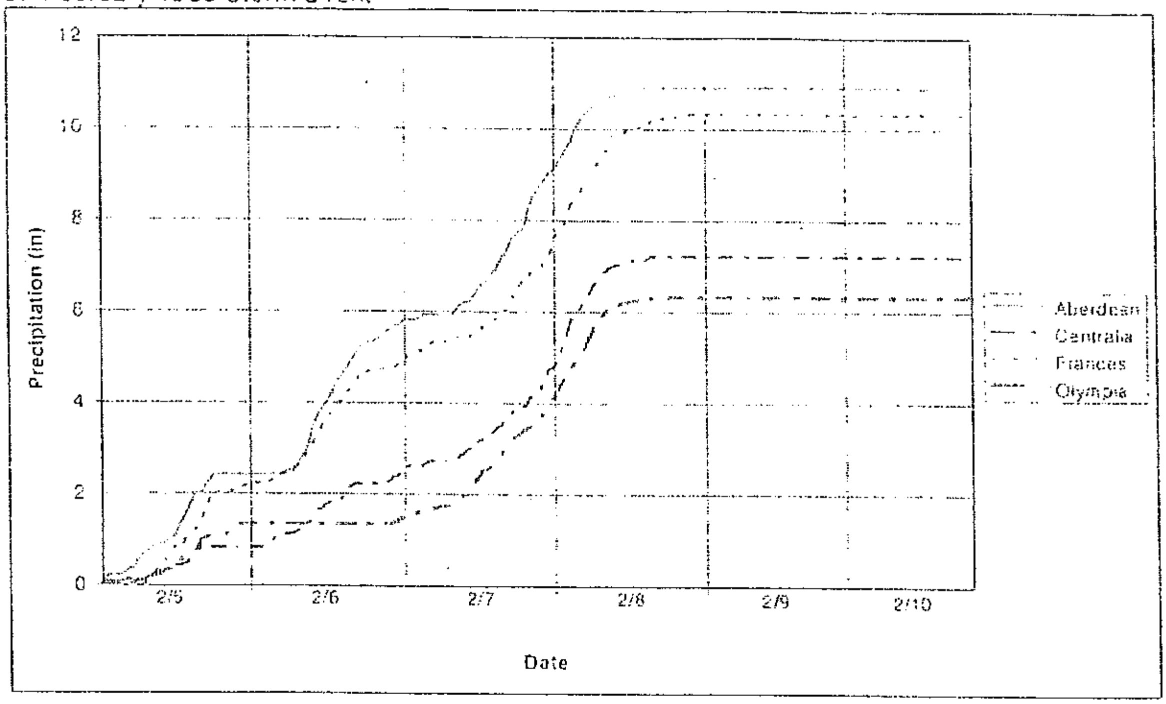


Figure 3-3: Accumulated Rainfall Curves

a. February 1996 Storm Event



b. November 1990 Storm Event

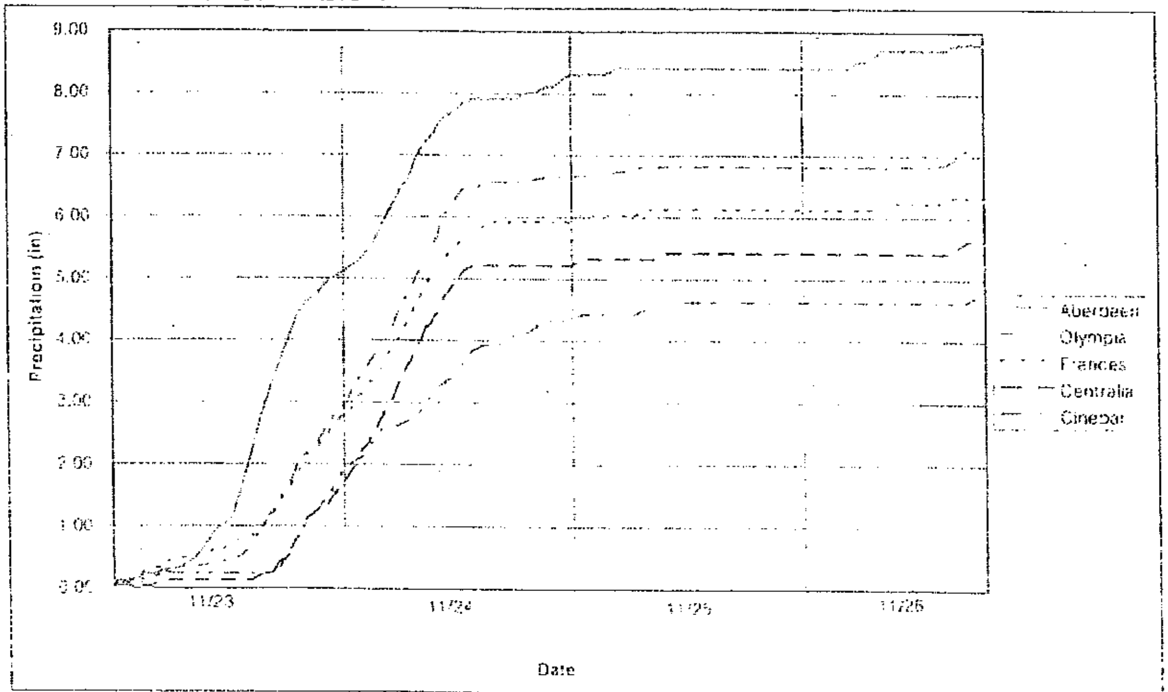
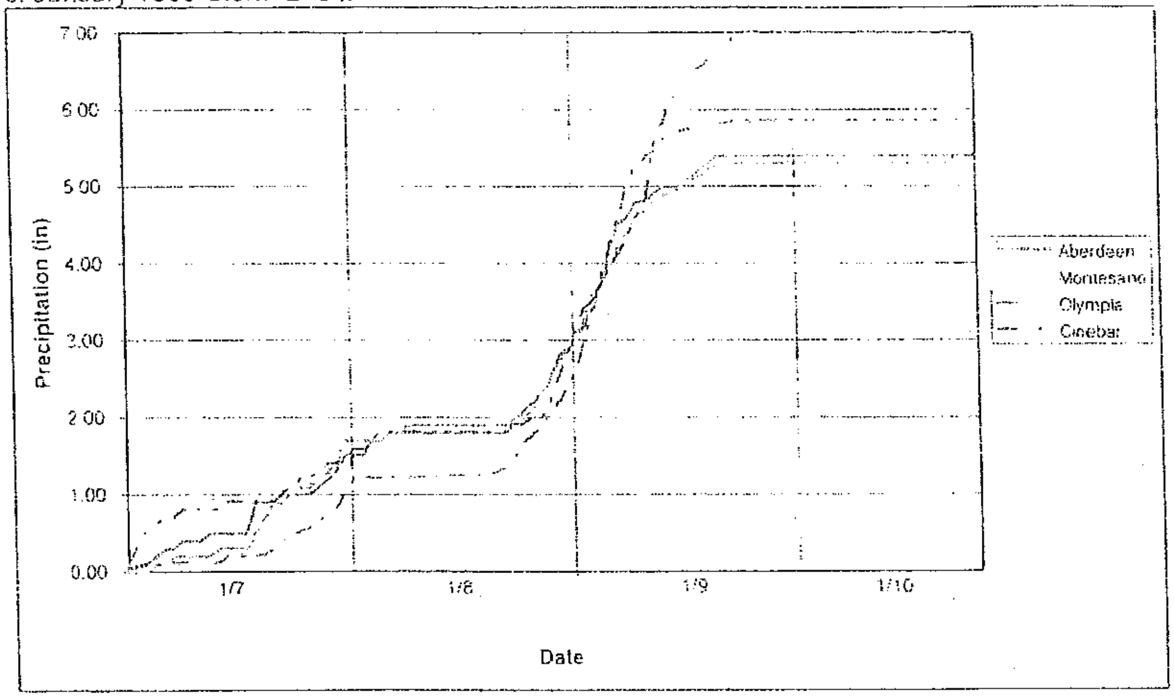


Figure 3-3: (cont.)
Accumulated Rainfall Curves

c. January 1990 Storm Event



d. January 1972 Storm Event

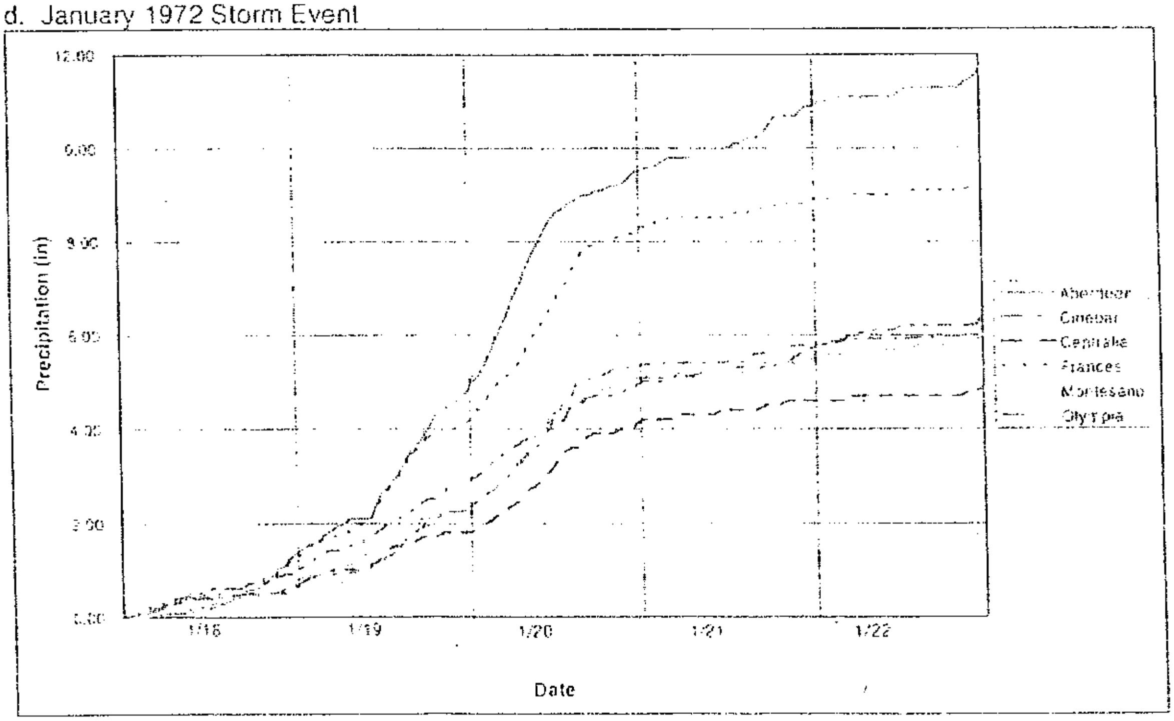
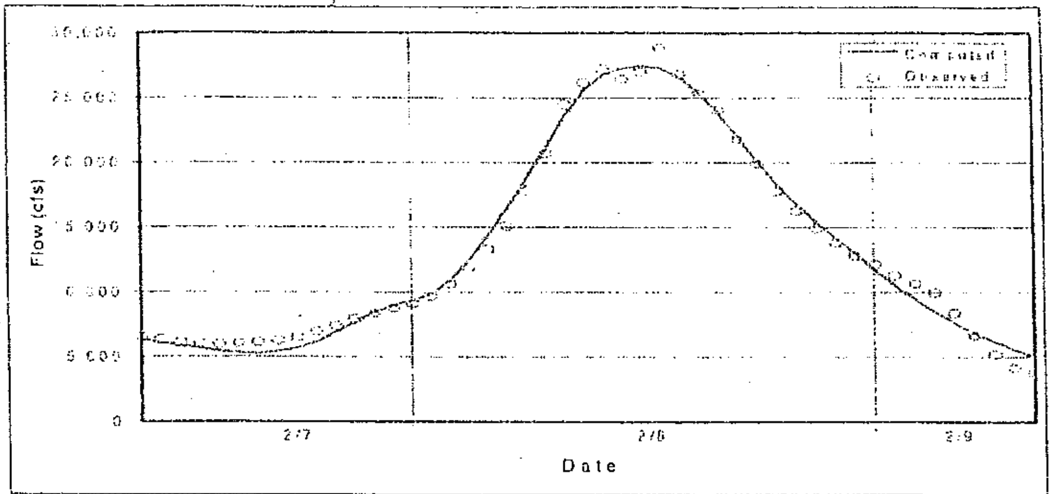
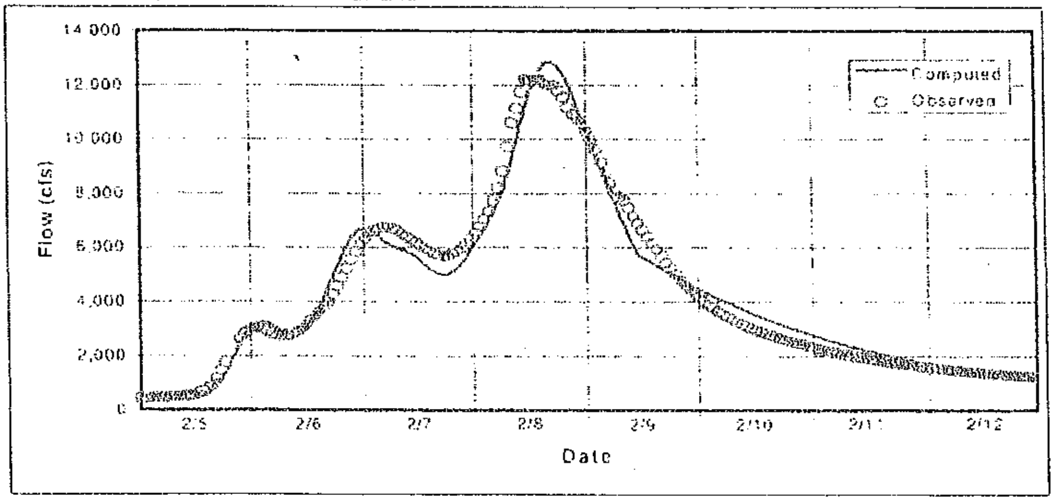


Figure 3-4
Comparison of Computed and Observed Hydrographs for the February 1996 Flood

a. Chehalis River near Doty



b. Newaukum River near Chehalis



c. Skookumchuck River near Vail

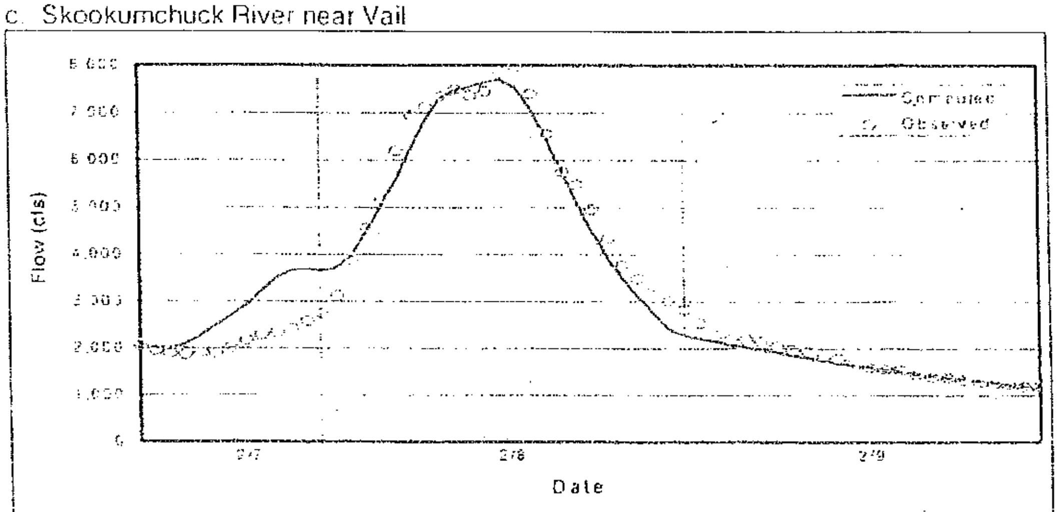
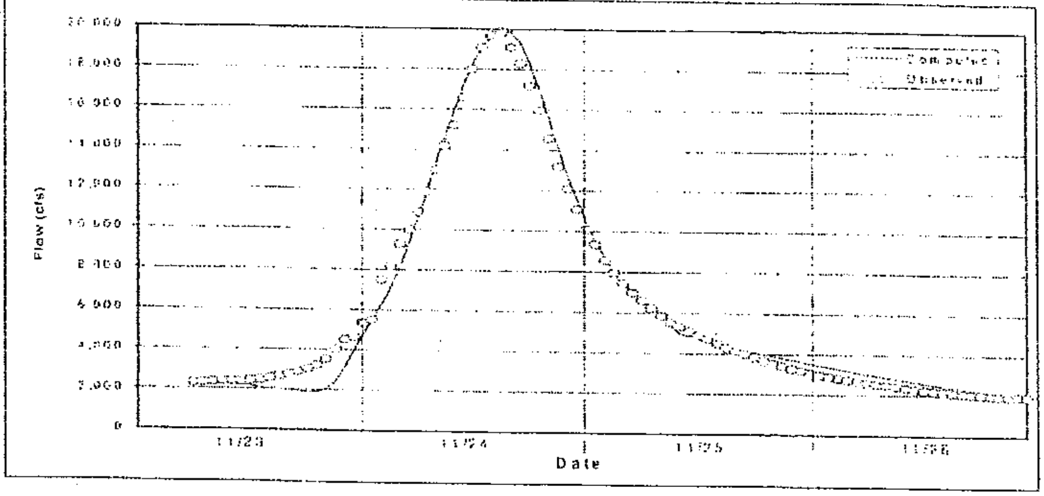
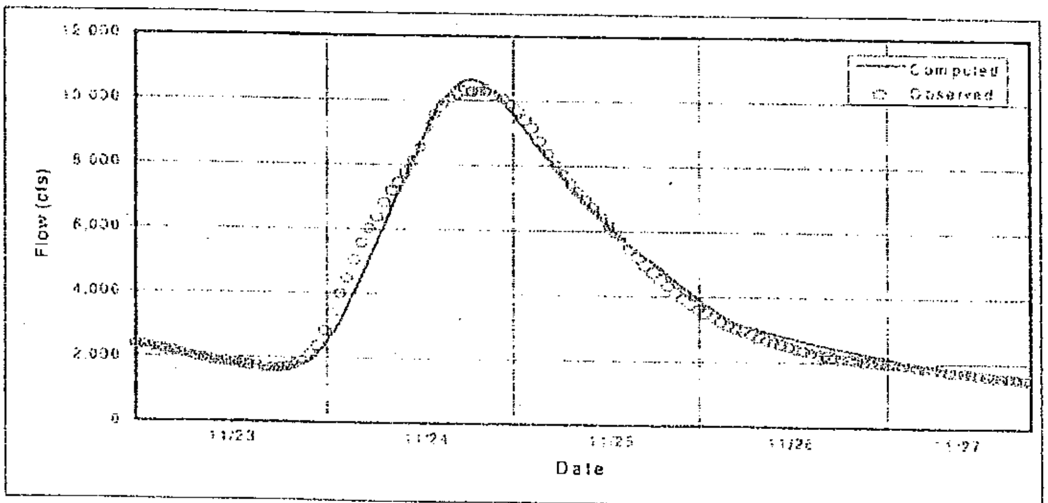


Figure 3-5:
Comparison of Computed and Observed Hydrographs for the November 1990 Flood

a. Chehalis River near Doty



b. Newaukum River near Chehalis



c. Skookumchuck River near Vail

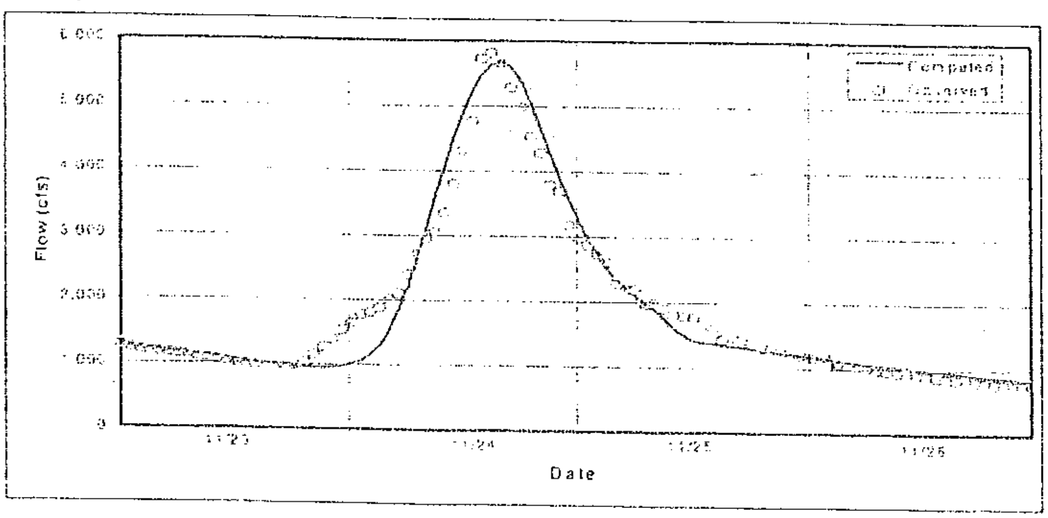
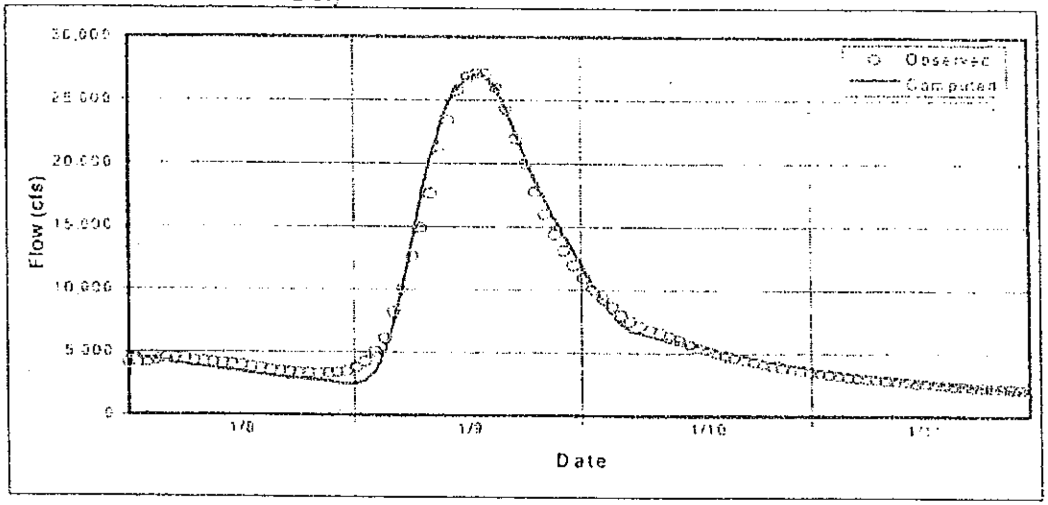
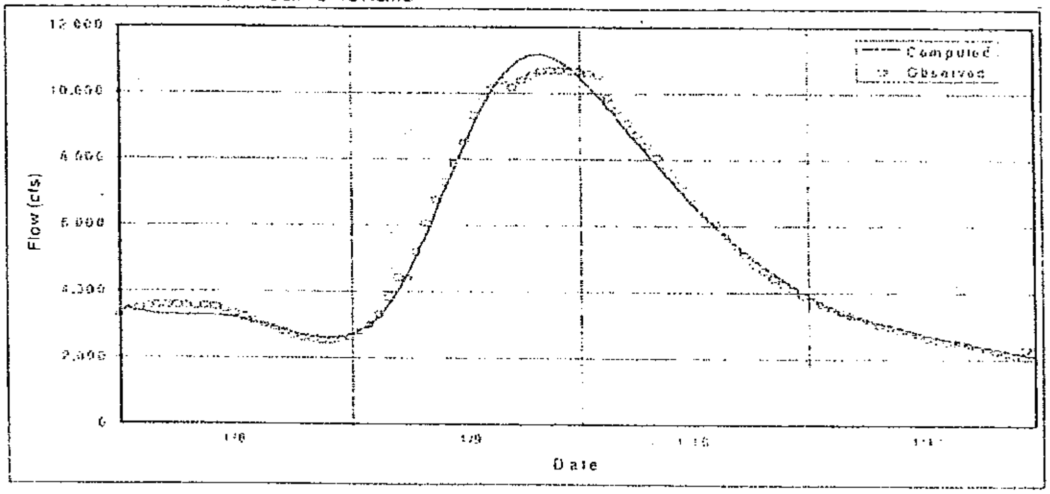


Figure 3-6:
Comparison of Computed and Observed Hydrographs for the January 1990 Flood

a. Chehalis River near Doty



b. Newaukum River near Chehalis



c. Skookumchuck River near Vail

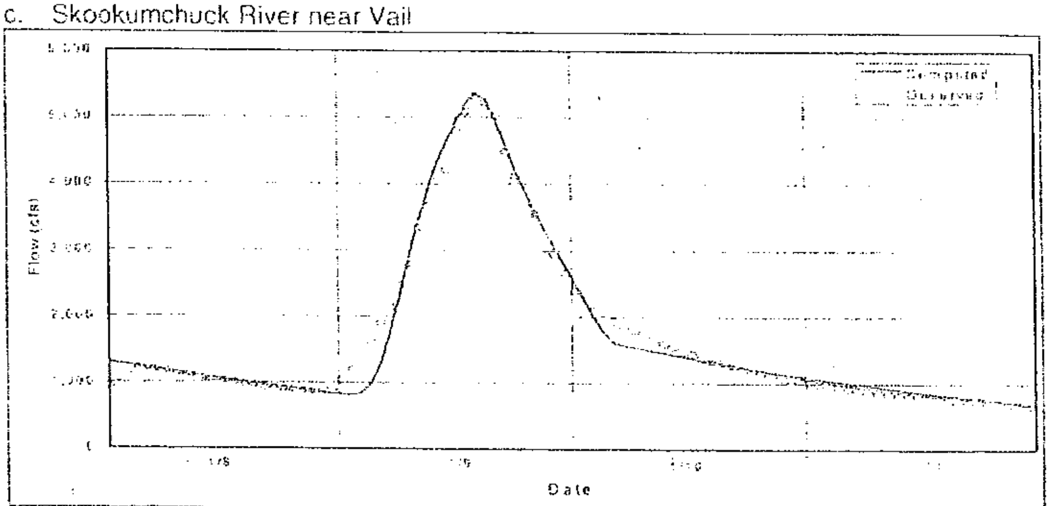
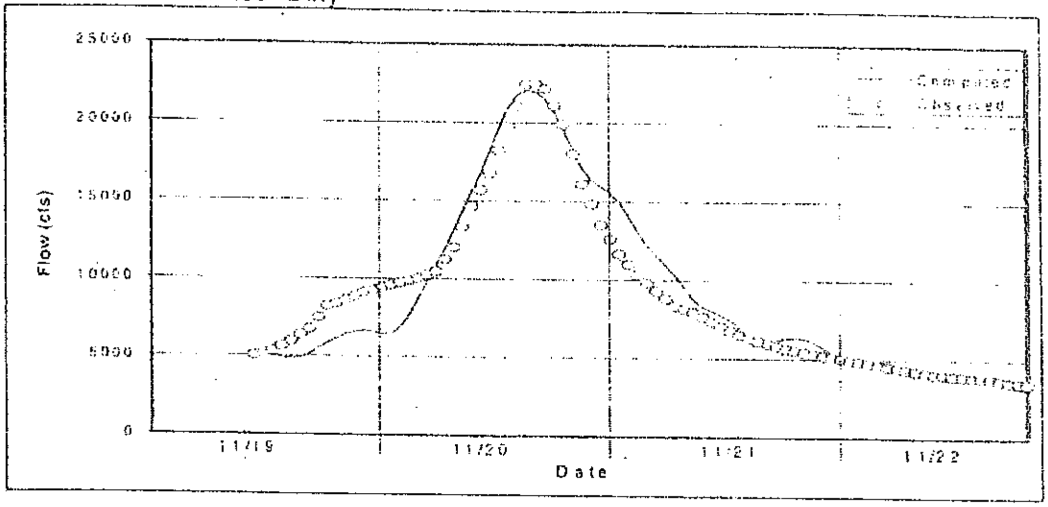
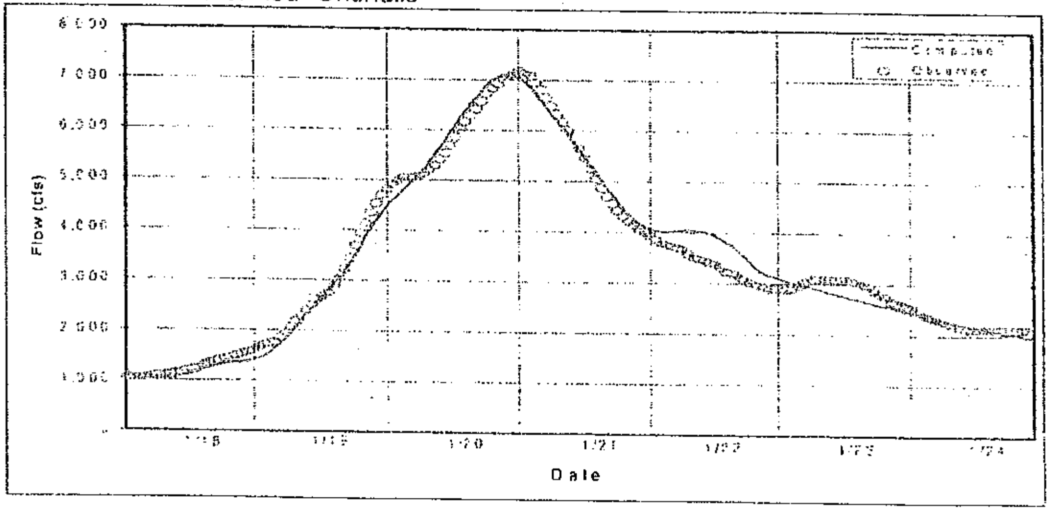


Figure 3-7:
Comparison of Computed and Observed Hydrographs for the January 1972 Flood

a. Chehalis River near Doty



b. Newaukum River near Chehalis



c. Skookumchuck River near Vail

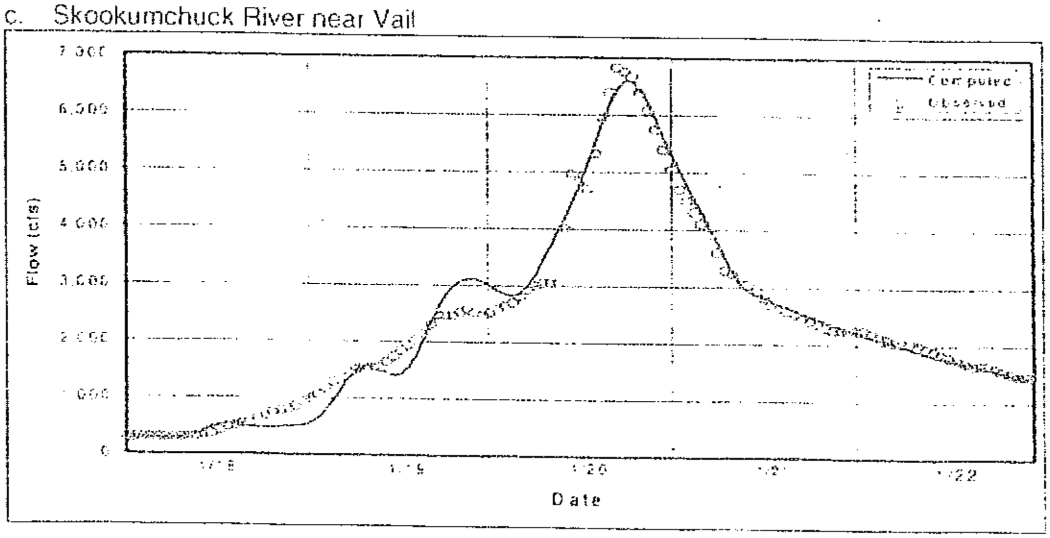
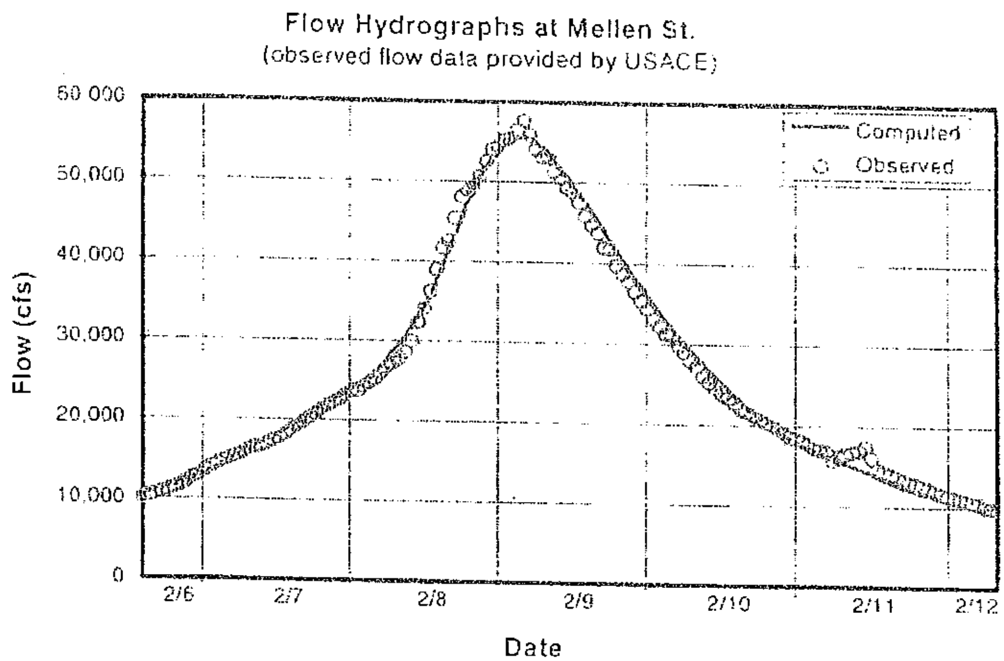


Figure 3-8:
Comparison of Computed and Observed Hydrographs on the Chehalis River at Mellen St. - February 1996 Flood



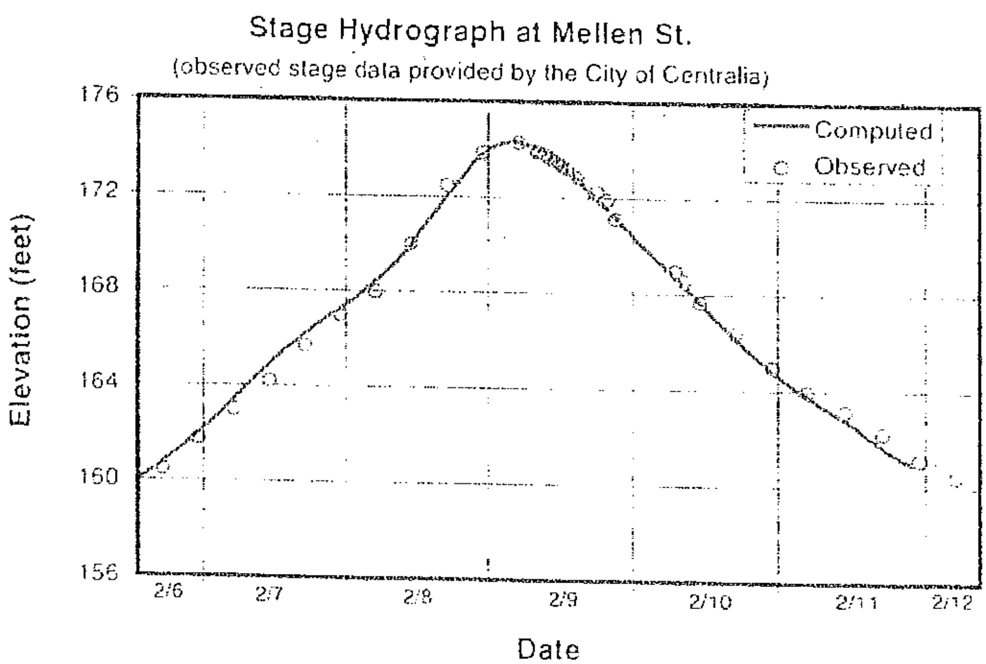


Figure 3-9:
Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Pearl St. - February 1996 Flood

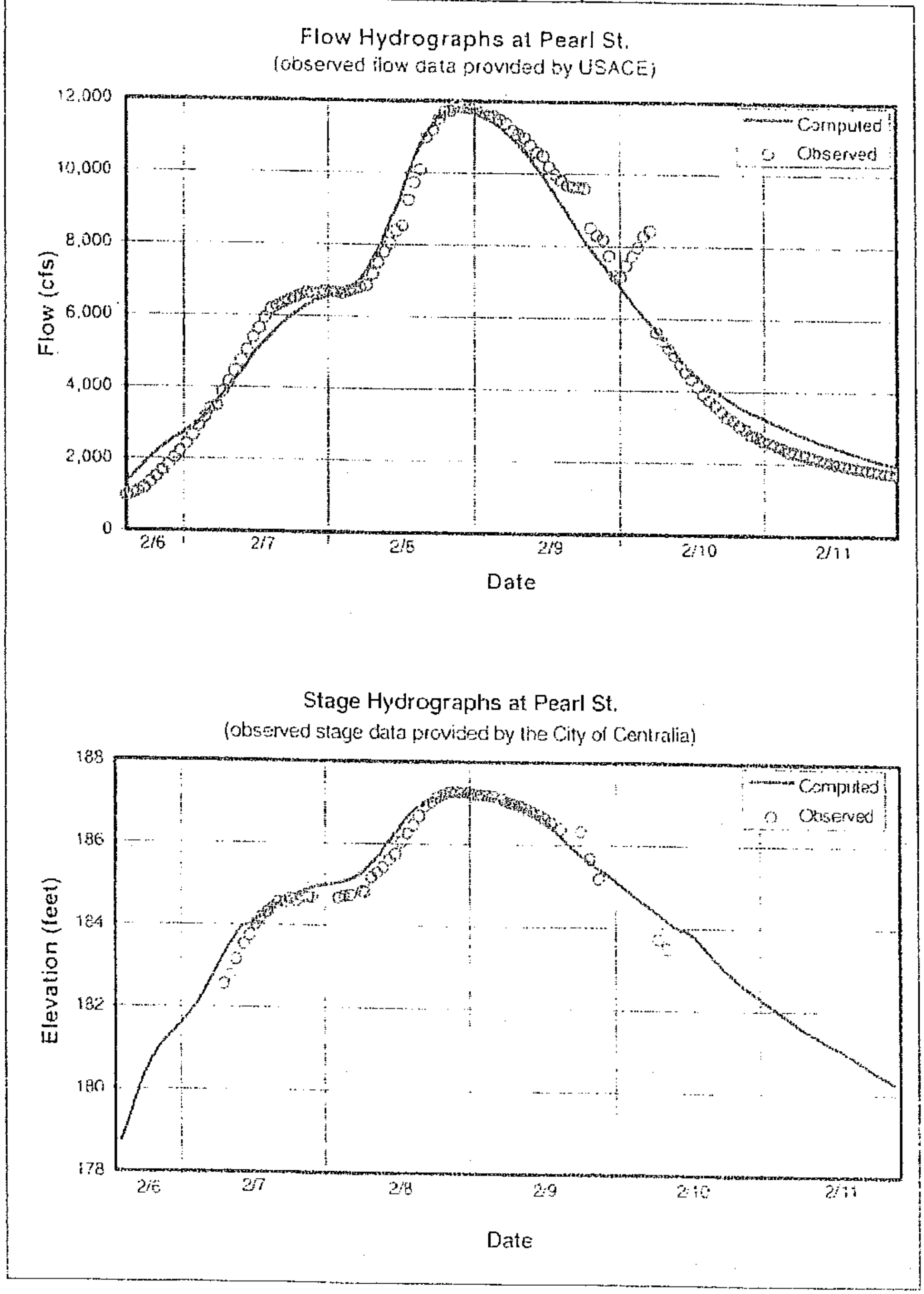
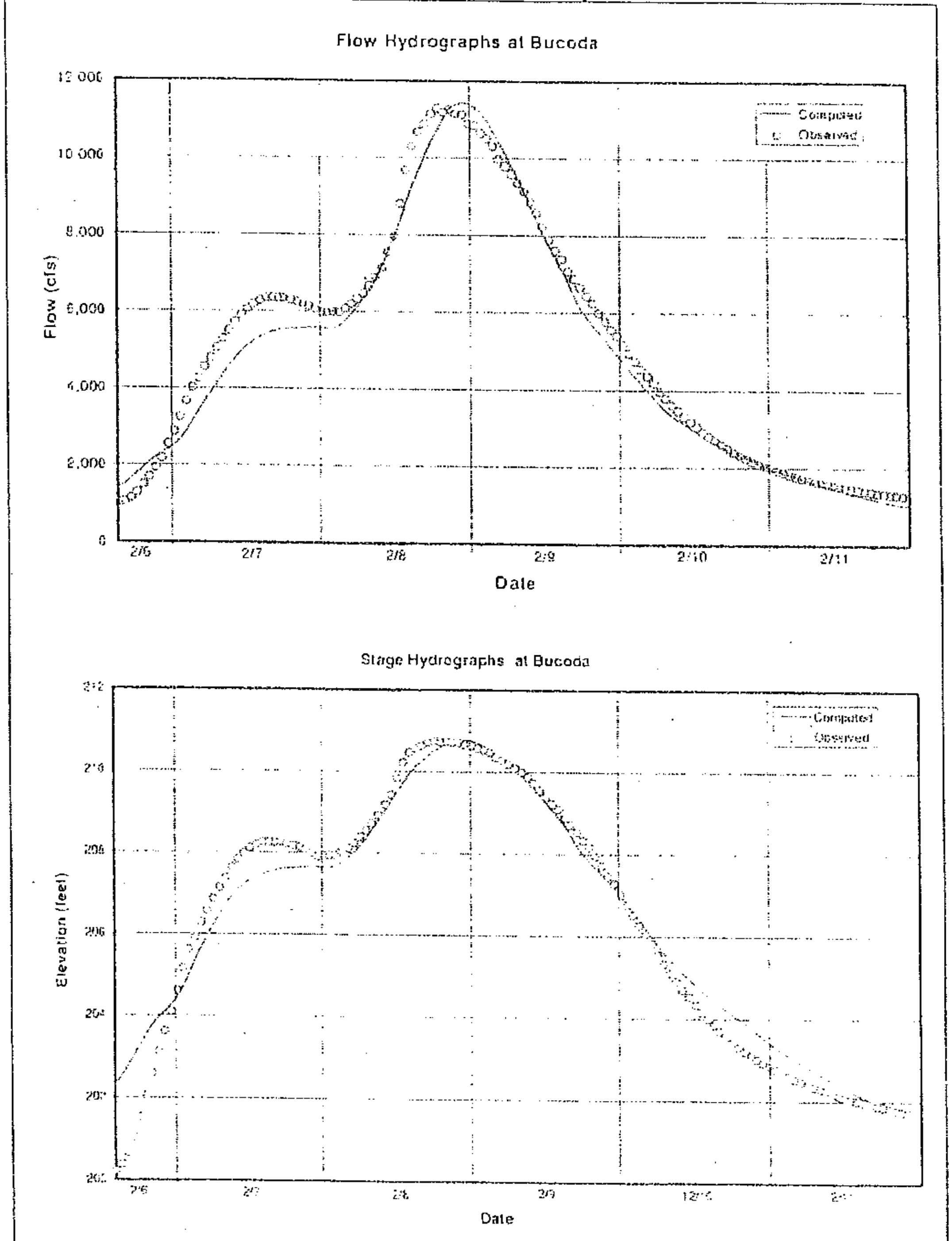


Figure 3-10:
Comparison of Computed and Observed Hydrographs on the Skookumchuck River at Bucoda - February 1996 Flood



(Note: observed stage data and stage-flow rating table provided by USGS)

Figure 3-11:
Comparison of Computed Water Surface Profiles and Observed High Water Marks on the Chehalis River for the February 1996 Flood Event

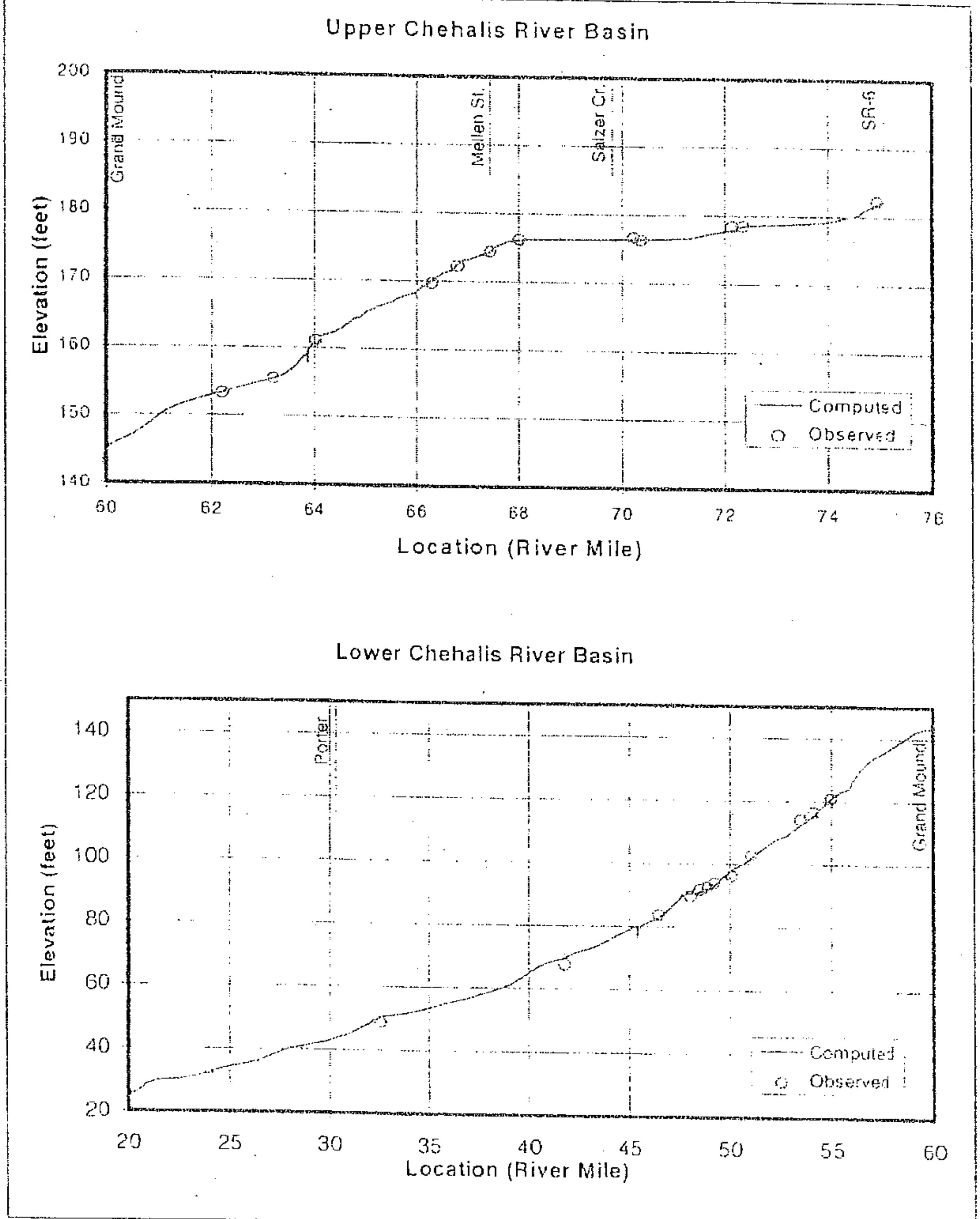
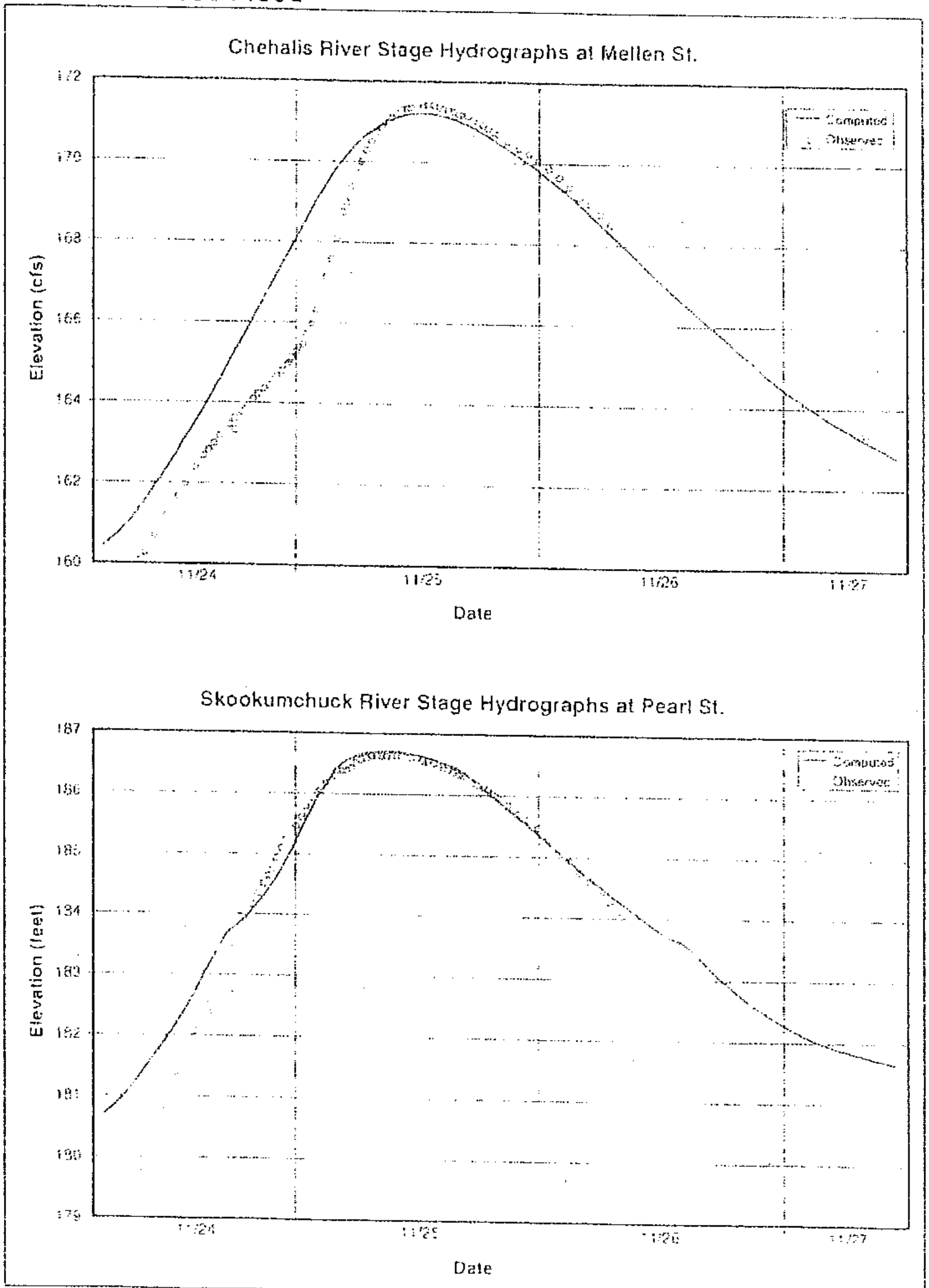
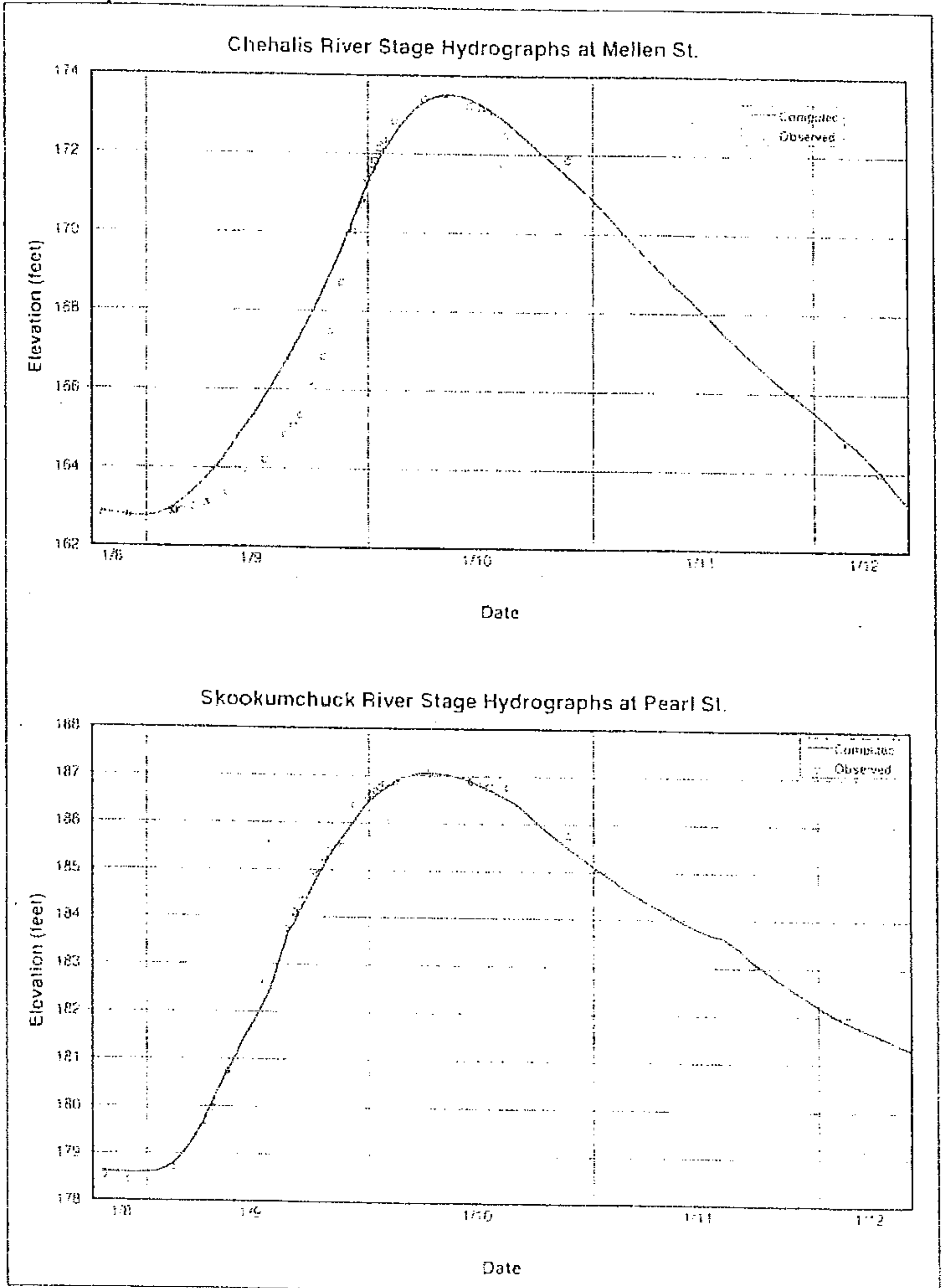


Figure 3-12:
Comparison of Computed and Observed Stage Hydrographs
November 1990 Flood



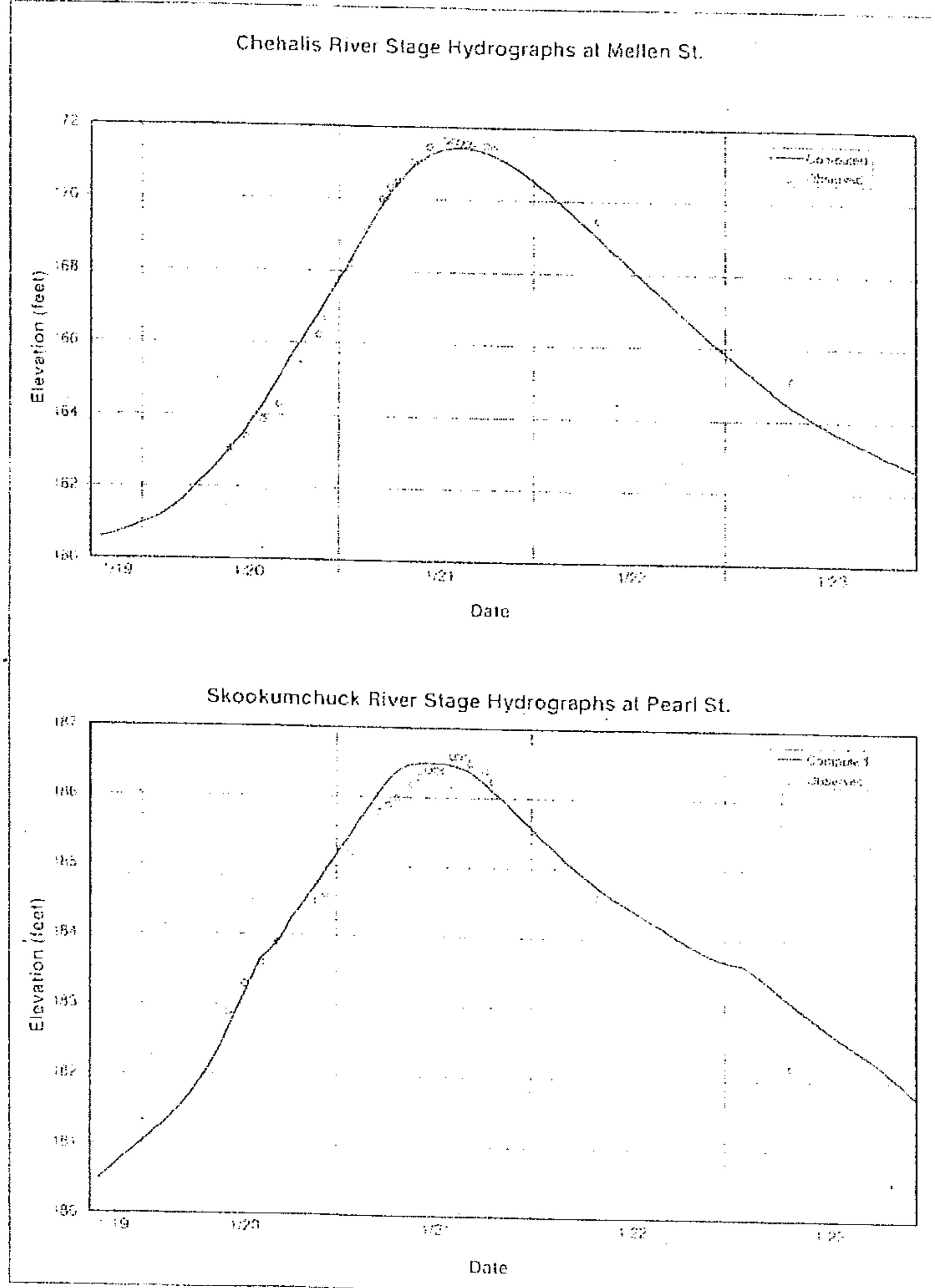
(Note: observed stage data provided by the City of Centralia)

Figure 3-13:
Comparison of Computed and Observed Stage Hydrographs
January 1990 Flood



(Note: observed stage data provided by the City of Centralia)

Figure 3-14:
Comparison of Computed and Observed Stage Hydrographs
January 1972 Flood



(Note: observed stage data provided by the City of Centralia)

Figure 3-15:
UNET Computed Flow Hydrographs on the Chehalis River
February 1996 Flood

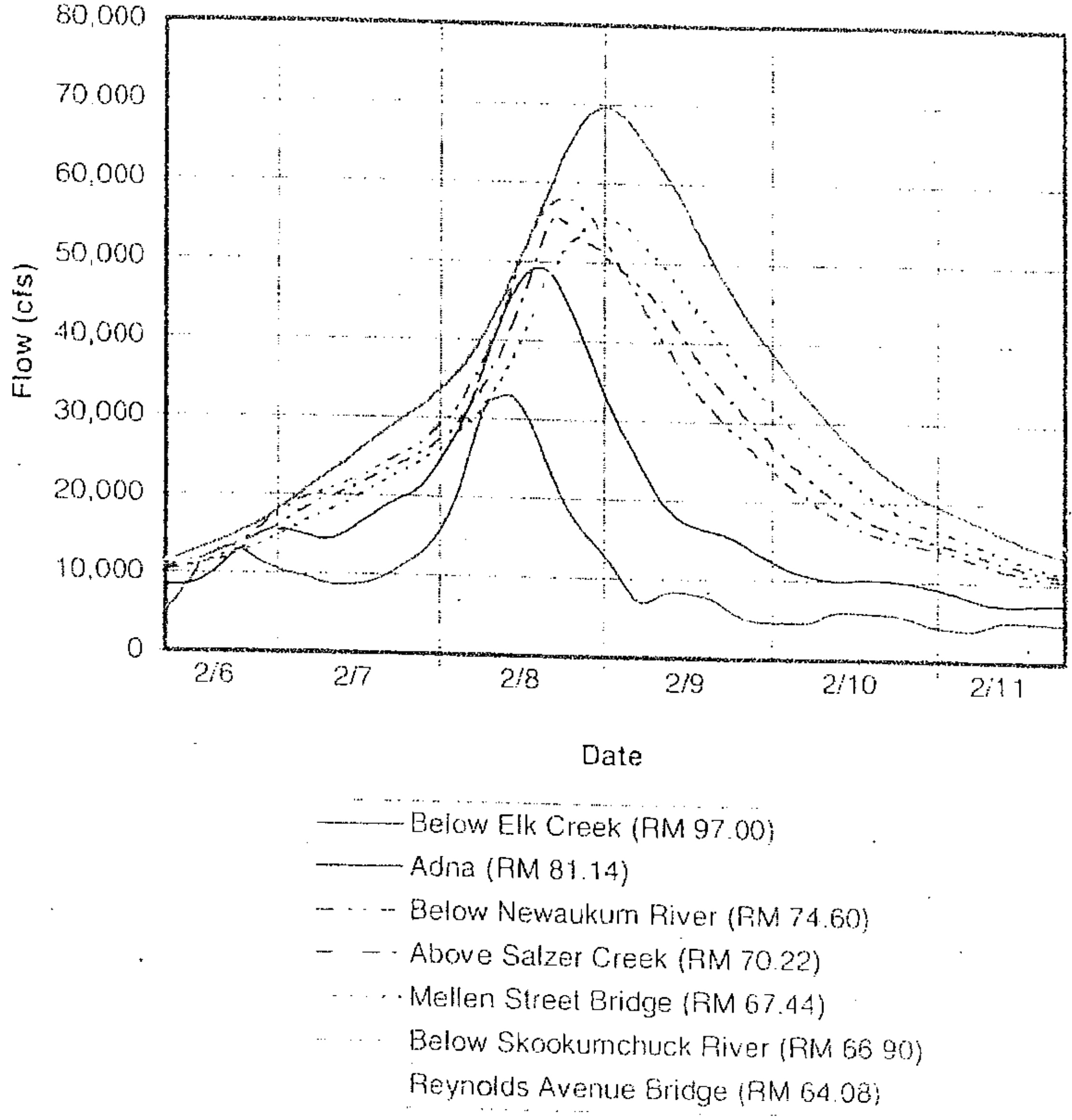


Figure 3-16:
UNET Computed Flow Hydrographs on the Chehalis River
November 1990 Flood

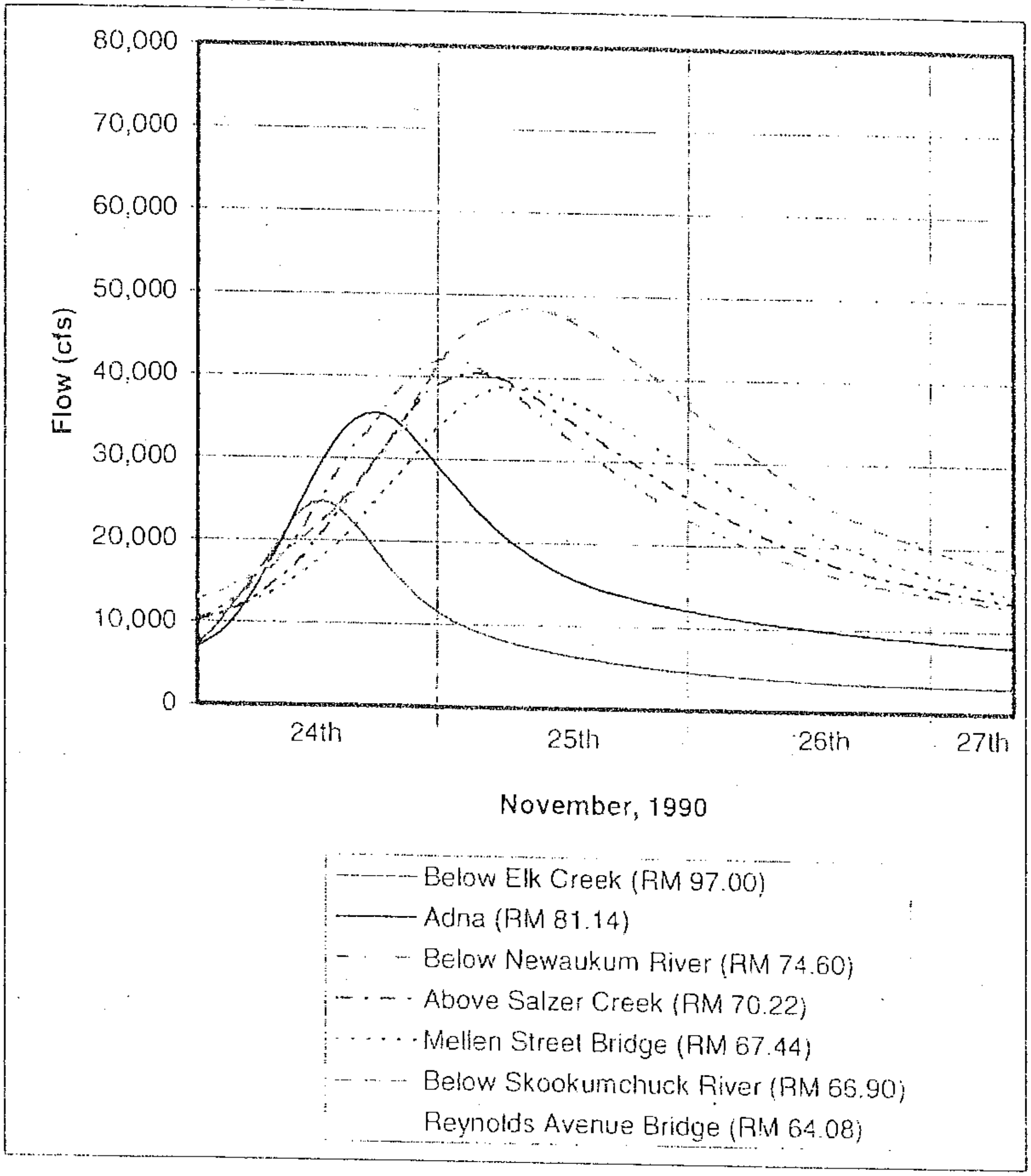


Figure 3-17:
UNET Computed Flow Hydrographs on the Chehalis River
January 1990 Flood

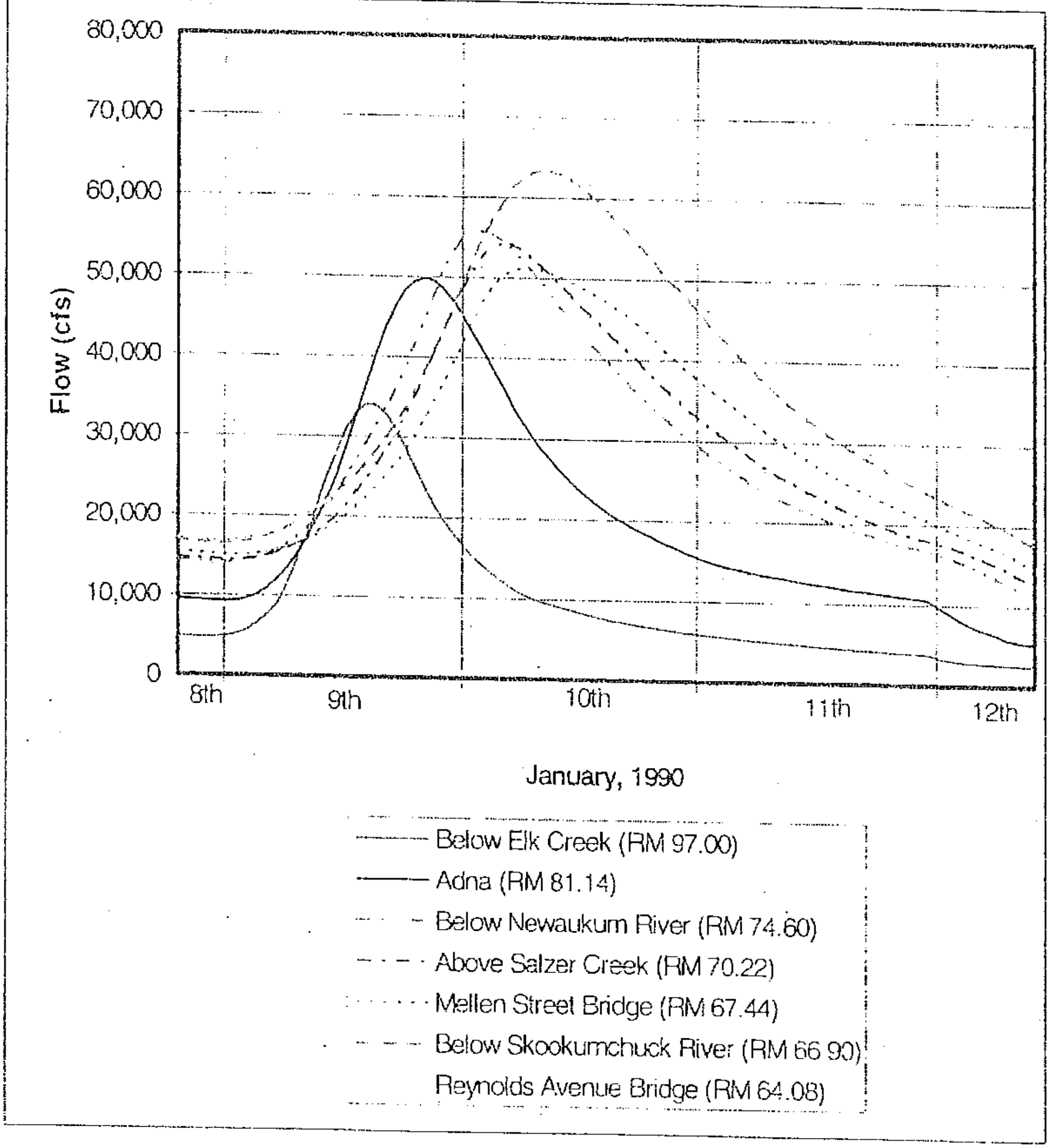


Figure 3-18:
UNET Computed Flow Hydrographs on the Chehalis River
January 1972 Flood

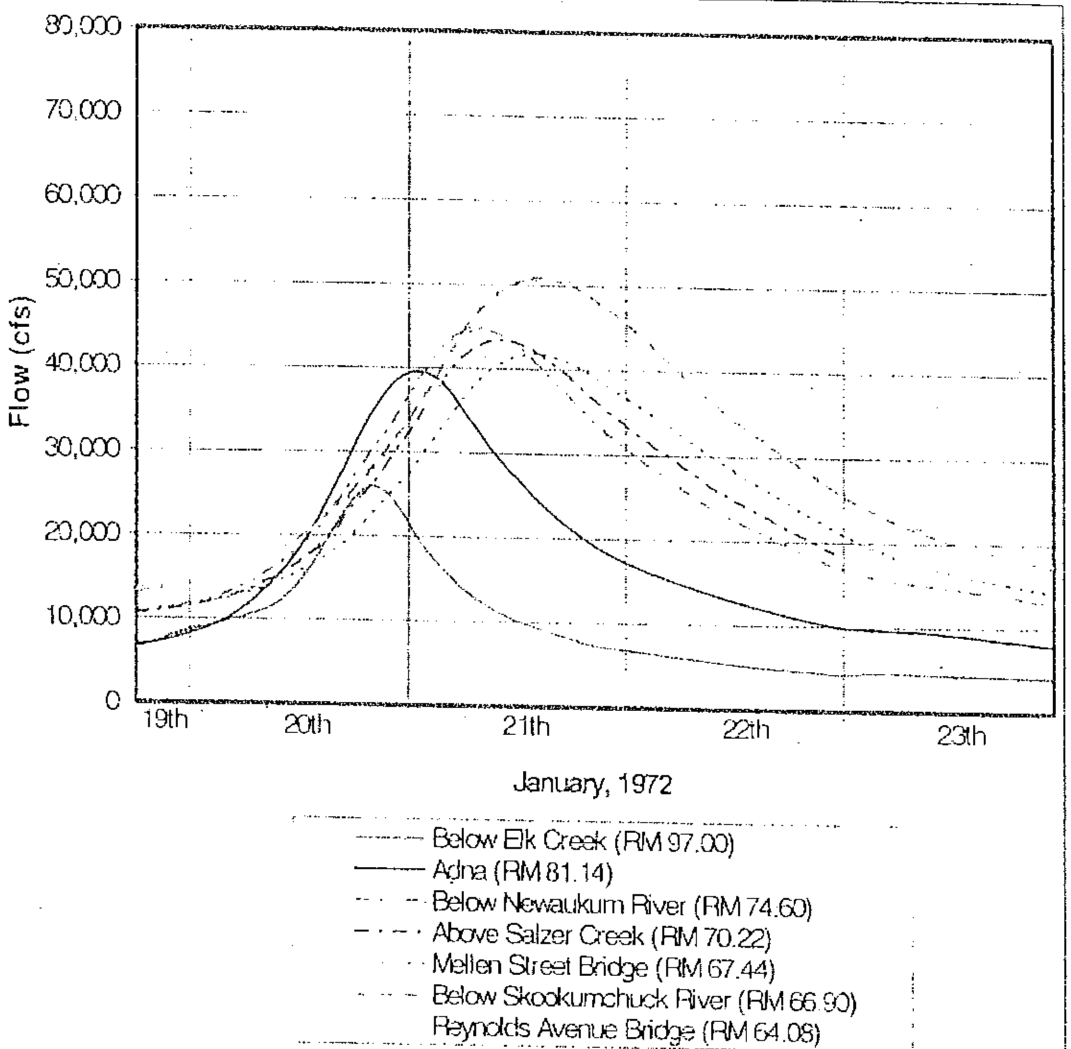
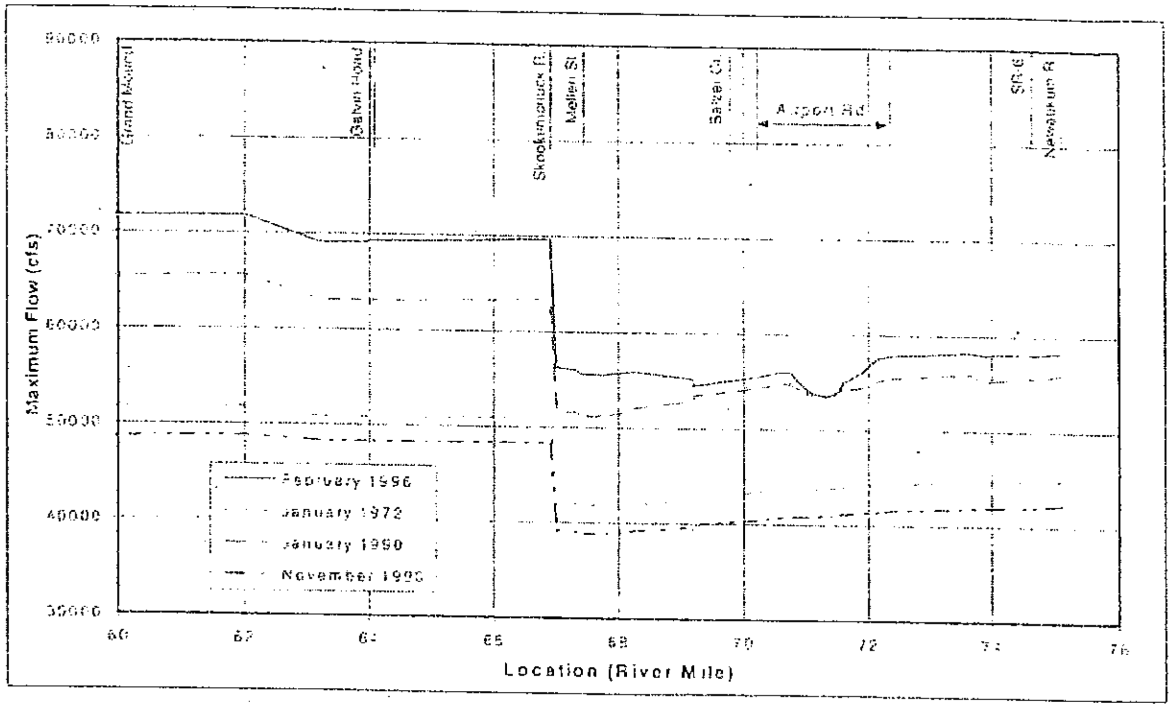


Figure 3-19:
UNET Computed Profiles on the Chehalis River

a. Peak Flows



b. Flood Stages

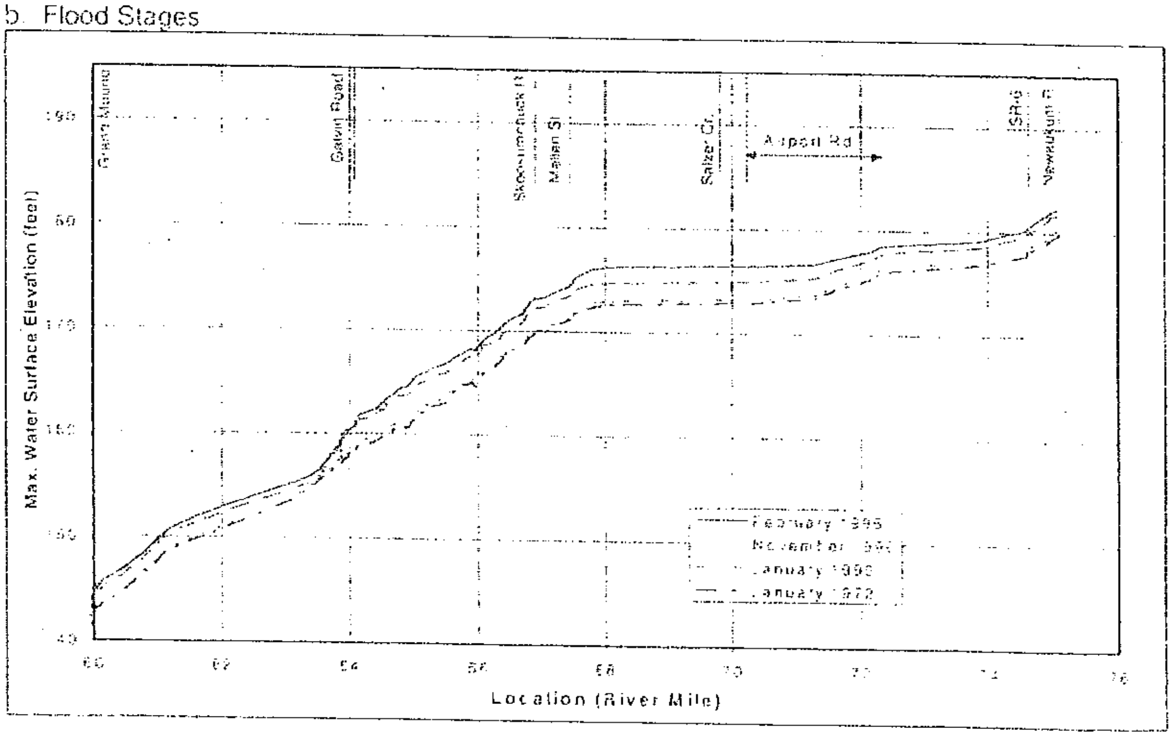
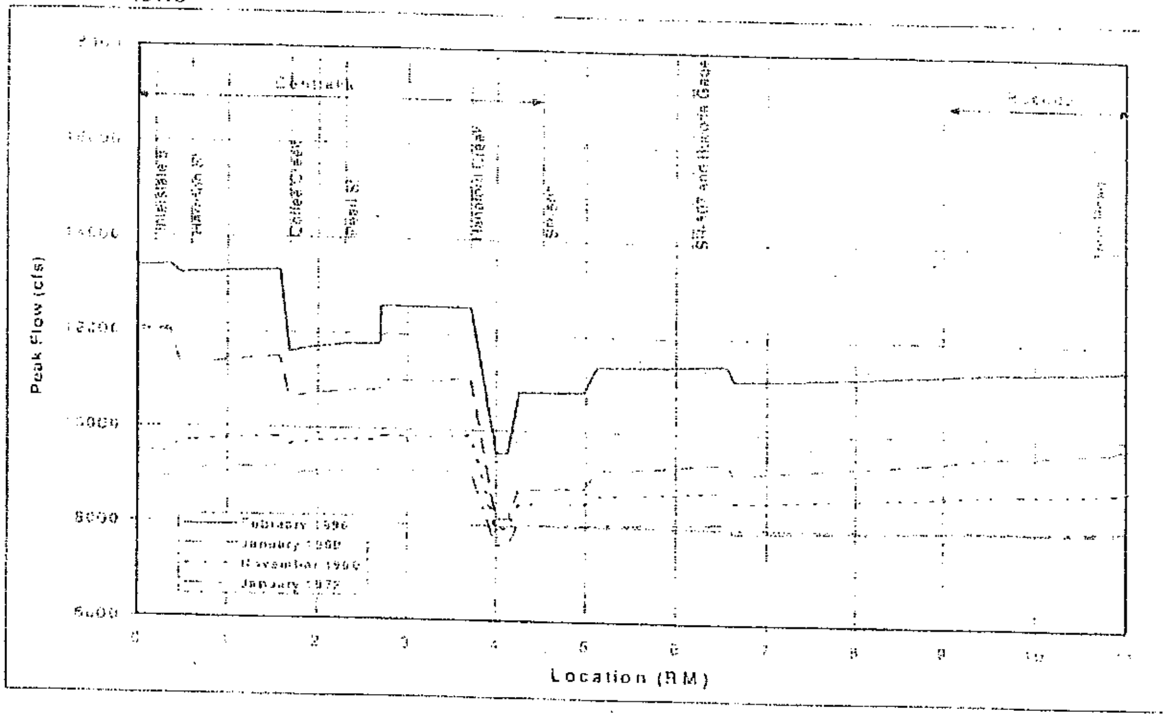
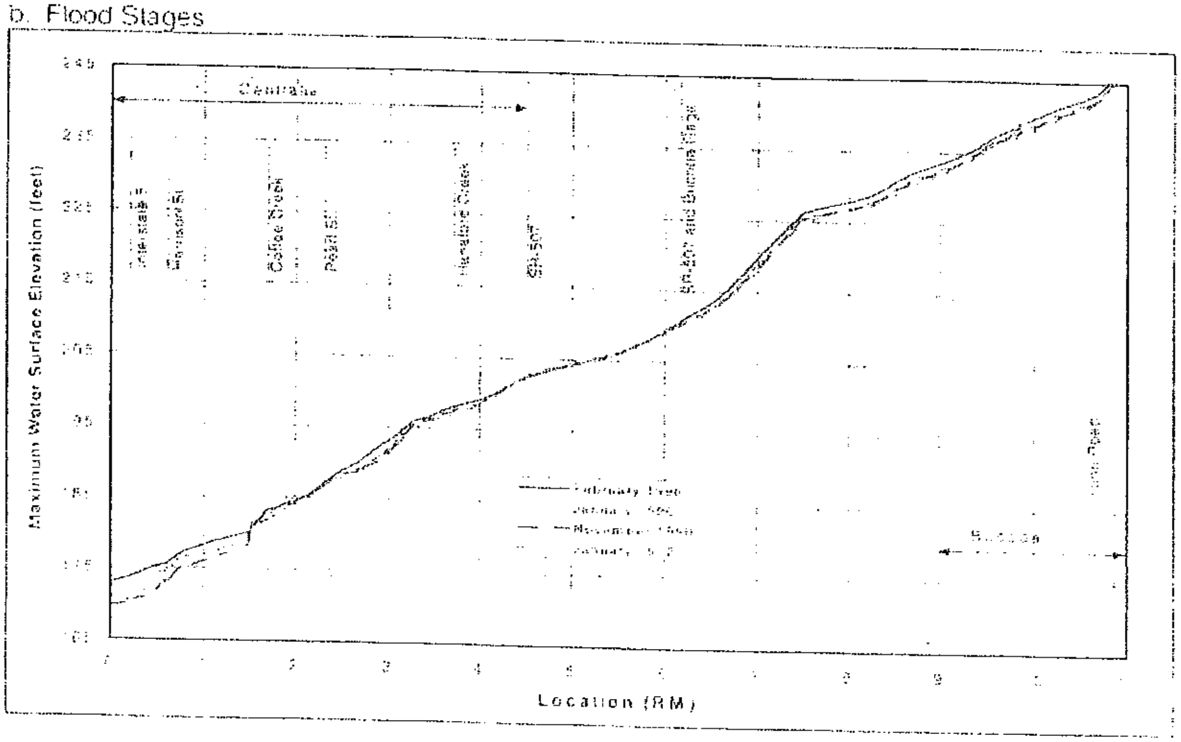


Figure 3-20:
UNET Computed Peak Flow Profiles on the Skookumchuck River

a. Peak Flows



b. Flood Stages



4. Flooding Impact Reduction Alternatives

4.1. Introduction

USACE has studied flood control options on the Chehalis River since 1931. Initial study efforts (1931-1949) considered multipurpose storage projects, but none were found to be economically justified. Studies resumed in 1966 at the request of local governments following severe flooding in the basin. Through 1971, study efforts concentrated on identifying the significant flood problems in the basin and possible solutions. At that time, preliminary results indicated that large-multipurpose projects remained unjustified, but local protection projects for urban areas appeared to be economically justified.

Feasibility level studies for flood control in the Centralia-Chehalis area began in 1975. In 1980, USACE made a tentative recommendation for a levee system to protect 2,080 acres, primarily in the City of Centralia. Protection for the City of Chehalis and other nearby areas was not found to be economically justified. Centralia agreed to be the local sponsor for the USACE proposed project, but asked USACE to again review the possibility of modifying Skookumchuck Dam for flood control before proceeding with the levee project. In December 1982, USACE completed the Centralia Flood Damage Reduction Feasibility Report. The report reviewed the alternatives that USACE had considered, and recommended modifications to Skookumchuck Dam to provide flood control storage.

USACE began pre-construction engineering and design in 1988. In 1990, USACE completed its revised flood damage appraisal, preliminary design, cost estimate and preliminary project evaluation. Even after several revisions to the design, USACE determined that the project could not be economically justified, and all feature design work was ceased. In 1992, USACE published a wrap-up report on the studies that had been performed to date.

The previous studies performed by USACE that proved the modifications to Skookumchuck Dam to be economically infeasible focused primarily on providing benefits to the Skookumchuck River Valley and the City of Centralia. Since USACE performed these studies, two major floods in the basin have caused the closure of I-5. With the inclusion of I-5 flooding impacts in the analysis, the potential benefits to reducing flooding in the Centralia-Chehalis floodplain could now prove to be substantially greater, raising the likelihood of an economically justified project.

4.2. No-Action Alternative

4.2.1. Description of Alternative

It is assumed that, if no project is undertaken to reduce the impacts of flooding currently affecting the Centralia-Chehalis area, flood damage will continue as documented for historical events. It is also assumed that one and possibly two projects addressing specific flood damage areas will be implemented. The two projects are: the USACE Long Road Dike Project and the WSDOT proposal to widen and raise the grade of I-5 in a 2.9 mile reach in the Centralia-Chehalis Area. Current scheduling for the Long Road Dike Project suggests that it may be built prior to any decision regarding the flood damage reduction project discussed in this report, although the project identified in this report would likely preclude the need for the Long Road Dike Project. The WSDOT I-5 Project is scheduled to go out to bid in 2004, but the portion of the project which involves raising I-5 could be eliminated if the project recommended herein is implemented.

Continuation of Existing Flood Damage Conditions

Since 1971, Lewis County has experienced 11 flood disasters which have significantly affected industrial, commercial, agricultural and residential areas in Lewis County (USACE, 1982 and Washington State Military Dept., 1995). The majority of the impact from these floods occurred in the urbanized and agricultural floodplain areas in the Centralia-Chehalis area near the confluence of the Chehalis and Skookumchuck Rivers and their tributaries, including China, Coffee, Newaukum, Salzer and Dillenbaugh Creeks. Under the No-Action alternative, floodplain boundaries would be as shown in Figure 5-24. Existing average annual flood damage costs described in Section 4.2.3 would continue and most likely increase gradually.

USACE Long Road Dike Project

The Long Road Dike Project (LRDP) was designed by USACE under the authority of Section 205 of the 1948 Flood Control Act, as amended, in response to a request by the Lewis County Diking District Number 2. Lewis County requested federal assistance in providing protection to the Long Road District (LRD) from flooding caused by the Chehalis River backing up Salzer Creek. A Draft Environmental Assessment (DEA) was distributed for agency and public review by USACE on December 16, 1997 (USACE, 1997b). Review comments were due on January 15, 1998. The DEA shows construction scheduled for the summer of 1999. It is likely that this project will be built prior to any decision regarding the flood damage reduction project discussed in this report.

The LRD contains about one hundred acres, in the shape of a right triangle, located partially in the City of Centralia and partially in Lewis County. The sides of the triangle are formed by I-5 to the southwest, the

Tacoma Eastern Railroad (TERR) to the east and Mellen St. to the north. The south corner of the triangle, where the TERR begins to parallel I-5, is not completely closed off. The LRDP proposes to construct a dike across the low area at or near this portion of the triangle, where the existing non-federal embankments on the east and west sides of the triangle, combined with the new levee, could provide protection from up to a 45-year flood to the approximately 116 housing units, church and convalescent home in the LRD.

The proposed cross-levee would stretch about 2,200 feet between the railroad and I-5 embankments, using a "reverse L-shape" to avoid impacts to wetlands that run along the southern portion of the railroad embankment. The top of the levee is designed to be at elevation 177.0 feet (NGVD datum). This could provide complete protection from floods resulting from a 45-year event. Greater protection is not reasonable because flood waters resulting from larger events could overtop the low divide between China Creek and Salzer Creek backflooding the LRD.

According to the DEA, the total value of the improvements in the LRD is approximately $5,300,000. Based on 1996 prices and conditions, average annual flood damage within the LRD is estimated to be $84,800. The total construction cost of the proposed dike is estimated at $507,000. Average annual benefits resulting from prevention of flood damages totals $50,300. The average annual costs, evaluated at 7-3/8 percent interest rate over a 45-year economic analysis period, including allowances for operation and maintenance, amount to $43,500. Thus, the project has a net economic benefit of $6,800, resulting in a benefit-to-cost ratio of 1.2 to 1.0. The LRD would be responsible for operating and maintaining the project at an estimated average annual cost of $5,000.

WSDOT I-5 Project

WSDOT is proposing a project (the I-5 Toutle Park Road to Maytown Project) to widen and make various other improvements to I-5 to improve traffic flow and safety in the vicinity of Centralia-Chehalis. Implementation of this project will require that WSDOT and FHWA standards for minimum flood clearance be met. These standards state that the mainline pavement must not be flooded during the 50-year flood event (FHWA and WSDOT, 1997). FHWA manuals require that the interstate highway system be designed to be two feet above the 100 year flood boundary (WSDOT, 1997).

Based on recent recalculation of flood frequency curves for this area by USACE (USACE, 1997a), the minimum flood clearance requirements are not currently being met in a 2.9-mile section of I-5 between Chamber of Commerce Way Interchange in Chehalis and the Mellen St. (SR 507) Interchange in Centralia. Implementation of WSDOT's improvement project will require that I-5 be raised to meet the minimum flood clearance requirements in this section, unless other measures are taken to alter and reduce existing flood stage levels in the area.

Compared to widening without the grade change, widening of the roadway with the grade change would require additional fill, and construction of an expensive retaining wall. As discussed in Section 4.2.2 below, the additional fill and elevation of the embankment would incrementally add to the loss of floodplain storage in the area.

The construction cost of widening and raising I-5 from the existing grade to two feet above the 100-year flood elevation is estimated by WSDOT to be $321 million ($353 million if preliminary engineering by WSDOT is included) (WSDOT, 1998). The construction cost of widening I-5 without raising is estimated by WSDOT to be $223 million ($245 million including preliminary engineering), and the incremental cost associated with raising I-5 is $98 million ($108 million with preliminary engineering).

A Draft Environmental Impact Statement (DEIS) was issued for the I-5 Toutle Park Road (Exit 52) to Maytown (Exit 95) Project in January, 1997. Comments received on the DEIS indicate more information is needed regarding impacts of the project on flooding. USACE is in the process of finalizing a "Post Flood Study" report which provides updated flood information on the discharge and stage for the 50-year and 100-year floods on the Chehalis River in the vicinity of Centralia, and addresses the effects of potentially raising the road surface elevation of I-5 in the Centralia- Chehalis area. Based on conversations with WSDOT staff, the Final EIS for the I-5 Toutle Park Road to Maytown Project will be prepared as soon as the information from the USACE Post Flood Study report is available. The project is currently scheduled to go to bid in 2004.

4.2.2. Environmental Consequences of No-Action

USACE Long Road Dike Project

An analysis was conducted to determine the effect, if any, that construction of the LRDP would have on mainstem Chehalis River flood water surface profiles. The project would remove the LRD from the total overbank storage area currently available in the Centralia-Chehalis region for all floods up to the 45-year design event. However, the total volume associated with the area removed from storage is very small compared with the total amount of storage available in the Centralia-Chehalis region. The analysis determined that there would be no measurable change in Chehalis River flood water surface profiles for events when the LRDP would affect valley storage. In addition, the use of the area south of the levee alignment as a borrow site could replace some of the lost storage volume.

The LRDP would not require any relocation of buildings or facilities, nor is it expected to negatively affect any environmental resources. New or disturbed surfaces (including contractor staging and access areas) will be covered with topsoil and seeded with grass. Following construction of the levee, the borrow site could be developed as a wetland by the LRD, Lewis County or WSDOT.

WSDOT I-5 Project

A Draft Environmental Impact Statement was prepared by WSDOT and FHWA (FHWA and WSDOT, 1997) to describe the affects of the I-5 Toutle Park Road to Maytown Project (including raising I-5) on all aspects of the environment. In summary, the main concern with raising I-5 is the filling of wetlands on both sides of I-5. Because of this, compensatory mitigation for wetland losses is proposed at other locations within the project area. In addition, traffic circulation during construction will require additional efforts on the part of local police departments.

If implemented alone, the WSDOT project would protect I-5, but could negatively impact the rest of the region by exacerbating the damage caused by a normal flood event. The additional fill and elevation of the embankment would incrementally add to the loss of floodplain storage. Preliminary analyses by USACE suggest that raising I-5 to the 50- and 100-year flood levels will produce a 0.05 and 0.82 foot increase, respectively, in water surface elevation on the Chehalis River upstream of the Mellen St. Bridge.

4.2.3. Economic Consequences of No-Action

Estimated flood damages in Lewis County have exceeded $60 million since 1990, not considering damages resulting from I-5 being closed for days. Flood hazards affecting economically significant areas within the Chehalis River floodplain fall into two general categories: 1) widespread inundation, which affects industrial, commercial and agricultural areas, and 2) localized bank erosion, which affects primarily agricultural lands.

The general order of magnitude of flood damages and the proportion of those damages which have an impact on the economically productive sectors of the economy can be seen from partial data available on the January 1990 flood. According to the USACE (1991), direct damages from the January 1990 flood event in the Chehalis River floodplain totaled $19,189,000 in 1990 dollars. Estimates for the February 1996 flood, the highest of record, are still outstanding, but the cost of a four-day closure of I-5 alone has been estimated to exceed $100 million (EMHCO and Associates, 1996).

If no action is taken to reduce flood stages in the area, flood damage will continue as documented for historical events, and WSDOT will spend approximately $98 million ($108 million with preliminary engineering) to raise I-5.

4.3. Non-Structural Alternatives

The following alternatives are non-structural methods of reducing flood damages in the Centralia-Chehalis area. However, they would not significantly reduce flood stages to benefit I-5 flooding impacts (ENSR, 1994).

4.3.1. Watershed Management

This alternative involves the use of watershed management measures, including reforestation, timber harvest control, and development control to reduce the amount of erosion and silting of streams, and to decrease the magnitude of peak runoff associated with flooding in the basin. Although watershed management could have significant environmental benefits, including improvement in water quality and fish and wildlife habitats, watershed management in the basin would have little effect on major floods in the Centralia-Chehalis area. This is due to the nature of flooding in the Chehalis River Basin. Major floods in the basin occur in the winter and are caused by intense rains falling on already saturated soils and snow. Watershed management would have little effect on the basin's hydrologic response to these flood events. Watershed management measures have been undertaken in the basin under the direction of the Natural Resource Conservation Service (NRCS) and the State of Washington. Lewis County has also developed and adopted a Comprehensive Flood Hazard Management Plan which emphasizes mostly non-structural measures to reduce flood hazards.

4.3.2. Flood-Proof Structures

This alternative would involve flood-proofing residential, commercial and industrial structures in the Centralia-Chehalis area that are currently subjected to flooding. Residential buildings would be raised so that the first floor would be above the 100-year flood level. Commercial buildings would be modified so that openings below the flood level are watertight. Existing floodplain zoning would continue, with no new buildings permitted in the floodplain. According to the December 1994 Comprehensive Flood Hazard Management Plan for Lewis County (ENSR, 1994), 1,300 residential and 130 commercial or industrial buildings would need flood-proofing in the Centralia area alone.

Flood damages to residential, commercial and industrial buildings could be largely eliminated. Flood damages to public streets and utilities would continue, as would disruption of road access, police, fire and ambulance services, and deposition of silt and debris. USACE decided that this alternative could not be economically justified. The Federal Emergency Management Agency (FEMA) recently provided funding to raise 55 houses, in the City of Centralia, above the February 1996 flood level.

4.3.3. Evacuation and Relocation

This alternative involves moving all residential, commercial and industrial buildings in the Centralia-Chehalis area out of the floodplain and relocating them to a flood-free site. Due to the tremendous amount of investment currently in the floodplain, this alternative is not considered politically or economically feasible. According to the December 1994 Comprehensive Flood Hazard Management Plan for Lewis County (ENSR, 1994), 2,390 residential and 315 commercial or industrial buildings would need relocation in the Centralia area alone, including much of Centralia's central business district.

4.4. River Channel Excavation and Levee Alternatives

The following alternatives were investigated by USACE (ENSR, 1994) and involve excavation directly in the river channel, or the construction of levees, or a combination of the two.

4.4.1. Channel Clearing

In this alternative, vegetation and debris would be cleared out of the main channel of the Chehalis River. Removal of the vegetation and debris would decrease flow resistance and provide an increase in flow capacity of the channel. This alternative would require annual maintenance to ensure continued effectiveness. USACE determined in its study (ENSR, 1994) that the increase in flow capacity provided by this alternative would be insignificant compared to the flood discharges, and would not benefit I-5 flooding.

Channel clearing would affect the quality of habitat for resident fish and could affect migration and rearing habitat for anadromous fish. Elements which provide habitat complexity (e.g., presence of varying water depths, woody debris, side channels) are not abundant in the Chehalis River, and the removal of vegetation and debris would further simplify fish habitat in the mainstem. Channel clearing would also reduce the availability of food and instream cover for juvenile fish, alter flow regimes, and potentially elevate water temperatures. Bank erosion would likely increase, and water quality in the project area and dowstream could be affected by the introduction of sediments. These impacts would be periodic and long-term because channel clearing would be conducted annually.

4.4.2. Channel Dredging

In this alternative, sections of the river where flow is constricted would be excavated and enlarged. USACE evaluated four variations of this alternative in their study (ENSR, 1994). Three of the four variations involved excavation in the mainstem of the Chehalis River and in the Skookumchuck River. All three variations included removal of a "hump" in the riverbed profile of the Chehalis River at RM 65 to RM 67. The estimated excavation quantities ranged from 480,000 to 2,000,000 cubic yards of material. The estimated water surface reduction ranged from 1.5 feet to 5 feet at Centralia. The fourth variation involved excavation of about 1,000,000 cubic yards of material from the Newaukum River. This was estimated to lower the 100-year flood stage by about 2 feet at the Labree Road Bridge upstream of Chehalis. USACE concluded that channel dredging was not an economically feasible alternative.

Channel dredging could result in potentially significant environmental impacts and would raise issues related to permitting feasibility. Although direct mortality of fish and spawning disturbance could be avoided by conducting the work within the seasonal work "window" approved by WDFW, water quality would be affected during construction as a result of sediment releases. Channel erosion could continue after construction, and affect aquatic resources both locally and downstream. Dredging of the river channel would result in long-term changes to fish habitat, including disturbance of spawning and rearing habitat for anadromous species. The alternatives which considered dredging in the Skookumchuck and Newaukum Rivers and/or dredging in the Chehalis River near river mile 61 would impact known salmon spawning areas by disturbing or removing gravel substrates and eliminating the pools and riffles needed for rearing. Food resources for rearing juveniles could be diminished.

Depending on the level of stage reduction, the habitat available for fish could be reduced, particularly during low flows. Water temperatures could be increased. The U.S. Fish and Wildlife Service (USFWS) identified as a concern the accumulation of oxygen-demanding detrital matter in the excavated areas (USFWS 1975). If this were to occur, low dissolved oxygen levels could cause the excavated reaches to be impassible to fish. This condition, which is thought to occur presently in the Chehalis River between Chehalis and Centralia, could be magnified by channel dredging.

4.4.3. Channel Excavation with Levees

USACE considered dredging approximately 3,000,000 cubic yards of material over 9 miles of the mainstem of the Chehalis River in the Centralia area (ENSR, 1994). Some of the excavated material would be used to construct 20 miles of levee along the banks of the Chehalis River, Skookumchuck River and Salzer Creek to protect about 5,800 acres of land. USACE concluded that this alternative was not economically justified.

As with channel dredging, channel excavation and levee construction would raise significant concerns regarding environmental impacts and permitting feasibility. Channel excavation would affect fish migration, spawning, and rearing habitats. Because annual maintenance would be required to maintain channel capacity, these effects would be periodic and long-term.

The construction of levees would disturb a large area of wetland and riparian habitat. Removal of trees and shrubs from the streambanks would increase the potential for erosion, at least temporarily until vegetation could be established on levee slopes. Stream water temperatures, which are of concern under existing conditions, could be further elevated by the decrease in overwater shading. Removal of riparian vegetation would affect future recruitment of woody debris, simplify the aquatic habitat, and reduce its value for fish rearing and migration. These effects would be most significant on the Skookumchuck River and Salzer Creek.

Disturbance of wetland and riparian areas would also have potentially significant impacts on wildlife species dependent on these habitats. As proposed, the planting of vegetation on levee slopes would not replicate the existing vegetation community or structure. In addition to the direct disturbance, wetlands which are dependent upon overbank flows for recharge would most likely experience reductions in size and alteration in vegetation type. Wetlands of this type are extensive along Salzer Creek and occur in many locations along the Chehalis mainstem. Small mammals (including fur-bearers), resident waterfowl, and upland gamebirds would be particularly affected by the direct and indirect effects of levee construction.

There are several recorded archaeological sites located near the Chehalis River, and it is possible that there are other sites or artifacts that could be disturbed by levee construction.

Property owners in the area have expressed significant concern with the potential for trespassing, vandalism, loss of privacy, and aesthetic impacts posed by levee construction.

4.4.4. Urban Area Levees

USACE evaluated a number of locations in the cities of Centralia and Chehalis where levees could be built to protect urban areas (ENSR, 1994). In its 1982 report, USACE found that for some segments along the Chehalis and Skookumchuck Rivers and Salzer and China Creeks it might be economically justified to build levees. Currently, USACE is pursuing only one small levee project, the Long Road Dike Project in the Salzer Creek area. This project is described in the No-Action Alternative (Sections 4.2.1 and 4.2.2.).

The construction of levees under this alternative would have environmental impacts similar to those described above, although the reduction in the number and length of the levee segments would reduce the magnitude of the impacts.

4.4.5. Levees with River Modification

USACE also considered an alternative to straighten and enlarge the Chehalis River between the confluence with the Newaukum River and the confluence with the Skookumchuck River (ENSR, 1994). In addition to the channel straightening and enlargement, levees would be built along both banks of the Chehalis and Skookumchuck Rivers. USACE concluded that this alternative was not economically justified.

Of the previously-studied flood impact reduction alternatives, channel straightening and levee construction would incur the greatest environmental impact. Channel straightening would essentially eliminate fish spawning and rearing habitat in the Chehalis River reach between Chehalis and Centralia. Migration of anadromous fish could be affected by changes in stream hydraulics. As described above, straightening of the channel and construction of levees on the relocated banks would have significant detrimental impacts on wetland and riparian habitats and wildlife species.

4.5. Floodway and Floodplain Excavation Alternatives

4.5.1. Introduction

The concept of these alternatives is only to increase high-flow hydraulic capacity of the Chehalis, Skookumchuck or Newaukum Rivers while maintaining the normal-flow channel hydraulic capacity. This increase in high-flow hydraulic capacity would be achieved by excavating areas of the floodway or floodplain. The alternatives analyzed include the excavation of a bench in the floodway adjacent to the river channel, and excavation of a secondary flood overflow channel in the floodplain. Both floodway and floodplain excavation alternatives for increasing high-flow capacity would also cause an increase of peak flood flow downstream. An examination of the two alternatives is provided below.

4.5.2. Floodway Excavation

In this alternative, the floodway adjacent to the river channel would be excavated and terraced to provide additional flow area for higher flow events. The floodway terrace elevation would be set such that only during significant floods would the river flow into the enlarged area. As a result, the excavation could be done completely in the dry, thus reducing the costs and eliminating some of the environmental and permitting concerns posed by channel excavation. In addition, normal and low flows would be left unchanged, unlike in the river channel excavation alternatives analyzed by USACE.

Floodway excavation was examined along portions of the Chehalis, Skookumchuck and Newaukum Rivers. Along the Chehalis River, floodway excavation was examined between RM 64.90 (2.5 miles downstream of the Mellen St. Bridge) and RM 75.08 (confluence with the Newaukum River). Floodway excavation was also examined in the lower two miles of both the Skookumchuck and Newaukum rivers. Maximum water surface and velocity profiles were plotted for the river reaches of interest. River reaches with constricted flow, and resulting high velocities and head losses, were targeted as areas that would provide the most benefit from floodway excavation. Based on the velocity profiles, the reaches with the highest velocities are between RM 64.90 and RM 67.44 (Mellen St. Bridge), and the area around the SR6 Bridge (RM 74.60). Maximum velocities in the lower Skookumchuck and Newaukum rivers were typically much slower due to Chehalis River backwater effects during flood peaks. Therefore, floodway excavation in these reaches would not be as cost effective.

A number of different floodway excavation configurations were modeled to help determine the most cost effective and efficient layouts. In order to eliminate flooding of I-5 during a 100-year event equal in size to the 1996 flood, a water surface reduction of approximately 4 feet would be required at the north end of the airport (RM 70.6).

The significant environmental issues associated with floodway excavation would primarily involve disturbance of wetlands and riparian habitats. Other issues include a potential increase in erosion, stream sedimentation, and disposal of excavated materials. There would be impacts to fisheries habitats, although properly designed bank excavation could provide a net habitat benefit by providing important backwater refuge for fish during high flows. For more detail on environmental issues associated with floodway excavation, refer to Section 5.10.2.

4.5.3. Secondary Flood Bypass Channel

Introduction

Similar to the floodway excavation alternatives, the secondary flood bypass channel alternatives would increase the area of flow during high flow events. As the name implies, a secondary channel would be excavated to provide the additional flow area required. The channel would be excavated completely in the dry. The entrance elevation to the channel would be set such that flow entered the channel only during significant flood events. The remainder of the time the channel would remain dry. The channels would likely be grass lined and have a rock armored entrance and exit to prevent scour. Four different secondary channels were evaluated, with three of the channels off of the mainstem of the Chehalis River between RM 65.90-68.25. The remaining channel alternative would be off of the Skookumchuck River. The following sections briefly describe the alternatives.

Mainstem Chehalis River

Three alternative alignments were considered off of the mainstem of the Chehalis River. All three alignments cut across the large western bend in the Chehalis River due west of the City of Centralia. Alignment 'A' would start downstream of the Mellen St. Bridge at about RM 67.3 and would end at about RM 66.5. This design would be the least expensive to construct; however, due to the wide channel widths required, there would be no advantage to a secondary channel compared to floodway excavation. Alignment 'B' would start upstream of the Mellen St. Bridge at about RM 67.6 and would end at about RM 66.3. This design would provide more benefit; however, it would require the purchase of a large number of private homes and commercial properties as well as the construction of two or three bridges. Alignment 'C' would start at about RM 68.0 and would end at the mouth of Scammon Creek at RM 65.9. This design would provide slightly more benefit than 'B' and would avoid some of the larger properties; however, it would require the construction of three bridges and would require excavating out lower Scammon Creek.

Construction of any of the alternative secondary channels off the Chehalis mainstem would have less effect on wetlands than floodway excavation, but impacts to wetlands and riparian areas would not be completely avoided. Construction of a secondary channel along Alignment 'A' would require excavation through wetlands at the channel's downstream end. Construction along either Alignment 'B' or 'C' would also involve excavation through wetlands. The total area affected could be reduced through modification of the alignments. As with any of the alternatives which modify flood stages, the recharge of wetlands through overbank flooding would be affected by construction of a secondary channel.

Construction of any of the secondary channels could alter channel and substrate conditions near RM 65.9, and affect potential fish spawning habitat at that location. The potential stranding of fish in the secondary channel following high flow events would be a concern. This potential would be more of a concern for a channel following Alignment 'C', because of its greater length-to-width ratio.

Scammon Creek, which likely provides valuable off-channel rearing habitat for fish, would be affected by channel construction along Alignment 'C'. Excavation would disturb the lower end of the creek, from the mouth to a point approximately one-half mile upstream. Although the creek channel could be reconstructed within the larger flood channel, the habitat quality would be significantly reduced. The periodic conveyance of flood flows through the channel would most likely prevent the reestablishment of valuable habitat elements in the excavated reach of Scammon Creek.

The impacts of secondary channel construction to the built environment would be substantial. Numerous residents and businesses could be displaced, and agricultural lands would be affected. A channel along Alignment 'B' would also require the relocation of medical facilities. Channel excavation along any of the alignments would require the construction of one or more bridges along existing roadways.

Skookumchuck River

This alternative would involve diverting a portion of the flow in the Skookumchuck River during flood events. This secondary overflow channel would start at approximately RM 1.5 of the Skookumchuck River. The channel would be routed under I-5, near the Reynolds Avenue underpass, and would connect up with some existing small lakes, and then a remnant channel of the Chehalis River. The channel would empty back into the Chehalis River at approximately RM 60.5, 6.5 miles downstream of the Skookumchuck's confluence with the Chehalis River. It was assumed that the channel would be designed to divert up to 5,000 cfs.

Construction of a secondary channel off the Skookumchuck River would affect fish habitat in the lower river, including spawning habitat for fall and spring chinook salmon. Of potential benefit would be a reduction in both streambed scouring and the destruction of salmonid redds; conversely, diversion of flood flows could negatively affect channel-forming and maintenance flows in the Chehalis River downstream of the confluence.

Because of the length of this alignment, scoured areas would form in the high flow channel and stranding of fish following flood events would be a concern.

The hydrologic recharge of wetlands and riparian areas in the lower 1.5 miles of the Skookumchuck River would most likely be affected by the reduction or elimination of overland flows. In the absence of periodic recharge, wetland and riparian vegetation communities would change to upland vegetation types. Negative impacts to wildlife dependent on wetlands and riparian areas would be expected.

Construction of a secondary channel along this alignment would have a large impact on the built environment, including residential, industrial, and commercial properties, farmlands, roads, and other public facilities.

4.6. Flood Control Dam Alternatives

4.6.1. Introduction

The concept of the following alternatives is to retain flood flows through the use of flood control storage. Stored water would be gradually released once flood peak flows have passed downstream. Alternatives include the following: use of the existing Skookumchuck Dam for flood control, construction of new major upstream dams, construction of small headwater dams, and creation of temporal storage in the floodplain through the use of dikes.

4.6.2. Skookumchuck Dam Modifications

Introduction

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The drainage area above the dam is nearly 62 square miles and the highest elevation in the basin is approximately 3,600 feet. The dam was constructed in 1970 to supply water for the Centralia steam generation plant. The dam, as it currently exists, is an earthfill structure approximately 190 feet high above bedrock with the top of the dam at elevation 497 feet. The project is essentially a fill and spill operation. The limited outlet capacity of the dam, which consists of two 24-inch Howell Bunger valves with a combined discharge of approximately 220 cubic feet per second (cfs), causes the reservoir to fill to the spillway crest at elevation 477 feet early in the flood runoff season. Once the reservoir is full, flood inflow to the reservoir passes over the 130-foot wide ungated spillway, which has a discharge capacity of 28,000 cfs at elevation 492 feet. Storage capacity of the reservoir between the normal minimum pool at elevation 400 feet and the spillway crest at elevation 477 feet is 31,000 acre-feet.

USACE Studies

Preliminary investigations by USACE indicate that flood control storage could be feasible at Skookumchuck Dam without jeopardizing the steam plant water supply. Use of this project for flood control would require the addition of larger outlet works, and preferably, a spillway crest gate. USACE investigated several alternatives for modifications, which are presented in detail in the USACE's December 1982 and February 1992 reports (USACE, 1982, 1992).

In their December 1982 report, USACE recommended a design that would have provided 17,000-28,500 acre-feet of flood control storage. The design consisted of a new 135-foot high multi-level intake tower and 12-foot diameter outlet tunnel with a design discharge of 3,000 cfs. In addition, the existing spillway would have been widened slightly, and 17-foot-high by 136-foot-wide steel bascule gates would have been installed on top of the spillway to provide control of reservoir pool elevations up to elevation 492 feet. For a 200-year flood event on the Skookumchuck River, the proposed design would have reduced water surface elevations along the Skookumchuck River by 2.5 to 4.0 feet. Downstream of the confluence with the Chehalis River, the proposed project would have reduced water surface elevations by 0.5 feet.

Preliminary design work on the USACE recommended Skookumchuck Dam Modification Project was halted in 1990 when preliminary economic analysis indicated that the project lacked economic justification. In the course of its preliminary design work, the USACE considered several alternative arrangements. The steel bascule gate design was discarded due to its high cost and safety concerns surrounding the possibility that the gates could get stuck, or that they would not be operated properly during a major flood event. Alternatives were evaluated which would modify the operation of the dam for flood control and provide additional outlet capacity, but would not increase the existing storage capacity. The primary arrangements considered were: addition of an intake tower and tunnel, modified spillway with gate in slot, modified spillway with sluice gate, and short spillway tunnel. The final two arrangements were estimated to be the least costly to construct. All of the alternative designs would provide 11,900 acre-feet of storage. None of the alternatives appeared to USACE to be economically justified, so all design work was suspended.

Rubber Weir Alternative

This alternative was developed as an alternative to the USACE's steel gate design. The alternative would include modifications to the existing spillway to allow for the placement of an approximately 15-foot high and 136-foot long inflatable rubber weir on the existing spillway crest. The spillway would also be modified to allow for two new 10-foot by 16-foot gated sluiceways. Preliminary estimates based on routing of the February 1996 flood event through the reservoir indicate that a potential flood storage capacity of approximately 24,000 acre-feet could be provided. This volume of storage would reduce the February 1996 flood stage on the Skookumchuck River by 1.2 to 4.4 feet, and on the Chehalis River by about 0.3 to 0.5 feet.

Environmental Issues

The significant environmental issues associated with modification of the Skookumchuck Dam involve maintenance of water quality within and downstream of the reservoir, maintenance of adequate instream flows and reservoir levels for fishery resources, and potential impacts to wildlife habitat as a result of changes in reservoir levels and downstream flows. For more detail on environmental issues related to dam modification, refer to Section 5.10.1.

4.6.3. Upstream Flood Control Dams

Introduction

Upstream flood control dam projects could be constructed to reduce flooding impacts downstream. USACE investigated five potential locations for large multi-purpose storage dams in the Upper Chehalis River Basin in the course of its flood control studies (USACE, 1982). The five locations consisted of two sites on the Newaukum River, one site on the South Fork Chehalis River and two sites on the mainstem of the Chehalis River, upstream of the Newaukum River. All five alternatives were determined to be economically infeasible.

As part of this Pre-Feasibility Analysis of Alternatives, topographic and geologic maps of the Upper Chehalis River Basin were studied for potential single-purpose flood control dam sites. The five sites studied by USACE were reevaluated, along with three additional sites. The additional sites include two sites on the mainstem of the Chehalis River, upstream of the sites USACE investigated, and one site on Elk Creek. Construction of one or more of these dams would reduce the frequency and severity of flooding in the Centralia-Chehalis area.

Based on a preliminary review of available geologic information, site conditions appear to preclude large concrete structures. The relatively soft, deeply weathered foundation materials would likely require significant over-excavation to obtain sound bearing conditions. The most likely dam type suitable for these sites would be earthen embankment. The foundation and topographic requirements for earthfill dams are less stringent than for other types of dams. There appears to be sufficient suitable fill material nearby all of the sites.

For the purpose of developing pre-feasibility construction costs estimates, the typical construction layout for the dams was assumed to be very similar to that used for the existing Skookumchuck Dam. The dam would be designed as a non-overflow structure with a 2.5:1 (H:V) upstream face and a 2:1 (H:V) downstream face. Outlet works and a spillway would be provided on one of the abutments. The following sections briefly describe each of the sites.

Newaukum River Sites

The Newaukum River rises in the easternmost part of the Chehalis River Basin and flows westerly for about 30 miles, joining the Chehalis River at the City of Chehalis. The Newaukum drains an area of 155 square miles at the USGS gage (RM 4.1). The lower 13 miles of the basin are very broad (over 2 miles wide) and flat. From RM 13 to RM 28, the valley narrows somewhat to 0.5 mile wide, although it is still quite flat. This topography provides a great deal of natural overbank storage during flood events, which results in a significant attenuation of peak discharges. As a result, the downstream benefit of a flood control dam would probably be small relative to the cost involved.

USACE evaluated two dam sites in the Newaukum River Basin (USACE, 1982). One site is located on the North Fork Newaukum River and had an estimated flood control storage of 9,000 acre-feet. The other site is located on the South Fork Newaukum River and had an estimated flood control storage of 15,000 acre-feet. The North Fork dam was estimated to reduce discharge of a 100-year flood at Grand Mound by 2,000 cfs, and the South Fork dam was estimated to reduce flows by 3,000 cfs. Either of these flow reductions would translate into flood stage reductions of approximately 0.3-0.4 feet at the Mellen St. Bridge. Neither dam was determined to be cost effective. The USACE estimated cost of construction of the dams in

1998 dollars would be approximately $90 million and $125 million, respectively, which would make them very expensive for the small benefit provided. Smaller scale single-purpose flood control dams at either of these sites would have less flood storage, yet would only be slightly less expensive to construct than the USACE's alternatives. These sites were determined to be economically infeasible.

South Fork Chehalis River Site

The South Fork Chehalis River drains an area of 48 square miles at the old USGS gage site (RM 6). The lower portion of the basin up to RM 9 consists of a broad, flat valley with small creeks draining the hills on either side. Above RM 9 to RM 15, the valley narrows somewhat from 1.5 miles wide to 0.75 mile wide. There are no good flood control dam sites available below RM 15. Above RM 15, a suitable site could probably be found, but the contributing area would be too small to provide significant downstream benefit.

USACE investigated one site on the South Fork Chehalis River at approximately RM 10 (USACE, 1982). The dam at this site would have an estimated flood control storage of 16,000 acre-feet. The estimated discharge reduction of a 100-year flood at Grand Mound was 5,000 cfs, which would translate into a water surface reduction of approximately 0.7 feet at the Mellen St. Bridge. The USACE's estimated cost of construction of the dam in 1998 dollars would be approximately $120 million, which would make it very expensive for the small benefit provided. A smaller scale single-purpose flood control dam would cost only slightly less and would provide even less benefit. This site was determined to be economically infeasible.

Mainstem Chehalis River Sites

The Chehalis River above RM 77.5 (old USGS streamgage site) drains an area of 434 square miles (including the South Fork Chehalis River). Four potential single-purpose flood control dam sites were identified on the mainstem of the Chehalis River. Two of the sites were previously studied by USACE for large multi-purpose dams. These four sites appeared to have more potential than the sites on the Newaukum or South Fork Chehalis River, and were examined in greater detail.

Ceres Hill Site

The first potential Upper Chehalis River Basin site is at approximately RM 86.6 of the Chehalis River in a canyon downstream of the confluence with the South Fork Chehalis River. Based on available geologic information, this site appears to have up to 20 feet of primarily sand and gravel alluvium in the valley bottom. This would require some form of foundation treatment, such as an augercast curtain wall, to prevent piping under the dam. This would add to the cost of construction. In addition, suitable finer grained materials for construction of the dam would have to come from farther away than at the other sites. This would add to the cost of hauling and would add to the overall construction cost.

With a spillway crest at elevation 240 feet, the resulting reservoir would cover an area of 3,300 acres and have a flood control storage volume of approximately 48,000 acre-feet. This storage volume would result in a flood stage reduction of approximately 1.8-1.9 feet at the Mellen St. Bridge for an event similar to the February 1996 flood event. The dam would be over 50 feet high and would cost approximately $164 million to construct, which equals $86 million per foot of stage reduction. Based on information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 130 buildings, 27,000 feet of highway SR-6 and an additional 63,000 feet of local roads and 37,500 feet of railroad track.

The USACE design scheme for this site (USACE named it Ruth Dam site) involved the construction of a much larger dam with flood control storage of 108,000 acre-feet. USACE estimated the potential reduction in discharge at Grand Mound of a 100-year flood to be 24,000 cfs. This would have resulted in a stage reduction of approximately 3.4 feet at the Mellen St. Bridge for the February 1996 flood event. The USACE estimated construction cost of the dam in 1998 dollars would be approximately $433 million, which equals $127 million per foot of stage reduction, assuming that cost sharing for other (non-flood control) purposes is insignificant.

Neither of these design schemes is cost-effective in comparison with other alternatives evaluated as part of this study for the same magnitude of flood stage reduction.

Meskill Dam Site

The Meskill site is upstream of the confluence with the South Fork Chehalis River at approximately RM 93.4. The foundation appears to be highly fractured basalt over soft marine sandstone and siltstone with no alluvium mapped on the canyon floor. The juxtaposition of the hard rock over the top of the soft rock could result in significant differential settlement.

With a spillway crest at elevation 280 feet, the resulting reservoir would cover an area of 1,500 acres and have a flood control storage volume of approximately 30,000 acre-feet. This would result in a flood stage reduction of approximately 1.1-1.2 feet at the Mellen St. Bridge for an event similar to the February 1996 flood. The dam would be over 50 feet high and would cost approximately $267 million to construct, which equals $222 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 90 buildings, 27,000 feet of local roads, 19,000 feet of railroad track, and require the relocation of 12,000 feet of highway SR-6.

USACE considered this site as well (USACE, 1982), and evaluated a slightly larger structure with a flood storage capacity of 54,000 acre-feet. USACE estimated the potential reduction in discharge at Grand Mound of a 100-year flood to be 16,000 cfs with the construction of this dam. This would have resulted in a stage reduction of approximately 2.3 feet at the Mellen St. Bridge for the February 1996 flood event. The USACE estimated construction cost of the dam in 1998 dollars would be approximately $230 million, which equals $101 million per foot of stage reduction, assuming cost sharing for other (non-flood control) purposes is insignificant.

Neither of these design schemes is cost-effective in comparison with other alternatives evaluated as part of this study for the same magnitude of flood stage reduction.

Doty Canyon Dam Site

The Doty Canyon dam site is located upstream of the town of Doty at RM 100.8. The foundation conditions at this site would be similar to those at the Meskill site. There appears to be moderately deep soil cover (approximately 10 feet) on the side slopes, and a similar depth of river channel deposits on the canyon floor.

With a spillway crest at elevation 385 feet, the resulting reservoir would cover an area of 1,700 acres and have a flood control storage volume of approximately 60,000 acre-feet. This would result in a flood stage reduction of approximately 2.4 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would be over 90 feet high and would cost approximately $283 million to construct, which equals $118 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would inundate approximately 105 buildings, 20,000 feet of local roads, 22,000 feet of railroad track, and require the relocation of 25,000 feet of highway SR-6.

This design is not cost-effective in comparison with other alternatives evaluated as part of this study for the same magnitude of flood stage reduction.

Charlie's Hump Dam Site

The fourth site on the mainstem of the Chehalis River is located south of Pe Ell, above the valley floor in the area called Charlie's Hump. The site is founded on basic intrusive rock of gabbro, diabase or basalt. The rocks are fine grained and are likely to be moderately weathered and highly fractured with about 5 feet of soil cover.

With a spillway crest at elevation 600 feet, the resulting reservoir would cover an area of 700 acres and have a flood control storage volume of approximately 44,500 acre-feet. This would have resulted in a flood stage reduction of approximately 1.7-1.8 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would be over 180 feet high and would cost approximately $76 million to construct, which equals $42 million per foot of stage reduction. From information provided by USGS 7.5 minute quadrangle sheets, the reservoir would not inundate any buildings, but it would inundate about 10,000 feet of existing local road.

This design is not cost-effective in comparison with other alternatives evaluated as part of this study for the same magnitude of flood stage reduction.

Elk Creek Dam Site

The final dam site evaluated is located approximately 3.5 miles west of the town of Doty at RM 2.8 of Elk Creek. The foundation consists of soft marine sandstone and siltstone.

With a spillway crest at elevation 440 feet, the resulting reservoir would cover an area of 1,300 acres and have a volume of approximately 32,000 acre-feet. This would have resulted in a flood stage reduction of approximately 1.1-1.2 feet at the Mellen St. Bridge for the February 1996 flood event. The dam would over be 75 feet high and would cost approximately $82 million to construct, which equals $68 million per foot of stage reduction. From the USGS 7.5 minute quadrangle sheets, the reservoir would inundate only a few buildings, and 8,500 feet of local road.

This design is not cost-effective in comparison with other alternatives evaluated as part of this study for the same magnitude of flood stage reduction.

4.6.4. Small Headwater Dams

In its studies, USACE also investigated the feasibility of building several small headwater dams for temporarily restraining flood flows (USACE, 1982). USACE evaluated twelve sites in the drainage above Centralia-Chehalis. The combined flood storage capacity of all twelve dams would be only 14,500 acre-feet, with an estimated reduction in flow at Grand Mound of 3,000 cfs for a 100-year flood event. The 3,000 cfs flow reduction would result in flood stage reduction of approximately 3 inches. In 1998 dollars, the USACE estimated cost to construct the twelve dams would be approximately $113 million, which would equate to approximately $350 million dollars per foot of flood stage reduction. Because of the poor benefit-to-cost ratio, this alternative was not investigated further.

4.6.5. Environmental Issues

The potential environmental impacts of the upstream flood control dam alternative can be divided into reservoir effects and downstream effects.

Reservoir effects would occur as a result of the inundation and alteration of fish and wildlife habitats as well as inundation of structures, agricultural lands, roads and other public and private facilities. Dam construction at any of the sites would create a barrier to fish passage.

At each of the reservoir sites, wetlands and riparian areas are interspersed with upland habitats. At several of the potential reservoir sites, much of the riparian vegetation has been removed and the riparian zone is limited to a narrow (50 -100 ft) band adjacent to the stream. These areas would be inundated, with a resulting loss of wildlife feed, cover, nesting, and roosting areas, including habitat for threatened and endangered species such as bald eagles and spotted owls. It is expected that some of this habitat would be replaced by the establishment of riparian vegetation around the perimeter of the reservoir.

In-stream habitats, particularly transportation, spawning, incubation, and rearing habitats for anadromous fish, would be replaced by a lake environment. The miles of in-stream habitat lost would vary, depending upon the reservoir location. Particularly affected would be spawning habitat for spring and fall chinook salmon, coho salmon, and winter steelhead. Reservoir creation would provide lake habitat for resident fish, including rainbow and cutthroat trout.

The upstream flood control dam alternatives would result in the inundation of a substantial number of structures and private property as well as roads, rail lines, and other facilities.

Potential downstream effects would include changes in the quality of water flowing out of the reservoir and changes in downstream water temperatures. Wetland and riparian areas that are dependent on overbank flows for recharge would most likely experience reductions in size and alteration in vegetation type. These changes could result in a long-term reduction of large, woody debris to the stream; reduction in shade cover; elevation of stream temperatures, and loss of instream cover for fish. Attenuation of minor flood flows would change channel substrates downstream. In terms of fish habitat, these changes could be positive or negative. Spawning areas which are currently subject to scouring could be spared; conversely, channel-forming and maintenance downstream of the dam could be negatively affected by flow alterations.

4.6.6. Flood Storage Dikes on the Floodplain

The concept of this alternative is to construct one or more flood storage areas in the floodplain. This would be accomplished by enclosing a large area with a dike. During floods, the floodwaters would overflow into the dike enclosed storage area. Stored floodwaters would then be released slowly through a downstream outlet. This type of flood storage operation would not be as efficient and effective as that provided by a flood control dam. Placing flood control storage in the floodplain is also not as effective as utilizing storage in the headwaters. In the floodplain, the flows are already rather attenuated and a much larger storage volume is required for an equivalent stage reduction.

Based on preliminary model runs, approximately 40,000 acre-feet of storage volume would be needed in the floodplain to achieve a 1-foot stage reduction at the Mellen St. Bridge. Assuming a ten-foot storage depth, this would require approximately 4,000 acres of land. In order to achieve more significant stage level reductions, a very large area would be required, which makes the alternative impractical. Preliminary cost estimates also indicate that this alternative is not cost effective on its own. The concept could prove to be cost effective at providing an additional incremental benefit if it were combined on a smaller scale with one of the excavation alternatives. Material excavated from the floodway or floodplain, that would otherwise have to be disposed of, could be used to construct the enclosure dikes.

Because of the large land area required, environmental impacts of this alternative could be substantial. The elements of the environment that could be affected would not be defined until potential storage sites were located.

5. Recommended Alternative

5.1. Introduction

Based on the evaluation of alternatives presented thus far, it appears that a promising solution to the flooding problems in the Centralia-Chehalis area would be the combination of two alternatives. The first component of the solution is the floodway excavation between approximately RM 64.9 and RM 70.6, including modifications of the existing Mellen St. Bridge abutment. The second component is the Skookumchuck Dam modifications to provide flood control storage.

The floodway excavation component alone could reduce a 100-year flood stage by approximately 4 to 8 feet on the Chehalis River, enough to substantially reduce flood damages and sufficient for keeping I-5 above the 100-year flood level. Preliminary cost estimates indicate that this component would be the least costly option for achieving the magnitude of flood stage reduction desired. However, the floodway excavation alone would result in peak flow increases downstream during floods and would not be acceptable to downstream floodplain communities.

The Skookumchuck Dam modifications alone could provide substantial flood control storage, up to 24,000 acre-feet, and could significantly reduce flood stages along the Skookumchuck River floodplain. A preliminary cost estimate indicates that this alternative would be the least costly option among all storage dam alternatives evaluated for providing flood control storage of this magnitude. In addition, this alternative would have the least environmental impacts of all storage dam alternatives, as the dam already exists. However, the Skookumchuck Dam component alone would have very little effect on the Chehalis River flood stage (less than 0.5-foot flood stage reduction) and would not be economically feasible, as the benefit-to-cost ratio would be less than 1.0.

A combined project including both the floodway excavation component and the Skookumchuck Dam modifications would overcome the shortfalls that each component would have if implemented separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck River peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway excavation. The substantial flood reduction benefits that can be achieved by the floodway excavation would be more than the total cost required to excavate the floodway (including the Mellen St. Bridge modifications) and to modify Skookumchuck Dam for the flood control storage provision. The combined project would, therefore, become economically feasible and would also reduce the peak flood flow discharging downstream from the floodway excavation area.

The combined floodway excavation in the Mellen St. Bridge vicinity with Skookumchuck Dam modifications would not solve some localized flooding problems beyond the direct backwater effects from the mainstem of the Chehalis River. Additional minor flood control projects would still be needed to address localized effects. Flood stage reduction in the City of Chehalis floodplain, east of I-5 and between the 13th St. and Main St. (SR-6) interchanges, will not be significantly addressed by the floodway excavation in the Mellen St. Bridge vicinity. Therefore, options to address the flooding in this area were also considered.

5.2. Components of the Recommended Alternative

The recommended alternative for the project is the combination of floodway excavation in the Mellen St. Bridge area with modifications to Skookumchuck Dam, as well as measures to reduce the flooding in the City of Chehalis floodplain (between the 13th St. interchange and the Main St.-SR-6 Bridge). The UNET model was used to evaluate the benefits and impacts of the combined components. A brief description of the components and development recommendations is provided below.

5.2.1. Chehalis River Floodway Excavation

Floodway excavation along the Chehalis River is proposed from approximately 2 miles downstream of its confluence with the Skookumchuck River (RM 64.90) to the north end of the Centralia-Chehalis Airport (RM 70.60), near its confluence with Salzer Creek. As described previously, the design would involve terracing the floodway in areas where the flow is currently constricted in order to increase the high-flow hydraulic capacity of the Chehalis River during flood events. Floodway excavation was also evaluated between the Galvin Road Bridge (RM 64.08) and the Newaukum River mouth (RM 75.08). Between these two limits, numerous variations of excavated width and excavation location were modeled. Pre-feasibility cost estimates were then developed to help determine which arrangements appeared to be the most cost-effective.

Excavation Reaches

Among all variations modeled with the developed UNET model, floodway excavation between RM 64.90 and the north end of the Chehalis-Centralia Airport (RM 70.60) appears to be the most efficient and cost-effective design. Two optional excavation schemes for this reach of the river were evaluated further as the recommended alternative. The Option 1 excavation scheme would involve excavating approximately 2.8 million cubic yards of material between the hump location (RM 65.95) and one-half mile upstream of the Mellen St. Bridge (RM 68.02). UNET modeling of this scheme resulted in 4.49 feet of flood stage reduction at the mouth of Salzer Creek (RM 69.79) and 3.79 feet at the Mellen St. Bridge gage (RM 67.44) during the February 1996 event. The Option 2 excavation scheme would involve excavating approximately 7.2 million cubic yards of material between RM 64.90 and RM 70.60 (the north end of the airport). UNET modeling of this scheme resulted in 7.01 feet of flood stage reduction at the mouth of Salzer Creek and 7.27 feet at the Mellen St. Bridge gage during the February 1996 event. Either of these options would also provide an opportunity to create off channel rearing habitat to benefit anadromous fish, and opportunities for other habitat improvements. An overview of the floodway excavation location as it was modeled is shown in Figure 5-1.

Excavation Elevation and Width

For both optional excavation schemes, the floodway was assumed to be excavated to an elevation above the normal flow stage. Option 1 has an average excavation width of about 500 feet, and Option 2 has an average excavation width of about 600 feet. In the next phase of studies, design of the floodway excavation, including dimensions, elevations and location will be optimized. A schematic section view of the floodway excavation, not including vegetation planting which is expected to be required, is shown in Figure 5-2.

Mellen St. Bridge Modifications

The Mellen St. Bridge section of the Chehalis River is one of the most restrictive sections for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. Currently it is envisioned that the right-bank (east-bank) would be excavated. In conjunction with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway. A schematic sectional view of the bridge is shown in Figure 5-3.

The existing wastewater treatment plant for the City of Centralia is located immediately downstream of the Mellen St. Bridge. Studies are currently underway to investigate the possibility of moving the treatment plant to a downstream location. The current site has very little room for expansion to meet the future needs of the area.

Disposal of Excavated Material

One of the major considerations for the floodway excavation is determining an appropriate location for disposal of excavated material. Several possibilities exist: constructing setback levees adjacent to the excavation, finding a downstream location in the floodplain, finding an upstream location in the floodplain, construction of setback levees between the Mellen St. Bridge and the south end of the airport to create additional flood storage areas, temporarily stockpiling material for use in the proposed I-5 widening project, construction of levees to help alleviate flooding on localized areas, or a large remote disposal site. Due to the large volumes of excavation being considered, it is likely that a combination of some of these possibilities would be required. More detailed design studies of the sites for final selection will be performed in the next phase of project development.

Because of the large volumes of material being proposed for excavation, and the space limitations adjacent to some of the excavated reaches, it is unlikely that all of the material could be placed immediately adjacent to the excavation. This possibility would be the most cost-effective where feasible.

Several sites downstream of the mouth of the Skookumchuck River have been considered as potential sites for a new wastewater treatment plant. It is possible that one or more of these sites could be used for disposal of excavated material. In addition, some fill could probably be utilized in any new treatment plant construction. The material could be used to either raise the treatment plant site, or help provide protection to the site from flood conditions. A downstream disposal site would be most economical for excavation downstream of the Mellen St. Bridge. Potential concerns of filling in the floodplain will be modeled and the impacts evaluated in the next phase of studies.

Upstream of the Mellen St. Bridge, fill could potentially be placed in areas along the west side of the valley, up against Scheuber Road. Upstream disposal areas would be most economical for floodway excavation upstream of the Mellen St. Bridge.

Between the Mellen St. Bridge and the SR-6 Bridge, levees could be constructed to enclose one or more areas to create additional storage during a flood event. During a flood, floodwaters would overflow the upstream bank at a predetermined flood stage and fill the enclosed area. The ponded water would then drain slowly through a downstream outlet.

According to WSDOT, close to one million cubic yards of fill material would be required for construction of the proposed I-5 widening project between Chehalis and Centralia. Some of the floodway excavation material could be temporarily stockpiled to be used as fill in the widening project.

Small levee projects similar in scale to the proposed Long Road Dike Project could be built with excavated floodway material to help with localized flooding problems. Small diking projects would likely only require a small percentage of the total volume of material being excavated.

A remote site (anything that is not in the immediate Centralia-Chehalis area) would be the least economically desirable of any of the possible disposal sites available. The costs of hauling excavated materials escalate dramatically with increases in haul distances.

Land Acquisition

The first step in the land acquisition process is to identify the property and property rights necessary for the project. Since the project will use federal and state funds, it will be essential to follow federal and state laws and procedures governing acquisition, as outlined in the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970" (Uniform Act). The Uniform Act defines what an acquiring agency must do to assure owners are receiving fair market value for land and other program benefits. Some of the major elements outlined in the Uniform Act are:

- Determination of just compensation
- Negotiations
- Relocation assistance
- Property Management

All negotiations subject to the Uniform Act are also subject to the laws and requirements of the state, as well as any applicable local ordinances.

5.2.2. Skookumchuck Dam Modifications

General

The proposed structural modifications to Skookumchuck Dam to permit flood control operation during winter months involve modification to the existing spillway to add 1) flood control outlet works including two gated flood control outlet sluices, and 2) a crest weir at the top of the existing spillway. The addition of the crest weir at the top of the existing spillway will also require that modifications be made to the ogee crest and the spillway chute. A conceptual layout plan and sections of the modifications are shown in Figures 5-4 through 5-6. Figure 5-7 presents an artist rendering of the modifications. Further design and operation analysis will be performed in the next phase of studies to optimize the design modifications. Brief descriptions of the modifications are provided below, following the discussions on dam safety and reservoir regulation considerations.

Dam Safety Considerations

The proposed modifications to Skookumchuck Dam must enable the project to safely pass the Probable Maximum Flood (PMF) outflow of 28,000 cfs at a maximum design pool elevation of 492 feet. During the PMF, approximately 24,000 cfs would be discharged over the modified spillway, and 4,000 cfs would be discharged through the proposed flood control outlet.

The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while considering contingencies such as surcharge, wind wave runup, and embankment settlement. Five feet is considered to be adequate freeboard. The dam embankment currently has a top elevation of 497.0 feet. The maximum design pool level is at elevation 492.0 feet.

PacifiCorp (formerly Pacific Power & Light) had a dam safety and seismic stability analysis performed on the dam in 1988, which the USACE later reviewed. USACE determined that, with the new operation for flood control, the embankment would suffer distress during the design earthquake, but would not fail and did not require any modification (USACE, 1992). More recently, PacifiCorp had a FERC (Federal Energy Regulatory Commission) Part 12 dam safety inspection performed in 1996. Stability analyses were performed for normal operating conditions, PMF, rapid drawdown, and seismic loading conditions. The embankment dam, spillway and all other structures were found to be safe for all cases investigated (Black & Veatch, 1996). Dam safety and stability would have to be reviewed with any proposed changes to the reservoir operation for flood control.

Reservoir Regulation Considerations

USACE developed a preliminary flood control operation rule curve as part of its studies (USACE, 1992). The USACE rule curve provided flood control storage of 11,900 acre-feet between elevations 453 and 477 feet from November 1 to February 1. After February 1, the reservoir would be allowed to refill. PacifiCorp felt that filling of the reservoir prior to the spring runoff season was essential to ensure containment of the basin snow melt. Drawdown of the reservoir would begin each year in early to mid September and would continue until elevation 453 feet was reached, around the first of November.

USACE performed a water supply study of the Skookumchuck reservoir as part of its studies to determine if sufficient storage would be available to meet minimum instream flow requirements for fisheries and power diversion with the addition of flood control storage and water supply (USACE, 1992). USACE assumed that PacifiCorp would divert its entire 80 cfs water right, and determined that minimum instream flow and water supply requirements could be met in all years with the USACE proposed flood control operation rule curve.

Flood control storage of 24,000 acre-feet could be provided between pool elevation 445 and 492 feet. This storage is sufficient to contain the peak flow of the February 1996 flood and would reduce the peak flood stage at the Pearl St. Bridge by 1.40 feet. This is equivalent to reducing the flood stage from a 70-year recurrence interval to a 10-year recurrence interval. A new reservoir operation rule curve would need to be developed for the recommended flood control alternative; and, a more detailed reservoir drawdown and release study will be performed to ensure water supply requirements can be met.

The flood control operation rule curve must ensure releases in accordance with the existing fishery flow agreement. The agreement between PacifiCorp and WDFW provides a minimum instream flow of 140 cfs from September 10 to October 31 for salmon spawning. Incubation flows begin on November 1 or at the completion of spawning as determined by WDFW. A minimum of 95 cfs is supplied until March 31. From April 1 through August 31, rearing flows are set at a maximum of 95 cfs or natural river flow plus 50 cfs, whichever is less. Rearing flows may be adjusted downward as determined by WDFW to preserve water for use during the spawning period. The instream flow agreement also provides for instream water temperatures of 50° to 55° F. These temperatures must be maintained, to the maximum extent possible, depending on reservoir and climatic conditions. The minimum instream flow requirements apply to the bypass reach, but not to the main channel below the dam for a length of approximately 600 feet (USACE 1988). WDFW has expressed a desire to establish a minimum instream flow for this reach.

The dam modifications as proposed include adding a 15-foot high weir above the existing spillway crest at elevation 477. This will provide approximately an additional 9,000 acre-feet of storage. This additional storage could potentially be available to augment summer low flows downstream.

Flood Control Outlet Works

The flood control outlet works would be located within the existing spillway and would consist of an approach channel and two gated sluiceways. The flood control outlet must be able to discharge approximately 4,000 cfs at the minimum flood control pool of elevation 445 feet in order to evacuate the reservoir within a maximum of 3 to 4 days following a major flood that fills the reservoir to elevation 492 feet. This would allow the flood control storage to be evacuated in a timely manner to allow for the next flood event, which could potentially occur right after reservoir evacuation. Precise design discharge capacity will be determined in the next phase feasibility study for project optimization. A preliminary design description is provided below. The design configuration, dimensions and elevations described below will be optimized in the next phase. Concerns with flood release timing and potential downstream riverbank erosion problems will be addressed in the next phase as well.

A trapezoidal-shaped channel, approximately 250 feet long, would be excavated within the existing spillway approach channel. The existing spillway approach channel is excavated in rock and has an invert elevation of 464 feet. The new sluiceway approach channel would have a bottom width of about 50 feet, an invert elevation of approximately 436 feet, and 1H on 10V sloping sides. Approximately 24,000 cubic yards of rock would need to be excavated to construct the channel.

A section of the existing ogee spillway would be removed and a new spillway section containing two gated sluices would be constructed. The two sluice gates would each be approximately 16 feet wide and 10 feet high. The sluices would be designed for a capacity of 4,000 cfs at the minimum flood control pool elevation of 445 feet. An emergency bulkhead would be supplied to allow for dewatering of the gates. The existing fish sluice would be moved if necessary. Detailed evaluation and optimization of the sluiceway and gate arrangement will be accomplished during the next stage of studies.

USACE performed a preliminary analysis of a short spillway tunnel as an alternative to installing sluices in the existing spillway. This arrangement consisted of an intake structure just upstream of the right abutment of the existing spillway bridge. Water would flow through the intake into a 165-foot long tunnel in the rock forming the left abutment of the dam embankment. Flows would discharge into the existing spillway chute. The approach channel would be similar to that for the spillway sluice arrangement. USACE felt that there could be some potential cost savings with this arrangement over the sluiceway arrangement. However, the hydraulics for the short tunnel arrangement would be more complex than that for the sluiceway arrangement. This option will be evaluated in greater detail in the next phase of studies.

Spillway Crest Weir

For the PMF discharge of 28,000 cfs, the spillway crest will be submerged due to hydraulic control at the chute entrance. The discharge capacity of the existing uncontrolled side channel spillway is 28,000 cfs at the maximum design pool elevation. Modifications to the spillway would be required to enable use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and to provide the PMF discharge capability. The modifications include adding a crest weir, modifying the ogee crest, and modifying a portion of the spillway chute.

A 15-foot high by 136-foot wide inflatable rubber weir would be added to the existing spillway crest. Inflatable rubber weirs have been used very successfully in North America, Europe and Asia. The weir consists of a heavy-duty, reinforced rubber body that is anchored to a concrete foundation and inflated with air. The height of the weir can be varied by adjustments of the pressure within the tube. If necessary, the weir can be quickly deflated to allow for an unrestricted flow of water over the spillway. Deflation of the weir is carried out automatically so that the weir is inherently safe under all conditions. Other types of spillway crest weirs will be evaluated and compared in the next phase of studies.

The existing spillway chute is located in a rock excavation on the left abutment. The chute bottom converges from a width of 40 feet to 25 feet and has 1H on 4V side slopes. The walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. During the PMF discharge, the water surface in the chute would overtop the concrete lined portion of the walls, but would still be contained within the excavated rock channel. This rock material has been identified as being highly fractured and susceptible to freeze thaw damage. In order to protect the rock portion of the chute, the rock slopes would be lined with shotcrete up to the PMF water surface profile. The invert of the plunge pool below the spillway would also be excavated out and lowered to make room for the new spillway sluices.

5.2.3. Flood Stage Reduction in the City of Chehalis Floodplain

The City of Chehalis experiences flooding between the 13th St. interchange and the Main St. (SR-6) interchange. Two railroads pass under I-5 between these two interchanges, creating openings in the I-5 embankment. During major flooding on the Newaukum River, floodwaters from the Newaukum River spill over into nearby Dillenbaugh Creek and flow through the railroad openings to the east side of I-5. The Mellen St. Bridge vicinity floodway excavation, as presented previously as part of the recommended alternative, would not substantially reduce this flooding.

Several possibilities exist to reduce the flooding in this area. Flood stages on the Chehalis and Newaukum Rivers could be lowered by floodway excavation in the area of the SR-6 Bridge to the Newaukum River mouth. Another possibility would be to construct small levees between the Newaukum River and Dillenbaugh Creek to keep the two hydraulically separated during floods, or to construct small levees along portions of Dillenbaugh Creek to prevent floodwaters from inundating homes and businesses. Floodway excavation could also be combined with small levee construction.

Floodway excavation on the Chehalis River from shortly downstream of the SR-6 Bridge (RM 74.55) up to the mouth of the Newaukum River (Chehalis RM 75.08) was evaluated. The SR-6 Bridge embankment constricts flood flows on the Chehalis River in much the same way as the Mellen St. Bridge downstream. This flow constriction is partially responsible for backing up Newaukum River flood flows. Floodway excavation of approximately 800,000 cubic yards of material in this reach of the Chehalis River would result in approximately 1.5 feet of peak flood stage reduction on the lower Newaukum River (RM 1.0) for a flood event such as the February 1996 event. Floodway excavation in this area may be extended downstream if further flood stage reduction is required.

Due to insufficient data, this design alternative could not be adequately examined at this time. In the next phase of work, flood stage reduction in the City of Chehalis floodplain, between the 13th St. and Main St. Interchanges and in the SR-6 Bridge vicinity, will be examined in greater detail, after more river cross-sections are surveyed, design alternatives are evaluated, and flood stage reductions optimized.

5.3. Flood Stage and Peak Flow Reductions

Providing 24,000 acre-feet of flood control storage at Skookumchuck Dam would substantially reduce flood stages and peak flows on the Skookumchuck River. Excavation of parts of the Chehalis River floodway would achieve substantial flood stage reductions on the Chehalis River. The amounts of flood stage and peak flow reductions at various locations along the Skookumchuck and the Chehalis rivers were estimated by comparing the differences between pre-project and post-project conditions. The calibrated UNET model for the existing baseline (or pre-project) conditions, as described in Section 3, was modified to incorporate the Skookumchuck Dam flood control operation and the Chehalis River floodway excavation.

As a result of the recommended Skookumchuck Dam modifications, the dam would be operated for flood control during flood events. In this pre-feasibility analysis, the Skookumchuck Dam flood control operation was assumed to follow a simplified release schedule. This schedule includes releases being maintained at a minimum outlet discharge of 200 cfs prior to passing of the flood peak, then being gradually increased at a rate of 400 cfs per hour after the flood peak is over, and finally being maintained at a maximum dishcarge of 4,000 cfs for up to three to four days to completely evacuate the stored flood water, making the 24,000 acre-feet flood control storage available for the next storm event. This simplified release schedule for flood control operation is only an approximation and will be analyzed in detail and optimized for design and operation during the next phase of project work.

Two Chehalis River floodway excavation options were incorporated into the UNET modeling. Option 1 would require a total excavation of approximately 2.8 million cubic yards of river bank material and would achieve a 100-year flood stage reduction of approximately 4 feet in the area upstream of the Mellen St. Bridge to the lower Salzer Creek floodplain east of I-5. Option 2 would require an excavation of approximately 7.2 million cubic yards and would reduce the 100-year flood stage by approximately 7 to 8 feet in this area. The existing I-5 low point (elevation 169) along the Centralia-Chehalis Airport stretch is five feet below the low point (elevation 174) of both the Tacoma Eastern Railroad embankment to the east and the Airport Road dike to the west. A four-foot flood stage reduction resulting from the Option 1 floodway excavation would keep I-5 from being flooded by a 100-year flood event. A seven- to eight-foot flood stage reduction resulting from the Option 2 floodway excavation would provide further flood damage reduction benefits to the floodplain communities, and additional freeboard to the railroad embankment and the Airport Road dike protecting I-5 from flooding.

Runs of the modified UNET model for the post-project conditions were executed, incorporating the recommended Skookumchuck Dam flood control operation and the Chehalis River floodway excavation. Run results for the post-project conditions in comparison with modeling results for the pre-project conditions are shown in Table 5-1 through Table 5-3 and Figure 5-8 through Figure 5-23. Brief summaries of the results shown in the tables and figures are provided immediately below.

Figure 5-8 through Figure 5-11 show comparisons of pre-project and post-project flood stage and peak flow profiles on the Skookumchuck River for the February 1996, November and January 1990, and the January 1972 floods. A summary of flood stage reductions at various locations on the Skookumchuck River is presented in Table 5-1. Comparison of the flood stage and peak flow profiles indicates that overbank flows flooding the City of Centralia streets and buildings under the pre-project conditions would be almost completely eliminated upon completion of the recommended project.

Figure 5-12 through Figure 5-15 show comparisons of pre-project and post-project flood stage and peak flow profiles on the Chehalis River for the February 1996, November and January 1990, and the January 1972 floods. A summary of flood stage reduction at various locations along the Chehalis River between SR-6 and the Mellen St. Bridge, including the lower Salzer Creek area, is presented in Table 5-2. Comparison of the profiles for the two largest events (the February 1996 and the January 1990 floods) indicates that overtopping of the Airport Road dike and the Tacoma Eastern Railroad embankment, causing I-5 to be flooded, would be eliminated as a result of implementation of the recommended project. This is true for either the Option 1 or Option 2 floodway excavation scheme.

Table 5-3 shows a comparison of pre-project flood frequency and post-project equivalent flood frequency based on the modeled flood stages and the associated flood frequency numbers revised by USACE in late 1997 (USACE, 1997a) for the existing basin conditions. This comparison is shown at the Mellen St., Pearl St. and Bucoda gage locations for the four selected flood events. For example, the February 1996 flood stage at the Mellen St. location corresponds to the 100-year flood level under existing conditions. Upon completion of the recommended project with the Option 1 excavation scheme, the February 1996 flood stage at Mellen St. would be reduced to the 15-year flood level under existing conditions. If the Option 2 excavation scheme is implemented, the February 1996 flood stage at Mellen St. would be further reduced to the five-year flood level under existing conditions.

Figure 5-16 through Figure 5-19 show comparisons of pre-project and post-project flow hydrographs on the Skookumchuck River at both the Bucoda and Pearl St. locations for the February 1996, the November and January 1990, and the January 1972 floods. This comparison indicates that a substantial flood peak reduction could be achieved at these two locations with the Skookumchuck Dam flood control operation. At Bucoda, the peak flow reduction could be over 4,000 cfs, or 50% of the pre-project peak flow. At Pearl St., the peak flow reduction could be over

3,000 cfs, or 25% of the pre-project peak flow. These peak flow reductions are substantial and more than adequate to off-set the peak flow increases on the Chehalis River, which are the result of increased high-flow hydraulic capacity caused by the floodway excavation.

Figure 5-20 through Figure 5-23 show comparisons of pre-project and post-project flow and channel velocity hydrographs on the Chehalis River at the Galvin Road Bridge (RM 64.08) for the four selected flood events. The Galvin Road Bridge is located immediately downstream of the recommended floodway excavation area. The flow comparison at this location indicates that the post-project peak flow for any of the four flood events modeled would be reduced from the pre-project conditions. The peak flow reduction, though small (up to 2,150 cfs), would mean that the flood stage downstream of the project area would also be slightly reduced, though immeasurably (less than 0.2 feet). The channel peak velocity comparison between pre-project and post-project conditions indicates a conclusion similar to the flow comparison. Channel peak velocity downstream of the project on the Chehalis River would be slightly reduced, but probably immeasurably.

In addition, the UNET model was modified to evaluate the effects of the floodway excavation of approximately 800,000 cubic yards of material in the SR-6 Bridge vicinity of the Chehalis River. Table 5-4 summarizes a comparison of pre- and post-project flood stages and recurrence intervals on the Newaukum River for the four studied flood events.

Figure 5-24 shows a comparison of pre- and post-project approximate inundation areas for the 100-year flood. The post-project flood stage reduction includes the effects of floodway excavation in the Mellen St. Bridge area, modifications to Skookumchuck Dam, and floodway excavation in the SR-6 Bridge area. This map is preliminary only and will be refined in the next phase of work.

Table 5-1:
Comparison of Pre-Project and Post-Project Flood Stages on the Skookumchuck River

Flood	Location RM (river mile)	Pre-Project Max. WS El (ft)	Post-Project Option 1 Max. WS El (ft)	Post-Project Option 1 Stage Reduction (ft)	Post-Project Option 2 Max. WS El (ft)	Post-Project Option 2 Stage Reduction (ft)
Feb-96	10.86 (Upstream of Tono Rd. Bridge)	246.75	242.87	3.88	242.87	3.88
	6.17 (Bucoda Gage)	210.78	207.51	3.27	207.51	3.27
	4.51 (SR-507)	202.46	200.38	2.08	200.38	2.08
	2.3 (Pearl St.)	187.21	185.87	1.34	185.87	1.34
	0.6 (Harrison St.)	175.91	172.96	2.95	172.13	3.78
Jan-90	10.86 (Upstream of Tono Rd. Bridge)	245.89	242.23	3.66	242.23	3.66
	6.17 (Bucoda Gage)	210.49	207.51	2.98	207.51	2.98
	4.51 (SR-507)	202.80	200.87	1.93	200.87	1.93
	2.3 (Pearl St.)	187.11	184.85	2.26	184.85	2.26
	0.6 (Harrison St.)	174.44	170.95	3.49	169.82	4.62
Nov-90	10.86 (Tono Rd.)	245.39	242.45	2.94	242.45	2.94
	6.17 (SR-507 and Bucoda Gage)	210.24	207.72	2.52	207.72	2.52
	4.51 (SR-507)	202.65	201.06	1.59	201.06	1.59
	2.3 (Pearl St.)	186.74	184.99	1.75	184.99	1.75
	0.6 (Harrison St.)	173.17	170.03	3.14	169.46	3.71
Jan-72	10.86 (Tono Rd.)	244.90	242.40	2.50	242.40	2.50
	6.17 (SR-507 and Bucoda Gage)	209.96	207.72	2.24	207.72	2.24
	4.51 (SR-507)	202.47	201.05	1.42	201.05	1.42
	2.3 (Pearl St.)	186.54	184.68	1.86	184.68	1.86
	0.6 (Harrison St.)	173.08	169.32	3.76	168.46	4.62

Table 5-2: Comparison of Pre-Project and Post-Project Flood Stages on the Chehalis River

Flood Event	Location RM (river mile)	Pre-Project Max WS El. (feet)	Post-Project Option 1		Post-Project Option 2	
			Max WS El. (feet)	Stage Reduction (feet)	Max WS El. (feet)	Stage Reduction (feet)
Feb-96	74.60 (upstream of SR6 Bridge)	180.47	180.03	0.44	179.95	0.52
	72.35 (S. end of airport)	178.53	177.56	0.97	177.38	1.15
	71.30 (Airport Road)	176.67	172.87	3.80	171.41	5.26
	70.22 (N. end of airport)	176.40	172.10	4.30	169.70	6.70
	69.79 (Salzer Creek confluence)	176.39	172.01	4.38	169.47	6.92
	67.70 (upstream of Mellen St. Bridge)	175.69	171.10	4.59	167.73	7.96
	67.44 (downstream of Mellen St. Bridge @ gage)	174.30	170.69	3.61	167.21	7.09
	Salzer Creek RM 0.4 (E. of I-5)	176.64	171.91	4.73	169.27	7.37
Jan-90	74.60 (upstream of SR6 Bridge)	180.19	179.86	0.33	179.78	0.41
	72.35 (S. end of airport)	177.28	176.11	1.17	175.77	1.51
	71.30 (Airport Road)	175.26	171.28	3.98	169.18	6.08
	70.22 (N. end of airport)	175.01	170.91	4.10	168.43	6.58
	69.79 (Salzer Creek confluence)	174.96	170.82	4.14	168.22	6.74
	67.70 (upstream of Mellen St. Bridge)	174.48	170.12	4.36	166.79	7.69
	67.44 (downstream of Mellen St. Bridge @ gage)	173.51	169.90	3.61	166.51	7.00
	Salzer Creek RM 0.4 (E. of I-5)	174.89	171.03	3.86	168.55	6.34

Table 5-2 (Cont.)
Comparison of Pre-Project and Post-Project Flood Stages on the Chehalis River

Flood Event	Location RM (river mile)	Pre-Project Max WS El. (feet)	Post-Project Option 1 Max WS El. (feet)	Post-Project Option 1 Stage Reduction (feet)	Post-Project Option 2 Max WS El. (feet)	Post-Project Option 2 Stage Reduction (feet)
Nov-90	74.60 (upstream of SR6 Bridge)	178.03	177.67	0.36	177.53	0.50
	72.35 (S. end of airport)	176.05	175.22	0.83	174.99	1.06
	71.30 (Airport Road)	173.48	169.99	3.49	168.39	5.09
	70.22 (N. end of airport)	172.95	168.98	3.97	166.58	6.37
	69.79 (Salzer Creek confluence)	172.88	168.85	4.03	166.33	6.55
	67.70 (upstream of Mellen St. Bridge)	172.18	167.96	4.22	164.52	7.66
	67.44 (downstream of Mellen St. Bridge @ gage)	171.21	167.65	3.56	164.07	7.14
	Salzer Creek RM 0.4 (E. of I-5)	172.83	168.80	4.03	166.24	6.59
Jan-72	74.60 (upstream of SR6 Bridge)	178.45	178.08	0.37	178.00	0.45
	72.35 (S. end of airport)	176.47	175.61	0.86	175.39	1.08
	71.30 (Airport Road)	173.89	170.28	3.61	168.82	5.07
	70.22 (N. end of airport)	173.35	169.22	4.13	166.89	6.46
	69.79 (Salzer Creek confluence)	173.29	169.08	4.21	166.63	6.66
	67.70 (upstream of Mellen St. Bridge)	172.55	168.11	4.44	164.69	7.86
	67.44 (downstream of Mellen St. Bridge @ gage)	171.45	167.77	3.68	164.20	7.25
	Salzer Creek RM 0.4 (E. of I-5)	173.22	168.96	4.26	166.38	6.84

Table 5-3:
Comparison of Pre-Project and Post-Project Flood Stage Recurrence Intervals on the Chehalis and Skookumchuck Rivers (based on flood stages under existing flood conditions)

Stream & Location	Flood Event	Pre-Project Recurrence Interval (year)	Post-Project Option 1 Recurrence Interval (year)	Post-Project Option 2 Recurrence Interval (year)
Chehalis River @ Mellen St..	Feb-96	100	15	5
	Jan-90	50	10	4
	Nov-90	20	5	<2
	Jan-72	20	5	<2
Skookumchuck River @ Pearl St.	Feb-96	70	10	10
	Jan-90	60	10	10
	Nov-90	30	7	7
	Jan-72	25	5	5
Skookumchuck River @ Bucoda	Feb-96	180	5	5
	Jan-90	30	5	5
	Nov-90	25	4	4
	Jan-72	25	4	4

Table 5-4:
Comparison of Pre-Project and Post-Project Flood Stages and Recurrence Intervals on the Newaukum River (RM 1.02) (based on flood stages under existing flood conditions)

Flood Event	Pre-Project			Post-Project		
	Max. Flow (cfs)	Max. WS El. (ft.)	Recurrence Interval (year)	Max. WS El. (ft.)	Stage Reduction (ft.)	Recurrence Interval (year)
Feb.-96	12,890	182.76	45	181.29	1.47	10
Jan.-90	11,300	182.27	20	180.98	1.29	5
Nov.-90	10,700	180.91	15	180.16	0.75	3
Jan.-72	7,288	180.86	5	179.34	1.52	<2

5.4. Cost Estimates

Pre-feasibility cost estimates were developed for the recommended project, including both Option 1 and Option 2 floodway excavations in the Mellen St. Bridge area. All costs are presented in 1998 dollars and exclude interest during construction. The estimates include contractor's overhead and profit, sales tax, engineering and permitting, and a contingency appropriate to this phase of studies.

It should be noted that the estimated costs are prelminary only, and are contingent upon approval of the proposed design by resource agencies and other interested parties. The final project costs for the proposed design would also depend on final design details and price factors, and could vary from the estimates presented here.

Quantity estimates were made from work items and materials for the main components of the proposed design. Approximate unit prices were developed from previous cost estimates by USACE and WSDOT, bid prices from similar projects, and quotes from manufacturers and contractors.

The estimates are broken into three parts: Skookumchuck Dam modifications, floodway excavation, and total overall project costs, including annual operation and maintenance (O&M) costs. The costs associated with floodway excavation in the SR-6 Bridge area were incorporated into the costs for Options 1 and 2 floodway excavations in the Mellen St. Bridge vicinity.

The estimated construction cost for the Mellen St. Bridge area Option 1 floodway excavation including the SR-6 Bridge area floodway excavation is $39,968,137. The cost breakdowns are shown in Table 5-5. The estimated construction cost for the Mellen St. Bridge area Option 2 floodway excavation including the SR-6 Bridge area floodway excavation is $82,600,855. The cost breakdowns are shown in Table 5-6. The major cost item for the floodway excavation is for the material excavation, hauling and filling. The costs presented are based on the assumption that suitable disposal sites could be found within 3-5 miles of the project site. If suitable nearby sites cannot be located, higher material hauling costs could result in higher project costs. The estimated construction cost for the proposed modifications to Skookumchuck Dam is $10,716,392. A breakdown of this cost is shown in Table 5-7.

A summary of overall project costs and estimated annual O&M costs is included in Table 5-8, which presents a summary of the recommended project Option 1 and Option 2 costs. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area Option 1 excavation scheme, and the SR-6 Bridge area floodway excavation would be $50,684,529 and would have annual O&M costs of approximately $220,000. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area Option 2 excavation scheme, and the SR-6 Bridge area floodway excavation would be $93,317,247 and would have annual O&M costs of approximately $270,000. The O&M costs consist of annual flood control operation of Skookumchuck Dam, as well as maintenance costs for clearing debris and excess vegetative growth from the floodway excavation.

Table 5-5:
Pre-Feasibility Cost Estimate
Floodway Excavation
Mellen St. Bridge Area Option 1 and SR-6 Bridge Area

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$600,000	$600,000
Surveying	275	AC	$265	$72,875
Clearing and Grubbing	275	AC	$2,500	$687,500
Access Roads	1	LS	$75,000	$75,000
Excavation and Fill	3,620,000	CY	$4.50	$16,290,000
Bridge Extension	1	LS	$4,810,000	$4,810,000
Mitigation	1	LS	$1,500,000	$1,500,000
	Subtotal			**$24,035,375**
	Contingency (@35%)			$8,412,381
	Subtotal (w/contingency)			**$32,447,756**
	Sales Tax (@7.9%)			$1,898,795
	Direct Construction Cost			**$34,346,551**
	Engineering and Permitting			$4,121,586
	Land Aquisition			$1,500,000
	Total Cost (Feb. 1998 Price Level)			**$39,968,137**

Table 5-6:
Pre-Feasibility Cost Estimate
Floodway Excavation
Mellen St. Bridge Area Option 2 and SR-6 Bridge Area

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$1,250,000	$1,250,000
Surveying	475	AC	$265	$125,875
Clearing and Grubbing	475	AC	$2,500	$1,187,500
Access Roads	1	LS	$237,500	$237,500
Excavation and Fill	7,975,000	CY	$4.50	$35,887,500
Bridge Extensions	1	LS	$6,400,000	$6,400,000
Mitigation	1	LS	$4,500,000	$4,500,000
	Subtotal			**$49,588,375**
	Contingency (@35%)			$17,355,931
	Subtotal (w/contingency)			**$66,944,306**
	Sales Tax (@7.9%)			$5,288,600
	Direct Construction Cost			**$72,232,906**
	Engineering and Permitting			$8,667,949
	Land Aquisition			$1,700,000
	Total Cost (Feb. 1998 Price Level)			**$82,600,855**

Table 5-7:
Pre-Feasibility Cost Estimate
Skookumchuck Dam Modifications

Item	Quantity	Units	Unit Cost	Amount
Mobilization	1	LS	$280,000	$280,000
Surveying	1	LS	$10,000	$10,000
Diversion and Care of Water	1	LS	$25,000	$25,000
Cofferdam	1	LS	$50,000	$50,000
Excavation	24,250	CY	$50	$1,227,500
Rock Support	1	LS	$450,000	$450,000
Concrete Demolition	750	CY	$150	$112,500
Cast-in-place Concrete	3,450	CY	$450	$1,552,500
Trashracks	2	EA	$100,000	$200,000
Slide Gates	2	EA	$175,000	$350,000
Bulkhead Gate	1	LS	$60,000	$60,000
Misc. Metals	1	LS	$50,000	$50,000
Rubber Weir	1	LS	$1,250,000	$1,250,000
Misc. Electrical	1	LS	$18,000	$18,000
Control House	1	LS	$40,000	$40,000
Mitigation	1	LS	$210,000	$210,000
Subtotal				**$5,885,500**
Contingency (@35%)				$2,059,925
Subtotal (w/contingency)				**$7,945,425**
Sales Tax (@7.9%)				$627,689
Direct Construction Cost				**$8,573,114**
Engineering and Permitting				$2,143,278
Total Cost (Feb. 1998 Price Level)				**$10,716,392**

Table 5-8:
Summary of Recommended Project Alternatives

Item	Recommended Alternative	
	Option 1	Option 2
Skookumchuck Dam Flood Control Storage	24,000 ac-ft	24,000 ac-ft
Floodway Excavation Quantities		
Mellen St. Bridge Area	2,820,000 cy	7,175,000 cy
SR-6 Bridge Area	800,000 cy	800,000 cy
Approximate Flood Stage Reduction		
Mellen St. Bridge Area	4 ft	7 to 8 ft
SR-6 Bridge Area	1.5 ft	1.5 ft
Total Construction Cost	$50,684,529	$93,317,247
Annual O&M Costs	$220,000	$270,000

5.5. Economic Evaluation

USACE recently completed a pre-reconnaissance evaluation of flood damage reduction estimates for the combined Skookumchuck Dam modifications and the Mellen St. Bridge vicinity Option 2 floodway excavation project for Lewis County. Based on February 1998 prices and conditions, the average annual flood damage reduction benefits were estimated to be $1,137,000 and $415,000 in the Skookumchuck area and the Chehalis area, respectively (USACE, 1998). Average annual benefits resulting from prevention of flood damage totals $1,552,000.

In addition to the benefits resulting from the prevention of flood damages, there is the added benefit that I-5 would not have to be elevated as part of WSDOT's I-5 widening project. According to WSDOT (1998), the incremental cost of raising the elevation of I-5 to two feet above the 100-year flood would be $107,953,555 including the cost of preliminary engineering. The estimated total cost for the combination of Skookumchuck Dam modifications, the Mellen St. Bridge area Option 2 excavation scheme, and the SR-6 Bridge area excavation is $93,317,247 with estimated annual O&M costs of approximately $270,000.

The project costs and all resulting benefits were evaluated at a 7-1/8 percent discount rate (the federal discount rate for water resource projects) over a 50-year economic analysis period. The total average annual benefits are estimated at $9,498,000 and the total average annual costs are estimated at $7,139,000, resulting in a benefit-to-cost ratio of 1.33 for the recommended project with the Mellen St. Bridge area Option 2 floodway excavation. Table 5-9 summarizes the potential project benefits and costs. The benefit-to-cost ratio would be greater for the recommended project with the Mellen St. Bridge area Option 1 floodway excavation.

Table 5-9:
Benefit-Cost Evaluation - Recommended Project with Option 2 Floodway Excavation

Item	Average Annual Figures
Annual Benefits	
Skookumchuck Area	$1,137,000
I-5 Cost Savings	$7,946,000
Chehalis Area	$415,000
Total Annual Benefits	**$9,498,000**
Annual Project Costs	
Skookumchuck Dam Modifications	$960,000
Floodway Excavation	$6,179,000
Total Annual Costs	**$7,139,000**
Benefit-To-Cost Ratio	**1.33**

5.6. Environmental and Permitting Issues

5.6.1. Skookumchuck Dam Modifications

Investigations conducted for the USACE Skookumchuck Dam Modification Project identified several potential environmental impacts relating to wildlife habitat and fishery resources, water supply, water quality, and dam safety. The following discussion is based upon those investigations and analyses; additional studies would be required during the next project phase to further define potential impacts that could occur if the recommended alternative is implemented.

The existing reservoir drawdown zone provides approximately 65 acres of vegetated habitat that is important to wildlife (USFWS, 1989). This zone is used by waterfowl, deer, elk, and other wildlife. Changes in reservoir levels associated with a new flood control operation rule curve could induce changes in vegetation and loss of wildlife food and cover. Water dependent mammals like beavers and muskrats could be negatively affected by fluctuations in wintertime reservoir levels.

Downstream of the dam, wetlands and riparian habitat along the Skookumchuck River could be affected by a reduction in overbank flow. The degree to which these wetlands are dependent on flood flows for recharge is not known at this time; to evaluate specific wetland areas that could be indirectly affected by flow modifications and to identify measures to avoid and minimize impacts to wetlands, surveys would be needed in the next study phase. Studies would also be required to assess the value of potentially-affected wildlife habitats, both within and downstream of the reservoir area.

Operational changes may affect resident fish inhabiting the reservoir, and under some conditions could impair the outmigration of juvenile steelhead (USFWS 1989). Such changes, which could occur if the reservoir pool failed to refill prior to the beginning of March, could result in insufficient water to pass outmigrating fish over the spillway. Operational changes could also potentially affect the supply of water to the WDFW fish rearing facility downstream of the dam. An analysis of the reservoir flood control operation rule curve would be needed to assess the likelihood of such events.

The existing maximum velocity on the Chehalis River is up to 12 fps downstream of the Mellen St. Bridge. The recommended alternative would bring the maximum velocity in this area down to approximately 3-4 fps. Upstream of the Mellen St. Bridge, the existing maximum velocity would be increased from about 2 fps to 4 fps. The estimated changes in velocity would reduce both sedimentation above the bridge and erosion below the bridge.

With flood control storage at Skookumchuck Dam, peak velocities would decrease along the Skookumchuck River. The recommended alternative would decrease the maximum velocities around Bucoda from about 2.5-8 fps to between 2-6.5 fps. Although the peak velocity would decrease, the time period during which the velocity is between 5 and 6 fps would increase. Whether or not effects of the increased duration of this range of velocity would result in scouring problems is currently unknown. Further analysis would be needed in the next phase of studies to determine the erodibility of the channel materials in various locations.

Other potential impacts to fish could occur as a result of changes in water temperatures, increases in reservoir turbidity, and the transport of sediments downstream. Increases in turbidity levels could result from erosion of exposed reservoir slopes during pool drawdown periods. Undefined at this time is the effect of flow changes on fishery resources. Beneficial effects could include a reduction in scouring of spawning beds; adverse impacts could result from rapidly changing river levels, especially during spawning and incubation periods. Due to the storage volume to be provided by the Skookumchuck Dam modifications, it is likely that seasonal streamflows could be augmented to enhance conditions for anadromous fish. An analysis of fish habitat under various flow regimes would be conducted to evaluate these opportunities.

Measures considered by USACE to mitigate for wildlife impacts associated with its Skookumchuck Dam modification proposal included the transfer of 50 acres of forested land for incorporation into the Skookumchuck Habitat Management Area and construction of wood duck nesting boxes. The level of mitigation required if the recommended alternative is implemented is not known at this time. Mitigation costs could be substantial and could include land acquisition as well as permitting, engineering, and construction costs.

5.6.2. Chehalis River Floodway Excavation

Floodway excavation would involve disturbance of wetlands and riparian habitats, and potentially could increase erosion and affect water quality. Although impacts to fish habitats would occur, floodway excavation would involve significantly less direct disturbance of instream habitats than channel excavation, and offers the potential to provide a net habitat benefit. Floodway excavation would also avoid the high level of impact to the built environment that would be associated with secondary channel construction.

Wetlands are interspersed with upland habitats along the entire proposed excavation length of the river. The area and magnitude of the potential impact to wetlands would depend on the ultimate floodway width and the reach or reaches selected for excavation. Wetlands are particularly extensive along RM 67, at the confluence with the Skookumchuck River, as well as in the areas between RM 69.5 and RM 70.5 (Salzer Creek mouth) and RM 71.5 and RM 75.08 (airport area to the Newaukum River); excavation in these areas would result in a relatively large area of wetland disturbance. Wetlands lying within the excavated floodway would be directly disturbed. Adjacent wetlands could also be indirectly affected by dewatering, either through interception of perched water tables or through reduction or elimination of periodic recharge by overbank flooding. The approximate locations of known wetlands have been mapped under the National Wetlands Inventory program. However, in the next study phase, site specific surveys would be needed to evaluate specific wetland areas that might be directly or indirectly affected and to identify measures to avoid and minimize impacts to wetlands.

Removal of wetland and riparian vegetation across the floodway width would significantly reduce the wildlife habitat value of these areas. The removal of natural vegetative cover from the floodway could fragment remaining adjacent habitats by removing their connection to the river. It is possible that these effects could be partially offset by reestablishing vegetation on the excavated floodway and along the shoreline. However, because of the need to maintain channel capacity, a cover of woody overstory vegetation cannot be reestablished on the benches. A buffer of woody overstory vegetation could potentially be reestablished along some reaches of the shoreline without significantly affecting floodway hydraulics.

Floodway excavation would increase the potential for erosion at least temporarily, until vegetation could be reestablished along the streambank. Implementation of Best Management Practices during and following construction would be particularly important to avoid impacts to water quality at the project site and downstream.

As described in Section 5.3.5, the large volume of material that would be generated by the excavation would require one or more sites for disposal. The specific environmental impacts associated with disposal of the excavated material would vary, depending on existing conditions at the site or sites selected for this purpose. Disposal of the material adjacent to the excavated area would most likely be the least environmentally desirable alternative, as it would significantly increase the area of wetland and riparian habitat disturbed. More desirable would be the beneficial use of the material in the construction of other projects. Such projects could include small levees to address localized flooding problems. The environmental effects of using the excavated material for the construction of small levees would be small, and would be dependent on site specific conditions.

Some of the excavated material could require special handling as a result of hazardous waste contamination. Because the Sewage Treatment Plant Landfill was used as an unregulated throw and burn site until the early 1970s, hazardous wastes may be present in soil and subsurface materials in this area (FHA and WSDOT, 1997). Investigations may be required during the next study phase to evaluate hazardous waste contamination in the project area.

A National Register-eligible archaeological site exists near the Mellen St. Bridge (FHA and WSDOT, 1997). Other recorded sites, including some that may be aboriginal townsites, occur in the project area. These and currently unrecorded cultural resources could be affected by project construction. An assessment would be needed in the next study phase to identify cultural resources that could be affected by project construction.

Excavation of the floodway would affect farmlands, but would have relatively little impact on existing structures and facilities. Facilities which would be affected include the Centralia Wastewater Treatment Plant and the Mellen St. Bridge. The existing wastewater treatment plant site is susceptible to flooding and provides insufficient space for plant expansion beyond the year 2025. Studies are underway to evaluate alternative sites for a new or modified wastewater treatment plant to meet the future wastewater service needs of the City of Centralia (CH2M-Hill, 1998).

Mitigation for unavoidable impacts to wetlands would be required under the provisions of the Clean Water Act and local critical areas ordinances; mitigation would also be required for impacts to fish and wildlife habitats. Mitigation costs could be substantial. Because the excavated floodway could be designed to bypass incised meanders, this alternative excavation provides opportunities to create valuable backwater refuge for fish at high flows. This type of mitigation action would be consistent with current efforts by tribal interests to create additional off-channel rearing habitat to benefit anadromous fish, and should be investigated further if the floodway excavation alternative is implemented.

5.7. Project Development Schedule

A preliminary development schedule for the recommended project is shown in Figure 5-25. This schedule assumes an optimistic, but possible development of the project that meets all public, agency, government and funding supports and includes four development phases of the project work. These phases are described below.

5.7.1. Phase I - Feasibility Study

This phase of work will be performed from Spring 1998 to Spring 1999. Two primary tasks of this feasibility study are: (1) negotiate an agreement to transfer Skookumchuck Dam ownership from the existing utility owners to a new local community owner yet to be identified, and (2) the project engineering and environmental feasibility analysis. A preliminary discussion with PacifiCorp, the existing owner representative and dam operator, has indicated that the existing owners are interested in relinquishing dam ownership as long as their Centralia Steam Plant can be continuously supplied with cooling water diverted downstream and augmented by dam storage during low flow months. The project engineering and environmental feasibility would involve optimization of project design features including the Skookumchuck Dam modifications, the Chehalis River floodway excavation in the Mellen St. Bridge vicinity, floodway excavation between the SR-6 Bridge and the mouth of the Newaukum River, as well as other associated technical work, environmental baseline and impact assessment and development of potential mitigation measures.

5.7.2. Phase II - NEPA/SEPA Compliance

Concurrent with, and following completion of environmental assessment relating to the project impacts, the project development would move into the NEPA/SEPA compliance phase. This work would be performed between Fall 1998 and the end of 1999. A total of 18 months for this phase of work is scheduled, assuming a NEPA/SEPA-EIS document is required. The actual length of this phase may be longer if issues cannot be resolved in a timely manner with resource agencies, or shorter if an EA document is determined to be adequate in lieu of the assumed EIS document. Work during this phase also includes a FERC (Federal Energy Regulatory Commission) license exemption amendment for the Skookumchuck Dam. In terms of safety, the existing dam has been under the FERC jurisdiction since FERC issued a license exemption to the dam owners when a small hydropower facility was added in early 1990. The recommended modifications of the dam will require the submittal of a license exemption amendment application to FERC. FERC must approve the application before construction of any modifications is started.

5.7.3. Phase III - Skookumchuck Dam Modifications

Near the end of Phase II in Summer-Fall 1999, and after the resolution of critical issues is achieved, project development would proceed with preliminary engineering design, permitting, and final design for the Phase III-Skookumchuck Dam modifications. Bids for construction could take place in Spring 2000 and construction could start in Summer 2000, taking advantage of low reservoir levels in the fall and winter months for all needed modification work. It is expected that the dam modifications construction can be completed by Spring 2001.

5.7.4. Phase IV - Chehalis River Floodway Excavation

The Phase IV work includes land acquisition, preliminary design, permitting, final design and construction for the Chehalis River floodway excavation including the Mellen St. and SR-6 Bridge modifications and construction of habitat features. This phase could proceed concurrently with the Phase III work described above. However, depending on the final design configuration of the floodway excavation and quantity of earth work, the excavation construction would most likely require 2 to 3 years.

It is expected that the earliest completion date for the project would be in early 2003.

5.8. Project Funding

A funding strategy will be developed that combines resources from benefited communities and agencies. The project will have local, state and federal benefits. The following list includes some potential sources.

5.8.1. U.S. Army Corps of Engineers (USACE)

USACE has programs designed for funding studies and construction of flood control projects. In order to become involved, USACE must have both congressional authority and funding through the appropriation process. The most likely authorities upon which USACE could rely to work on this project follow.

Section 401, 1986 Water Resources Development Act (P.L. 99-662) Chehalis River Basin Study Authority

Section 401 of the 1986 Water Resources Development Act authorized USACE to pursue the flood control operations described in the Interim Feasibility Report entitled "Centralia, Washington, Flood Damages Reduction" (USACE, December 1982) (hereafter referred to as "Feasibility Report"). The project included several structural modifications and additions to the Skookumchuck Dam. The project was authorized in 1986 at an estimated total cost of $19.9 million and an estimated federal cost not to exceed $15 million. This was based upon 75%-25% cost-sharing. Adjusted for inflation, the authorized project could now have a total cost of $26.7 million.

USACE began pre-construction engineering and design on the authorized project in 1988, and pursued the project through several preliminary design revisions. By 1992, they determined that the project could not satisfy the USACE benefit analysis requirement and ceased all work.

With appropriate authorization and funding, USACE could resume work under Section 401 at any time. If USACE elected to pursue the alternative recommended herein, however, this would increase the cost and lengthen the timeline, due to the slower USACE process. Alternatively, this authority can be used to provide federal reimbursements of costs (see the discussion of Section 211 below).

Work is in progress to determine which components of the recommended alternative, or parts of components, could be funded through this project authority. It is likely that the Skookumchuck dam modifications would fall under this authority. The recommended modifications are similar to the modifications and additions to the dam in the Feasibility Report, including the construction of a new outlet facility and the construction of a spillway crest weir and other modifications to the spillway.

It is uncertain whether this authority could be extended to the floodway excavation component of the recommended alternative, without amendment. The scope of the project, as described in the Feasibility Report, did not include excavation or bridge modification. If an amendment is required, the change would require Congressional authorization under the USACE regulations on post-authorization changes.

Section 211, 1996 Water Resources Development Act Construction of Flood Control Structures by Non-Federal Interests

Section 211 was added to the 1996 Water Resources Development Act, providing for federal reimbursement of local government costs on flood control projects under certain conditions. The flood control structures must be specifically authorized by Congress, but the USACE does not perform the study or the construction. Reimbursement of up to 65% is available, provided the Secretary of the Army approves the design and plans, construction is monitored by the Secretary of the Army, and costs are reasonable.

Use of this section allows the non-federal interest to pursue traditionally USACE projects, without the long time-line and high costs associated with most USACE projects. As discussed above, a flood control project is authorized under Section 401 of the 1986 Water Resources Development Act, but the extent of the authorization is not yet determined. At a minimum, use of this section could apply to the proposed dam modification under the recommended alternative with an estimated cost of $10.7 million. It is also possible that the authorization could be amended, if necessary, to include additional project elements.

Still at issue is whether the original non-federal cost-share of 75%-25% authorized under Section 401 would apply, rather that the 65%-35% cost-share provided under section 211.

Challenge 21: Flood Hazard Mitigation and Riverine Ecosystem Restoration Initiative

Through their new Challenge 21 Initiative, the USACE will focus on non-structural solutions to reducing flood damages, while maintaining the flexibility to use more traditional structures where appropriate. USACE will create a framework for more effective coordination of federal flood programs and will create partnerships with communities to develop comprehensive solutions to reducing flood damages and improving quality of life. The program focus will be on watershed-based solutions that can include the restoration of riparian and wetland ecosystems. The federal share will be 50% of the cost for studies and 65% for project implementation.

USACE is considering the Chehalis River Basin as a candidate watershed project under this program. The recommended alternative will further USACE goals by providing a comprehensive solution to the basic flooding problem and by providing for habitat enhancements. Local government will pursue the possibility of additional funding for the recommended alternative under this program.

5.8.2. Federal Highway Administration (FHWA) and Washington State Department of Transportation (WSDOT)

One of the primary goals of the recommended alternative is to address flooding on I-5 in Centralia-Chehalis. The WSDOT and FHWA have several programs that could assist in project funding. For example, FHWA has programs for bridge construction. Funding for the Mellen St. and SR-6 Bridge modifications can be sought through one of these programs.

FHWA also provides funding to state transportation agencies in the form of general road funds, cost-shared 80% federal and 20% state. These funds are allocated according to state priorities. Earmarking at the federal level is extremely difficult. However, if the state budgets for road funds in a future year for this project, FHWA will provide a letter verifying that a particular project is eligible for road funds. This assurance can be used as security for a loan or bond issue to free up funds at an earlier date.

FHWA is working with WSDOT on the use of road funds to widen I-5, which would include the cost of raising the highway to address the flooding problem. The estimated cost is approximately $98 million ($108 million including preliminary engineering) just to raise I-5. Construction of the recommended alternative could eliminate or reduce the scope of raising I-5, resulting in substantial cost savings. Lewis County is coordinating with WSDOT to ensure that the recommended alternative is included as an alternative analyzed in the Environmental Impact Statement (EIS) of the WSDOT on elevating the freeway. WSDOT supports a basin-wide approach to finding solutions to transportation problems. However, local government must continue to work closely with the WSDOT to ensure that the WSDOT will have the authority to participate in identifying and implementing the best solution for I-5 flooding.

5.8.3. Washington State Legislature

In 1998, the Washington State Legislature appropriated $600,000 to continue work on alternatives for flood management and flood hazard reduction projects in the Chehalis Basin. Funds will be distributed to counties within the Basin by WSDOT for further study of the cause of flooding and options for flood hazard reduction. This appropriation is intended to further this project.

5.8.4. Washington State Department of Ecology

The Washington State Department of Ecology (WSDOE) uses the Flood Control Assistance Account Program (FCAAP) to help local authorities reduce flood hazards and flood damages, and to protect and enhance state resources. The fund receives appropriations from the state legislature, some of which are used at the discretion of the WSDOE, and some of which are earmarked for specific projects. Discretionary funding generally requires local cost-sharing of 25% for planning projects and up to 50% for flood damage reduction projects, but recognizes in-kind contributions.

FCAAP funds are granted biennially with a focus on projects determined to have the greatest benefit based on the most recent flood experience. Grants are subject to eligibility requirements and the states share generally ranges from $50,000 to $150,000 for planning projects and from $6,000 to $40,000 for flood damage reduction projects. There is stiff competition for the limited amount of funding available through this program. The application process for the next biennium starts in October-November 1998 for grants awarded in May-June of 1999.

FCAAP funding of $50,000, originally allocated to the City of Centralia in the previous biennium (July 1995- June 1997) for work on the Skookumchuck Dike, was reallocated by WSDOE and expended on the initial survey work for this project in 1997. In addition, Lewis County received $100,000 in FCAAP funding this biennium (July 1997- June 1999) for this Pre-Feasibility analysis. A request is currently being made of WSDOE for additional funding through this program.

5.8.5. Local Flood Control District

Lewis County has taken the lead position in the effort to identify and implement a solution to the chronic flooding problems from the Chehalis River. In this role, Lewis County has obtained wide participation of stakeholders. The County is now formalizing a partnership with the City of Centralia, the City of Chehalis, Grays Harbor County, Thurston County, and the Chehalis Confederated Tribes.

Identified collectively as the Basin Governments, these stakeholders may seek voter approval of a local Flood Control District. If formed, it is anticipated that this District will solicit funds from a variety of sources, and will assess properties within the District based upon a benefit analysis. At some time in the future, the Flood Control District may issue bonds. The District will be used to cover local cost-sharing requirements and the costs of operations and maintenance of the flood control structures.

Lewis County has formed a county-wide flood control zone district which already has taxing authority, even though that zone may not be the solution relative to construction and maintenance of these projects.

5.8.6. Conclusion

At this time, specific funding sources and cost-sharing proportions cannot be determined. Based upon previous experience with projects whose beneficiaries are outside the local community, it would be reasonable to expect cost-sharing in the range of 60% federal, 30% state, and 10% local community. If we assume a $100 million project, the local community, under this type of cost-sharing arrangement, could expect to contribute $10 million.

Figure 5-1: Floodway Excavation Plan Overview

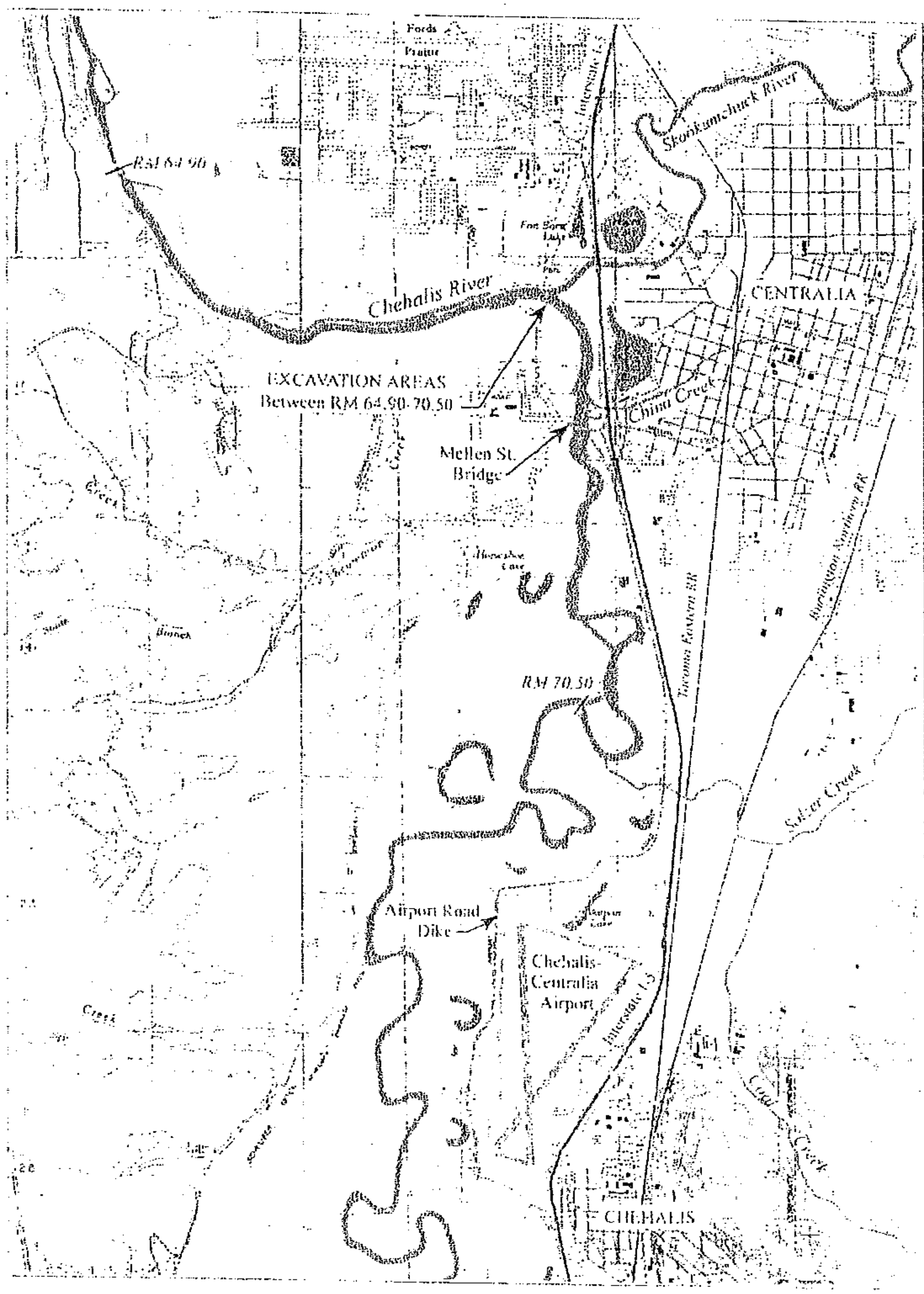


Figure 5-2:
Typical Floodway Excavation Section

Note: plantings not shown

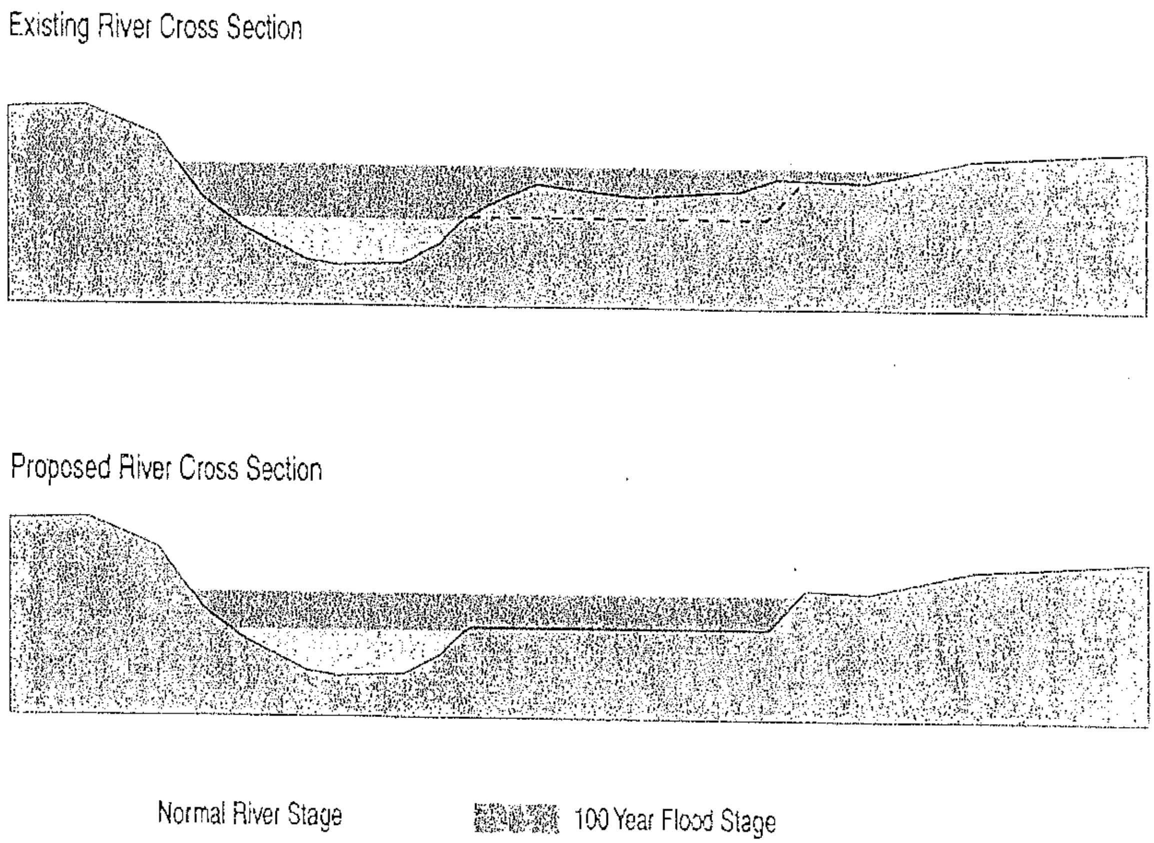


Figure 5-3:
Mellen St. Bridge Modification, Section View

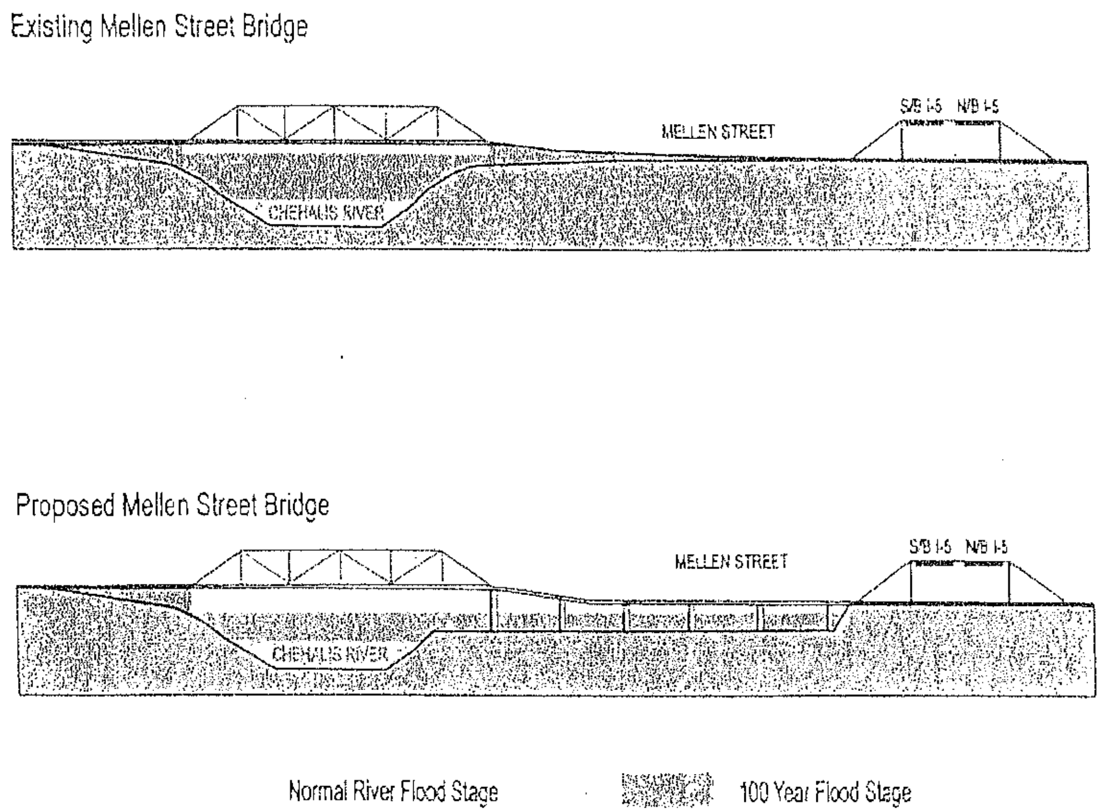


Figure 5-4:
Skookumchuck Dam Spillway Modifications - Plan View

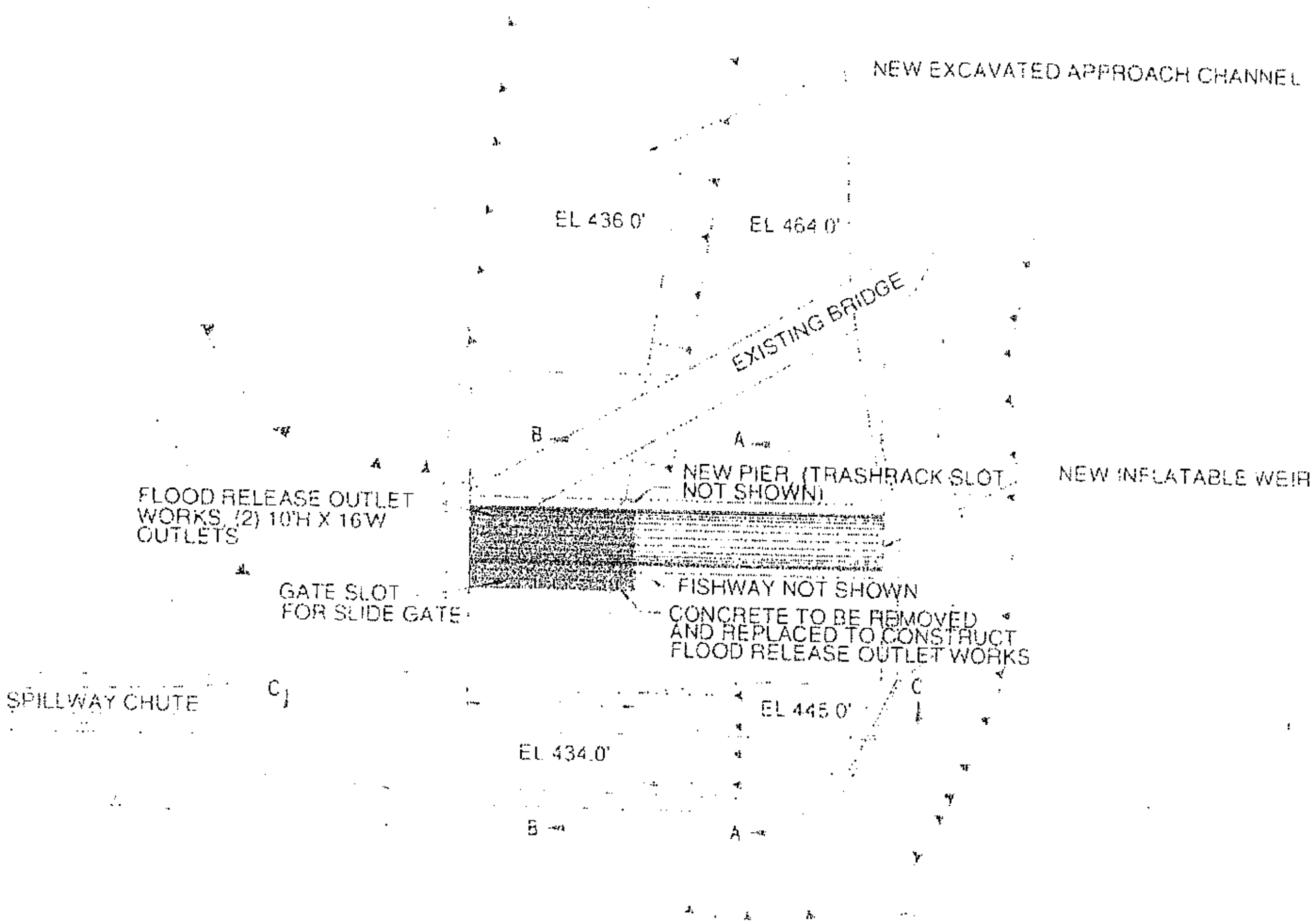


Figure 5-5:
Skookumchuck Dam Spillway Modifications - Downstream Elevation

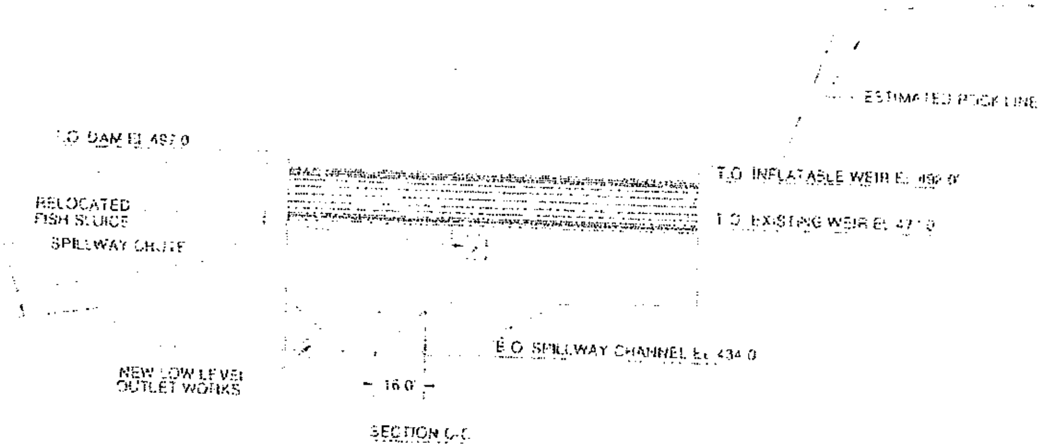


Figure 5-6:
Skookumchuck Dam Spillway Modifications - Sections

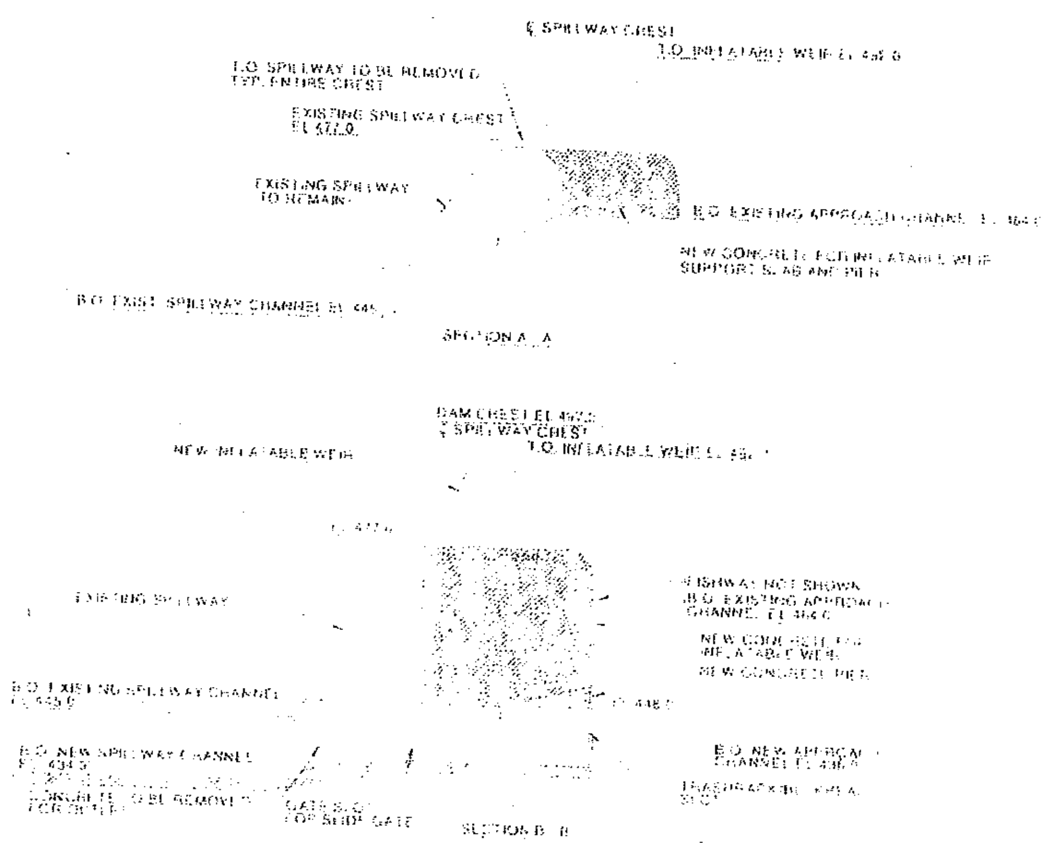
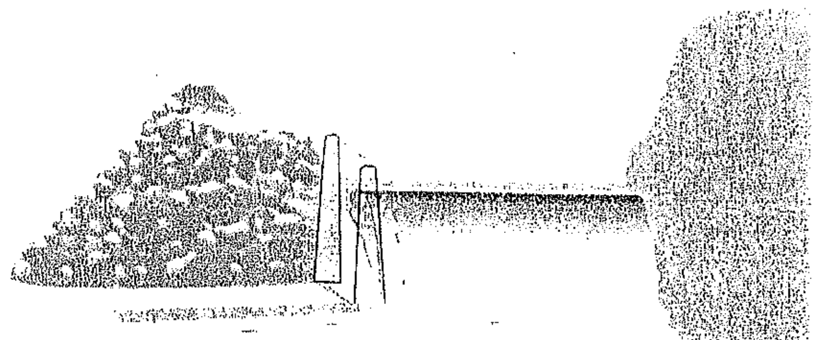
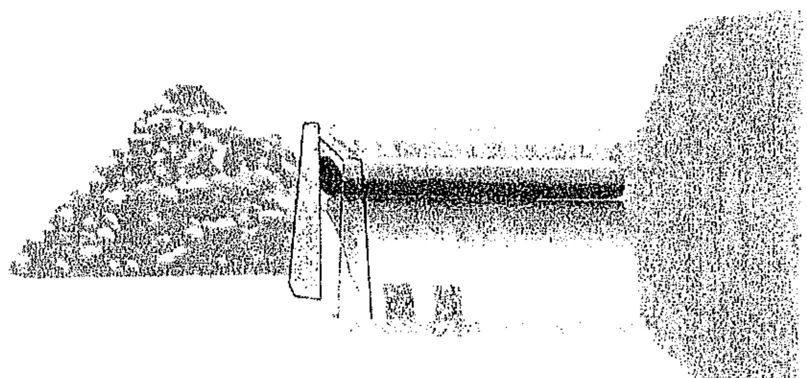


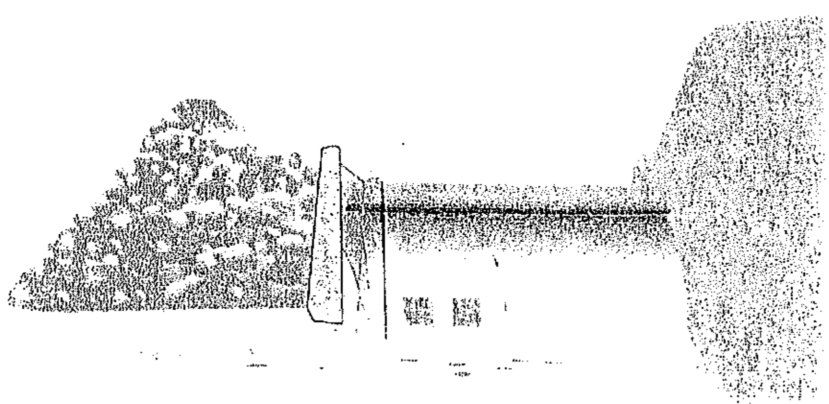
Figure 5-7:
Skookumchuck Dam Spillway Modifications, Section View, Artist Rendering



Existing Skookumchuck Dam Spillway



Modified Skookumchuck Dam Spillway with Rubber Weir Inflated



Modified Skookumchuck Dam Spillway with Rubber Weir Deflated

Figure 5-8:
Comparison of Pre-and Post-Project Flood Profiles on the Skookumchuck River - February 1996 Flood Event

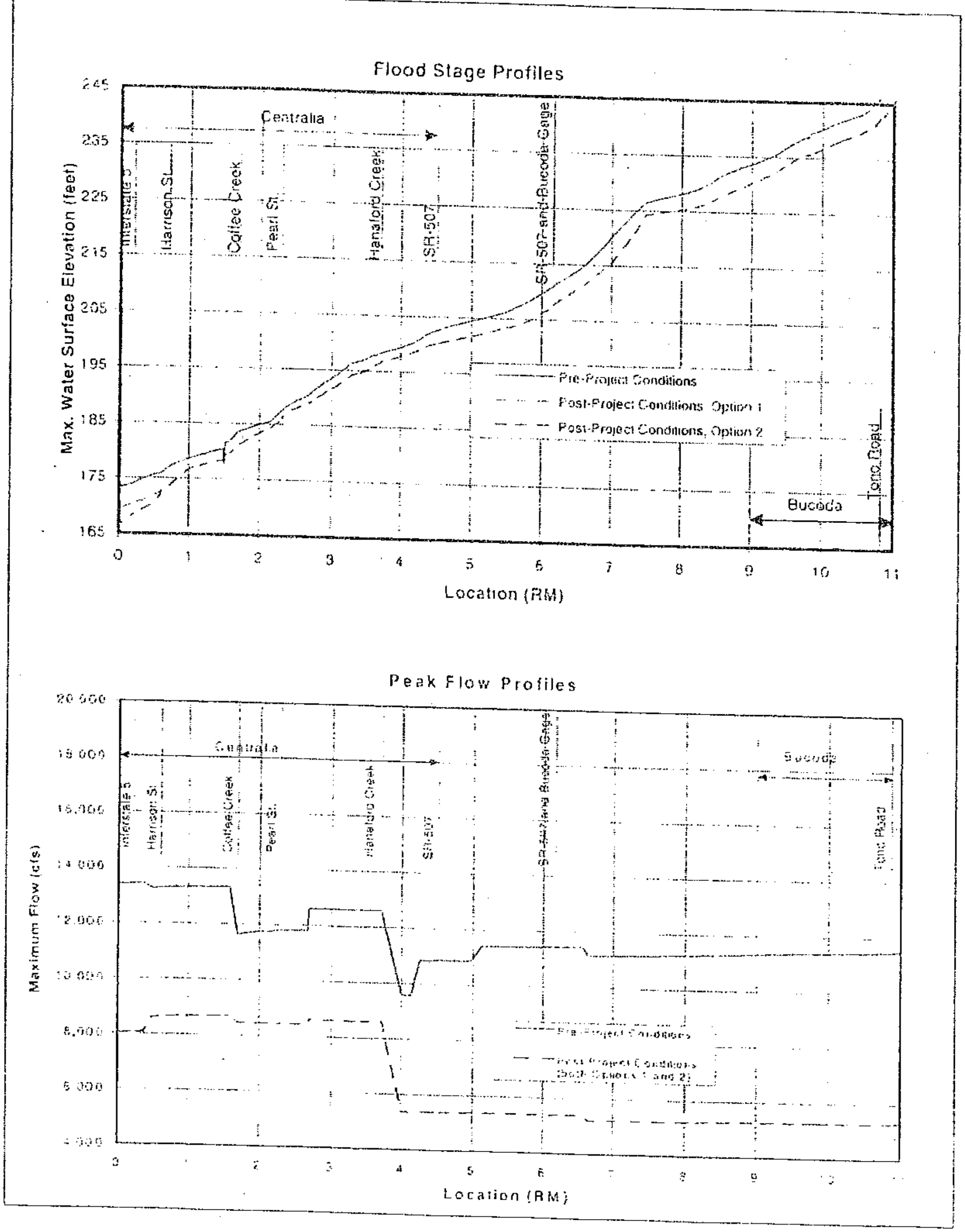


Figure 5-9:
Comparison of Pre-and Post-Project Flood Profiles on the Skookumchuck River - November 1990 Flood Event

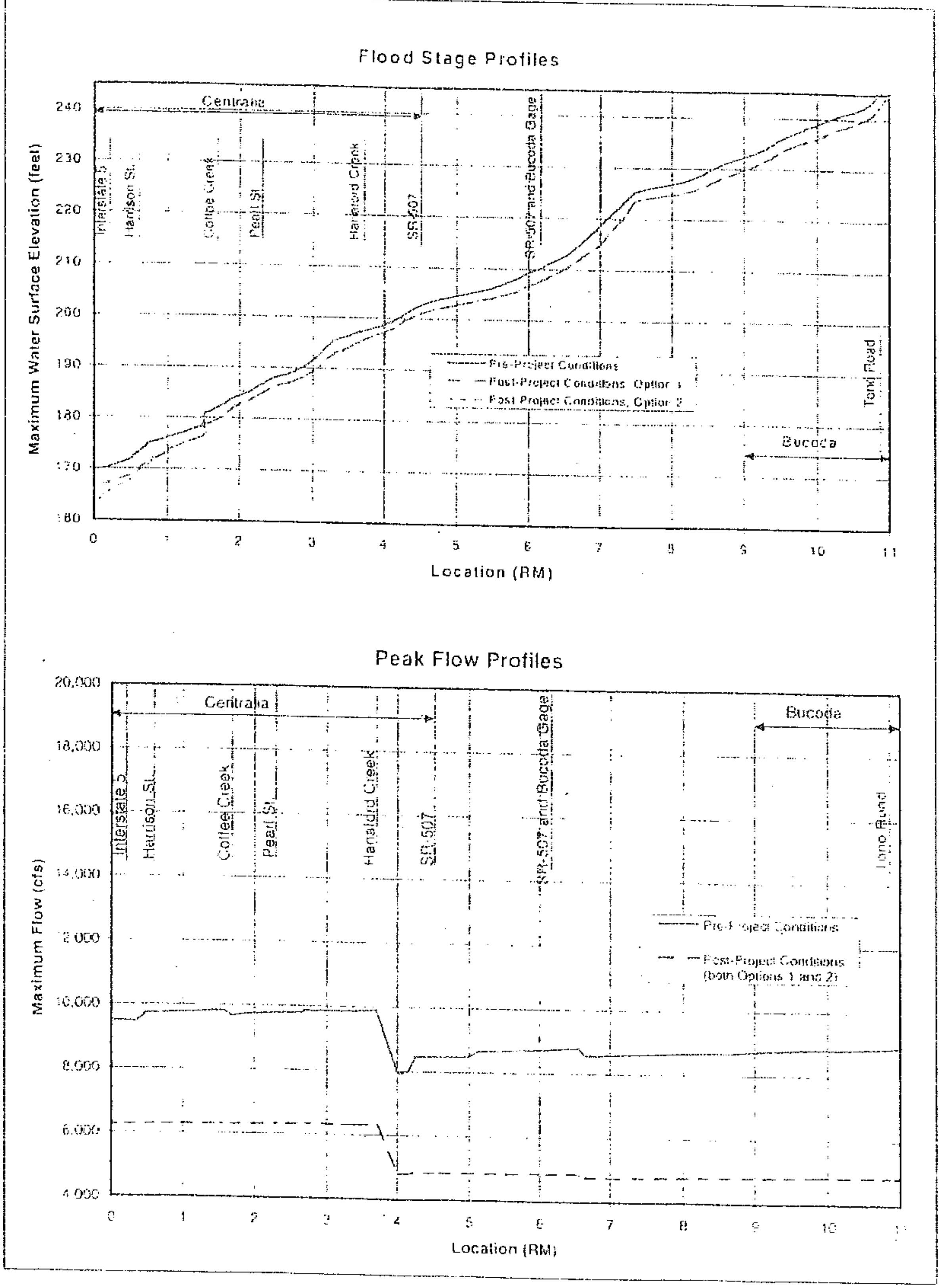


Figure 5-10:
Comparison of Pre-and Post-Project Flood Profiles on the Skookumchuck River - January 1990 Flood Event

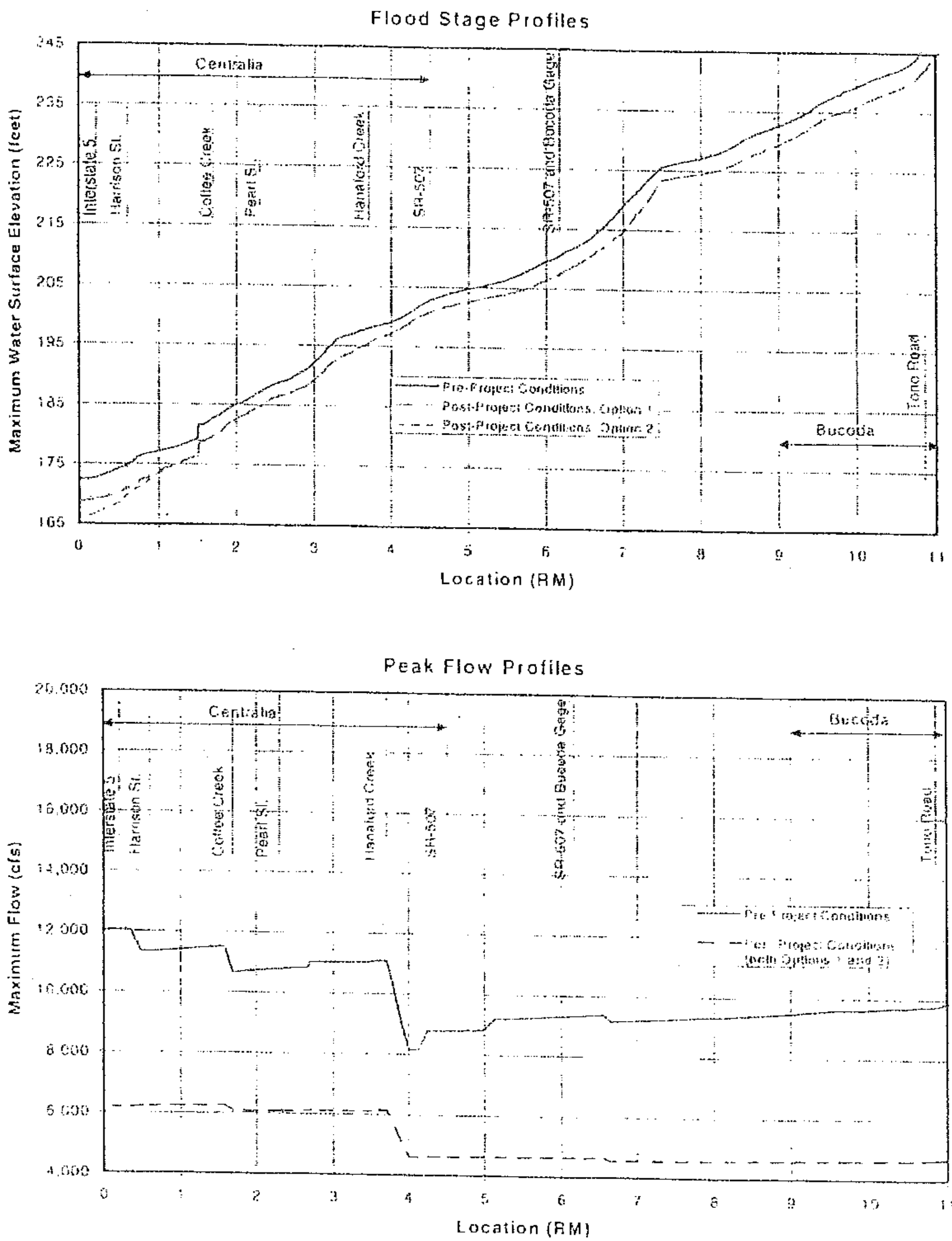


Figure 5-11:
Comparison of Pre-and Post-Project Flood Profiles on the Skookumchuck River - January 1972 Flood Event

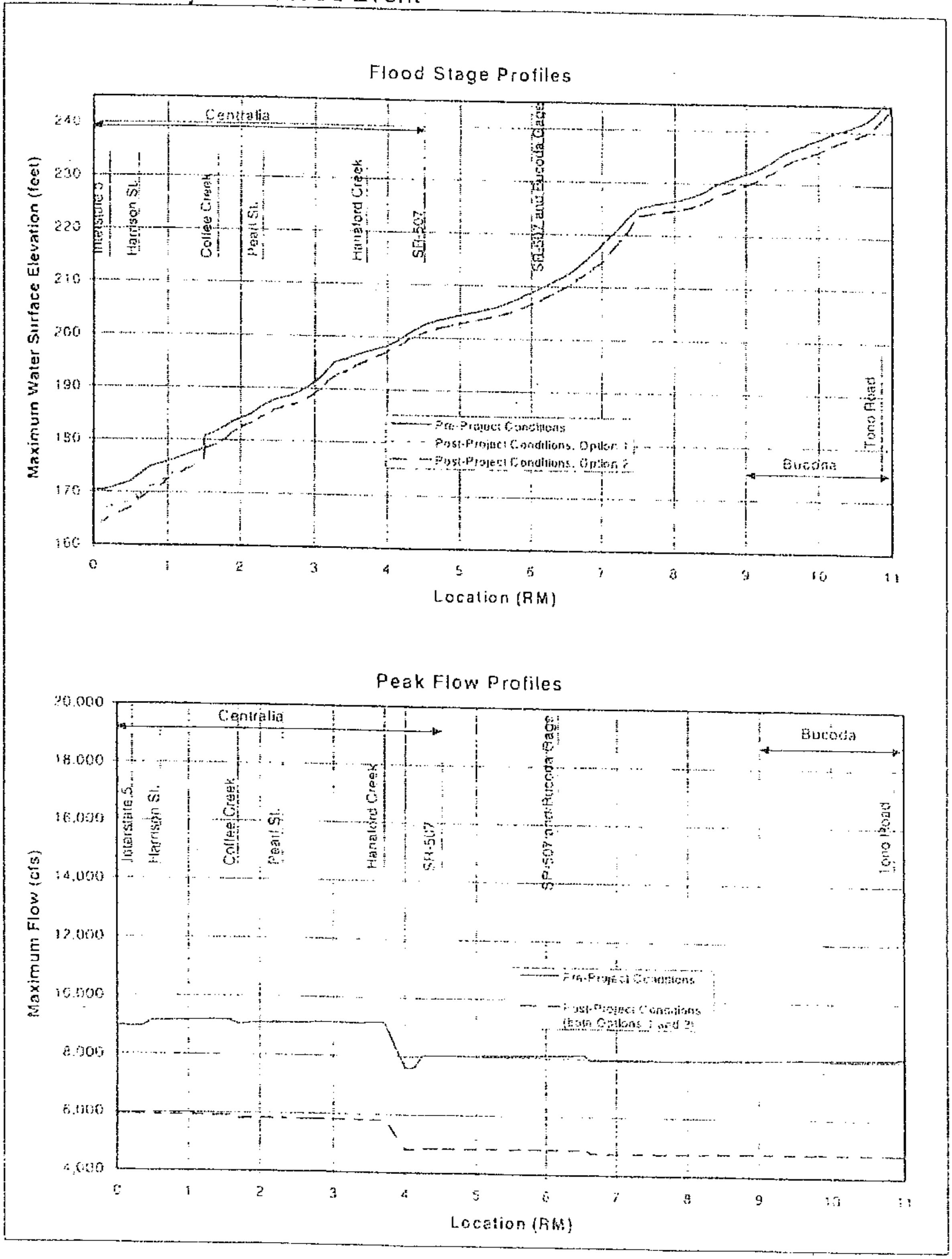
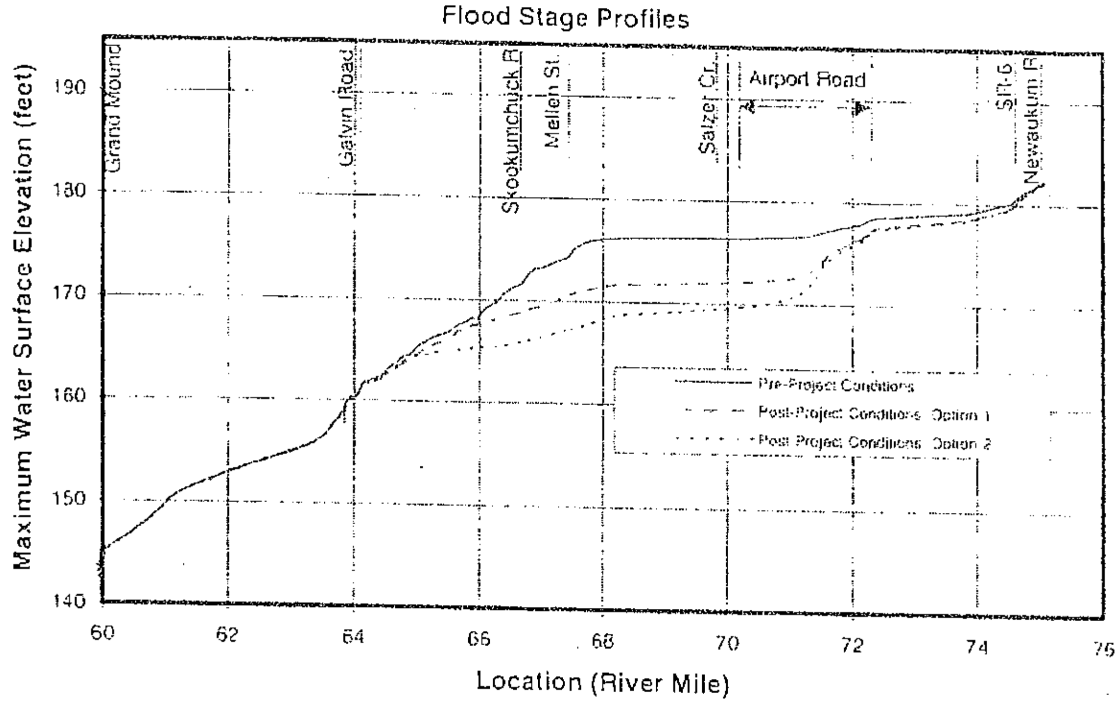


Figure 5-12:
Comparison of Pre- and Post-Project Flood Profiles on the Chehalis River - February 1996 Flood Event



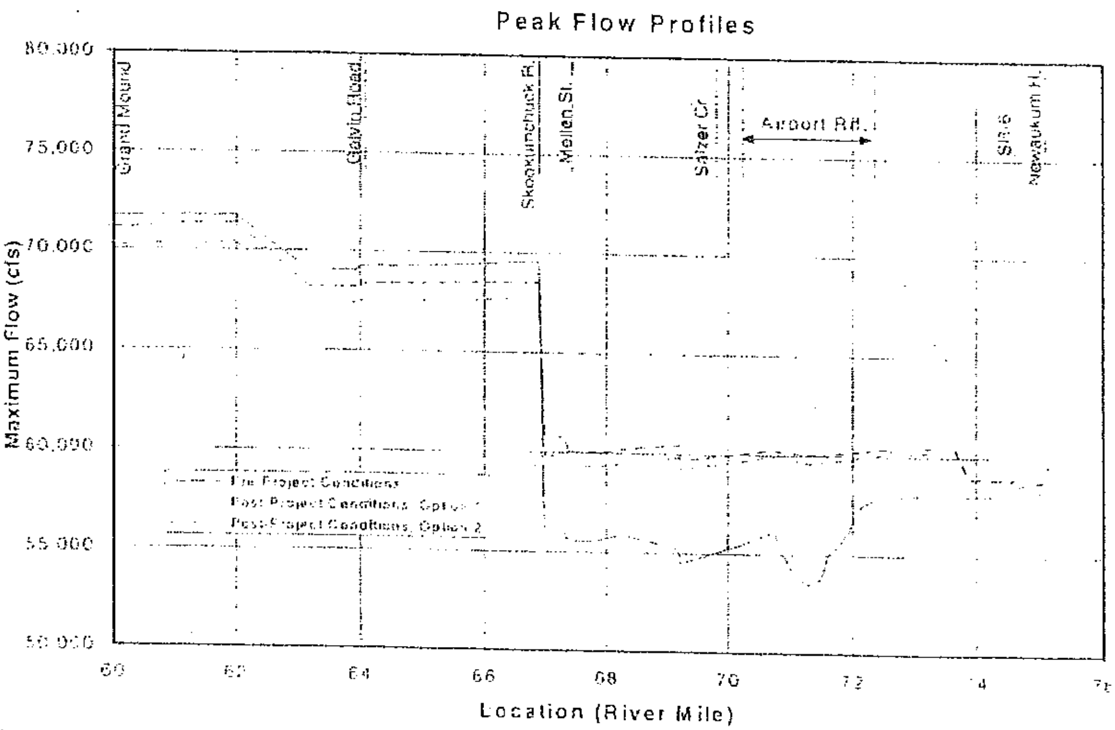


Figure 5-13:
Comparison of Pre- and Post-Project Flood Profiles on the Chehalis River - November 1990 Flood Event

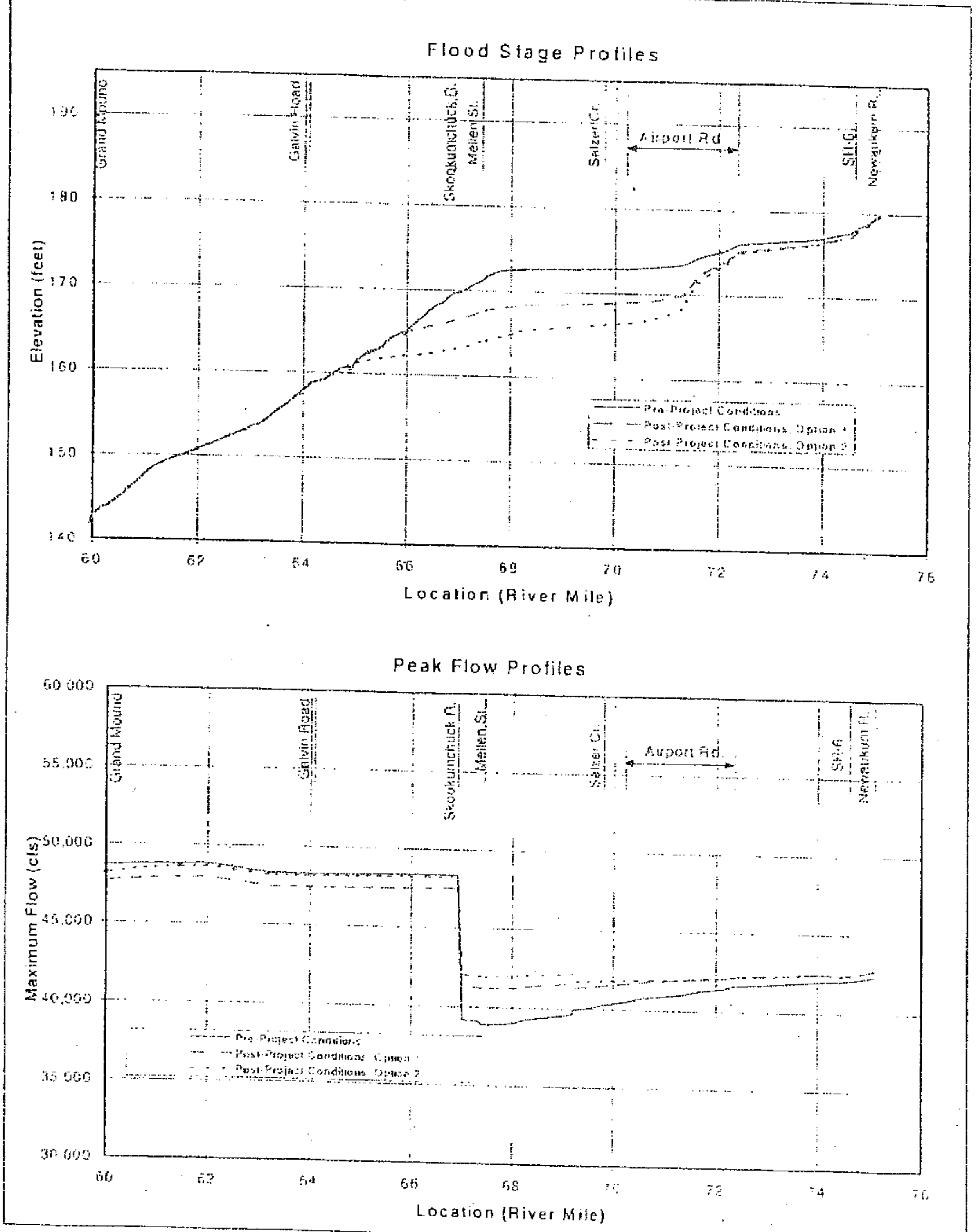
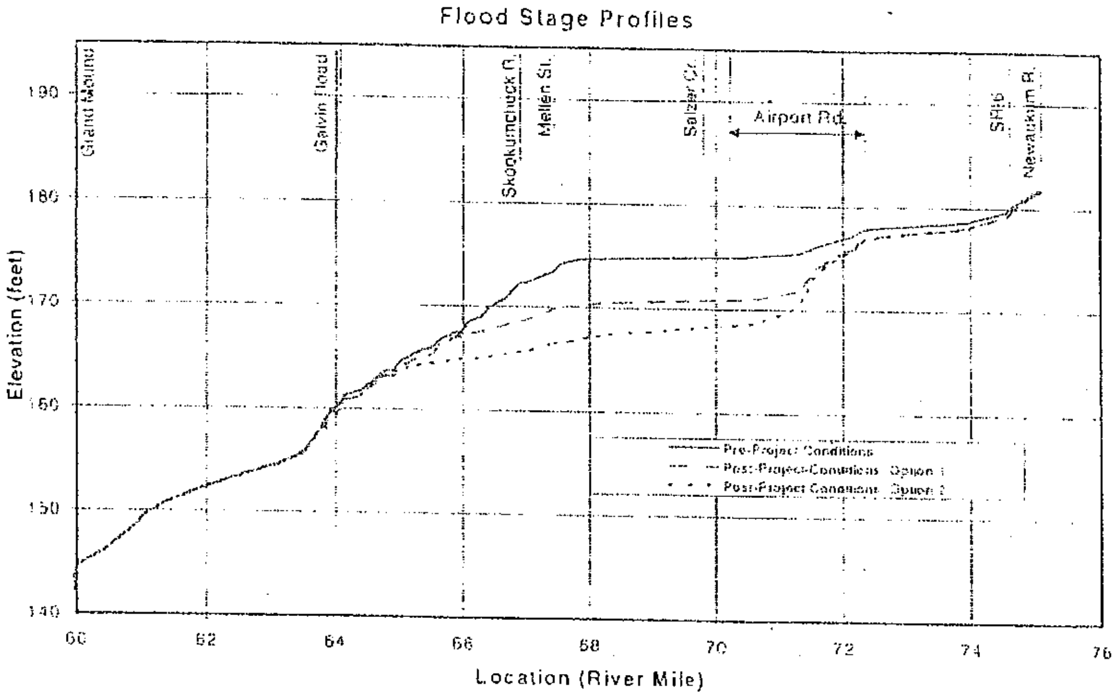


Figure 5-14:
Comparison of Pre- and Post-Project Flood Profiles on the Chehalis River - January 1990 Flood Event



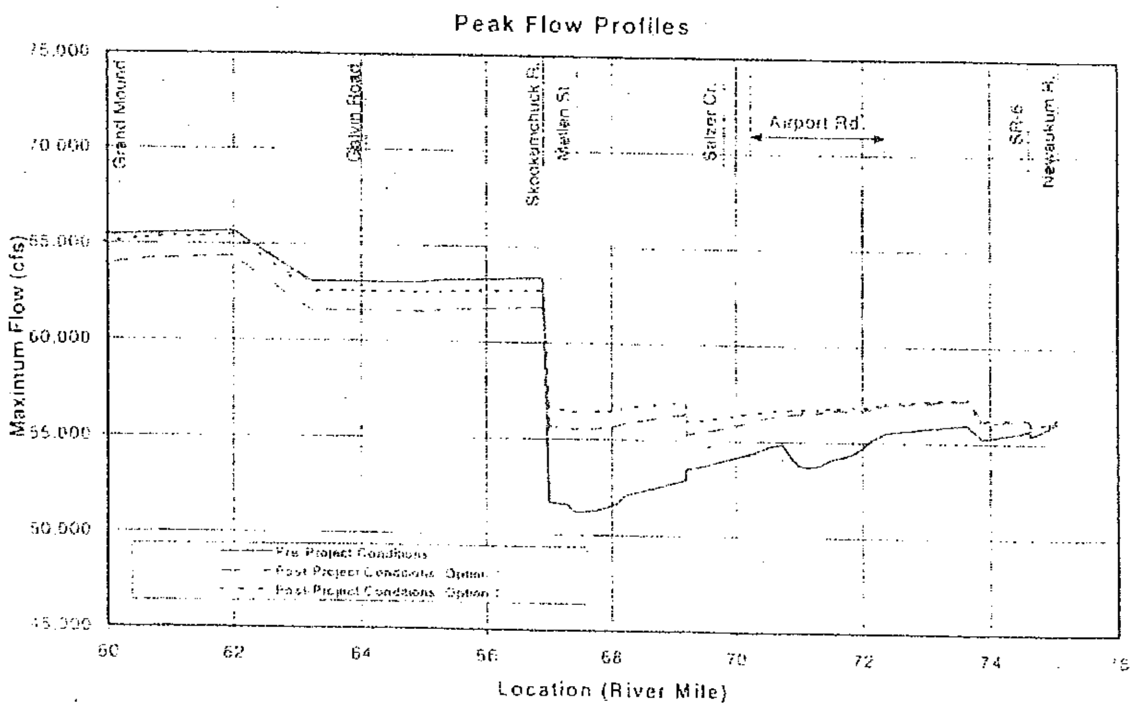


Figure 5-15:
Comparison of Pre- and Post-Project Flood Profiles on the Chehalis River - January 1972 Flood Event

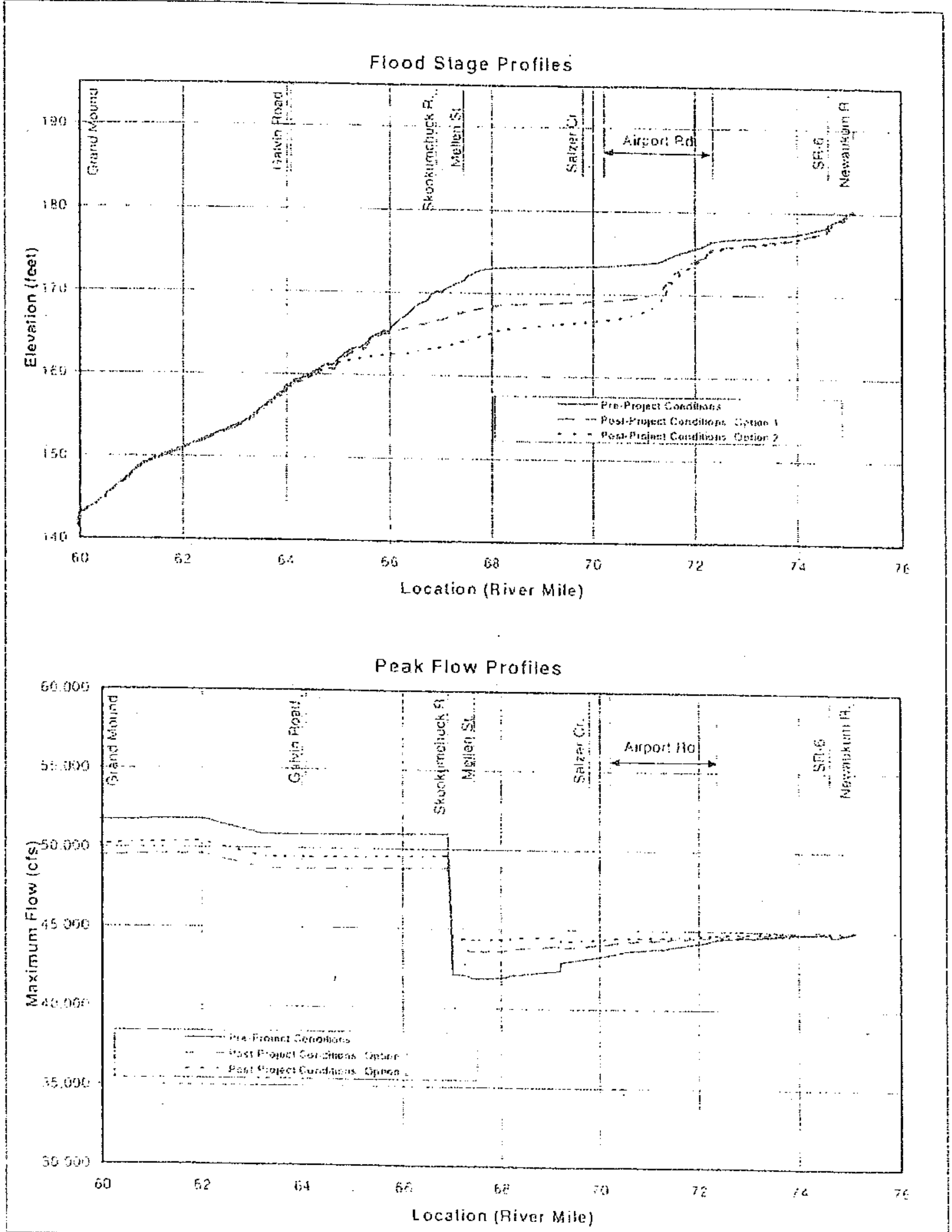
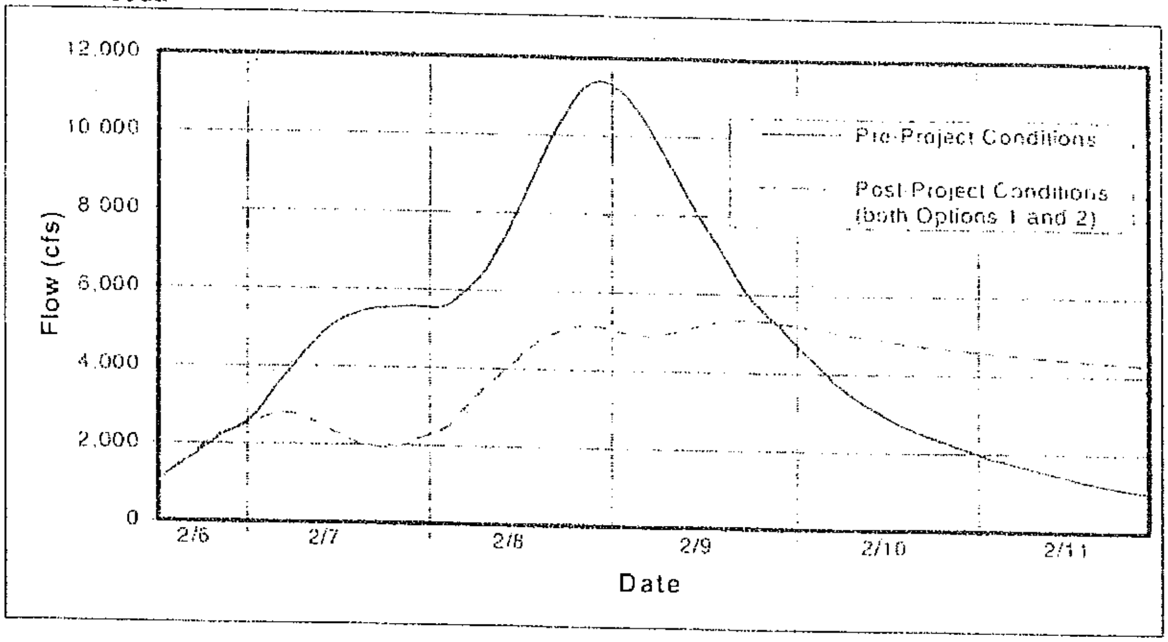


Figure 5-16:
Comparison of Pre- and Post-Project Flow Hydrographs on the Skookumchuck River - February 1996 Flood Event

a. at Bucoda



b. at Pearl St.

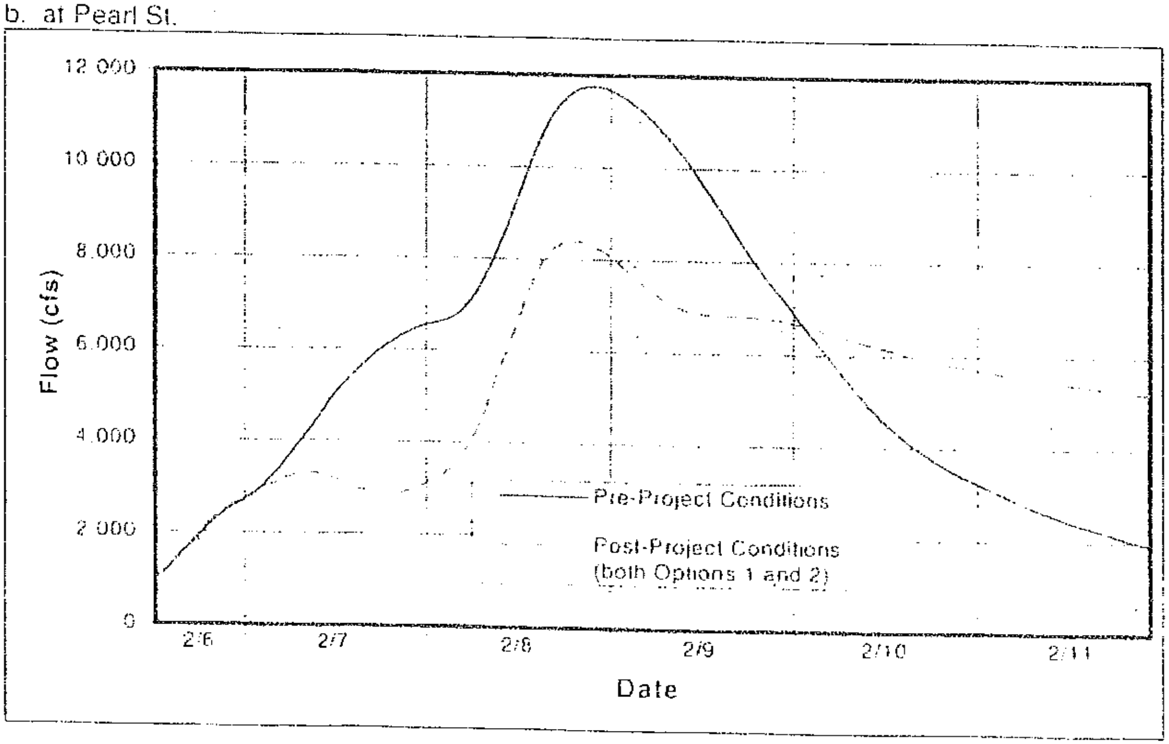
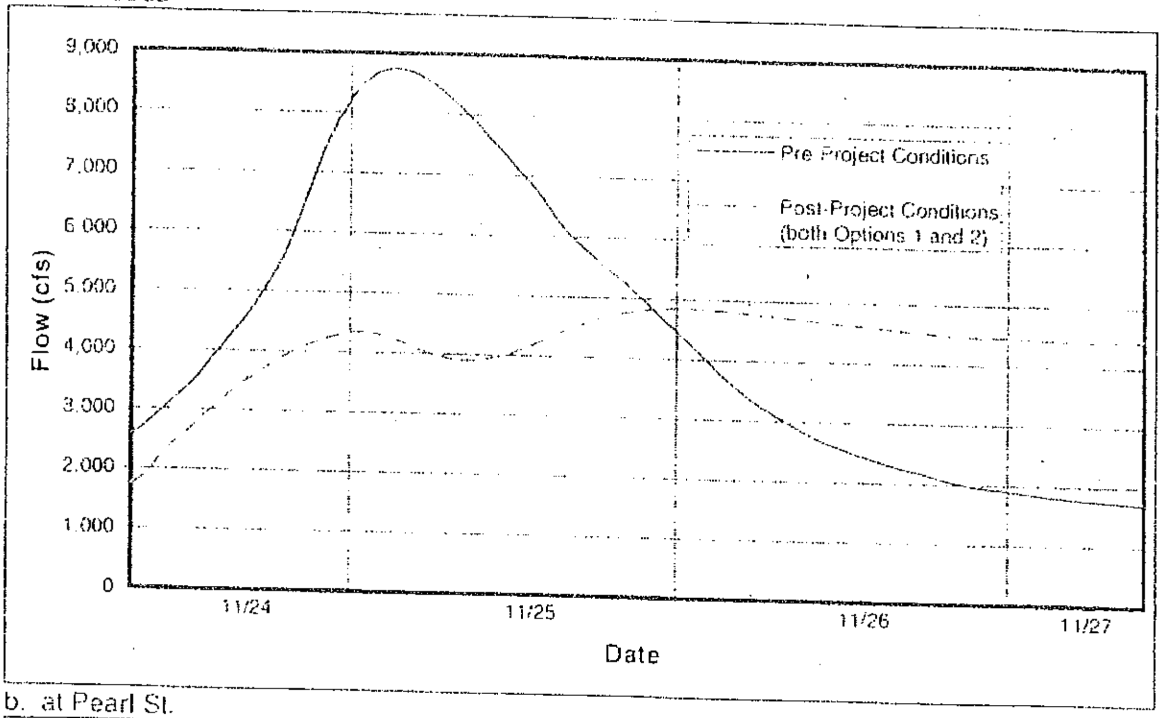


Figure 5-17:
Comparison of Pre- and Post-Project Flow Hydrographs on the Skookumchuck River - November 1990 Flood Event

a. at Bucoda



b. at Pearl St.

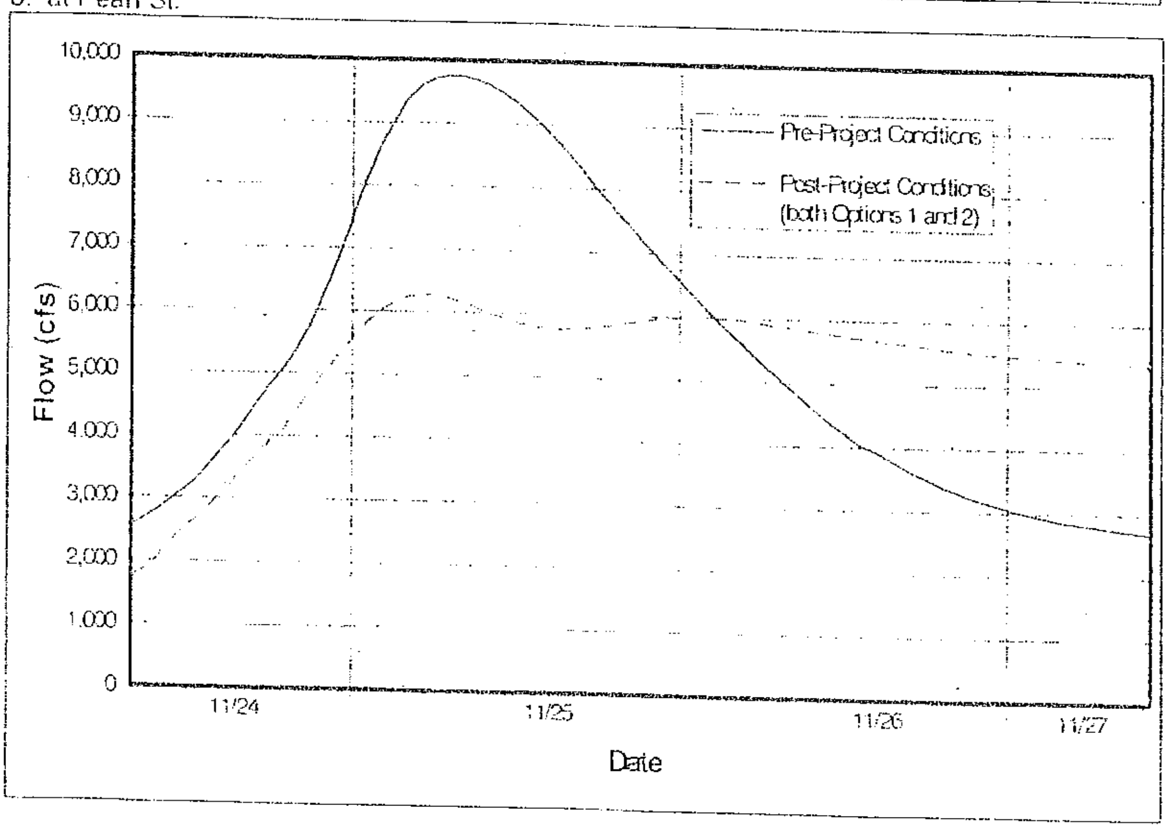
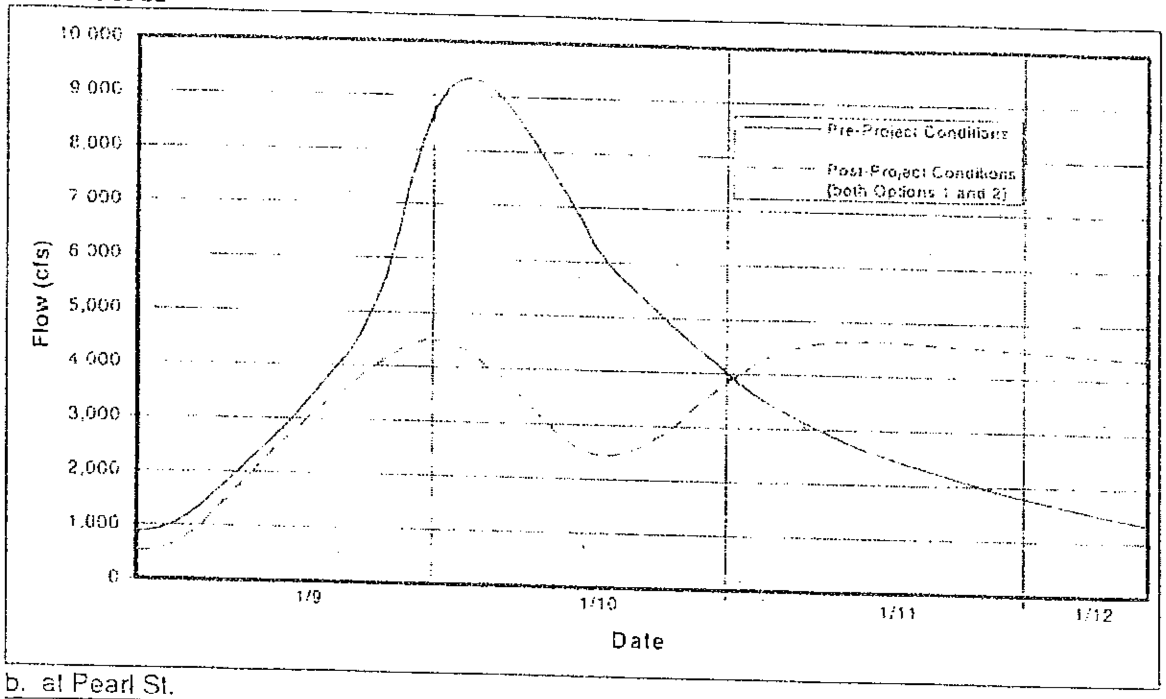


Figure 5-18:
Comparison of Pre- and Post-Project Flow Hydrographs on the Skookumchuck River - January 1990 Flood Event

a. at Bucoda



b. at Pearl St.

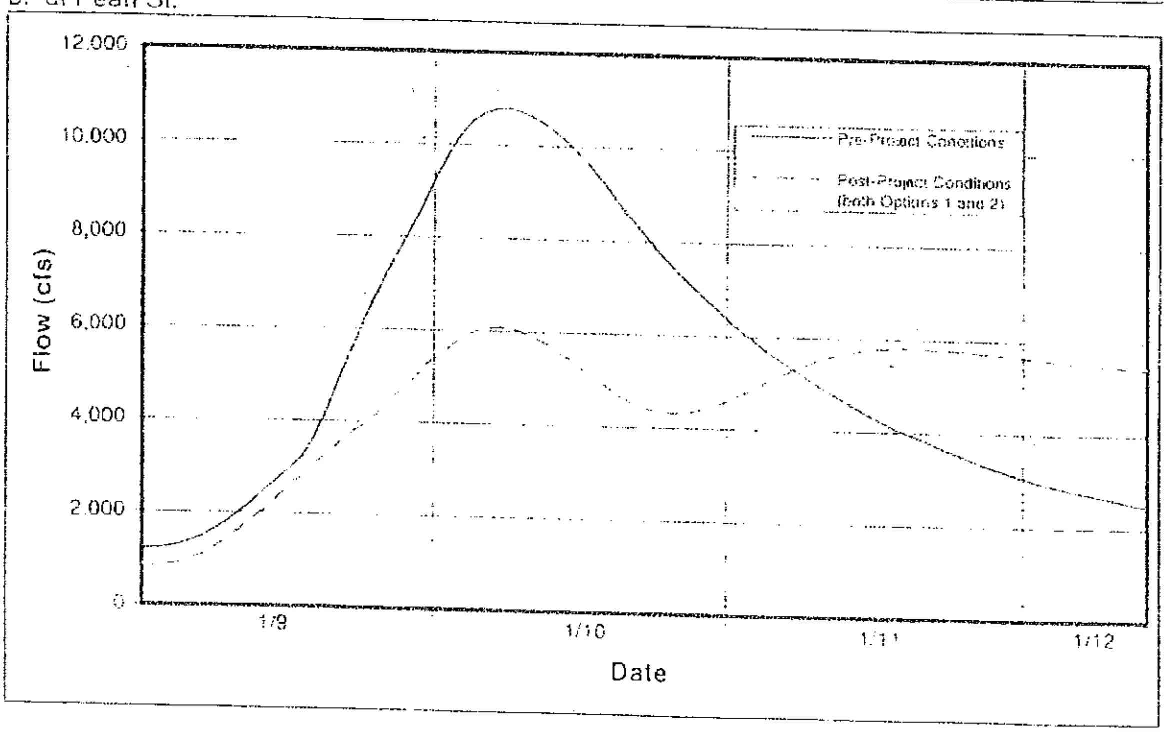
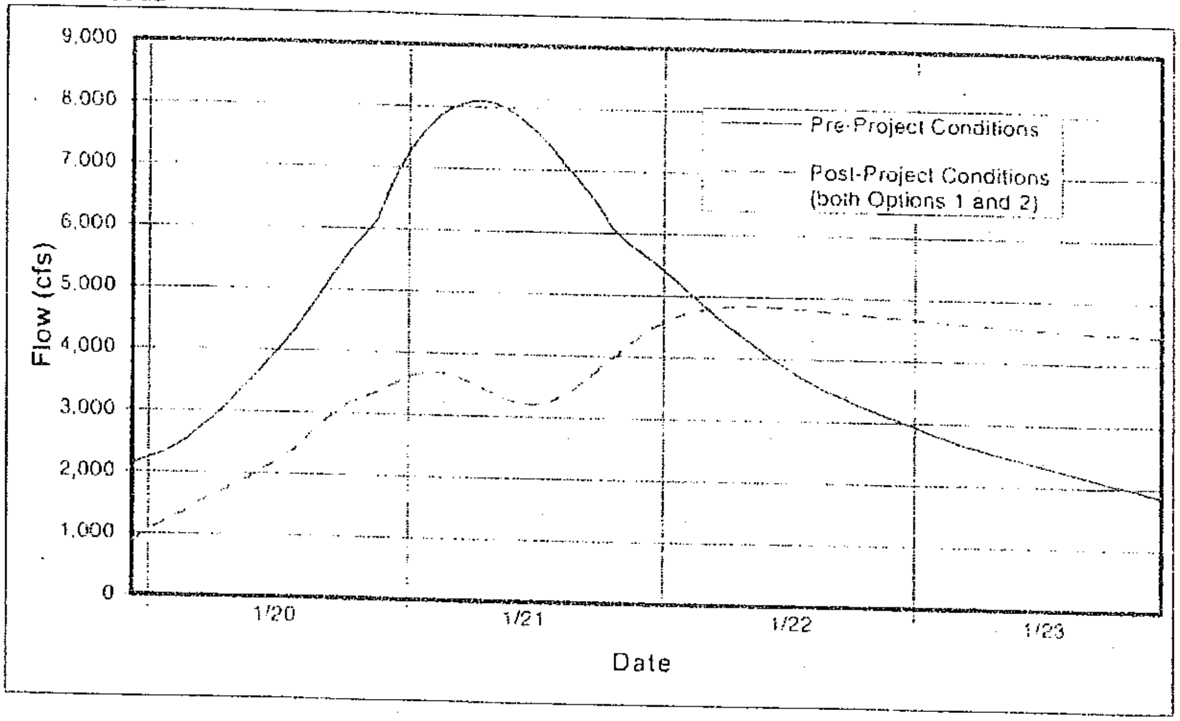


Figure 5-19:
Comparison of Pre- and Post-Project Flow Hydrographs on the Skookumchuck River - January 1972 Flood Event

a. at Bucoda



b. at Pearl St.

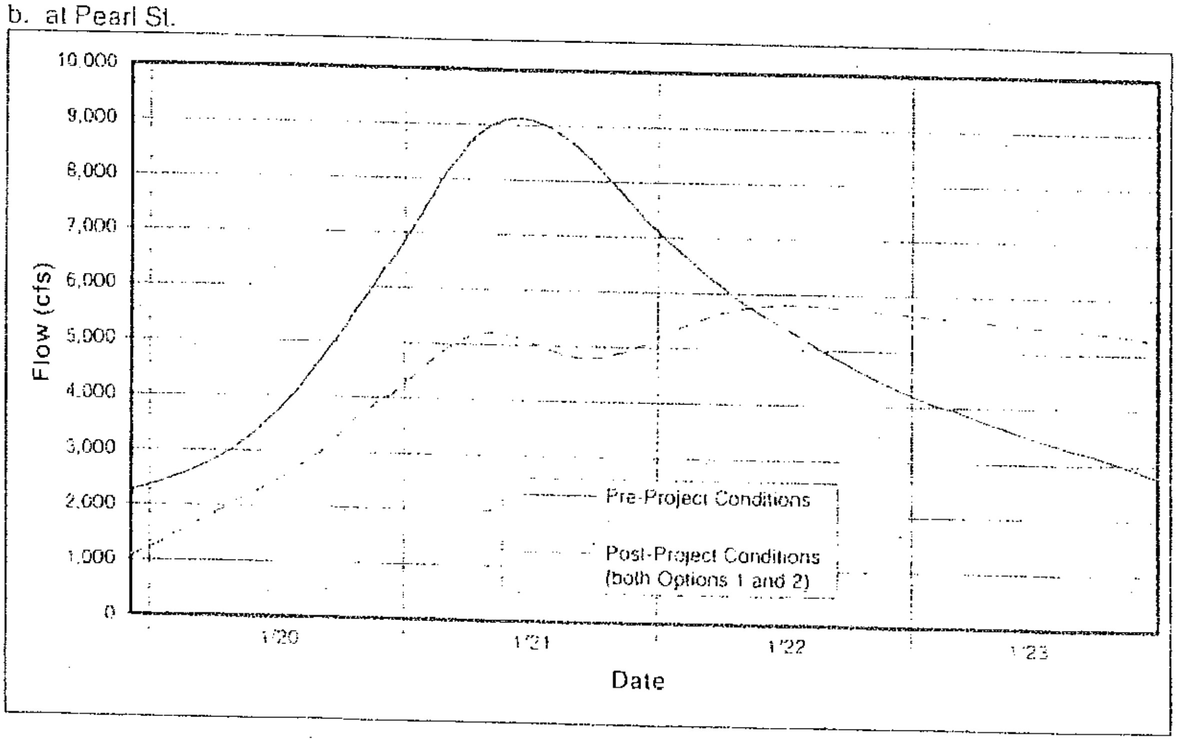
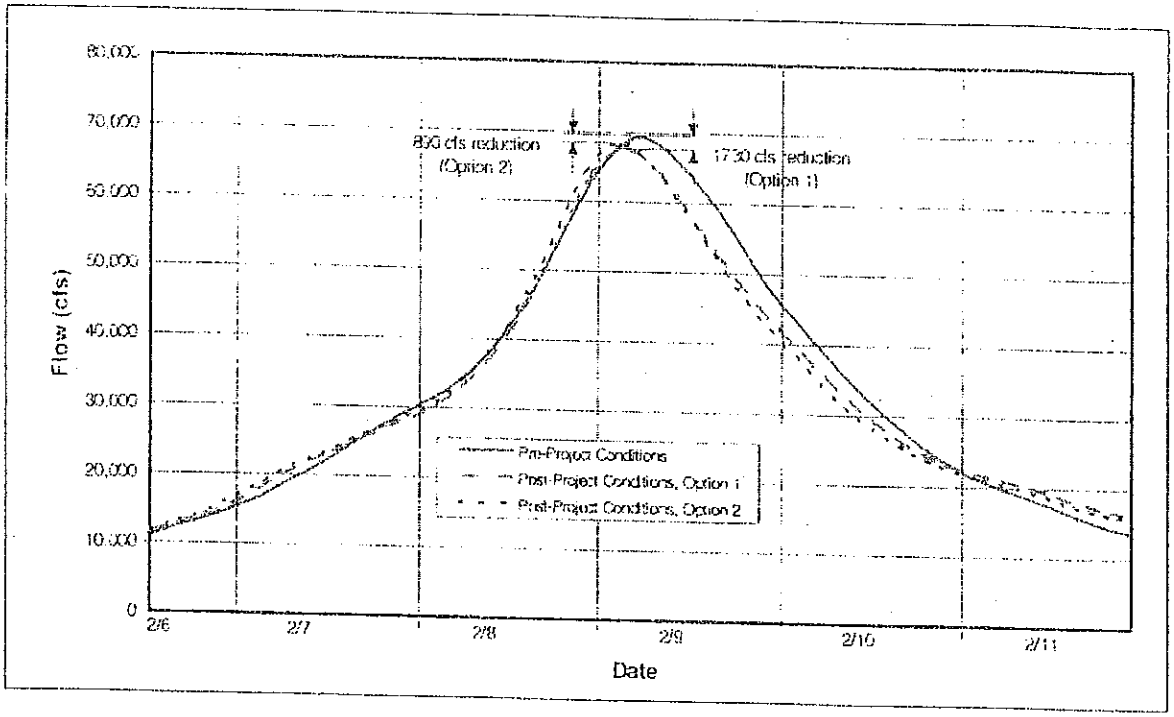


Figure 5-20:
Comparison of Pre- and Post-Project Flow and Channel Velocity Hydrographs at the Galvin Road Bridge - February 1996 Flood

a. Flow



b. Channel Velocity

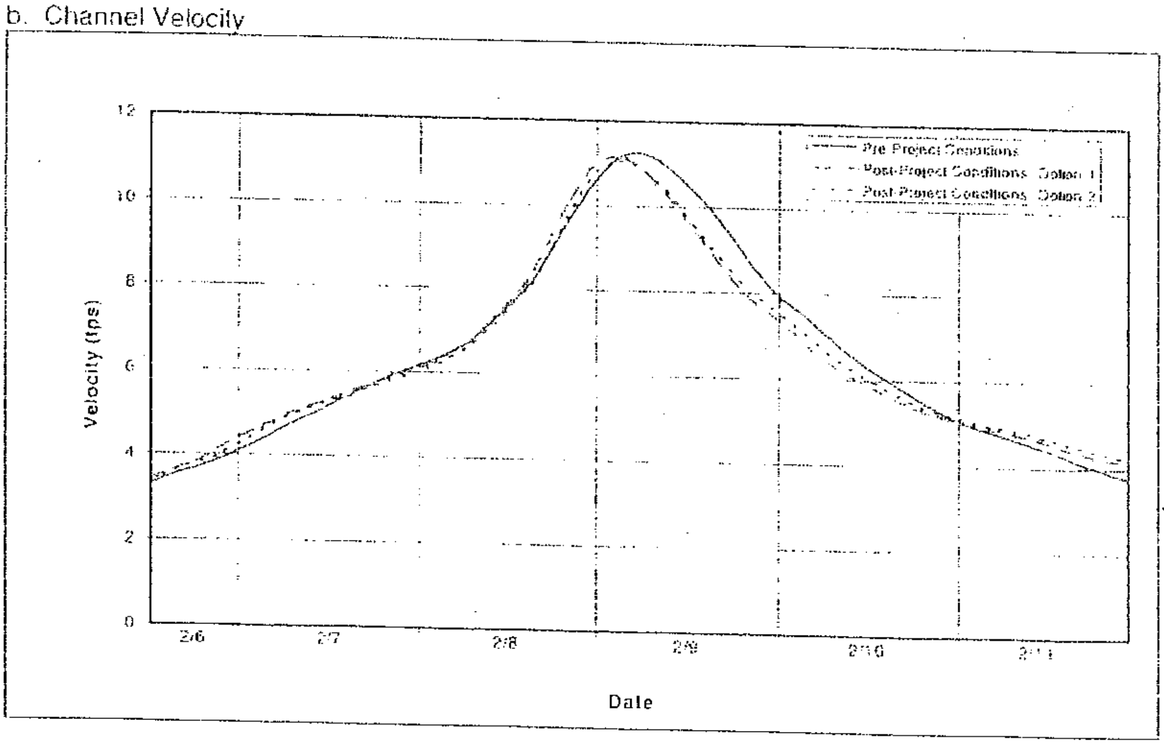
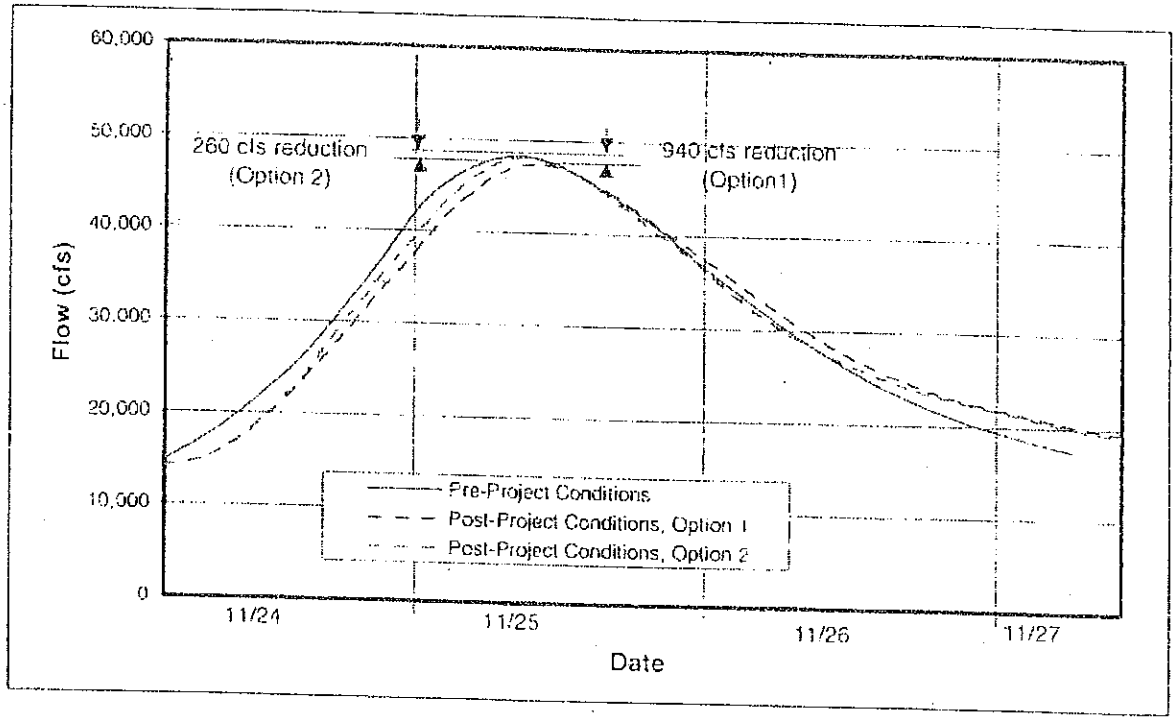


Figure 5-21:
Comparison of Pre- and Post-Project Flow and Channel Velocity Hydrographs at the Galvin Road Bridge - November 1990 Flood

a. Flow



b. Channel Velocity

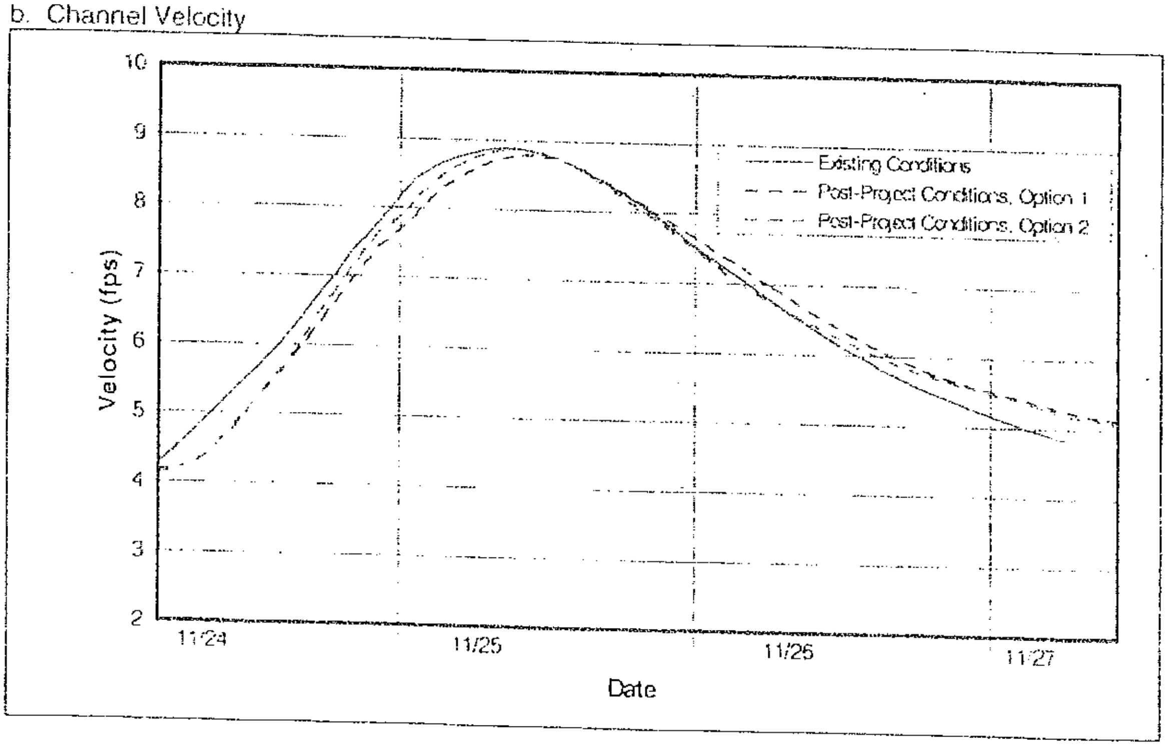
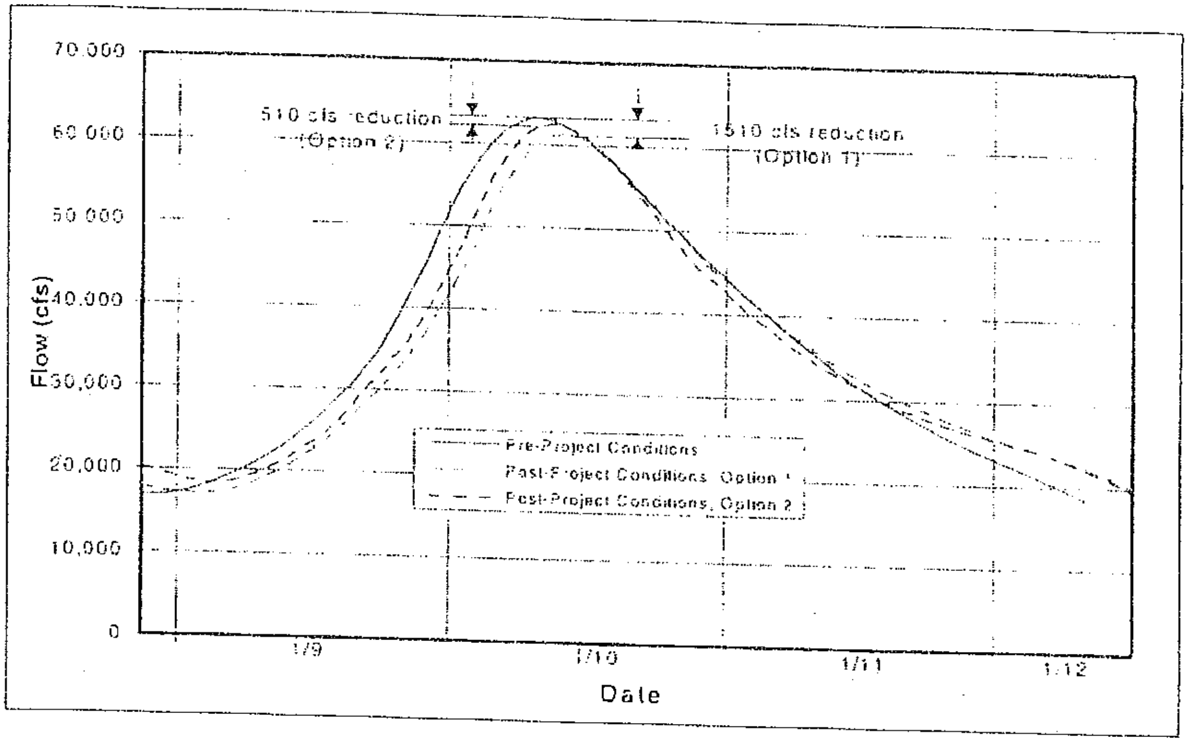


Figure 5-22:
Comparison of Pre- and Post-Project Flow and Channel Velocity Hydrographs at the Galvin Road Bridge - January 1990 Flood

a. Flow



b. Channel Velocity

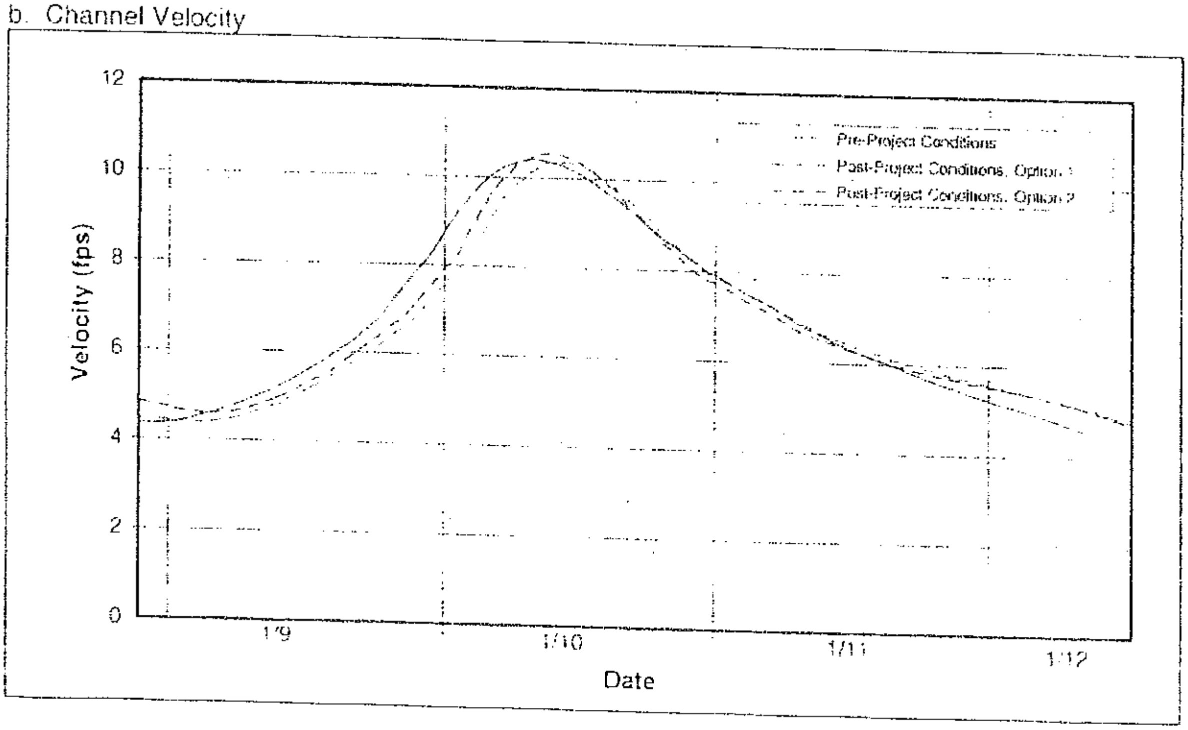
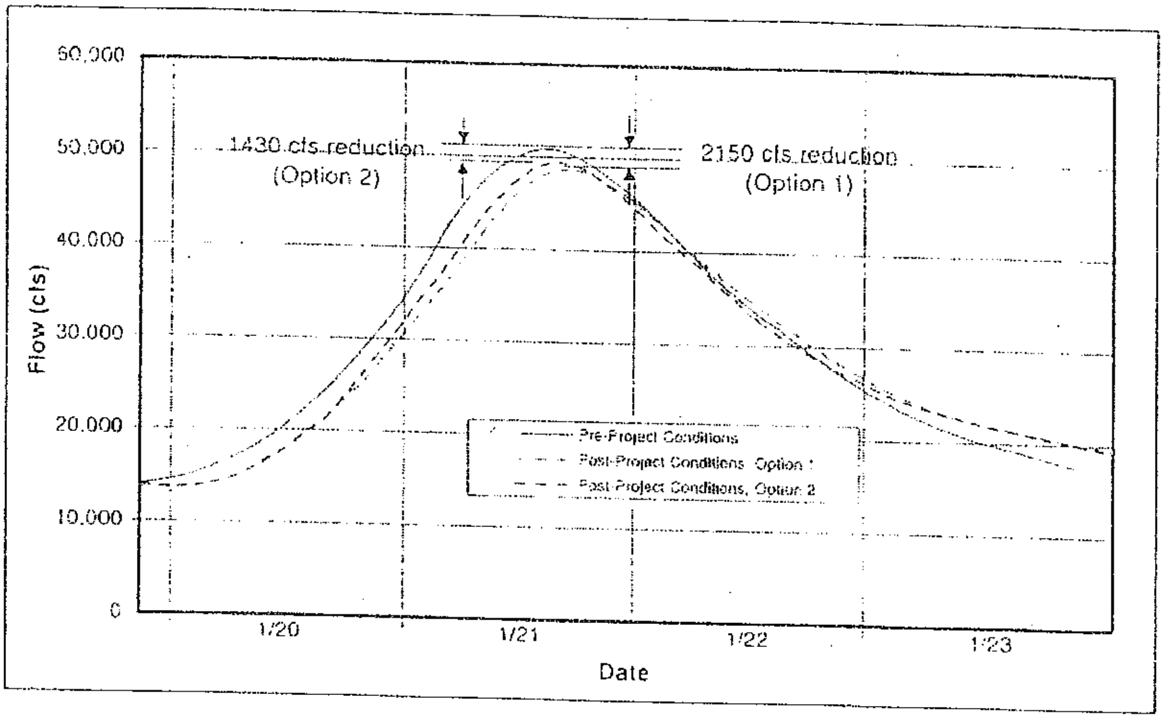


Figure 5-23:
Comparison of Pre- and Post-Project Flow and Channel Velocity Hydrographs at the Galvin Road Bridge - January 1972 Flood

a. Flow



b. Channel Velocity

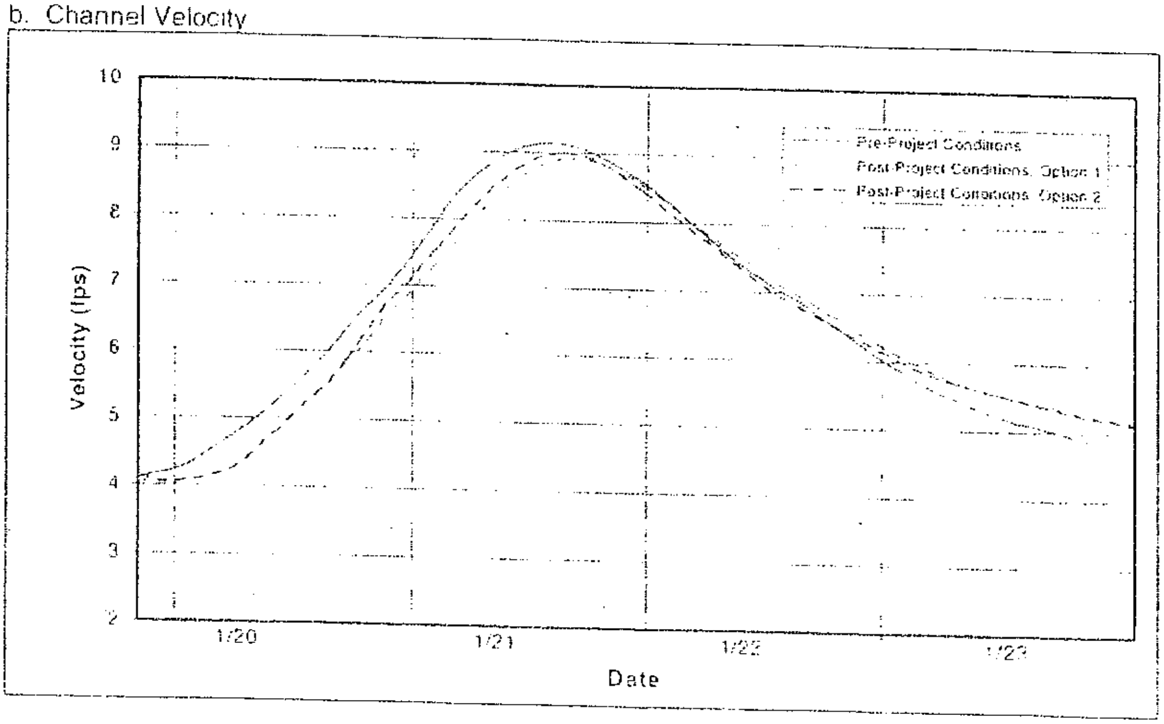
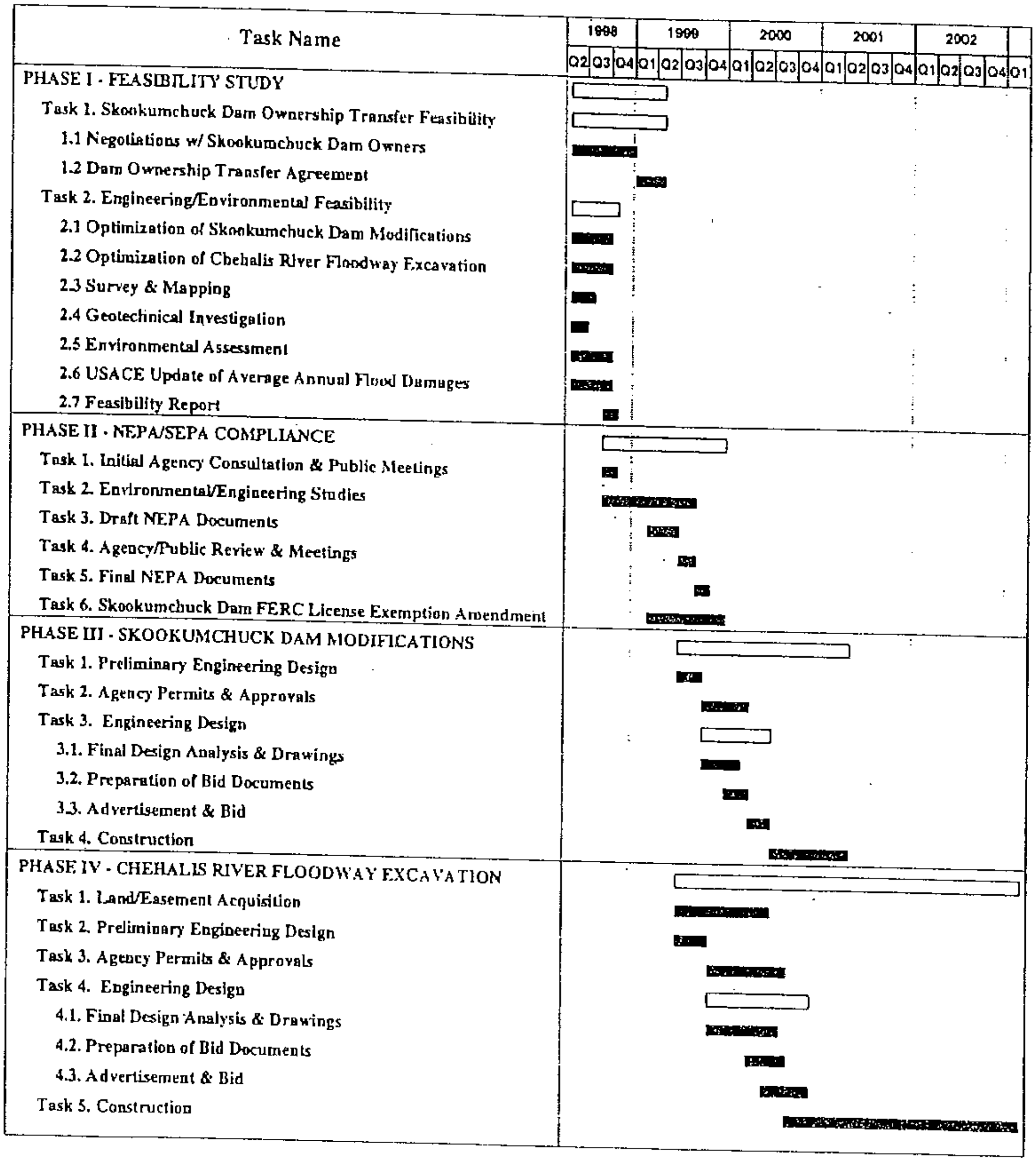


Figure 5-25:
Proposed Development Schedule for Recommended Alternatives



6. Conclusions and Recommendations

6.1. Conclusions

A baseline flood model representing the existing conditions of the Upper Chehalis River Basin was developed to evaluate the effects of various flood control alternatives, the results of which are included in this report. The model was used to evaluate headwater dams, such as the existing Skookumchuck Dam, and possible new dams on mainstem and tributary streams for their potential in providing cost-effective flood control storage for retaining peak flows. The model was likewise used to evaluate floodway excavations at various locations to improve floodway hydraulic capacity for flood stage reductions. This report also includes an evaluation of a No-Action alternative and several alternatives previously developed by USACE.

The No-Action alternative will likely result in construction of two projects which could be unnecessary if other measures are taken to reduce flooding in the area: 1) the Long Road Dike Project by USACE to protect the Long Road District from flooding and 2) raising of I-5 by WSDOT to protect it from flooding. Because these projects do not meet the needs of the greater Centralia-Chehalis area, and because the I-5 raising project is more expensive with fewer benefits than the recommended alternative, the No-Action alternative was rejected.

Three non-structural flood control alternatives were evaluated by USACE. Watershed management measures were rejected because they would have little effect on the Basin's hydrologic response during flood events. Flood-proofing structures by raising them above the 100-year flood stage could not be economically justified. Finally, the evacuation and relocation of all residential, commercial and industrial buildings in the Centralia-Chehalis area was not considered economically or politically feasible because of the tremendous amount of investment currently in the floodplain.

River channel excavation and levee alternatives were also investigated previously by USACE. Channel clearing was rejected because the increased flow capacity provided by the removal of all vegetation and debris in the river channel would be insignificant compared to the flood discharge. Channel excavation to increase flow capacity in restricted areas of both the Chehalis River and the Newaukum River proved to be economically unfeasible. Both alternatives also raised potentially significant environmental issues.

USACE also determined that channel excavation in conjunction with levee construction was not economically justified. Levees would disturb large areas of wetlands and archeological sites, increase erosion and increase stream temperatures. The construction of levees in an urban area would have fewer environmental impacts because of the reduction in the number and length of the levee segments. USACE found some urban segments economically justifiable and is pursuing the Long Road Dike Project.

Evaluated in this study was the alternative of modifying the Skookumchuck Dam to add flood control storage. Modifications would include the addition of high capacity outlet works and a spillway crest inflatable rubber weir. With these modifications, the dam could provide significant flood control storage and could significantly reduce flood stages along the Skookumchuck River floodplain. This alternative would be the least costly, with the fewest environmental impacts, of all other flood control dam alternatives because the dam already exists. However, this alternative would have little effect on the Chehalis River flood stage and would not be economically feasible alone.

Alternatives providing for the construction of new upstream flood control dams to reduce flooding impacts downstream were also evaluated in this study. Similar investigations performed by USACE were reviewed. All of the upstream flood control dams were determined to be extremely expensive and not cost effective in comparison with the other alternatives evaluated as part of this study for the same magnitude of flood stage reduction. The environmental impacts of new upstream dams were also potentially substantial.

Evaluated in this study was the alternative of excavating and terracing the floodway adjacent to the river channel to provide additional flow capacity for higher flow events. The excavation would be done in the dry to reduce costs and eliminate environmental concerns posed by channel excavation. A number of floodway excavation configurations were modeled to help determine the most cost effective and efficient layout. Excavation could reduce a 100-year flood stage substantially on the Chehalis River, thus, reducing the area flood damages and keeping I-5 dry from the 100-year flood level. Preliminary cost estimates indicate that this alternative would be the least costly option to achieve flood level protection of this magnitude. However, this alternative alone would result in peak flow increases downstream during floods. This would not be acceptable to downstream floodplain communities.

The study evaluated the excavation of a secondary overflow bypass channel along either the Chehalis River or the Skookumchuck River, at an elevation that would provide additional flow area only during high flow events. Three alternative alignments off the mainstem of the Chehalis River were rejected because the first required too great of a channel width to provide any advantage over floodway excavation, the second affected too many homes and businesses and the third required the construction of bridges which rendered the project not cost-effective. An alternative secondary channel on the Skookumchuck River was rejected for similar reasons.

No one alternative alone proved to be cost effective and able to provide the protection desired without harming downstream residents. However, it appears that a promising solution would be the combination of two alternatives. The first component of the recommended alternative is the floodway excavation in the Mellen St. and SR-6 Bridge vicinities, including modifications to the bridge abutments. The second component is the Skookumchuck Dam modifications to provide flood control storage. The combined project would overcome the shortfalls of these two components if evaluated separately. The Skookumchuck Dam flood control storage provision would retain the Skookumchuck peak flow in an amount greater than the increase of the Chehalis River peak flow resulting from the floodway excavation. The substantial flood reduction benefits that can be achieved by the floodway excavation would be more than the total cost required to excavate the floodway, including the bridge modifications, and to modify the Skookumchuck Dam for the flood control provision. The combined project would, therefore, become economically feasible and would also reduce the peak flood flow discharge downstream of the floodway excavation area.

6.2. Recommendations

It is recommended that the Skookumchuck Dam modifications be combined with the floodway excavation between RM 64.9 and RM 70.5 (Mellen St. Bridge area) to create one recommended project solution alternative for reducing flood damages in the general Centralia-Chehalis area. It is also recommended that a solution to the flooding between the 13th St. interchange and the SR-6 Bridge be included in the recommended alternative for further analysis. The following tasks are then recommended:

- An engineering and environmental feasibility analysis should be performed to optimize the project solution as outlined in this report, The 1998 Washington State appropriation of $600,000 should be used to optimize the Skookumchuck Dam modifications, the floodway excavations between RM 64.9 and RM 70.5 (including the Mellen St. Bridge modifications) and a design solution for the alternatives presented to achieve flood stage reductions in the vicinity of the 13th St. interchange and the SR-6 Bridge.
- A funding strategy should be developed to identify and obtain resources from benefited communities and agencies, including but not limited to USACE, FHWA, WSDOT, WSDOE, and any other federal, state, or local agencies benefited by the project.

- A NEPA/SEPA environmental compliance study should be performed when federal funds are made available.
- Efforts should be made to ensure that the alternative recommended herein is included in the Environmental Impact Statement of the WSDOT I-5 Toutle Park Road to Maytown Project and is selected as the preferred alternative, and that the project is optimized to include as many beneficiaries as is cost-effective.

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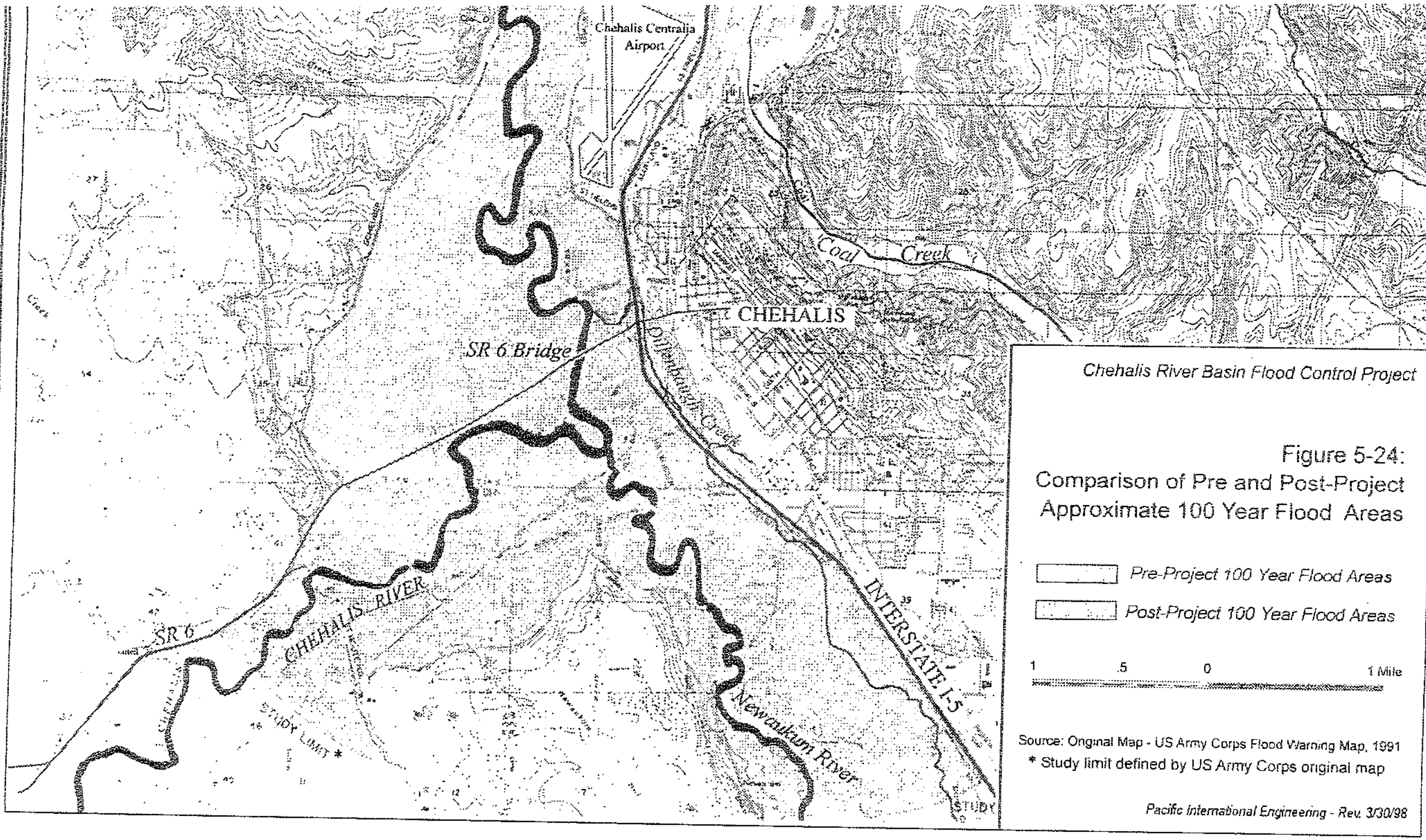
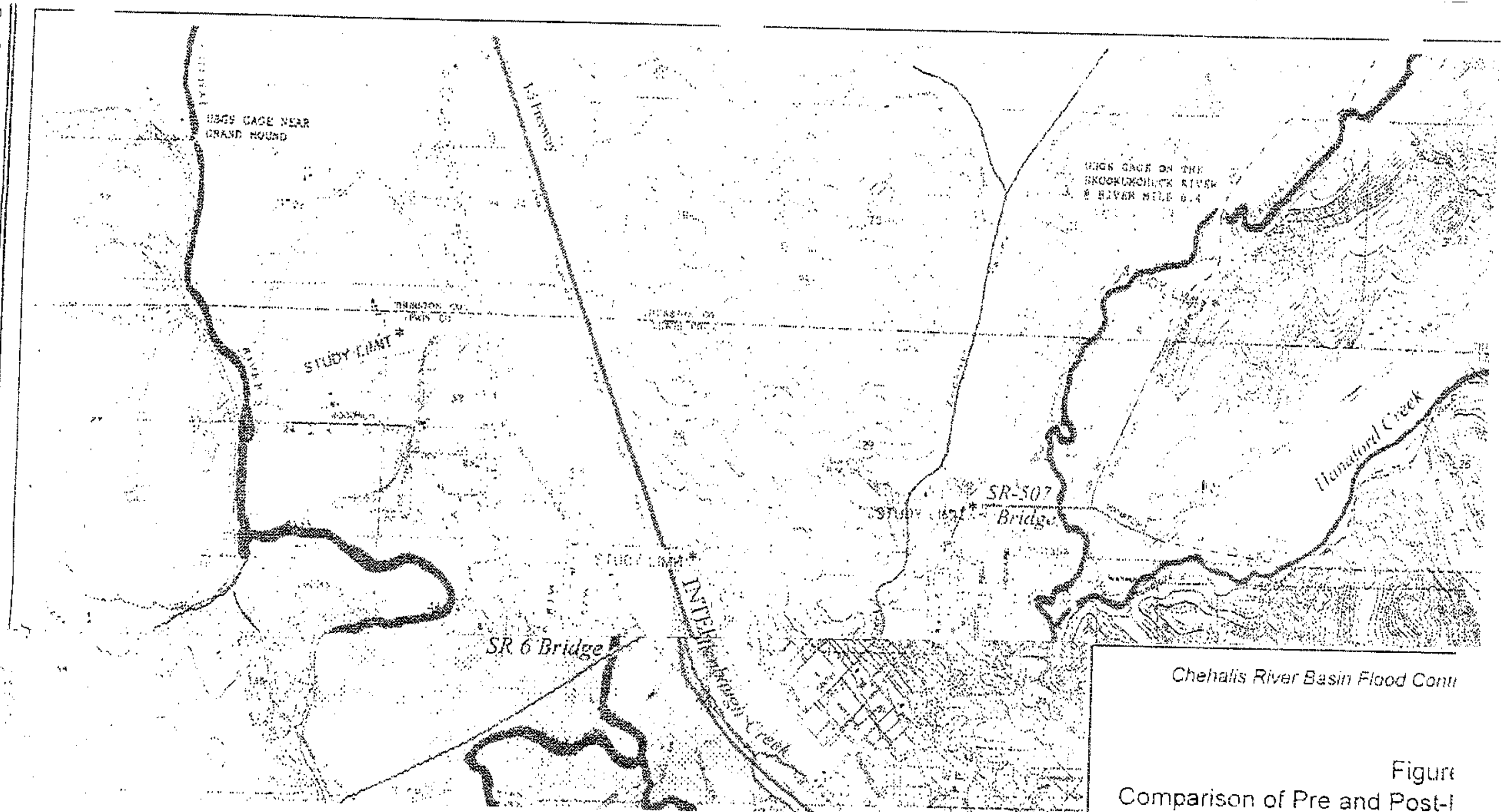


Chehalis River Basin Flood Control Project

Figure 5-24:
Comparison of Pre and Post-Project Approximate 100 Year Flood Areas

Source: Original Map - US Army Corps Flood Warning Map, 1991
* Study limit defined by US Army Corps original map

Pacific International Engineering - Rev. 3/30/98



Chehalis River Basin Flood Cont

Figure
Comparison of Pre and Post-