Additional Water Storage Project, Draft Feasibility Report & EIS

Howard Hanson Dam,
Green River, Washington
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prepared by
Seattle District
US Army Corps of Engineers

Tacoma Public Utilities

US Army Corps of Engineers®

DRAFT PROJECT FEASIBILITY STUDY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

EXECUTIVE SUMMARY

LEAD AGENCY: US Army Corps of Engineers, Seattle District

TYPE OF ACTION: Legislative

This combined Draft Feasibility Report and Environmental Impact Statement (DFR/EIS) addresses the Howard Hanson Dam (HHD) Additional Water Storage (AWS) Project Study which was initiated by Seattle District, US Army Corps of Engineers at the request of Tacoma Public Utilities (TPU). The study was begun in August 1989 to determine if HHD could be used to meet the Municipal and Industrial (M&I) water supply needs of the Puget Sound area. In 1994, in response to a change in federal law, the scope of study was expanded to include ecosystem restoration.

Northwesterners have grown increasingly concerned about the availability and quality of regional drinking water sources. This concern and focus on water supplies is a result of recent droughts, which led to water rationing measures; our ever-expanding population; and the region's escalating inability to support salmon and other species dependent on rivers and streams. In turn, people and planners have recognized that water, like all resources, is finite and will become a limiting factor in the region's growth and development. The salmon and steelhead crisis, as evidenced by the proposed listing of the Puget Sound chinook salmon as a threatened species, also emphasizes that the region's anadromous fish require an abundant, reliable, clean water supply and that they are currently losing to the numerous and competing demands on this finite resource.

Between 1911 and 1913, the City of Tacoma constructed a 17-foot-high water supply diversion dam at river mile 61.0. At that time, because of the diversion dam, upstream passage of anadromous fish to the Upper Green River watershed (Upper Watershed) ceased. Howard Hanson Dam was constructed in the early 1960's and was authorized to provide flood control, downstream low flow augmentation (LFA), irrigation, and M&I water supply. The irrigation and water supply portions of the authorization were never implemented. The HHD project has provided an estimated $695 million in flood damage prevention through 1996 and billions of dollars worth of commercial and industrial development, in the protected floodplain, resulting in employment opportunities, while allowing Tacoma to meet its drinking water quality objectives.

In the absence of anadromous fish in the Upper Watershed, HHD was constructed with low level water conveyance outlets only. Juvenile hatchery winter steelhead, coho, and fall chinook have been planted in the Upper Green River watershed since 1982, 1983, and 1987 respectively. Outmigrating juvenile fish resulting from these watershed plantings have had to traverse the slack water reservoir and locate the deep water outlets to exit the project. Survival of these juvenile fish has been poor; in fact, without the HHD AWS project, future planting of juvenile coho and chinook above HHD will likely cease.

At present, the Corps stores approximately 26,000 acre-feet (ac-ft) of water behind HHD for downstream LFA during the summer and fall. An additional 5,000 ac-ft of water for LFA is authorized through a Section 1135 restoration project. Tacoma presently diverts 113 cubic feet per second (cfs) of water, at their diversion dam, to provide M&I water to Tacoma under their first diversion water right (FDWR). Tacoma is also authorized to divert 100 cfs of M&I water under its Second Supply Water Right (SSWR). This 100 cfs SSWR is conditioned by the Tacoma Public Utilities/ Muckleshoot Indian Tribe (TPU/MIT) Agreement, which establishes minimum in-stream flows for the Green River through each calendar year. These flows exceed the current state established minimum flows.

The baseline condition for this project includes conditions as a result of all current operating projects and facilities. These include: 1) the existing HHD project, which is used for flood control during the late fall and winter and for spring storage of 26,000 ac-ft of water for summer LFA; 2) the HHD Section 1135 Fish and Wildlife Restoration Project, which authorizes storage of an additional 5,000 ac-ft of water for LFA, a "without project" feature; 3) TPU's Pipeline Projects, Pipeline No. 1 (P1), which was constructed to carry Tacoma's FDWR, and 4) Pipeline No. 5 (P5), which will carry TPU's SSWR. TPU was granted a permit, under Section 404 of the Clean Water Act, to construct P5. Construction is scheduled to be complete by 2003, before the HHD AWS project is scheduled to be implemented, this is a "without-project" feature.

A final array of four reservoir storage alternatives were considered to provide M&I water supply for the Tacoma area and ecosystem restoration improvements on the Green River. The alternatives are: 1) no action; 2) a single-purpose water supply project with increased conservation storage of 22,400 ac-ft for M&I water supply and fish passage as mitigation; 3) a dual-purpose water supply and ecosystem restoration project with immediate full implementation of the AWS project, with increased storage of 22,400 ac-ft of M&I water supply and 9,600 ac-ft of LFA water; and 4) the preferred alternative, a dual-purpose water supply and ecosystem restoration project with phased implementation: Phase I, storage of 20,000 ac-ft for M&I water supply; and Phase II, additional storage of 2,400 ac-ft for M&I water supply and 9,600 ac-ft for LFA.

Over the past 8 years, the Corps and TPU have worked with the US Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (WDOE), and the Muckleshoot Indian Tribe (MIT) to scope, conduct, and evaluate the feasibility studies for the HHD AWS project. As part of this long term evaluation process, the resource agencies and the MIT participated in an intensive technical review of the feasibility studies with the Corps and TPU. During this period, the resource agencies and the MIT evaluated technical study conclusions, identified concerns and data gaps, and discussed how those concerns and data gaps might be addressed. Adjustments to the project have been made based on agency and tribal input and on the results of the additional studies that have been conducted during the past years.

As a result of this coordination, the preferred project alternative was designed to be implemented in the two phases mentioned above. Phase I includes construction of all mitigation features having to do with raising the pool to elevation 1,167 feet and all ecosystem restoration features. This includes a full height fish passage facility, right abutment drainage remedies, and Phase I fish and wildlife habitat mitigation. Tacoma's SSWR (up to 100 cfs/day or 20,000 ac-ft over a different time period) will be stored in the spring for M&I use in the summer and fall. Timing and rate of storage will be adaptively managed while delivery will be at a rate established by Tacoma. Phase II includes construction of all remaining AWS project mitigation features required for a pool raise to elevation 1,177 feet. Under Phase II, an additional 2,400 ac-ft of M&I water plus 9,600 ac-ft of LFA water will be stored, for a combined total of 32,000 ac-ft of water storage under the HHD AWS project. Delivery rate of the stored M&I water will be established by Tacoma and delivery rate of the LFA water will be adaptively managed by the Corps, TPU, the resource agencies, and the MIT.

Restoration of fish passage through HHD is the keystone of the AWS project ecosystem restoration. Improved fish passage, increased instream flows, and fish and wildlife habitat restoration measures all provide historic opportunities to restore and maintain self-sustaining and harvestable runs of salmon and steelhead for the Green River. The phased implementation and adaptive management measures proposed for the project allow for the flexibility to make adjustments to ensure the protection of fish and wildlife. The goal – to satisfy regional water supply needs for the 50-year project life – is nearly achievable under Phase I and can be achieved under Phase II. The storage of an additional 22,400 ac-ft of water for M&I water, as proposed in the ultimate development, will provide a stable cost effective water supply for the region well into the next century.

As a result of the phased implementation and adaptive management proposal, NMFS, USFWS, and WDFW endorsed the Phase I project proposal and indicated a willingness to implement Phase II if it could be demonstrated that Phase II impacts could be sufficiently minimized and mitigated.

Total cost of the proposed project, in October 1997 dollars, is $74,908,000. The federal share would be $36,284,000 and the non-federal share would be $38,624,000. The non-federal sponsor would be required to pay 100% of the cost attributable to M&I water supply and 35% of the cost attributable to ecosystem restoration with the federal government paying the remaining 65% of the cost attributable to ecosystem restoration.

Tacoma operates an unfiltered surface water supply in compliance with EPA requirements. Protection of water quality during both project construction and operation is of critical importance. Special measures to meet water quality objectives may need to be developed to insure quality drinking water for over 250,000 people.

The recommendation is that the existing Howard A. Hanson Dam project authorized by the River and Harbor Act of 17 May 1950 be modified to include the following:

1. New intake tower with new fish collection and transport facility including: a wet-well, a floating fish collector, a fish lock, a discharge conduit, a fish transport pipeline and monitoring equipment.
2. Mitigation features including management of riparian forests, planting of water-tolerant vegetation and maintenance of instream habitat in Phase I and Phase II.
3. Ecosystem restoration features other than fish passage including gravel nourishment, a side channel reconnection project, and river and stream habitat improvements.
4. Right abutment drainage remediation
5. New access bridge and access road
6. New buildings, or additions to existing buildings, including: an administration, a maintenance and a generator building.
7. Change reservoir operation (Phase I) to store 20,000 ac-ft of M&I water to elevation 1,167 feet in the spring for release in the summer and fall.
8. Change reservoir operation (Phase II) to store an additional 12,000 ac-ft of water, 2,400 ac-ft for M&I water supply and 9,600 ac-ft of water for LFA, to elevation 1,177 feet in the spring for release in the summer and fall.

Recommendations contained herein reflect the results of this extensive study, formulation, and coordination effort and are respectfully submitted by Tacoma Public Utilities and the Corps for authorization to proceed with construction and operation of Phase I of the Howard Hanson Dam Additional Water Storage Project.

SEND YOUR COMMENTS TO:
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SECTION 1. STUDY OBJECTIVES AND NEEDS

1.1 STUDY AUTHORIZATION

This study is being conducted under Section 216, Public Law 91-611, Review of Completed Projects, River, Harbor and Flood Control Act of 1970.

1.2 STUDY OBJECTIVE

The Howard A. Hanson Dam (HHD) Additional Water Storage (AWS) Project study was initiated by the Seattle District, US Army Corps of Engineers (USACE; the Corps) in August 1989 to address how the existing federal HHD Project could meet water supply needs of Puget Sound residents (Figure 1-1). In response to a change in federal policy in 1994 making environmental restoration a higher federal priority, the study objective was expanded to include environmental (ecosystem) restoration.

1.3 STUDY AREAS

The Region of Influence (ROI) for water supply is Pierce and south King Counties and Seattle, Washington (Figure 1-2). ROI, for environmental restoration, is defined as the HHD reservoir and associated lands above the dam to an elevation of 1,240 feet; the mainstem Green/Duwamish River; the associated tributaries to the Green River; and lands within 1 mile of the river. For purposes of describing existing conditions and impacts, discussions are divided into the Upper (above HHD) and the Lower (below HHD) Green River watersheds (Figure 1-3). Right and left riverbank designations are from the vantage point of looking downstream, and river miles indicate distance upstream from the river outfall into Elliot Bay. The prominence of HHD within the watershed, as well as differences in habitats and level of development above and below the dam justify this division. Exceptions to this include the discussions of aquatic habitat and fisheries, which are a dominant concern in the watershed and are thus covered in more detail. The discussions in Appendix F, Environmental, Part 1, Fisheries Mitigation and Restoration, and this Draft Feasibility Report/Environmental Impact Statement are divided into specific river reaches.

The study areas and divisions of river reaches for purposes of this study may vary somewhat from those used for the 1996 Environmental Impact Statement for the Continued Operation and Maintenance of Howard A. Hanson Dam, Green River, Washington and the 1996 HHD Section 1135 Fish and Wildlife Restoration Study efforts, just as they differ to a degree from one another. These are not contradictions; rather they reflect the focus in each case that best addresses the objectives at hand.

1.4 GREEN RIVER BASIN DESCRIPTION

The Green River basin is located in the southern portion of King County, Washington, and drains an area of 483 square miles (Figure 1-3). The Green River flows west and north from the Cascade Mountains 75 miles to join with the Black River forming the Duwamish River. The Duwamish River empties into Elliott Bay in Puget Sound 12 miles further downstream. Tributaries to the Green River include Mill Creek (river mile (R.M.) 24.2), Big Soos Creek (R.M. 33.8), Newaukum Creek (R.M. 41.2), North Fork Green River, (R.M. 65.5), Smay Creek (R.M. 76.8) and Sunday Creek (R.M. 86.2). The western third of the basin is largely industrialized and includes portions of the cities of Seattle, Tukwila, Renton, Kent, and Auburn. The Muckleshoot Indian Reservation is located northeast of Auburn. The remainder of the basin is used for agriculture, recreation, and forestry.

The physical environment of the Green River system strongly reflects King County and the Puget Sound region's social change and economic growth since construction of Howard Hanson Dam.

The mouth of the river at Elliott Bay and the lower portion of the river have been dredged and channelized to facilitate navigation. It has been estimated that over 98% of the presumed historical estuarine wetland at the mouth of the Duwamish has been filled to provide land for industry and urban development.

The river above Auburn generally retains its natural sinuous path until it enters the Green River Gorge (at R.M. 45.6). From the gorge to HHD (at R.M. 64.5) the Green River maintains the characteristics of a natural mountain river. Above HHD the river generally flows through steep, mountainous terrain, restricted by narrow valley walls to its headwaters (at R.M. 88) on Blowout Mountain near Stampede Pass.

The Green River is a valuable economic, cultural, recreational and ecological resource. Intrinsically, the value of the river resource is directly related to the quality of the water. Green River water is used for a variety of purposes. The river is the main source of water supply for the City of Tacoma and is used for municipal and industrial purposes. The City of Tacoma built (in 1913) and maintains a water supply diversion dam at RM 61. Since construction, the Diversion Dam has isolated the Upper Watershed and restricted adult fish passage to Lower river areas. The Lower Watershed supports valuable fisheries used by commercial, tribal, and recreational interests. The river is used extensively for recreational boating, rafting, swimming, and other activities.

Except for the project, there is little streamside development above the dam. Much of this area is within the City of Tacoma's protected watershed. The rest is owned by private timber companies, the Washington Department of Natural Resources (DNR), or the Unites States Forest Service (USFS) and is managed as part of the Mt. Baker-Snoqualmie National Forest. In the future, lands owned by private timber companies will increase as federal lands are traded to consolidate the "checkerboard" ownership in the Upper Watershed.

HHD provides flood damage reduction in the Green River Valley and an increased level of flood protection to landowners and local governments. Following dam construction in 1963, the valley continued to transform from agriculture to major industrial, commercial, and residential uses. Between 1950 and 1960 was a period of improved transportation infrastructure that produced lower freight costs and a drive toward the purchase, aggregation, and development of large scale industrial and commercial centers. Industrial expansion, in the mid 1960's in the lower Green River Valley included the development of two major Boeing facilities in Kent and Auburn. The presence of Boeing brought subcontractors, suppliers, and support functions into the lower valley area. Industrial growth was further encouraged when a listing of lots for potential industrial sites of more than 50 acres was compiled by the Bonneville Power Administration in the 1960's. Sites included many in the lower Green River Valley. By the late 1960's, the land use in the valley had shifted from a dominance of agricultural to a wide variety of industrial and commercial uses. By the early 1970's, farming in the valley was substantially reduced, and much of the land was either left vacant or converted to industrial/commercial use. During the 1980's, land use in the valley further diversified to include not only industrial, manufacturing, and warehousing uses, but service industries and commercial offices. Today the Green River Valley is primarily classified as industrial with some residential, commercial, and farmland areas.

1.5 EXISTING HOWARD A. HANSON DAM PROJECT

1.5.1 Authorized Project Purposes

The project is currently operated to provide winter and spring flood control and summer low flow augmentation for fish and fish resources. Two other uses are also authorized: (1) irrigation water supply, and (2) municipal and industrial water supply. The project has never been operated for water supply; and irrigation is no longer a priority in the valley.

1.5.2 Original Project: Sponsor and Cost Sharing

Farmers historically had been searching for ways to reduce flooding in the Green River Valley. In June 1936, the Flood Control Act was passed authorizing a preliminary examination and survey for flood control. In November 1937, a public hearing was held jointly by the Department of War and Agriculture in Seattle. Local interests stressed the need for flood control. A survey report was ordered by the Chief of Engineers (US Army Corps of Engineers) in June of 1938. In October 1948, the Chief Engineer approved the submission of a combined navigation and flood control survey report. Different possible means for flood control were considered including channel improvements, storage, or some combination of the two. After detailed studies and cost estimates, rectification through channel improvements alone was disregarded as a possibility.

The authorization for the dam, initially named Eagle Gorge Reservoir, came from the Rivers and Harbors Act of 1950 (Public Law 516, 81st Congress, 2nd Session, 17 May 1950). In July 1951, President Truman issued a directive against all new starts for planning or construction unless certified as necessary for national defense. In November 1951, a brief was forwarded stating Seattle's industrial area was already occupied and that expansion by the Government, as well as private industry, must be in the Green River Valley, with the requested flood control. On May 14, 1952, the President approved the project. The project was renamed Howard A. Hanson Dam by the Act of Congress July 28, 1958 and signed by the President August 6, 1958. The dam was named after Howard A. Hanson, a prominent attorney and civic leader, in recognition of his active sponsorship of the project. Construction was complete in 1962. HHD is a 100% federally funded and operated project. King County was the original local sponsor and provides a minimal support for annual operation and maintenance costs for flood protection.

1.5.3 Site Description and Selection

Three sites were investigated by the Corps District Engineer in 1933. This investigation concluded that a dam six miles upstream from Auburn was not feasible due to potential loss of salmon spawning area. Of the proposed sites, Eagle Gorge was found to be the most cost effective and the only site situated far enough upstream (beyond a man-made upstream barrier for anadromous fish runs) to serve the combined function of flood control, low flow augmentation, irrigation, and water supply.

The HHD Project is located on the Green River 35 miles southeast of Seattle, 25 miles east of Tacoma, seven miles upstream from Kanaskat. The dam itself is at river mile 64.5 (Figure 1-3). The project lies entirely within the City of Tacoma municipal watershed and is closed to the public.

The Green River Valley at the dam site presently consists of a post-glacial canyon. Based on geologic mapping, pre-construction investigations, and observations during construction, Corps geologists postulate the presence of a deeper, older buried channel immediately north of the dam, beneath the dam's right abutment. The buried channel is deeply incised in rock and was filled, eroded, and partially refilled with glacial, fluvial and lacustrine related material. Subsequently, the north wall of the valley collapsed, creating a large rock slide mass that covered the older valley floor and forced the Green River against the south valley side where the present canyon is located. Landslide debris overlies portions of the bedrock surface at the dam site, and forms the upper portion of the right abutment. The left abutment is bedrock.

1.5.4 Original Project Description and Operation

HHD is a subsidiary earth-filled structure composed of rolled rock fill, sand and gravel core, drain zones, and rock shell protection. A plan view of the dam is shown in Figure 1-4. The embankment is 235 feet high and 500 feet long and has an inclined core of sand and gravel material. The dam is 960 feet thick at the base decreasing to 23 feet thick at the crest. The total length of the dam is 675 feet. The intake structure also includes trash rack bars, a deck for debris removal, one tractor type emergency gate, and gate hoist equipment located in the gate tower.

The outlet structure consists of a gate tower and intake structure with two tainter-type gates, a concrete horseshoe-shaped outlet tunnel, a gate controlled bypass, and a stilling basin. No fish passage facility was included in the original project design.

The 900-foot-long, 19-foot-diameter flat bottom horseshoe-shaped outlet tunnel passes normal flow released for project regulation. The tunnel is controlled by two 10-foot-wide by 12-foot-high regulating tainter gates at the bottom of the reservoir pool (invert elevation 1035 feet). Low-flow releases during the summer conservation period are made through a 48-inch bypass intake located about 35 feet above the bottom of the pool. This outlet has a capacity of approximately 500 cfs at maximum conservation pool (elevation 1069 ft). A cross-section of the dam with elevations of important features is shown in Figure 1-5.

The gate controlled spillway is anchored in rock on the left abutment and in a concrete monolith adjacent to the embankment. The spillway is a concrete ogee overflow section with two 30-foot-high by 45-foot-wide tainter gates to control major flood flows and prevent overtopping of the dam. The lowest elevation of the gates is 1,176 feet. The downstream chute has a curved alignment and is paved for a distance of 712 feet downstream from the weir. The tainter gates permit storage to 1,206 feet without spillway discharge. The maximum spillway discharge is 115,000 cfs at the spillway design flood pool elevation.

The reservoir (conservation pool) extends approximately 4.5 miles eastward from the dam along the main river channel and four miles northerly up the main tributary of the North Fork of the Green River. The reservoir is normally maintained at minimum level (about elevation 1,070 feet) from the end of October to the end of March to provide flood control storage space. The reservoir provides 106, 000 ac-ft of flood control storage at elevation 1,206 feet. Beginning around April the reservoir begins to fill to a maximum pool elevation of 1,141 feet to provide summer and early fall low flow augmentation: during selected drought years, storage is brought to 1,147 ft or 30,400 ac ft. At full conservation pool level, the summer/fall reservoir impounds 25,400 ac-ft with a surface area of 732 acres. The reservoir operational goals are to store excess storm flows, prevent winter and spring flooding and provide additional water from storage for low-flow periods in the summer and fall for conservation of fish resources.

There are four buildings on the project site.

- The Administration Building is located in a fenced compound on the right dam abutment.
- The Fuel Dispensing Station and Flammable Materials Storage Building is located approximately 200 feet north of the Administration Building on Access Road A.
- The Storage and Staging Quonset Hut is adjacent to Access Road No. 3, approximately 472 feet south of the intake structure.
- The Turbidimeter installation is located seven miles upstream from the dam.

The project site includes various gravel surfaced roads which provide access to the dam, stilling basin, intake structures, and the reservoir.

Flows are regulated manually by adjusting gate controls at the dam with direction from the Corps' Water Management Section. The reservoir is kept as low as possible (essentially empty) during the flood season so that runoff from the watershed above HHD can be impounded as needed. The highest pool elevation attained is 1,183.5 feet, in 1996. To date, it has not been necessary to use the spillway. The reservoir is drawn down, in normal years, to an elevation around 1,070 feet by November 1st to provide full flood storage capacity in the reservoir. During the winter months, flow is regulated to a maximum of 12,000 cfs at Auburn during flood events.

Normal river flows pass through the outlet tunnel in the dam's left abutment. When the river flow reaches flood stage, projected at 12,000 cfs at Auburn, discharge from the dam is reduced and water is impounded in the reservoir. As river flows return to normal following a flood, the water impounded in the reservoir is released at a rate which ensures safe discharge within channel capacity in the downstream area and minimizes damage to levees from sloughing during evacuation of storage. Flood control operations are in accordance with parameters of the project's congressional authorization, so there is little flexibility to operate for other purposes during the flood season.

Floating debris is collected during periods of high water by three stationary booms at the dam. Larger floating or sunken debris usually passes through the outlet tunnel and passes downstream, although it may lodge against the intake structure trash rack. This debris is removed periodically from the trash rack. The debris which is collected at the stationary booms is removed when reservoir conditions permit and is towed by barge to temporary holding areas. When the conservation pool is at its maximum elevation the debris is towed from the temporary holding areas to burning areas. When water conditions permit, the reservoir is raised three to 5 feet above the normal full conservation pool to facilitate movement of debris to the upper holding areas. When the pool level has been lowered and ground conditions permit, the booms and salvageable material are removed. Generally, the rest is sawed and piled by bulldozers for burning. Recently, some of the larger collected debris has been used in environmental restoration projects by the Corps and other resource agencies. This practice will increase in the future.

Aside from flood control operation, during the late spring, summer, and early fall HHD has a range of operational choices within the parameters of the authorized used of the dam. Throughout the years that HHD has been in operation, many downstream changes have occurred in area land use, recreation, fisheries, resource allocation, and environmental awareness. All of these external influences have resulted in operational changes and manipulations, primarily manifested in the refill timing of the conservation pool and instream flow needs. The intent of operational changes is to provide the most responsive and equitable utilization of water among sometimes competing resource users.

1.5.5 Subsequent Project Structural Modification

The first significant flood pool, which briefly attained elevation 1,161 feet, occurred in February 1965. At that time, a spring abruptly broke out at elevation 1,134 feet about 350 feet downstream from the downstream right abutment toe. The spring was controlled by a gravel blanket supported by a crib wall. In 1968, a drainage tunnel was constructed at elevation 1,100 feet and extending 640 feet into the right abutment. Twelve relief wells were drilled to intersect and extend 20 feet below the tunnel floor. This system appears to have adequately controlled abutment leakage during the flood pools experienced to date.

Numerous piezometers have been installed within the dam embankment and abutments; geotechnical instrumentation is concentrated on the right abutment. The piezometers are monitored regularly, and a program of maintaining, upgrading, and installing new instruments has been implemented since completion of dam construction, and continues to the present.

The Corps performed a seismic analysis of the intake tower. Results of the analysis indicated that the tower would not withstand the maximum design earthquake at the project site. The Corps completed structural modifications to remedy the situation.

1.5.6 Subsequent Project Operational Changes

The management of HHD is a continually evolving process within the constraints of its authorized purposes. Since the completion of the project in 1962 the population of the Green River valley and the entire Puget Sound region has increased. Land use in the lower valley has shifted from primarily rural and agricultural to a mix dominated by urban and industrial uses. The role of tribal governments, state, and local agencies in the management of Green River and its resources has significantly changed. The Corps has undergone a general shift from a rigid operation procedure to a more adaptive management approach and is currently involved with other agencies in their resource management activities.

Flood control is clearly the first priority of the operation and management of HHD during the winter flood season and is largely inflexible. The flexibility in the Congressional authorization lies in the operation of HHD during refill for conservation storage. Water management is more complex after the end of the flooding season. During the spring, the project switches from its primary role (flood storage) to its secondary role (conservation storage for low flow augmentation). Each year's water control strategy begins with the spring snowmelt. The formation of the annual water control plan typically begins in March, though the actual date depends on seasonal and weather factors. During the switch from flood to conservation storage, the amount of water released from HHD is reduced below the level of inflows allowing the project to refill.

Conservation storage operation involves a dynamic set of daily, weekly, and seasonal adjustments to releases, from the project, designed to meet the variety of needs for water resources in the Lower Watershed. Providing the maximum range of options and maintaining the highest level of flexibility during conservation storage are major elements of the current operational strategy. Adjustment of outflows in response to several external factors are necessary. Discharges are adjusted to reflect changing weather and inflow conditions; to provide additional instream flows to protect fisheries resources; to respond to community requests for specific instream flows for community activities (such as streambank clean-up programs); provide white water recreation opportunities; and to respond to emergency requests for instream flow changes (such as during search and rescue operations).

The current reservoir refill and conservation management strategy was developed as a result of drought conditions in 1992 that resulted in the lowest April through June inflows into the project since the completion of HHD. The management strategy has been continued because of its success. Reservoir refill begins generally in mid-April. Refill timing and release rates are based on target instream flows that are adjusted yearly in response to the existing weather conditions, snowpack, the amount of forecasted precipitation and biological input from fisheries and other resource managers. Refill is conducted in a way that attempts to provide optimum flows to downstream fisheries (e.g., wild steelhead that are spawning in the lower river at that time) while balancing the need for refill of the reservoir to a full conservation pool elevation of 1,141 feet. The full pool level is required to provide the maximum flexibility in relation to instream flow augmentation later in the season.

Problems with this current operating strategy arise in the conflict between management of different fish species and areas of the watershed. High flow releases from HHD may increase the survival of juvenile salmon outmigrating from the Upper Watershed. If steelhead in the Lower river spawn during these high flows, the steelhead eggs may be dewatered as flows subsequently drop during the 50-day steelhead egg incubation period.

These water management conflicts are partially a result of a lack of available information on the flow requirements for all species that are found in the Green River Watershed. As more is learned about the resource needs of the fishes of the Green River, this information can be incorporated into the present adaptive management strategy implemented by the Corps for the operation of HHD. This process is dynamic and requires ongoing inter-agency coordination before and during refill, and during summer low flow augmentation. The strategy will continue to evolve as experience is gained, coordination and forecasting techniques improve, and resource needs change.

1.5.7 Changes Resulting From Current 1135 Project

In 1996, under authority of Section 1135 of the Water Resources Development Act of 1986 Seattle District Corps of Engineers conducted a study of potential modification of HHD to improve fish and wildlife habitat within the reservoir and restore natural river functions for fish habitat improvement. The resulting recommended plan was approved for implementation in May 1997.

In general, the selected alternative involves providing 5,000 ac-ft of additional summer conservation pool storage during drought years once every 5 years on average; changes in operation for fish flow augmentation; physical habitat improvements in the reservoir area; and minor modifications to the intake tower: note, recent negotiations have resulted in the change to yearly storage if the Additional Water Storage proceeds. The proposed project modifications are consistent with the project purpose of low-flow augmentation, and provide a positive benefit to fish and wildlife resources.

Six categories of alternatives were examined for accomplishing the goal of restoring and improving fish and wildlife. The study analyzed the benefits and impacts of:

- various pool sizes (additional storage);
- storage frequencies;
- storage refill strategies;
- release schedules; and
- in-reservoir improvement opportunities.

The specific mix of alternatives selected from the above five categories is based on the overall criteria of maximizing improvement opportunities while minimizing potential impacts. The proposed modifications consist of:

- an additional summer storage volume of up to 5,000 ac-ft (6-foot pool raise) during dry years expected to occur once every 5 years on average;
- an adaptive storage frequency that initially assumes additional storage during drought conditions – once every 5 years on average, with the expectation that this can be modified through adaptive management so the 5,000 ac-ft of water could be stored as often as every year as more information is gained about the effects on juvenile salmonid survival;
- an adaptive reservoir refill strategy (the current operational storage strategy) which allows maximum flexibility to adjust refill rate and release of flows downstream to meet a variety of needs;

- an adaptive release schedule that initially assumes 5,000 ac-ft of additional storage will be used to maintain a minimum downstream flow of 250 cfs at the USGS gage on the Green River near Auburn, with the flexibility to address conditions which may change from year to year (e.g., decline of particular stock of fish, short-term precipitation patterns); and
- a selection of in-reservoir habitat enhancements based on the cost effectiveness and incremental cost analysis.

Opportunities to improve fish and wildlife habitat conditions in the reservoir include establishing streambank vegetation and greater plant diversity in the reservoir tributaries, placement of floating islands in the reservoir, and providing fish passage to the upper reaches of selected tributaries.

1.5.8 Concerns Resulting From Project Operation

The complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the standpoint of hydrogeology. At least two major aquifers are present with the possibility that others may exist. The lower aquifer with base elevation about 1,000 feet is found within the buried valley's alluvial materials. Pervious zones in the overlying glacial and slide materials form the upper aquifer, the probable source of the seepage problem on the downstream slope of the right abutment.

Considering the steepness of slopes surrounding the reservoir, producing harmful turbidity, the reservoir has been remarkably free from slides other than small failures of colluvium. Between mid-May and mid-June, slides from apparent saturation are noticeable between Charley Creek and the upper reservoir. These slides have not affected the HHD or reservoir operation, but may affect future debris removal. Since filling and operating of the reservoir one significant landslide has occurred. This was a rotational failure in early December 1995 following a period of intense rainfall. The slide occurred 1.7 miles upstream of the dam. The slide caused no damage to HHD. (See Appendix E, Geotechnical Considerations.)

Corps philosophy in dam design is that dams capable of placing human life at risk or causing a catastrophe should they fail, are to be designed to safely pass an inflow design flood computed from probable maximum precipitation (PMP) over the watershed upstream from the dam site. The PMP for the HHD area has recently been revised upward from that in existence at the time of original design. Recent review of the impact of the revised PMP and other original design assumptions has raised some issues regarding performance of the spillway and flood control outlet works during extremely large flood inflows on the order of those generated by a PMP. These issues are currently being evaluated by the Corps. In no way should these issues be construed to reflect negatively on the overall safety or operational adequacy of HHD.

A localized low area included in the original design and construction of the project exists upstream along the left abutment near full pool. It may be necessary to construct an earth embankment or other type of closure section in this area to prevent overflow during extreme inflow events. If so, the new closure section will be designed in accordance with current Corps standards and construction would occur outside of the additional storage implementation.

Some deviation from normal operation and regulation can be expected during construction periods, either downstream of the project or in the reservoir, during inspection of gates and other operational equipment, and during operations and testing for the fishery that may be performed from time to time by the Corps or other interests. There have also been occasions in the past when special requests have been received from law enforcement agencies for reduced flows to search the river for drowning victims. These deviations will be considered on a case-by-case basis and any regulation coordinated between all parties concerned.

1.6 FACTORS POTENTIALLY AFFECTING EXISTING PROJECT

1.6.1 Project Operation Problems

a. Debris. Winter floods bring floating debris down from the upper reservoir area. Debris is mostly in the form of wind-blown tree branches and entire trees. The debris is held behind the log booms until the temporary pool drops. During the spring, the debris floats again as the pool is raised for the low-flow augmentation season. Operators collect the debris using small boats. A preferred storage area is used that requires a temporary pool raise of 3 to 5 feet above the elevation of 1,141 feet. There usually is no problem with this routine operation; however, a more formal procedure should be established for the retention and drawdown of this water. This operation is intended to reduce large woody debris in the reservoir; however, some floating debris can make it under the log booms and should be considered when designing physical features for environmental improvements.

Woody debris management for fish and wildlife is included as a project purpose in this study.

b. Downstream Fish Passage. Young (juvenile) salmon (coho and chinook) and steelhead that are moving downstream to lower river rearing areas or migrating to saltwater (Puget Sound) must pass through one of two HHD outlets, the flood control tunnel or the low flow 48-inch bypass pipe. The flood control tunnel (1,035 foot elevation) is regulated by 2 large radial gates that control the discharge by presenting a barrier to flow. At flows less than 500 cfs, the 48-inch bypass is used (1,069 foot elevation). Refill of the project typically occurs between early April through June when the pool is filled from low pool, 1,070 foot elevation, to the full conservation pool, 1,141 feet (plus 3 to 5 feet for debris removal). This spring refill coincides with the main out migration period of these juvenile fish. As the pool fills the outlets are submerged to depths from 35 to 112 feet. As inflow to the reservoir recedes, outflow from the dam is routed to the 48-inch bypass pipe (flows less than 500 cfs).

Current annual survival of juvenile salmon and steelhead migrating through these two HHD outlets is estimated between 5% to 25% (estimated from fish passage model and on-site monitoring data – US Fish and Wildlife Service). The low survival rate is primarily a function of two factors — 1) the spring refill of the reservoir submerging the dam outlets; and 2) low survival of juveniles as they pass through the outlets. From studies at other Corps and public utility storage projects, it has been found that these juvenile fish require a near surface outlet (typically 5- to 20-foot depth) with a high discharge capacity outlet (exact volumes depend on site conditions). Therefore, at a time when these fish need high flows and a shallow outlet, the project is reducing outflow (refill) and creating a deeper outlet (from 35- to 112-foot depth). The reservoir refill and resulting deepwater outlets delay and entrap the juvenile migrant fish (40% to 70% of all fish may become entrapped). Fish that are delayed or entrapped beyond a certain time (biological window of opportunity) may not migrate to saltwater and may not contribute to the returning adult population. During low flows, fish that "sound" (dive) to reach the deep outlets experience high mortality from impacts at sharp bends or turns within the 48-inch bypass. Direct mortality in the bypass pipe can range from 1% to 100% depending on the amount of flow, water temperature, pool elevation, and time of year.

Improved downstream fish passage is a project purpose of this study.

1.6.2 Project Operations Constraints

a. Flood Control. The entire authorized space of 106,000 ac-ft is required for flood control. This means that there can be no storage for other purposes during the flood control season. Any reservoir water remaining in the fall must be released prior to the start of the rainy season. In the spring, the gradual accumulation of storage for conservation purposes must not overlap with storage space needed for flood control. New construction activity in the forebay must consider a plan to draw the reservoir down from elevation 1,070 feet or construct a barrier in the pool and pump water out in order to work in dry conditions.

b. Conservation Pool. The authorized conservation pool is elevation 1,141 feet. A change in authority must be obtained before water is stored above elevation 1,141 feet for extended periods: in recent years the pool has been stored above 1,141 feet for short periods (2 weeks or less) to clear debris. The use of the conservation storage to provide a minimum flow of 110 cfs is intended to have 98% reliability. This is a constraint on providing instream flow in excess of 110 cfs because drawdown below the guide curve would reduce the reliability of future flows at 110 cfs. Water for additional low-flow augmentation must be stored above the 1,141 foot guide curve.

c. Two Outlets. There are only two outlets that could be used to pass downstream migrating fish (see Paragraph 1.6.1 b.). The invert of the spillway is at elevation 1,176 feet and cannot be used for routine operations. This leaves the flood control tunnel, elevation 1,035 feet, and 48-inch bypass, elevation 1,069 feet. The flood-control tunnel has a modest slope; however, the entrance has an undesirable vertical plunge to be used for fish passage. The 48-inch bypass also has a steep plunge and narrow bend which is undesirable for fish passage. Fish passage mortality can only be reduced with extensive modification of the intake structure.

d. Water Quality. The Tacoma Water Division diverts unfiltered water at its diversion headworks downstream. The Corps has an agreement with Tacoma to provide clean water to the extent that the inflow allows. A small pool in the forebay covers sediment that would cause turbid water if the river was in a free-flow condition through the reservoir vicinity (this pool is otherwise known as the "turbidity pool". The accumulation of stored water must use elevation 1,070 feet as the starting point for zero storage.

e. Section 1135 Project. Implementation of the Section 1135 project is scheduled to begin in 1999 with the construction of approved fish and wildlife measures. These restoration measures will include the installation of over 250 logs and/or root wads for fish and waterfowl habitat improvements, fertilization of 24 acres of meadow habitat, planting of 48.5 acres of water tolerant plants, and minor improvements to the intake tower for maintenance access. A test-pool to store the additional 5,000 ac-ft, to elevation 1,147 feet, should occur in 2000 and will be used to evaluate the success of the restoration projects. Following the implementation of the restoration measures, HHD would be authorized and available to supply the additional 5,000 ac-ft in any year meeting the adaptive management storage criteria. The 5,000 ac-ft will be used to maintain summer flows of 250 cfs at the USGS gage at Auburn.

1.6.3 Treaty Tribes Rights, Agreements, Corps Trust Responsibility

The Muckleshoot and Suquamish Indian Tribes are involved on many levels in the Green/Duwamish River Basin. The northern section of the Muckleshoot reservation lies within the Middle Green River. The Muckleshoot Tribe planning department administers land use and environmental policy within the boundaries of the reservation. The Muckleshoot Tribe has co-management responsibilities with the State of Washington for the fisheries resources within its usual and accustomed fishing areas, which include Lake Washington, the Green, Cedar, and upper Puyallup/White River basins. The Suquamish Tribe shares in this co-management within the Duwamish estuary and Elliot Bay. Fishing, hunting, gathering of native plant material, and access to the river, wetlands, and forests of the basin above and below HHD provide essential economic and spiritual sustenance to the Muckleshoot and Suquamish people (USFS, 1996).

As co-managers of anadromous fish resources, the Muckleshoots are directly involved in the operation of the existing HHD Project. Technical staff represents the Tribe each year during pre-season forecasting, seasonal refill, and summer flow augmentation coordination of reservoir operations. Their input along with the Washington Department of Fish and Wildlife (WDFW) has dramatically altered the form of refill and release operations. In addition to input to project operations, the Muckleshoot Tribe has become the primary manager of fish resources in the Upper Green River. In the last few years, the Muckleshoots have taken over most stocking of hatchery reared juvenile fish above HHD. The stocking of juvenile fish is considered a first step in recovery and restoration of anadromous salmon and steelhead above HHD. Since HHD was not built for juvenile fish passage, project refill operations have seen a dramatic shift to try and accommodate the passage of these juvenile migratory fish. The Muckleshoots are leading recovery efforts and consider HHD and existing project conditions as the impediment to permanent recovery. Lastly, the tribe and state, as co-managers of harvest, have the most direct impact on the numbers of adult salmon and steelhead that ultimately spawn in the river below HHD and/or that could reach the dam for passage above the dam.

The City of Tacoma, sponsor of the Howard Hanson Dam Additional Water Storage Project, has a unique and active relationship with the Muckleshoot Indian Tribe. Since the 1970's, the City has been actively involved with the Muckleshoot people in a negotiation to rectify past fish and wildlife damages related to construction and operation of the Tacoma Diversion Dam. The Diversion Dam was built at RM 61, 3.5 miles downstream of HHD, in 1911-1913 and was the first complete barrier to adult salmon migration. Adult salmon have not been released above the Diversion since 1913 and steelhead have just begun to be re-introduced since 1992. This low head dam is not considered a barrier to downstream fish passage of juvenile salmon and steelhead. A few juveniles are killed when they are entrained into the existing water diversion intake: a new screen and juvenile bypass will be built under Tacoma's Second Supply Water Right Project.

In addition to this process of reclaiming historical resources, the two parties have recently signed the Muckleshoot/Tacoma Mitigation Agreement (Agreement), whereby all past and future claims by the Muckleshoot people have been settled through a combination of financial and natural resource remedies. Included in this Agreement are several planned provisions important to restoration of anadromous fish to the Upper Green River. These provisions include: 1) a fish restoration facility – a "naturalized" rearing facility for re-establishing salmon and steelhead; 2) a fish ladder and adult collection facility to provide adult fish passage above the diversion dam and around HHD; and 3) higher, guaranteed minimum flows to protect instream resources.

The Agreement developed new, higher minimum flows (at Auburn) over Washington Department of Ecology (WDOE) requirements. For a particular year, instream flows are set by the summer month conditions, beginning on July 1. The summer month flow conditions as stated in the Agreement are, "*For Wet Years the minimum continuous instream flow shall be 350 cfs. For Wet to Average Years the minimum continuous instream flow shall be 300 cfs. For Average to Dry Years the minimum continuous instream flow shall be 250 cfs. For Drought Years, the minimum continuous instream flow shall range from 250 to 225 cfs, depending on the severity of the drought.*" Flows at Auburn must be at or above these requirements before Tacoma can divert water for their Second Supply Water Right Project.

As part of these negotiations and the Agreement, the City of Tacoma became sponsor of the HHD Section 1135 Restoration Project whereby 5,000 ac-ft of water is stored in drought years to provide additional augmentation for meeting the higher minimum flows. The Corps is not an active party to the Agreement, however the Agreement does reference pre-defined storage zones in the existing reservoir. The Corps is in a position to maintain support to both parties and typically acts as a facilitator in water management discussions on the Green River.

The Corps of Engineers, like Tacoma, has an active relationship with the Muckleshoot Indian Tribe (MIT). Unlike Tacoma, the Corps has a federal trust responsibility with Native Americans. This trust responsibility puts more stringent requirements on Corps actions as far as protecting the rights and resources of Native Americans, especially those related to anadromous fish.

1.6.4 Regional Water Supply Planning

To meet the increasing demands for water and with limited opportunities for developing additional new water supplies, utilities in Washington have found it necessary to plan and manage resources in a more water efficient and comprehensive manner. This approach allows utilities to more effectively manage issues such as droughts, state regulations, and the high development costs of new projects. The existing project, while authorized to provide up to 20,000 ac-ft of storage for water supply, is currently not operated for nor is reservoir space used to directly provide water supply.

1.6.5 Fish and Watershed Resource History, Management, and Outlook

Eight anadromous salmonid species historically or currently use the Green River system. These species include chinook, coho, chum and sockeye salmon *(Oncorhynchus tshawytscha, O. kisutch, O. keta, O. nerka)*, steelhead and sea-run cutthroat trout (*O. mykiss, O. clarki clarki*), Dolly Varden and bull trout (char; *Salvelinus malma, S. confluentus*). Races of salmon and steelhead historically or currently present include spring, summer, and fall chinook, winter and summer steelhead. Native, resident salmonids include rainbow and cutthroat trout and mountain whitefish (*Prosopium williamsoni*). Additional information on life-history types and stock status is discussed in Appendix F, Part One, Section V: Downstream Migration of Anadromous Salmonids through the Lower Green River.

The Green/Duwamish River watershed is a fundamentally altered ecosystem. To date, 97% of the Green/Duwamish River estuary has been filled, 70% of the flows of its former watershed have been diverted out of the basin, and about 90% of the once-extensive floodplain is no longer flooded on a regular basis. The Green/Duwamish River today is still an important producer of fish and wildlife resources, especially anadromous fish (salmon, steelhead, sea-run cutthroat, and char). However, plant and animal populations, including anadromous fish, continue to decline due to increasing human activities within the watershed.

The changes to the Green/Duwamish watershed are a result of a continuing series of man-made actions with much of the recent degradation resulting from ecosystem function and process changes associated with construction and operation of HHD. HHD has created two basic changes to the system: 1) it has added a second physical barrier that has further disconnected the upper and lower river (the MIT Agreement will remove the Tacoma Dam as an upstream barrier); and 2) altered the hydrologic regime of the river which has resulted in dramatic reductions in flooding of the historic floodplain and constrained the river channel into a single channel form. The disconnection and flow regime change has severely reduced the capacity of the watershed to produce salmon and steelhead. Specific factors that limit anadromous fish abundance in the Green River related to HHD are: 1) the lack of fish passage through HHD disconnecting the Upper Watershed or 45% of the entire basin; 2) disconnection of the floodplain and important rearing and spawning habitat from the lower mainstem river; and 3) loss of mainstem spawning gravels.

HHD was originally authorized and built without fish passage facilities. Above the dam there are 221 square miles of watershed area and 106 stream miles of historic salmon and steelhead habitat. Different authors have estimated that this Upper River watershed area could produce a run of over 30,000 adult salmon and steelhead (see Section 2, Part 1, Appendix F). In 1929, the State Department of Game estimated that 90% of the coho salmon and steelhead habitat in the Green River could be found above the Tacoma Diversion Dam (Fuerstenberg et al. 1996). After inception of the HHD Project, beginning in 1982, anadromous fish (coho salmon, chinook salmon, and steelhead) have been re-introduced into the upper watershed under state and tribal fish management. As discussed in Paragraph 1.6.3, the City of Tacoma/Muckleshoot Mitigation Agreement will/can provide permanent upstream fish passage around the Tacoma Dam and HHD.

As discussed in Paragraph 1.6.1b., current survival of juvenile salmon and steelhead migrating through HHD is estimated between 5-25% (estimated from fish passage model and on-site monitoring). Because of these low juvenile survival rates through the existing project, restoration of self-sustaining, naturally reproducing fish stocks above HHD is highly unlikely. Tacoma currently operates a temporary adult fish trap at their barrier dam (under the Muckleshoot Agreement a permanent fish ladder and trap will be built). Since 1992, returns of adult fish have ranged from 30 to 150 steelhead and from 50 to 300 adult salmon. Trapped adult steelhead are either released above the dam for natural spawning, or a selected few are used to rear fry for outplanting in the upper watershed to try to maintain the small run. Adult salmon are not currently released above the dam, but releases above the dam may begin next year. Because of the uncertainty of restoring these fish runs, neither the state nor the tribe have developed comprehensive management plans, including adult spawner escapement goals, for juvenile and adult fish.

Large, diverse, natural spawning (as opposed to hatchery spawned) populations are considered critical to the long-term survival and production of wild and hatchery runs of salmon and steelhead through maintenance of genetic diversity. The National Research Council (1996) summarized the need for these healthy natural populations: "... unless enough fish are able to spawn, there will not be enough fish produced to compensate for all the sources of mortality imposed by human activities and to provide sustainable runs of wild salmon. Increasing the number of adult that return to spawn (escapement) will enhance opportunities for evolution of genetic diversity through colonization, straying, and competition, and will bolster nutrient input to streams."

Besides their importance to genetic diversity and the tribal, commercial and recreational fisheries, natural spawning anadromous fish have been recognized as a critical link in aquatic food webs in the Pacific Northwest. They are considered a "keystone" species upon which producers and consumers from the bottom to the top of the food chain depend (Wilson and Halupka 1995). Rearing in the rich-ocean waters, adult salmon return to nutrient poor streams with a wealth of ocean nutrients, enriching the food-web from primary producers to top carnivores. At the top of the food web, at least 22 species of wildlife, including black bear, mink, river otter, and bald eagle, feed on salmon carcasses (Cedarholm et al. 1989). At the base of the food web, salmon carcasses provide a significant, if not major amount of nitrogen to streamside vegetation as well as large amounts of carbon and nitrogen to aquatic insects and other macroinvertebrates (Bilby et al. 1996). Some researchers suggest that a minimum escapement level for natural spawners may be needed to maintain the integrity of the aquatic food chain: this level may be higher than escapement goals required to maintain salmon populations (Bilby et al. 1997).

Abundance of natural spawning salmon and steelhead in the Lower Green River has severely declined in the past 50 years, not unlike salmon populations throughout the Pacific Northwest. Fuerstenberg et al. (1996) presented a 50-year comparison between natural spawner counts from 1938-1942 and 1987-1991: in the late 1930's (more than 20 years after completion of Tacoma Diversion Dam) over 110,000 chinook, chum coho, pink salmon and steelhead were counted while in the late 1980's over 27,000 chinook, coho, chum salmon and steelhead were counted. Both native pink and chum salmon stocks are considered functionally extinct. The chum run is being re-built with stock from other South Puget Sound rivers. Since the 1930's counts, the coho salmon, chinook salmon, and steelhead spawner counts are reduced by 66, 82, and 64%, respectively. Most of the natural salmon production has been replaced by hatchery spawned and reared fish. Of the seven original anadromous stocks of salmon, steelhead, and cutthroat trout, only one stock, winter steelhead, is considered native, wild and healthy.

Local salmon and steelhead harvests in the Green/Duwamish are co-managed by the WDFW and Muckleshoot and Suquamish Indian Tribes. These harvests include commercial, sport, subsistence and cultural uses. Harvest rates can vary widely year to year based on ocean survival conditions, international harvest agreements between Canada and United States interests and freshwater rearing conditions. Escapement goals and harvest rates vary between fish species and between hatchery or natural origin fish. The Lower Green River (below the Tacoma Diversion) escapement goals required for natural spawning fish to maintain each run (self-sustaining) are: 1) 8,700 coho salmon; 2) 5,700 chinook salmon; and 3) 2,000 winter steelhead. No escapement goals have been established for the Upper Green. Harvest rates for salmon populations in the Green/Duwamish River peaked in the 1980's: chinook salmon harvest for all Puget Sound ranged from 69-83% (NMFS press release February 27, 1998); coho salmon harvest in the Green River was assumed to average 90% from 1986-1991 (WDFW draft Wild Salmonid Policy, 1995). In the 1990's with five years of El Niño ocean conditions (1992-1995, 1997) harvest years have been drastically reduced with total closures in selected years. Over the long-term, harvest rates are lower than the peak 1980 years, but higher than the 1990's: coho salmon is less than 70%; chinook salmon is less than 60%; and for winter steelhead the average is approximately 35% (1977-1992).

These harvest rates provide one more mortality factor influencing the number of adults returning to spawn that are required to maintain existing runs or that could be necessary for recovery and restoration of natural runs above the Upper river man-made barriers (Tacoma Diversion and HHD). Recent harvests (1992-1996) have been greatly reduced from the long-term average; most biologists believe that reduced ocean survival resulting from climatic changes (El Niño) is the main cause for the reduced fish numbers. These reduced numbers of returning adults have resulted in the closure of commercial salmon harvesting in most of the saltwater along the entire west coast over the last 3-4 years. The harvest rates for wild salmon and steelhead may remain reduced in the future; the WDFW is considering a wild salmonid policy that could increase the escapement of natural spawners.

Hatcheries have been used for more than 100 years in attempts to mitigate the effects of human activities on salmon and to replace declining and lost natural populations. In addition, they have also been used to expand upon natural production to provide additional harvest opportunities. As a result, a major proportion of salmon populations in the Green River now consists largely of hatchery fish. Federal and state fish and wildlife agencies are considering major changes to many traditional hatcheries and how new hatcheries are managed and operated throughout the Pacific Northwest (NRC 1996; WDFW 1997). The change in emphasize involves an integrated hatchery program of planning, management, and operation to minimize impacts of hatchery fish on natural salmon and steelhead production and to maximize recovery of depressed populations. The Muckleshoot/Tacoma Fish Restoration Facility (see Paragraph 1.6.3) follows this integrated approach and is planned primarily as a "restoration" facility to assist in re-introduction and recovery of Upper Green River salmon and steelhead.

Green River coho salmon, chinook salmon and steelhead are currently being reviewed for proposed listing under the Endangered Species Act (ESA). These fish runs are not reviewed as single watershed but are included in a larger regional group – the Puget Sound Evolutionary Significant Unit. In 1996, the NMFS made a preliminary review that Puget Sound chinook are considered "likely to become endangered" in the near future. On March 10, 1998, NMFS proposed listing Puget Sound chinook as a threatened species with the final decision of listing or nonlisting to occur in 12-18 months. Conditions for Puget Sound (and Green River) chinook have not improved since the preliminary review and proposed listing and therefore it is likely that they will be listed.

1.6.6 Forest Management Practices

Land ownership within the Green River watershed is a mixture of many private, tribal and public entities. Most of the private landowners are timber companies, including Weyerhaeuser Corporation; Champion International Corporation; CITIFOR; and Plum Creek Timber Company. Other landowners include Burlington Northern Railroad; Washington Department of Natural Resources; King County METRO; US Forest Service; and the City of Tacoma. Nearly all of the forest lands near the Howard Hanson Dam reservoir and the Upper Green River are owned by the Tacoma Public Utilities (specifically, Tacoma Water Division). Consequently, this section will only briefly discuss forest management by other owners, with greater detail provided on Tacoma's forest management.

a. Private Management. Nearly all of the lands in the Upper Green River Watershed are managed for timber production. The Washington Forest Practices Act (RCW 76.09, Rules WAC 222-22) was passed in 1992. This Act prompted watershed owners to form a watershed analysis team that establish specific forest practices rules for the Green River watershed. The rules provide the landowners predictability in planning for future harvest as well as provide guidance on riparian areas and identified sensitive areas, which are to be avoided by new road construction and during timber harvest. The Washington Department of Natural Resources administers the rules.

b. Forest Service. Federal Forest Practices Rules apply to public owners, assuring that public resources are being protected using the best available scientific information. In recent years, wildlife habitat management has been a driving force behind forest management in Northwest national forests. The Mount Baker/Snoqualmie National Forest prepared a management plan geared toward conservation of the northern spotted owl (*Strix occidentalis*). An important aspect of this plan is a goal of achieving 15% of the total USFS land in the Snoqualmie Pass Adaptive Management Area (AMA) will be old growth forest (>180 years of age). Presently, none of the three major sub-watersheds in the Green River Watershed (Upper Green; Middle Green; Lower Green) have achieved 15% of old growth stands. Consequently, the USFS has determined that it must preserve enough late successional stands to provide 15% old growth forest in these sub-watersheds in the future. Forest lands in early- to mid-successional stages would be targeted for commercial harvest. Fragmentation of late-successional and old growth stands has been identified as a difficulty for wildlife due to the resultant lack of travel corridors. A proposed land exchange with Weyerhaeuser Corporation would reduce USFS ownership in the Green River Watershed. An impact of land exchanges is that some old growth would be given up to commercial harvest. Much greater details on the management of USFS lands can be found in the Snoqualmie Pass Adaptive Management Area Plan EIS (1996), and the Green River Watershed Analysis (1996).

c. Tacoma. Tacoma's forest management objective in the Green River Watershed is to provide water quality protection and, to the greatest extent possible, benefits to fish and wildlife habitat in a financially self-sustaining manner through environmentally sound forest management that meets or exceeds regulatory requirements. To achieve this objective, Tacoma has divided its holdings into three management zones: Natural; Conservation; and Commercial. Tacoma places its Natural Zone around surface waters, including Howard Hanson Reservoir, Green River, and tributary streams. The zone extends from the average high water mark to the forested uplands, or property boundary, or a physical barrier, such as a road or powerline right-of-way. The Conservation Zone includes upland forest land, fields, rock outcrops, open lands, and wetlands, generally adjacent to the Natural Zone, especially where forest practices could impact wildlife habitat and water quality. Its boundary extends up to the Commercial Zone, property boundary, or physical barrier. The Commercial Zone is upland forest land where forest practices will not adversely impact wildlife habitat or water quality. Some 20% of Tacoma's lands are in the Commercial Zone; and 40% each is in the Conservation and Natural Zones. Management of these zones is summarized as follows:

(1) Natural Zone. Forest management is directed at preserving the health and vigor of the vegetative cover to reduce erosion. The long-term goal is to let natural succession develop mature (100-180 years old) and old growth (180+ years of age) seral stage habitats for associated fish and wildlife species. Old growth and mature seral stage forest stands will not be harvested. Occasionally, forest practices will be conducted as the need arises to: salvage trees damaged or killed by large natural catastrophic events (i.e., wind, fire, flood, insects, or disease) which may impact water quality or the health of the forest if not removed; modify wildlife habitat to attract deer and elk away from areas near the water supply; and do streamside restoration to minimize erosion and improve fish habitat. An exception to this goal will be approved major projects which will benefit water quantity, quality, and fish habitat requiring large scale forest management activities.

(2) Conservation Zone. Forest management in this zone will be directed at maintaining or improving the health and vigor of the vegetative cover for fish and wildlife habitat production. The long-term goal is to accelerate the development of existing even-age single storied stands into late successional multi-storied forest habitats. Regulated uneven-aged forest practices in conifer stands and even-aged forest management in hardwood stands will be conducted in this zone. These forest practices will be used to maintain, enhance or change wildlife habitat to attract deer and elk away from areas near the water supply and provide forage, cover (hiding and thermal), nesting, denning and dispersal habitat. Once the forest stands in this zone reach the mature seral stage, about 100 years of age, they will not receive a final harvest. More detailed discussion of harvest schedules is found in Section 8.2 of Tacoma's Forest Land Management Plan (1996).

(3) Commercial Zone. Forest management in this zone is aimed at producing merchantable timber at a sustainable level, and within certain environmental constraints. Both uneven- and even-age stands will be managed. The environmental constraints are regulated by the Washington State Forest Practices Act; Shoreline Management Act; Hydraulics Project Approval Act; Log Export Regulations; federal Endangered Species Act; and the 1995 Agreement between the Muckleshoot Indian Tribe and Tacoma Public

Utilities. The city has also imposed its own forest practices rules for management of city lands. These are described in detail in Section 6 of Tacoma's Forest Land Management Plan (1996). Harvest cycles are also discussed in this Plan (Section 8.3).

1.6.7 Flood Plain Development/Regulations

The existing project provides 500-year flood protection for the lower river. This kind of protection is considered a minimum for urban development. Storage behind HHD is dedicated to flood control from approximately November through March. However, if it can be shown that flood protection will not be compromised, preliminarily refill may begin as early as 15 February. Flood control provided by HHD is complemented and supplemented by a system of levees and the Natural Resources Conservation Service Black River Pumping Station.

HHD is operated for flood control so that the sum of the dam release and local inflow between the dam (RM 64) and Auburn (RM 32) will not exceed the control flow of 12,000 cfs at the Auburn gage. As local inflow increases, releases from the dam are decreased. Discharges of 12,000 cfs can be accommodated with risk. In some areas, the differential between river water surface and top levee is less than 1 foot. Flood control structures properly designed, constructed, and operated can reduce, but never completely eliminate, the probability of flooding. The possibility always exists that floods will occur which exceed the physical capabilities of the structures.

The development in the valley and consequent need to manage floods in all areas has now reached a point where the needs and capabilities of the various systems may be in danger of conflict. King County and the City of Renton have indicated during HHD AWS scoping that any chosen alternative should not adversely affect flood control in the valley. Further, they have suggested that flood control be included as a study purpose with the objective of modifying ramping rates and reducing maximums allowable flows at Auburn to accommodate levee and pumping needs.

Flood control is not included as a purpose in the HHD AWS Project, primarily because it would require an additional local sponsor. However, the study has been and will be carried out in a manner such that the recommended plan does not aggravate current flood control challenges.

1.6.8 Water Rights and Flow Requirements

The Corps augmentation of streamflow to the extent of providing 110 cfs below Tacoma's diversion began after HHD was constructed in 1962. The Washington Department of Ecology (WDOE) established an Instream Flow Protection Program in the 1980. This program included the development of administrative rules for instream flows on the Green River, one of 26 of the state's Water Resource Inventory Areas (WRIA). Under this rule, an instream flow restriction has been placed on the main stem Green River. All tributaries of the Green River, as well as all other small streams in the basin, are closed to further water appropriation. Existing water rights are not affected.

The presence of HHD on the Green River creates potential opportunity for additional, future stored waters and future water rights. The instream flow program recognizes that impoundment of surface waters in HHD reservoir is an available means of appropriating additional water resources in the Green River Basin. Instream flow hydrographs have been developed for two locations in the Green River Basin, at Auburn (RM 32.0) and at Palmer RM 60.4). Normal and critical year curves are supplied for the Palmer station only. Though the dam is a federal project, and is exempt from state control, the *use* of stored waters is subject to the state's authority in issuing water rights. A secondary application will be required for parties applying for beneficial use of water stored in a reservoir. Such a secondary application must refer to the reservoir as its source of water supply and show documentary evidence that an agreement has been reached with the owners of the reservoir to impound enough water for the purposes of the application.

INSTREAM FLOW CONTROL LOCATIONS

Control Location	USGS Gage Number	River Mile	Stream Management Reach
Green River near Auburn	12113000	32.0	From influence of mean annual high tide at low instream flow levels (approximately River Mile 11.0) to USGS Gage #12106700
Green River near Palmer	12106700	60.4	From USGS Gage #12106700 to headwaters.

INSTREAM FLOWS FOR FUTURE WATER RIGHTS IN THE GREEN RIVER BASIN

Month	Day	12113000 Normal Year Green River near Auburn	12106700 Normal Year Green River near Palmer	12106700 Critical Year Green River near Palmer
Jan.	1	650	300	300
	15	650	300	300
Feb.	1	650	300	300
	15	650	300	300
Mar.	1	650	300	300
	15	650	300	300
Apr.	1	650	300	300
	15	650	300	300
May	1	650	300	300
	15	650	300	300
June	1	650	300	300

Month	Day	12113000 Normal Year Green River near Auburn	12106700 Normal Year Green River near Palmer	12106700 Critical Year Green River near Palmer
	15	650	300	210
July	1	550	150	150
	15	300	150	150
Aug.	1	300	150	150
	15	300	150	150
Sept.	1	300	150	150
	15	300	150	150
Oct.	1	300	190	150
	15	350	240	150
Nov.	1	550	300	190
	15	550	300	240
Dec.	1	650	300	300
	15	650	300	300

In 1995, a written agreement was reached between the Muckleshoot Indian Tribe and the City of Tacoma regarding the Green/Duwamish river system. The Muckleshoot Indian Tribe is a federally recognized Indian tribe who has rights and responsibilities for the management of fish and wildlife resources and other natural resources of the Green/Duwamish river system. The City of Tacoma is the owner and operator of the municipal water system downstream of HHD through its Department of Public Utilities, Water Division. The agreement settles Muckleshoot claims against Tacoma arising out of Tacoma's municipal water supply operations on the Green River including the First and Second water diversions. The agreement establishes the commitment and framework for a long-term cooperative working relationship between the Muckleshoot Indian Tribe and Tacoma concerning the Green River. The Corps is not a party to the agreement; however, the Corps considers the instream flow requirements and other conditions of the Green River during its water management operations.

By management of its water supply diversions, Tacoma will provide the following minimum continuous instream flows which will vary with weather conditions during the summer months. The determination of wet, average, dry, and drought weather conditions is aided by the use of reference zones within Howard Hanson Reservoir that show available storage by date. The tabulation of the zones is too detailed for use in this appendix and is available in the Appendix D1, Hydrology. Before a decision is made to drop the instream flows from 250 to 225 cfs, consultation among the resource agencies, Muckleshoot Indian Tribe, Corps of Engineers, and Tacoma shall be used to explore alternatives to lowering the minimum continuous instream flow.

AUBURN INSTREAM FLOW BY WEATHER CONDITION

Summer Weather Condition	Auburn Instream Flow
Wet Years	350 cfs
Wet to Average Years	300 cfs
Average to Dry Years	250 cfs
Drought Years	250 to 225 cfs depending on the severity of the drought

Tacoma shall meet the continuous instream flow requirements at Auburn and Palmer whenever it is withdrawing water from the Green River with its Second Supply Water Right diversion. To the extent that these instream flow requirements are greater than the State Instream Flows, these instream flow requirements control the diversion action.

PALMER INSTREAM FLOW BY SEASON

Season by Dates	Palmer Instream Flow
July 15 to September 15	200 cfs
September 16 to October 31	300 cfs
November 1 to July 14 (all other days of the year)	300 cfs (same as the State Instream Flow)

AUBURN INSTREAM FLOW BY SEASON

Season by Dates	Auburn Instream Flow
July 15 to September 15	400 cfs
for other days of the year	refer to Instream Flow by Weather Condition

The agreement acknowledges that the operation of HHD for fish conservation is designed to protect against a drought that has a probability of occurrence of one in 50 years. While maintaining that standard, the parties agree that the operations should be modified during the summer to provide additional flows in the Green River for fish. Tacoma agrees that if the Corps modifies existing operations of HHD to release more water during the summer months and if fall precipitation does not occur in sufficient quantities to meet the instream flow requirements of the MIT/Tacoma agreement, Tacoma will restrict its withdrawals of water from the Green River by its First Diversion Water Right to allow the Corps to recoup water required to maintain its federally mandated minimum instream flows. Tacoma may rely on its well capacity to meet its demand requirements during the period it restricts its Green River withdrawals.

For future diversions, the agreement states that Tacoma shall not pursue any further diversion of the Green River from May through October of any year before the completion of the Howard Hanson Dam Additional Water Storage Project. If the additional storage project is approved, Tacoma will apply for a storage right for water stored at HHD as well as a diversion right to make use of that additional stored water.

1.6.9 Regional Power Outlook

Hydropower supply is not an authorized project purpose at this time and is not expected to be in the future. Federal hydropower requirements in the Northwest are being met through other sources.

1.6.10 Reopening of the BNSF Rail Line and Potential New 4-Mile Tunnel Construction

In January of 1886 the Bennett brothers received a contract from the Northern Pacific Railroad to bore a 16-foot-wide, by 22-foot-high and 10,000-foot-long tunnel through a mountain just north of Mount Rainier. Scheduled rail traffic started in July of 1887. Thus began the railroads' over 100-year involvement through Stampede Pass on the Upper Green River. The rail line proceeds out of Auburn and follows the river in an easterly direction, gaining elevation to the top of the pass at about the 3,700 foot elevation and then down the east side of the Cascade range where it connects to Cle Elum. For many years this line was one of three that connected eastern and western Washington. Bulk loads such as coal and ore were shipped east, while wheat and other agricultural products went west.

In 1983 the line was abandoned and became inactive. Thirteen years later, as a result of a local increase in container traffic at the Ports of Seattle and Tacoma, the Burlington Northern Santa Fe (the former Northern Pacific Railroad) spent over 130 million dollars to reactivate and upgrade the line. This upgrade included expanding the rail bed by placing additional rock in the Green River, and improvements of the tunnel and snow shed at the pass. It is anticipated that as many as eight train loads of double stacked intermodel cars will be routed through the Stampede Pass line on a daily basis to help alleviate some of the congestion on the other mainlines.

Although the Stampede Pass line provided the historic and economically important rail link between the east and west parts of the state, several environmental consequences are associated with its use. From an ecosystem perspective, utilities such as rail and power transmission lines fragment the landscape and disrupt the migratory patterns of large mammals. In many places the rail line is adjacent to the Green River. Disruption of river bed migration, loss of access to side channels and tributaries as well as localized impacts from instream filling with rock and ballast for the rail bed have been detrimental to the aquatic resources not to mention the expected results of the ill-fated critter that finds itself on the track at an inopportune time. Disturbance, such as noise is also a problem and a few local families have filed suit against the railroad.

These impacts are expected to continue into the future as the priority for rapidly routing container traffic back east takes on heightened importance in an increasing and competitive container market. One example of this type of activity can be seen in that the Regulatory Branch is currently evaluating a permit application to place a large amount of riprap to control scour around a railroad bridge west of Lester (in the Upper Watershed).

The applicant (Burlington Northern Santa Fe) also seeks to re-divert some of the current river flow back to its formal channel. There are some concerns about this proposal's effect on a local population of bald eagle. The railroad is also currently evaluating the potential of altering the rail line in the upper basin to lessen it's grade. This may include a new four mile long tunnel. If this proposition is realized there would be additional impacts related to the new construction which are dependent on it's alignment.

1.6.11 Recreational Desires

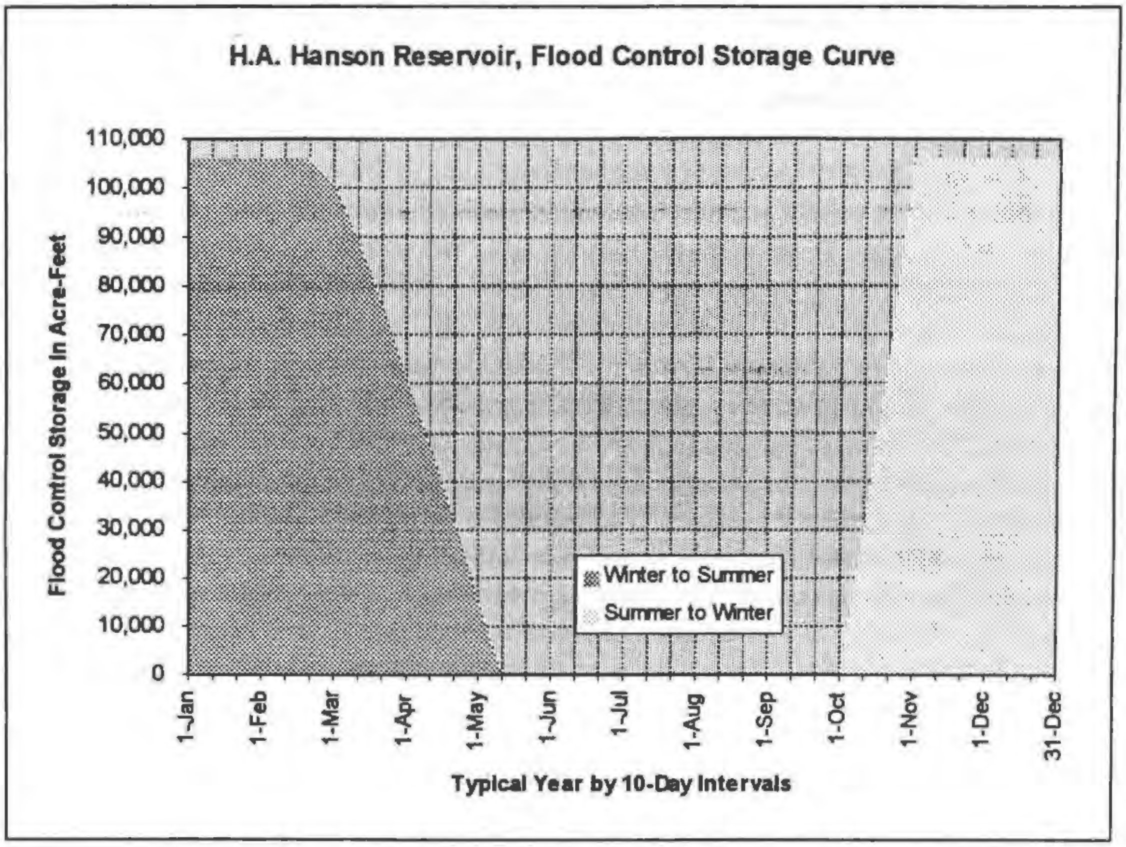
During scoping and public review of the HHD Operations and Maintenance EIS and scoping for this study, recreational use interests have expressed a desire for more emphasis on recreational use of the Green River. Concerns regarding recreational use of the river and the effects of HHD operations centered on the need for additional recreation use studies, aesthetic studies and economic analysis of effects of instream flows on recreation. The Corps recognizes the obligation to attempt to accommodate white water recreation in the operation of the project and has recently endeavored to minimize the impact of reservoir operations on natural flows as much as possible. The greatest need is to provide flows suitable for recreation on weekends for kayakers and river rafters. Flows between 1,200 and 3,500 cfs are optimum for the majority of recreations use. Commercial rafting outfits are especially interested in increasing the weekends in April when these flow conditions occur.

The Corps is committed to be more responsive to these needs and has invited members from The Rivers Council to represent the recreation community in the annual refill coordination process. Refill planning normally begins in March and generally extends through the conservation season. These meetings provide a process for consensus management of the Green River resources and resolution of fisheries, recreation and other conflicts. Including recreation as a specific objective of the GI Study is, however, precluded by current Corps policy.

1.7 EXISTING CONDITIONS

1.7.1 Flood Control

Howard Hanson Dam provides storage of 106,000 ac-ft for flood control from approximately October through March. The transition months, October and March are evaluated during real-time conditions to determine the need for providing 100% of the flood control allocation. Flood control storage is not needed outside of the winter period because the river adequately handles runoff from snowmelt and groundwater. The flood control zone is illustrated in the accompanying figure. The curves enclose the upper boundary of space required for flood control on the Green River. The actual slope of the Oct-Dec curve is variable depending on the duration of the low-flow season and the onset of fall rain.



Flood Control Storage Curve for Howard A. Hanson Reservoir (shaded area refers to volume of available storage required to satisfy flood control responsibilities).

1.7.2 Low Flow Augmentation for Fish Enhancement

The existing reservoir provides for 25,400 ac-ft of summer/fall storage; 24,200 ac ft is active storage available for "enhancing" instream flows below the project. This storage volume has a 98% refill reliability to maintain a minimum instream of 110 cfs at the Palmer gage (6 miles downstream of HHD). This storage volume and use has been considered enhancement of instream resources (including fish), not restoration, as provided under existing project authority. Augmenting flows during the summer and early fall alters the flow regime from HHD (RM 64) to the estuary (RM 7) during the period when 1) juvenile salmonids are rearing in the river; 2) steelhead eggs are incubating and fry are emerging, 3) adult chinook and coho salmon are migrating upstream; and 4) chinook salmon are spawning in the river. The existing storage volume and minimum flows are barely sufficient to provide for instream passage of adult salmon during low flow years and are insufficient to keep steelhead eggs watered. Since 1987, the City of Tacoma has voluntarily reduced their water supply diversion during at least 3 years to supplement HHD releases to maintain these minimum flows.

The Washington Department of Ecology and Muckleshoot Indian Tribe completed an instream flow study between 1987 and 1992. This study identified and recommended much higher instream flows than HHD provides for salmon and steelhead spawning and rearing habitat requirements. In addition to the instream flow study, the Tacoma/Muckleshoot Agreement stipulated a higher instream flow requirement for Tacoma prior to their diversion of Second Supply Water (flows listed in Paragraph 1.6.3). Even though HHD cannot provide for desired instream flows (or even minimum flows in selected years), it has been estimated that the river would run dry in 2 of 10 years without flow augmentation from the project (King County Surface Water Management 1984). Additional critical low flow capacity is clearly needed. To provide greater reliability in meeting the existing minimum flow and the Muckleshoot/Tacoma negotiated flows, the HHD Section 1135 project was initiated. The Section 1135 project provides for an additional 5,000 ac-ft of storage (30,400 ac-ft total storage) for flow augmentation under an adaptive management approach. This water is currently targeted for drought year use (estimated at once every 5 years on average) and only provides enough water for maintenance of minimum instream flows. Thus, it provides minimal, but critical restoration (see discussion of enhancement/restoration low flow augmentation in Paragraph 1.9.2 and 1.9.3). Without addition of this flow volume, minimum flows can drop so low that adult salmon can become physically delayed in lower river areas and may ultimately die.

1.7.3 Municipal and Industrial Water Supply

The existing project authorization included up to 20,000 ac-ft of M&I water supply storage as an authorized project purpose. Storage of M&I water supply has not, however, been implemented. The main without-project sources of summer/fall M&I water for the City of Tacoma consist of the Green River First Diversion, South Tacoma Well Fields, existing other wells, future wells and industrial re-use. Today, Tacoma has a surplus of M&I water to meet the needs of their customers; however, by year 2003, the utility is expected, based on a medium demand forecast and without-project resources, to be in need of developing a new water supply measure(s). Included as part of Tacoma's overall future demand for water are contracted water amounts to be supplied by Tacoma to Seattle and south King County. Seattle Water Department is currently in negotiations with Tacoma Water for Tacoma to provide Seattle with up to 25 millions gallons of water per day (mgd), during the summer demand period, via a water supply intertie which is currently planned for construction prior to construction of the proposed HHD AWS Project. Tacoma is also expected to supply up to 25 mgd to communities located in south King County. This water will be provided via Tacoma's Second Supply Water Right (SSWR) via Pipeline 5 (P5) which is currently planned for completion prior to 2003.

1.7.4 Irrigation (Agricultural Water Supply)

The authority to construct Howard Hanson Dam included irrigation water supply as a project purpose. Prior to construction of this dam, the Green River valley was primarily an agricultural area consisting of many crop farms and there was an expectation that additional irrigation water supply would need to be provided in the future. Construction of Howard Hanson Dam, however, significantly reduced the likelihood of flooding in the valley and without the threat of flooding, the valley economy changed from an agricultural community to a major commercial and industrial center. Subsequently, the demand for additional irrigation water has not developed and has actually been replaced by a demand for additional municipal and industrial water.

1.7.5 Recreation

The area below HHD is a regional recreational resource of particular value. Several park locations allow direct access to the river for activities such as fishing, floating, canoeing, kayaking, and hiking. The Green River Gorge is roughly 12 miles long, 500 to 1,000 feet wide, and up to 300 feet deep. The Gorge has areas with waterfalls and springs.

The Upper Watershed above the Tacoma diversion dams is basically undeveloped and closed to fishing within the City of Tacoma's watershed. Some recreational hunting is permitted annually. Public lands and some private lands in the Upper Watershed could be opened in the future if additional water treatment is implemented by Tacoma.

There is intense public interest in use of HHD to enhance white water recreational opportunities. In recent years, the Corps has taken these needs into consideration to the extent possible when making water management decisions.

1.7.6 Power

Hydropower is not an authorized project purpose, currently, and is not expected to be in the future. Federal hydropower needs in the Northwest are being met through other sources.

1.7.7 Ecosystem Restoration Opportunities

a. Low Flow Augmentation. Flow augmentation beyond existing HHD releases may be desirable to increase summer and fall low flows for: 1) meeting minimum flow volumes and depths for keeping steelhead eggs watered through July and August; 2) meeting minimum flow volumes and depths for adult upstream migration; 3) increasing adult salmon holding habitat; 4) creation of late-summer freshets to draw salmon to preferred upstream spawning areas; 5) meeting preferred fall spawning flows for salmon; and 6) reducing elevated stream temperatures that can stress or kill adults, delay spawning, and kill incubating eggs. There are currently no other means available to provide for additional flow augmentation.

The existing storage of 25,400 ac-ft allocated for low flow augmentation uses approximately one-fourth of the total potential reservoir space behind the dam. The facilities for regulating water flow are already in place, so there is a potential opportunity to store additional water for low flow augmentation. The additional storage would have to be compatible with the existing flood control authority and compatible with maintaining the existing required instream flow of 110 cfs. With careful attention to measurements and criteria for the use of additional storage, this becomes a viable option for further study. The formulation of a plan to implement the use of additional water storage would need to consider functional impacts on the Green River environment such as habitat restoration and fish passage through the dam.

A parallel Corps Ecosystem Restoration reconnaissance study has begun on the Green River (Green/Duwamish River Basin GI Ecosystem Restoration Study). This study also identified summer and fall flows as ecological limiting factors in the river. These low flows, besides limiting fish habitat, can be associated with other water quality concerns. Decreased low flows during summer and fall can influence 1) the amount of available freshwater habitat in the Duwamish estuary; 2) available dissolved oxygen in the river; and 3) dilution of nutrients and introduced pollutants in the river.

b. Habitat Restoration and Fish Passage

(1) Habitat Restoration. The Corps Ecosystem Restoration reconnaissance study has also identified a series of restoration strategies necessary to return the Green River to a more natural condition. Some of these strategies include:

- Improve connections between the mainstem river and floodplain/estuary habitats. Less than 10% of the floodplain and 3% of the estuary wetlands are connected to the river. Actions include removal or setback of levees, lower the elevation of side channel inlets, or addition of large wood to increase the mainstem water surface.
- Change river sediment loads and transport. Almost 50% of the watershed is above HHD and the dam traps a large sediment load. Up to 1,000 linear feet of lower river mainstem spawning habitat is losing gravel substrates each year. Actions are limited but could include placement of gravel in selected sediment deficient areas.
- Change river flows. Peak flows have been reduced to a maximum of 12,000 cfs at Auburn, water withdrawals have reduced minimum flows in major tributaries, and refill of HHD has altered the natural flow regime in the spring. Actions include altering HHD refill to mimic natural flow regime, altering timing of refill, and additional storage for flow augmentation.
- Improve instream habitat complexity and structure. Large wood is scarce from loss of the riparian zone; levees constrain much of the lower 35 miles. Actions include addition of large wood and removal or setback of levees.
- Reduce water temperatures in the mainstem. Loss of nearshore forests and lower flows have resulted in higher summer water temperatures, often near lethal limits for cold-water fish. Actions include provision of water control at HHD outlet, flow augmentation, improvement of riparian areas, setback or removal of levees.
- Increase natural nutrient loading levels. A reduction in natural spawners (and their carcasses) throughout the watershed has reduced critical inputs of marine-

origin nitrogen. Limited amounts of nitrogen reduces productivity of the entire aquatic food chain. The Upper Green River is probably severely deficient in natural inputs of nitrogen.

(2) Fish Passage. Under a strict ecosystem approach, fish passage should be considered habitat restoration. For this discussion, we will treat fish passage as a separate restoration item. Under the Green Duwamish Study "barriers to fish passage" was identified as a limiting factor in the Green River. In combination, HHD and Tacoma Diversion Dam currently isolate the Upper Green River (45% of the entire basin). In addition to these major barriers many tributaries have impassable culverts, and low flows can trap salmon in the lower river.

Actions or strategies to address these limiting factors include upstream passage around the dams, downstream passage at HHD, replacement of culverts, and augmentation of summer flows. Upstream passage around the Tacoma Diversion Dam and HHD is to be provided under the Muckleshoot/Tacoma Mitigation Agreement (discussed in Paragraph 1.6.3). Currently, a temporary fish ladder and trap is used to collect adult steelhead and salmon. All wild adult winter steelhead are trucked and released above HHD. Initial releases of wild salmon are planned to begin in 2004. A new, permanent fish ladder and fish collection facility is planned (under the MIT/Tacoma Agreement) and will be built in the near future. This adult collection and transport facility is designed to provide for fish passage of all wild adult salmon and steelhead around both dams.

As discussed in Paragraph 1.6.1b, there are no downstream fish passage facilities at HHD. Survival rates are only estimated and vary by species and years, but overall may range from 5% to 25%. Strategies to provide downstream fish passage through or around HHD can include – collection of juvenile fish before they reach the reservoir (upstream collector) with nets or a barrier dam, or collection of fish at the dam. A successful dam fish passage facility would require a surface inlet with a capacity to pass most outflow during the main smolt emigration period (late April through June) and to move fish from reservoir pool elevation down to the lower river through an unpressurized conduit.

1.8 WITHOUT-PROJECT CONDITION (ALTERNATIVE 1 – NO ACTION)

The without-project condition is defined as the condition most likely to prevail in the future if no project is undertaken.

1.8.1 Flood Control

The amount of flood control storage space is likely to remain the same as the existing conditions – 106,000 ac-ft up to elevation 1,206 feet. The flood control protection for Auburn would also likely remain at a discharge of 12,000 cfs.

1.8.2 Low Flow Augmentation for Fish Enhancement

This would continue existing storage of 25,400 ac-ft and maintenance of minimum instream flow of 110 cfs at Palmer. Under this condition the river will continue to experience low flows during summer and fall with associated impacts to fish and aquatic resources. In selected dry years this storage volume will be insufficient to provide for even the minimum flows at Palmer (110 cfs) and/or the MIT/Tacoma negotiated flows at Auburn (250-350 cfs). Additional development of the lower river and water withdrawals below the Tacoma Diversion could exacerbate this limiting factor. Refill of this storage volume will continue to entrap juvenile fish outmigrating from the upper watershed, thus precluding restoration of the fish runs in the upper watershed and impacting recovery efforts under the MIT/Tacoma Agreement.

1.8.3 Section 1135 Low Flow Augmentation for Environmental Restoration

The Section 1135 project provides for an additional 5,000 ac-ft of storage (30,400 ac-ft total storage) for flow augmentation under an adaptive management approach. This water is initially targeted for drought year use and only provides enough water for maintenance of minimum instream flows (250 cfs at Auburn). Thus it provides minimal, but critical restoration. Storage of this water exacerbates the existing poor passage conditions at HHD, reducing downstream survival by an undefined increment below survival experienced for the 25,400 ac-ft of storage. If land and water development within the basin continues, and summer run-off and instream flows continue to drop. The without-project condition assumes the 1135 Project is in place and operational.

1.8.4 Municipal and Industrial Water Supply

The without-project condition includes all existing water supply measures plus the addition of other measures expected to be implemented during the forecast period. Following is a list of items expected to occur and included as part of the without-project condition:

(1) Construction of Pipeline No. 5 will occur prior to project year one. Pipeline 5 is a water transmission line, with a capacity of 100 cfs (65 mgd), which will deliver water from Tacoma's water diversion structure located downstream of Howard Hanson Dam through several communities in south King County and on to Tacoma. This line will be used to transport water from the proposed project to Tacoma's service areas in need of additional water. The diversion operation of Tacoma's Second Supply Water Right will be a run-of-river operation without the use of storage at HHD;

(2) construction of new ground water wells;

(3) implementation of a proposed artificial recharge project;

(4) construction of a water supply intertie between Tacoma and Seattle water systems with a peak capacity of up to 62 cfs (40 mgd); and

(5) implementation of cost effective water conservation and non-structural measures.

Outputs of all existing and future structural water supply sources are based on 98% reliability. They will not be sufficient for Tacoma's projected needs. See Appendix B, Economic Analysis and Cost Sharing, for more information on the without-project condition associated with water supply.

1.8.5 Irrigation (Agricultural Water Supply)

While irrigation water supply is an authorized project purpose, it has never been implemented and is not part of this proposed project; nor is it planned for implementation as part of any other project. Therefore, the without-project condition does not include irrigation water supply.

1.8.6 Recreation

In the without-project condition, recreational needs will remain as described in existing conditions above.

1.8.7 Power

Hydropower is not an authorized project purpose, currently, and is not expected to be in the future. Federal hydropower needs in the Northwest are being met through other sources.

1.8.8 Ecosystem Restoration Opportunities

a. Low Flow Augmentation. Additional flow augmentation is not a viable restoration opportunity under the No Action Alternative. No other storage is available to meet increased instream flows other than HHD. A potential way of increasing the magnitude of flow from the existing storage allocation would be to decrease the existing reliability from 98% to something lower. The existing storage could provide an additional 10 to 20 cfs with a low reliability; however, the stored water would run out prior to the end of the low-flow season in approximately 1 out of 5 years. The shortage would occur in the fall and impact the adult salmon returning to spawn. The impact of this change of operation would likely not justify the small increment of water flow. A better opportunity would be to maintain the existing flow augmentation and look for a way to increase the reservoir storage level. The Section 1135 restoration authority has already been used to store 5,000 ac-ft for flow augmentation at HHD; it is highly unlikely this authority could be used a second time to store additional water behind the dam. Even if additional water were stored at HHD, the enlarged, deepened reservoir would further reduce the potential for restoring fish runs above the dam unless downstream fish passage facilities were provided.

b. Habitat Restoration and Fish Passage. Limiting factors and restoration strategies identified under Paragraph 1.7.7 are carried forward, including downstream fish passage through HHD. The MIT/Tacoma Agreement will be implemented providing for upstream fish passage facilities around the Tacoma Diversion Dam and HHD. It is unclear at this point how many, if any, of the other restoration strategies identified under the Basin Restoration Study will be implemented. This is a new use of an existing authority and no study has yet been carried to completion. Without restoration action under the Basin Restoration Study or the HHD AWS Project, many of the limiting factors in the river will continue to become more chronic or acute, further limiting the capacity of the system to sustain animal and plant communities. If downstream fish passage is not implemented under any of the current planning studies, the upstream fish passage provided under the MIT/Tacoma Agreement may become superfluous as few adults will return and/or juvenile fish plants in the Upper Green River may cease because of low survival through HHD.

An Endangered Species Act (ESA) listing of threatened or endangered fish will most likely occur for one or more anadromous species in the Green River. Prescriptions for recovery of these fish runs could be dramatic, including the need for addressing one or more of the restoration strategies and actions under Paragraph 1.7.7.

1.9 BASIN AND REGIONAL WATER AND RELATED LAND RESOURCE NEEDS

1.9.1 Flood Control

King County has expressed interest in reducing the flood control flow from 12,000 cfs at Auburn to some lower level. Engineering studies conducted in the past have shown there is no space in the reservoir to store extra runoff that would allow increased flow control. King County has also said that any use of storage for purposes other than flood control should not have an impact on the functional capability of the existing flood control. All alternatives proposed for study during plan are required to not impact the existing flood control capacity of HHD so this discussion is not needed for each separate alternative.

1.9.2 Green River Low Flow Augmentation

Under rules for the existing water conservation storage, flow augmentation is considered an enhancement to instream resources. Low summer and fall flows has been identified as a factor continuing to limit fish production in the Green River by the King County-led Green River Restoration team.

Additional flexibility in storage operations is needed to protect steelhead egg incubation. Existing storage capacity typically does not provide sufficient flows (above minimums) through July to cover areas where steelhead redds are incubating. Limitations of the existing refill rule curve have resulted in the dewatering of up to one-half of all steelhead eggs in a single year.

Additional storage capacity is also needed to augment flows in the summer and early fall for salmon and steelhead rearing. Following emergence, juvenile anadromous salmonids can spend up to two years rearing in the stream before beginning their downstream migration. Researchers have shown a positive relationship between the amount of summer and fall flow and the success of coho salmon and steelhead populations in Puget Sound. The Washington Department of Ecology, Department of Fish and Wildlife, King County, and the Muckleshoot Tribe have been strong proponents of additional summer flows to support these fish runs in the Green River (Williams 1975; Caldwell 1989; HHD O&M EIS 1996; HHD Section 1135 PMR 1996; Green-Duwamish Basin Restoration Plan 1996).

Additional flow augmentation is needed in late summer and fall to attract adult salmon to upper river areas and to maintain these flows for spawning. Existing storage only provides for meeting minimum summer flows. These flows are low enough that large adult salmon can become delayed or will hold and spawn in lower river areas that may be less desirable. Typically salmon move upstream following brief, natural freshets, existing storage usually cannot support this. Optimum fall spawning flows for salmon are 100% greater or more than existing minimums: Washington state minimum flows are 110 cfs at Auburn; MIT/Tacoma negotiated flows are discussed in Paragraph 1.6.8. The Washington Department of Ecology, Department of Fish and Wildlife, and Muckleshoot Tribe have been strong proponents of additional fall flows to meet identified instream flows levels that would support and increase these fish runs in the Green River.

There are concerns that storing additional water during the spring to satisfy additional flow augmentation during the summer and fall may have adverse impacts on Lower Watershed aquatic resources. Information on refill impacts are needed to ensure additional storage provides net environmental benefits.

1.9.3 Municipal and Industrial Water Supply

Common images of western Washington usually include green forests, salmon runs, Puget Sound and lots of rain. While rain is indeed plentiful, ranging from 31 to 44 inches annually throughout western Puget Sound during most years, the majority of that precipitation falls during the late fall and winter. Little or no rain is experienced during the summer and early fall season. Conversely, the greatest water demands occur during the summer season, particularly July and August, challenging utilities to better manage and stretch their existing resources to meet those demands. This occurrence is becoming more prevalent as the growth rate in the Puget Sound region continues to climb and the ability to procure additional water supply resources decline.

The need to supply or develop additional M&I water in a given region is primarily a function of population and employment growth over time. That is, economic growth in an area results in increased employment which in turn results in increased population – created primarily by in-migration. Both of these actions results in increased demand for additional water in all demand sectors (Residential, Industrial/Commercial, Public, etc.). Forecasts of employment and population growth in the Puget Sound region, including the water supply area serviced by Tacoma Water, show a significant increase over the forecast period. As a result, the need for additional water, even considering the implementation of the most cost effective conservation measure, is going to increase such that new water supply resources will need to be developed. For example, the Boeing Company has recently constructed a aircraft component manufacturing facility in a part of Tacoma Water's service area. This resulted in increased employment plus an increase in surrounding population which in turn increases the demand within the commercial/industrial, residential and public sectors for M&I water. As a result, the City of Tacoma has expressed an interest in developing the Howard Hanson Dam Project for the purpose of providing additional water supply to meet their forecast supply deficits.

1.9.4 Irrigation Water Supply

The Howard Hanson Dam Project was originally authorized for irrigation water supply, although this authority was never implemented. Irrigation water supply is not a proposed project purpose. The changes in the Green River Basin over time, with increased focus on industrial and residential use, makes it unlikely that the irrigation authority will ever be implemented.

1.9.6 Recreation

Recreation will continue to be a project operation consideration, but not a specific purpose.

1.9.7 Power

Hydropower is not an authorized project purpose, currently, and is not expected to be in the future. Federal hydropower needs in the Northwest are being met through other sources.

1.9.8 Environmental Restoration Opportunities

a. Low Flow Augmentation. The fish instream flow needs identified under Paragraph 1.9.2 are carried forward to this section as environmental restoration opportunities.

b. Habitat Restoration. The habitat limiting factors and restoration strategies identified under Paragraph 1.7.7 are carried forward to this portion as habitat restoration needs and opportunities.

SECTION 2. THE SCOPING PROCESS

2.1 NEPA (NATIONAL ENVIRONMENTAL POLICY ACT) OVERVIEW

Table 2-1 presents the status of compliance with statutes and executive orders affecting the HHD AWS study at the feasibility level. Follow-on compliance actions may be required in some regulatory areas during PED (pre-construction engineering and design) and during construction.

TABLE 2-1. STATUS OF PROJECT WITH APPLICABLE LAWS AND STATUTES

Federal Statutes	Full Compliance Date
Archaeological and Historic Preservation Act	May 1996
Clean Air Act of 1977, as amended	July 1997
Clean Water Act of 1977, as amended	November 1997
Coastal Zone Management Act	July 1997
Endangered Species Act of 1973, as amended	July 1998
Federal Water Project Recreation Act, as amended	July 1997
Fish and Wildlife Coordination Act, as amended	July 1998
Marine Protection, Research & Sanctuaries Act, as amended	July 1997
National Environmental Policy Act of 1969, as amended	July 1998
National Historic Preservation Act of 1966, as amended	May 1996
Watershed Protection and Flood Prevention Act, as amended	November 1997
Executive Orders (E.O.)	
Floodplain Management (E.O. 11988)	November 1997
Protection of Wetlands (E.O. 11990)	November 1997
Protection and Enhancement of the Cultural Environment (E.O. 1153)	November 1997

2.2 SCOPING THE DFR/EIS

2.2.1 Issues of Importance

Scoping in the context of NEPA as prescribed by the Council on Environmental Quality (CEQ) is the process of determining issues of importance to be included in the EIS process. This study has been in process for several years. Initial scoping occurred in 1991 (Federal Register Notice of Intent published January 25, 1991) but was essentially suspended while technical studies were carried out. The process was resumed in the summer of 1996. The following key areas were initially identified for analysis in the EIS:

1) Geology and Engineering Design
2) Water Management
3) Water Quality
4) Wetlands
5) Fisheries
6) Wildlife
7) Cultural Resources
8) Socioeconomic Resources

A second Notice of Intent to prepare an EIS was published in the Federal Register on July 9, 1996 to formally re-initiate the scoping process. A scoping notice and Environmental Impact Report Summary were mailed to all affected federal, state, and local agencies, Indian Tribes, and other interested private organizations, and their comments were invited. Comments were requested concerning project alternatives, mitigation measures, probable significant environmental impacts, and permits or other approvals. Public comment was sought during scoping in accordance with NEPA procedures. A public scoping process was conducted to clarify issues of major concern, identify any information sources that might be available to analyze and evaluate impacts, and obtain public input on the range and acceptability of alternatives. Corps and local sponsor planners conducted a public scoping meeting in Auburn on July 18, 1996.

2.2.2 Scoping Results

Verbal comments received during the July 18 scoping meeting, as summarized below, were augmented by six written comment letters regarding scoping the EIS. Commentors who submitted written responses are listed below.

Holly Coccoli, Muckleshoot Indian Tribe, Fisheries Department
Jay Cohen, Washington Recreational River Runners
Phil Fraser, City of Tukwila, Department of Public Works
Pete Jerry, Muckleshoot Indian Tribe, Hunting Committee
Jim Kramer, King County Surface Water Management Division
Patricia Sumption, Friends of the Green River

2.2.3 Scoping Summary

Comments and concerns received were reviewed by the Corps and classified according to general categories of common subject matter. The comments and concerns were responded to as appropriate in the study process and documented in this DFR/EIS. The issues of concern are grouped in seven categories.

a. Fisheries. Comments on fisheries issues centered around the need to assess the effects of increased summer habitat at the expense of spring habitat. Specific concerns included project effects on stream margin habitat features, side channel connectivity, smolt outmigration flows, salmon and steelhead incubation, and water salinity and temperature. Also requested was a discussion of the proposed changes in duration, timing, and magnitude or rate of refill, as well as a quantification of predicted impacts on smolt and fry survival and outmigration success, with particular emphasis on predation. Two commentors requested species- and lifestage-specific assessments of impacts. Also mentioned was inclusion of project effects on resident fish populations.

b. Wildlife. The Muckleshoot Indian Tribe Hunting Committee commented on project effects on elk and deer. Comments focused on the need for additional information on numbers of individuals that will be affected, as well as details on the proposed mitigation fields and inundated areas. Information specifically requested about the mitigation fields include location, shape, slope, and aspect of fields; distances to roads; forage species and biomass; effects on elk winter range; and effects on calving. Information requested on inundated areas included forage production after water recession and the potential effects of inundated non-meadow areas on deer. Friends of the Green River commented on possible negative impacts to forest wildlife species from conversion of forests to mitigation fields.

c. Recreation. Comments were received on the need to include an assessment of the effects of the project on river recreation, specifically white water rafting, kayaking, and canoeing. Comments centered on the potential reduction or elimination of spring boating opportunities due to earlier refill of the reservoir. Public meeting comments were directed to the potential to include recreation as a study purpose.

d. Flood Control Issues. Comments on flood control issues included considering the impacts of high flows on levees, riverbanks, and recreational trails. Two commentors requested that a risk analysis be prepared to address specific flood control issues such as required levels of existing levees; maximum allowed flows; assumptions for peak event flows downstream of the dam; current and proposed maximum ramping rates; and, level of downstream levee/riverbank maintenance and repairs resulting from discharges at 9,000 cfs, 11,000 cfs, and 12,000 cfs discharge levels at the Auburn gauge. Potential negative effects of flood control measures such as ramping on fisheries and river recreation were also noted. Flood control also was suggested as a project purpose.

e. Growth and Land Development. Several commentors mentioned the need to assess the effect of the alternatives on growth and land development in King and Pierce counties.

f. Additional Alternatives. The addition of alternatives was requested by several commentors. Suggestions included (1) allowing for variable level storage in response to proposed future reservoir outmigration monitoring; (2) enhancing environmental and recreational values without additional water storage; (3) enhancing wild fish populations and decreasing hatchery fish populations; (4) diverting Tacoma's water supply from a point downstream of the existing diversion dam; and, (5) removing Howard Hanson dam and/or the Tacoma Diversion dam.

g. Other Issues. Several other issues were mentioned in general terms in the comment letters. These included economic issues, water quality, and fish passage. Several commentors requested coordination of this EIS with the Howard Hanson Dam Operations EIS, and one commentor suggest that this EIS be delayed until completion of the Operations EIS and Section 1135 EIS. Also requested was information on the relationship of this project with the proposed construction of Tacoma's Pipeline 5.

2.2.4 Coordination and Further Public Involvement

This Draft Feasibility Study Report/EIS will be filed with the Council on Environmental Quality, and its availability for a 45-day review period will be published in the Federal Register. At the same time, the document will be furnished to a wide ranging list of federal, state, and local agencies; Native American governments; environmental interest groups; and other public and private entities and interested individuals. It will be available on request to others. There will be a public meeting. After the 45-day review, comments will be compiled and responses presented in a Final EIS (FEIS) for a further 30-day review after which a Record of Decision (ROD) will be prepared.

As a requirement of the US Fish and Wildlife Coordination Act, as amended, the US Fish and Wildlife Service prepares a Coordination Act Report (CAR) that reviews specific Corps feasibility studies. The CAR typically provides the USFWS view of the project including concurrence or non-concurrence and recommendations for protection of fish and wildlife populations and habitat. A copy of the draft CAR can be found in Appendix I: a final CAR will be included in the final report of the HHD AWS Project.

A Biological Assessment (BA) was prepared for terrestrial species and bull trout, and transmitted to USFWS. USFWS concurred with the BA in its letter of January 28, 1998: the complete BA and the USFWS response to the BA can be found in Appendix I. In the interim, the National Marine Fisheries Service (NMFS), on March 10, 1998, proposed to list as threatened the Puget Sound Evolutionary Significant Unit (ESU) of chinook salmon (*Oncorhynchus tshawytscha*). The BA for this proposed species is being prepared concurrent with the public review of this DFR/EIS, as there was insufficient time to prepare the BA and receive concurrence from NMFS prior to distributing the DFR/EIS for public review. We are expecting concurrence from NMFS on this procedure. The completed BA (for chinook) and NMFS concurrence will be incorporated in the Final FR and EIS.

In addition to the required NEPA scoping described in this section, the Corps and Tacoma have conducted ongoing, regular meetings with all fish and wildlife resource agencies and the Muckleshoot Indian Tribe since the inception of the HHD AWS Project. A full description of the various technical working groups and larger policy groups that have participated in and helped shape this study can be found in Section 3. Lastly, in the past 2 years there have been two intensive negotiation periods where resource agency directors from NMFS, USFWS, WDFW, and WDOE gave conditional acceptance to the phased project described in Section 4 of this DFR/EIS. In those negotiations, MIT has reserved judgment on the project. The letters of acceptance, including congressional and sponsor letters of support for the project, can be found at the end of Appendix I following the BA and CAR.

SECTION 3 – ALTERNATIVES

3.1 PRELIMINARY PLAN FORMULATION

3.1.1 Reconnaissance Study Alternatives and Evaluation

The Howard Hanson Dam (HHD) Additional Water Storage (AWS) Project study was conducted under Section 216, Public Law 91-611, Review of Completed Projects, River, Harbor and Flood Project.

3.1.1.1 Planning Objectives

The original purpose of the project, as defined in the 1989 Reconnaissance Study, was to determine if HHD is a viable source of additional water supply and if there is a federal interest in modifying the project to meet regional water resource needs. The primary project outputs were: (1) to provide 65 million gallons per day (mgd) of municipal and industrial (M&I) water at 98% reliability and (2) to increase summer instream flows (low flow augmentation) from 110 cfs (98% reliability) to 200 cfs. The additional 90 cfs would be at 75% reliability. Downstream fish passage was the mitigation for project impacts. A restoration objective was not defined as the authority for ecosystem restoration had not yet been created.

3.1.1.2 Planning Criteria

Additional water supply benefits were measured using the most likely least-cost water supply alternatives identified at the time as available to the City of Tacoma. Low flow augmentation benefits were not quantified. Mitigation associated with a higher pool for water supply and low flow augmentation was a fish passage facility.

3.1.1.3 Alternatives Considered

Three structural M&I water supply alternatives were formulated. A variety of additional structural and non-structural water supply alternatives were available but the City of Tacoma considered these non-viable at the time of the reconnaissance report.

a. Recommended Alternative: Additional Storage at Howard Hanson Dam. Provide 62,400 ac-ft of summer storage, an additional 37,000 ac-ft over existing storage, by raising the existing summer conservation pool from 1,141 foot elevation to 1,177 foot elevation. Storage blocks included 24,000 ac-ft for M&I and 13,000 ac-ft for flow augmentation.

b. Alternative Supply 1: Smay Creek Dam. Construct a water supply dam on Smay Creek located 10 miles upstream of HHD and tributary to the Green River.

c. Alternative Supply 2: Skagit River Pipeline. Construct a water supply pipeline to the Skagit River, 84 miles north of the Green River. The Skagit River was identified as a possible major regional source of water, which could easily supply large volumes of water.

3.1.1.4 Alternative Evaluation

In the Reconnaissance Report, Additional Water Storage at HHD was the least-cost of the three identified water supply alternatives provided by Tacoma and was carried forward into feasibility study as the recommended alternative (Table 3-1 below). The Additional Water Storage alternative cost includes provision for fish and wildlife benefits by increasing summer flows by 90 cfs at 75% reliability. A fish passage facility was considered as mitigation (cost $4 million) and was conceptualized as a variation on the Green Peter Dam "gulper", a downstream, juvenile fish passage facility on a Corps Portland District storage dam.

TABLE 3-1. COST OF RECONNAISSANCE STUDY ALTERNATIVE SOURCES OF WATER (IN 1989 PRICES)

Alternative	Cost (Million)	Capacity	Reliability	Cost/mgd (Million)
Additional Storage	$ 21	65 mgd	98%	$0.23
Smay Creek Dam	$106	65 mgd	98%	$1.63
Skagit River Pipeline	$270	90 mgd	98%	$3.00

The maximum additional water storage reservoir pool height (and storage volume) was established based on water supply and environmental needs, and geological limits. The highest pool elevation experienced at the time of the Reconnaissance Study was the 1,176.7 foot pool during the December 1975 flood. At that time it was assumed that the existing geological conditions could accommodate a raised pool up to elevation 1,177 feet without major fixes to the geological problem area, particularly seepage through the North Fork channel and the dam's right abutment pervious material. Using the 1,177 foot height, a series of hydrologic flow regimes were conducted to maximize the use of this storage between water supply and low flow augmentation. This hydrologic analysis demonstrated the operability of the project.

3.1.2 Initial Plan Formulation Strategy and Criteria (NED, EQ, RD, OSE)

Under the Reconnaissance Study, the primary project purposes were water supply for M&I and fish enhancement provided by instream low flow augmentation. Under the Preliminary phase of the Feasibility Study the project purpose was expanded, based on a new program authority, to incorporate ecosystem restoration as a project purpose which included: 1) low flow augmentation; 2) a downstream fish passage facility at the dam; and 3) habitat improvements for fish and wildlife.

Agency and public attitudes have increasingly focused on the need to identify and implement restoration projects to protect fish and wildlife resources in the Green River Basin. This local attitude change is reflective of the current state of regional public perception and environmental law. Concurrently with this intense emphasis on environmental protection and restoration, a change in federal policy (Water Resource Development Act 1994) occurred that authorized expansion of the Additional Water Storage Project from single purpose water supply to multipurpose water supply and ecosystem restoration. This policy change significantly affected the scope, process, and features of the HHD AWS Project. Environmental project features now are looked at as restoration opportunities.

3.1.2.1 Planning Objectives

Preliminary objectives formulated for the multi-purpose water supply and ecosystem restoration project were to provide: 1) cost effective and sufficient M&I water supply to meet the water needs of the project sponsor over the life of the project; 2) ecosystem restoration with a goal to establish healthy, naturally reproducing, self-sustaining runs of chinook and coho salmon and steelhead trout in the Upper Green River watershed above HHD; and 3) limited habitat restoration for selected ecosystem functions, processes or structures in the Green River Basin.

Historical anadromous fish runs are outlined in the Fish Passage Technical Committee 1990 Report and were discussed as: fall and spring chinook, coho, and winter-run steelhead. Bull trout/Dolly Varden may have been historically found in the Upper Green but have not been recorded since 1963 (WDFW records). The critical limiting factor to restoring fish runs to the upper Green River is adequate fish passage around Howard Hanson Dam; this includes passage for juveniles and adults. However, maintaining and restoring water quantity and quality to the lower river is also necessary. Functional restoration (hydrology) of the lower river should include increased flows during the low flow period, outflow temperature control during summer, and mimicking natural inflow and outflow during spring refill. The HHD AWS ecosystem restoration features will complement an overall Green River ecosystem restoration plan. A Duwamish/Green River Ecosystem Restoration Plan was initiated in FY 1996.

3.1.2.2 Preliminary Planning Criteria and Assumptions

In formulating a plan to meet the preliminary planning objectives, a number of planning criteria were considered. These criteria were used to screen and evaluate preliminary alternative plans for water supply and restoration measures.

a. Criteria Common to Water Supply and Restoration Measures

(1) Period of Analysis. The period of analysis for this study includes a 50-year period from 2003 to 2053. Construction begins in 2001 and is completed by 2003.

(2) Costs and benefits are in October 1997 prices. Project interest rate is 7 and 1/8 percent.

(3) Water supply and ecosystem restoration measures cannot adversely impact existing project purposes. HHD is designed to provide flood protection and summer water conservation storage to meet minimum instream flows. Water supply refill and storage must occur outside the flood control rule curve and cannot replace or impact reliability (98%) of storing the existing 25,400 ac-ft of conservation storage.

(4) Water supply and restoration measures must be in the Local Sponsor's best interest. The Sponsor's primary interest is in providing for regional water supply at a given rate with a given reliability. Reducing total M&I water supply storage or affecting water quality beyond a given level will preclude the Sponsor's meeting their project objective. Measures that exceed the Sponsor's ability to pay do the same.

(5) Water supply and restoration measures should be cost-effective per unit of output.

(6) The water supply and restoration measures must meet regulatory authorities and be politically acceptable to federal and state resource agencies, tribes, and sponsor. As this is a water supply project subject to federal and state water quality and fish and wildlife protection laws, political acceptance by resource agencies and tribes is critical to approval of the project. Conditional acceptance of phased water storage was granted through the Agency Resolution Process (discussed in Paragraph 3.1.2.3b).

(7) Based on Criteria No. 6, aspects of the project have been negotiated, in particular storage volumes for M&I and flow augmentation water supply.

b. Water Supply Criteria

(1) Value of water supply from Howard Hanson Dam is based on the least-cost water supply alternatives to the HHD AWS Project.

(2) Wells must not be in hydraulic continuity with existing surface water.

(3) Water supply measures must not adversely affect minimum in-stream flows.

(4) Water supply measures must provide 95% reliability and be of the same water quality as HHD.

(5) The water supply measure must not adversely affect water quality conditions – turbidity, dissolved oxygen, temperature, and saltwater intrusion.

(6) Water supply measures must avoid or minimize questions on water rights.

(7) The water supply source must be available, not just speculative.

(8) Water supply measures must avoid any overriding environmental problems.

c. Restoration Criteria

(1) Restoration measures must address overriding environmental problems. Basin analysis and interagency scoping has identified six aquatic habitat-limiting factors or restoration issues that the HHD AWS Project can address. These factors/issues include: 1) connection of the Lower and Upper Basin with improved fish passage at HHD; 2) minimum flows during summer and fall; 3) sediment transport in the mainstem river below HHD; 4) water quality; 5) side channel and floodplain habitat connectivity; and 6) stream habitat.

(2) Fish passage measures must meet design criteria provided by an independent technical committee. An interagency Fish Passage Technical Committee (FPTC) developed a series of biological and hydraulic design criteria (see the 1990, FPTC report entitled *Howard A. Hanson Dam Fish Passage Alternatives for Proposed New Operating Rule Curve*) that must be met to meet the project restoration objective. The objective of all design criteria is to provide downstream fish passage that equals or exceeds 95% survival. This performance measure is the standard applied by federal (NMFS) and state (WDFW) resource agencies to all new downstream fish passage projects.

(3) The restoration measures project area is limited. In accordance with Section 216 and in consideration of the ongoing Green/Duwamish River Basin Restoration Project General Investigation study, the HHD AWS habitat restoration features were primarily limited to areas near the HHD Project, i.e., dam, reservoir, and nearby locations upstream and downstream of the project.

(4) Restoration measures must be consistent with the Ecosystem Restoration Guidance. EC 1105-2-210 states that "Budgetary priority will be given to cases where Corps projects contributed to the degradation of the ecosystem." The EC also states that "The Corps' principal focus in ecosystem restoration will be on those ecological resources and processes that are directly associated with, or directly dependent upon the hydrologic regime of the ecosystem study." Since one purpose of the project is to restore the ecosystem, the project should avoid, wherever possible, requirements for fish and wildlife mitigation.

(5) Restoration measures must fall within the authorized project purposes. HHD is designed to provide flood protection and water conservation storage. Refill of the project

for additional storage for flow augmentation must not impact current flood control capabilities or ability to provide low flow augmentation to meet existing instream flow requirements.

(6) Restoration measures must be consistent with HHD AWS Project objectives. The preliminary project objectives were: 1) to provide a regional water supply at a given rate and given reliability; 2) to restore anadromous fish runs above HHD; and 3) restore selected ecosystem functions, processes or structures impacted by construction of HHD.

(7) Restoration measures must be consistent with the Green/Duwamish Basin Ecosystem Restoration Project. The overall objective of the Basin Restoration Project is to restore ecosystem functions and processes to a less degraded, more natural condition without reducing the level of protection of the flood control works in the lower basin.

(8) Are restoration measures dependent or independent of other projects? Restoration measures that occur above HHD are dependent on providing adequate downstream fish passage.

(9) Restoration measures must be consistent with existing fish and wildlife management. The WDFW is developing a Wild Salmonid Policy emphasizing long-term sustainability of wild salmon and steelhead runs. The MIT and WDFW maintain substantial harvests of salmon and steelhead for subsistence and cultural activities, commercial purposes and sport. The NMFS and USFWS provide recommended and prescribed fish passage and habitat criteria for proposed and listed threatened and endangered species.

(10) Restoration measures must be consistent with Howard Hanson Dam Master Plan objectives.

3.1.2.3 Study Advisory Committees

a. Fish Passage Technical Committee (FPTC). In 1989, a five-person expert committee was created to assist in formulating concepts, developing and evaluating alternatives, and selecting a final design for improving fish passage through the anticipated larger and deeper HHD reservoir. The five members were selected by the resource agencies, tribe, City of Tacoma, and Corps representatives as having the experience and technical expertise in dealing with fish passageways. Together, this group had over 150 years of research, design and evaluation experience. This FPTC included Ken Bates of the WDFW, Steve Rainey of the NMFS, Ed Donahue of Fish Pro, Inc., Phil Hilgert of Beak (now with R2 Resource Consultants), and Milo Bell, retired Corps researcher.

In 1990, the FPTC produced the report entitled *Howard A. Hanson Dam Fish Passage Alternatives for Proposed New Operating Rule Curve*. This report recommended studies and methodologies for evaluating fish passage alternatives and provided initial fish passage design criteria. In 1992 the FPTC was reactivated to assist in developing, evaluating, and selecting a feasibility level fish passage concept for the proposed project. The Corps took the lead in preparing design concepts of possible fish passage facilities under the guidance of the FPTC. During this process, resource agencies and tribe representatives participated as observers and participants to the interaction between the Corps designers and FPTC. In the winter of 1996, the FPTC provided final input in evaluating and selecting among the final fish passage alternatives.

Besides consideration of passage alternatives, the FPTC report also provided a framework of baseline studies necessary to assess the existing state of downstream fish passage at HHD as well as provide insights into potential changes in passage with the HHD AWS Project. These recommended fish studies resulted in a series of Baseline interagency monitoring studies performed by the USFWS, WDFW, the MIT, the Corps and the City of Tacoma. These studies have provided additional guidance in development of design criteria and evaluation of the fish passage alternatives. These studies were initiated in 1990 and will continue through the year 2000.

b. Agency Resolution Process. During the fall of 1995 and winter of 1996, the Seattle District Corps of Engineers and the City of Tacoma convened a series of resource agency meetings between technical and policy level appointees to discuss outstanding issues and concerns related to the current state of the HHD AWS Project feasibility study. An outgrowth of these series of meetings (Agency Resolution Process) was the Corps and Tacoma policy decision to propose a phased implementation of the HHD AWS Project. This phased approach was to 1) provide time to study further issues identified by the Agency Resolution Process that were not identified during earlier agency meetings in the feasibility study; and 2) to provide a means (adaptive management) to isolate and address specific management issues related to the HHD AWS Project.

c. Howard Hanson Dam Working Group. Since the inception of the HHD AWS Project, a core group of agency (NMFS, WDFW, WDOE) and tribal (MIT) biologists and policy representatives have worked with the Corps and the City of Tacoma in development and refinement of water supply, restoration and mitigation alternatives. Throughout the entire reconnaissance and feasibility process these representatives have interacted directly with the Corps and Tacoma in shaping the scale, components and details of each of the HHD AWS features. Coordination and interactions have occurred in conjunction with the FPTC, the Agency Resolution Process, and in numerous meetings/communications before, during, and after these two formal meeting formats. In particular, the Working Group was the committee responsible for selecting the final suite of project objectives and features.

d. Green River Fisheries Coordination Committee. Many of the members of the HHD Working Group serve in a dual capacity – working under the AWS Project as well as cooperating in operation of the existing project. Under the existing project, agency and tribal members have direct input into the daily operation of the dam, in providing resource protection, through the Green River Fisheries Coordination Committee (GRFCC, see HHD Section 1135 PMR). This dual capacity has resulted in additional input to the HHD AWS Project from the long years of experience Working Group members bring to the table. Specifically, members have voiced concerns about the maximum water capacity diversion (for water supply and flow augmentation) the Green River can sustain without long-term impacts. Under existing storage, recent years have seen major impacts to downstream fish resources. This concern was conceptualized by changes in baseline monitoring, HHD AWS Project objectives and features before, during and after the Agency Resolution Process. The formal change resulted in adoption of the Adaptive Management Plan with Phased Implementation of water storage.

e. **Green-Duwamish River Ecosystem Restoration Teams.** Under a separate Section 216 Feasibility Study, the Seattle District and King County performed a reconnaissance level basin study for ecosystem restoration opportunities in the Green River (Corps PMR 1997). A multi-agency panel participated in the formulation of habitat restoration measures with representatives from the USFWS, USFS, MIT, Suquamish Indian Tribe, WDFW, Trout Unlimited, City of Tacoma, Plum Creek Timber, WDNR, the Green River Alliance, the Duwamish Coalition, King County and the Corps.

Scientists from respective resource agencies participated in a watershed restoration team. Studies performed by team members included: 1) a Basin Analysis of significant ecosystem changes; and 2) a Limiting Factors Analysis to identify significant changes in ecosystem functions. These studies identified specific problems in the Basin and potential strategies to restore specific ecosystem functions or structures. The problems and restoration strategies identified were used to further expand the scope of mitigation and restoration measures considered and developed under the HHD AWS Project.

f. **Muckleshoot Indian Tribe.** The MIT has been involved with the HHD AWS Project from its inception. They are represented by staff biologists or planners on all of the above study committees. They have interests and policies that are unique to all other study partners. During the Agency Resolution Process, they were the one party not granting conditional acceptance to the project (see Paragraph 3.1.2.3b).

g. **Wildlife Technical Working Group.** The working group was established early in 1990 to address various wildlife impact and mitigation issues. The participants included biologists from the WDFW, the USFWS, the Muckleshoot Indian Tribe, the USFS, City of Tacoma Public Utilities, and the Corps. On occasion, contractors representing Tacoma and/or the Corps also participated in the meetings. The working group was particularly instructive with regard to identification of elk impacts. The mitigation plan that was developed was largely driven by the advice of this working group. The working group met regularly for five years. In addition to the mitigation plan, the working group also was instrumental in developing an elk and deer population monitoring program for the watershed, which will provide important information regarding the distribution of these species relative to the reservoir, and compared to the watershed as a whole. The monitoring is expected to continue beyond implementation of the additional water storage project, and it will be at least one measure of the success of the mitigation plan in providing viable habitat for elk.

3.1.3 Preliminary Alternatives Considered

Under preliminary scoping for the Feasibility Study, a series of conceptual categories of water supply and restoration measures were developed in response to the need for regional water supply and ecosystem restoration. Restoration measures include potential mitigation measures but are not broken out into the latter category in the preliminary formulation. Individual supply and restoration measures were identified within each category. These categories and measures of water supply and restoration were:

EXISTING CONDITION (Alternative 1, No Action)

M&I WATER SUPPLY:

- Additional storage at Howard Hanson Dam (Alternative 2)
- Wells (Alternative 3)
- Demand management (Alternative 4)
- Transfers from Other Systems (Alternative 5)
- New Storage and/or Diversion Facilities (Alternative 6)

INSTREAM FLOW (Alternative 7)

- Low Flow Augmentation (Alternative 7A)
- Mimic Natural Hydrology (Alternative 7B)

WATER QUALITY (Alternative 8)

- Dam Temperature Control and Water Quality Improvements <u>with</u> Water Supply (Alternative 8A)
- Dam Temperature Control <u>without</u> Water Supply (Alternative 8B)

FISH PASSAGE (Alternative 9)

- Downstream Fish Passage at the Dam <u>with</u> Water Supply (Alternative 9A)
- Downstream Fish Passage at the Dam <u>without</u> Water Supply (Alternative 9B)
- Upstream Fish Passage at the Dam <u>with</u> Water Supply (Alternative 9C)
- Upstream Fish Passage at the Dam <u>without</u> Water Supply (Alternative 9D)
- Upper Reservoir Downstream Fish Passage <u>with</u> Water Supply (Alternative 9E)
- Remove Existing Dam (Alternative 9F)
- Trap and Haul Facility at Tacoma Diversion Dam (Alternative 9G)
- Eliminate Existing Conservation Pool (Alternative 9H)

FISH CULTURE (Alternative 10)

- Increase Existing Hatchery Rearing (Alternative 10A)
- Permanent Supplementation Programs (Alternative 10B)
- Temporary Supplementation Programs (Alternative 10C)

HABITAT (Alternative 11)

- Side-channel Improvements (Alternative 11A)
- Stream and River Habitat Improvements (Alternative 11B)
- Reservoir Improvements (Alternative 11C)
- Terrestrial Habitat Improvements (Alternative 11D)

3.1.3.1 Water Supply Alternatives

Following are water supply alternatives considered.

3.1.3.2 Alternative 2 – Modification of Howard Hanson Dam

a. Alternative 2A – Additional Storage With Fish Passage Mitigation. This alternative was the evaluated alternative in the 1989 Reconnaissance study and consists of providing an additional 37,000 ac-ft of storage for water supply plus increasing the low flow augmentation from 110 cfs to 200 cfs. Summer pool elevation would go from the existing project summer conservation storage at elevation 1,141 feet to elevation 1,177 – a 36-foot increase or 37,000 ac-ft of additional storage. The additional storage would provide 65 mgd at 98% reliability plus it would produce an additional 90 cfs of low flow augmentation at 75% reliability. The reliability of the existing low flow of 110 cfs would remain at 98%. Mitigation would be provided using a fish passage facility.

b. Alternative 2B – Additional Storage Without Fish Passage. A project consisting of water supply and low flow augmentation without a fish passage facility for mitigation was also considered. The inlet elevation of the current by-pass pipe is at elevation 1,069 and the proposed pool elevation for water supply and low flow augmentation would be to elevation 1,177. It is difficult for juvenile salmon and steelhead to sound deep without a high volume release flow and as such they will find it very difficult to successfully migrate from the reservoir to the river downstream of the dam. As a result, most fish will remain trapped in the reservoir and fewer fish will be able to migrate to the ocean. In order to mitigate these impacts to salmon and steelhead, a fish passage facility capable of successfully passing juvenile salmon and steelhead is required. As a result, an alternative without a fish passage facility for mitigation was not considered practical or acceptable and was eliminated from further evaluation.

3.1.3.3 Alternative 3 – Wells

a. Alternative 3a – Lower Puyallup Lowlands. An evaluation of well potential in the lower Puyallup lowlands indicates that from 10-20 mgd of supply could be available. Each well would be between 300 and 600 feet deep and would produce about 1.5 mgd. These supplies have been found to contain iron and manganese which would require treatment. In addition, these well are at risk for salt water intrusion. The Washington Department of Ecology had indicated that continuity with surface water in the Puyallup River is likely, minimum instream flows have been established for the Puyallup River and the WDOE would not approve withdrawal of water from wells in hydraulic continuity with the Puyallup River during periods of low instream flow in the river. Since this source would not be available during the critical summer period, it is not viewed as a viable alternative.

b. Alternative 3b – Lower Puyallup Uplands. This potential source of water supply is estimated to be capable of 10-20 mgd. Water quality appears to be acceptable for use as a public water supply without additional treatment other than chlorinating. Each well would be about 300 feet deep with production of approximately 1.5 mgd per well. The aquifer also appears to be in hydraulic continuity with either Clarks Creek, a tributary to the Puyallup River or the Puyallup River directly. It is therefore subject to the same use restrictions as the lower Puyallup lowlands discussed in Alternative 3a above and has been eliminated from further consideration.

c. Alternative 3c – Clover and/or Chamber Creek. The South Tacoma Lakewood area is estimated to be capable of producing 15-30 mgd. Water quality problems do exist due to industrial contamination in the Fort Lewis area. Wells would be 400-500 feet deep and salt water intrusion is possible. Utilization of water from this source is included in the Pierce County Coordinated Water System Plan and the communities of Lakewood and Parkland currently rely on water from this source. Based on current usage of the aquifer and its inclusion as a key source under the Coordinated Water System Plan for Pierce County, this alternative was eliminated from further evaluation.

d. Alternative 3d – North Bend Aquifer. For several reasons the availability of a North Bend Aquifer is speculative at this time. It is not certain how much water is available and since this aquifer is in the headwaters of the Snoqualmie River it would most likely be in hydraulic continuity with that river. In addition, the North Bend aquifer is far closer to the east side communities of Issaquah, Bellevue, Redmond, Kirkland and even Renton than it is to Tacoma. Given the very high cost of a pipeline necessary to move the water from the North Bend area to Tacoma, it would be much more practical for this source to be used to serve those communities rather than Tacoma. Due to the uncertainties surrounding the availability and practicality of this water supply source, it was eliminated from further evaluation.

e. Alternative 3e – Tide Flats. Based on a study performed by Hart Crowser it is estimated that the aquifer below the Tide Flats area of Tacoma is capable of producing an additional 5 mgd during the summer and 4-day peak periods. Construction would consist of installing two additional wells capable of producing 2.5 mgd each and 2,000 feet of transmission pipeline needed to convey this water to Tacoma's distribution system.

f. Alternative 3f – Lone Star Sand and Gravel. This property contains the rights to develop an additional 9.3 mgd for used during the summer and 4-day peak periods. Construction would consist of installing a well, approximately 15,000 feet of transmission pipeline, and retrofitting a pump station to achieve an hydraulic gradient of 576 feet.

g. Alternative 3g – South Tacoma Aquifer. The South Tacoma Aquifer system has been an important source of water to Tacoma Water for over 90 years. There are currently 13 production wells which provide about 45 mgd. Based on assessments by Tacoma Water the aquifer could produce and additional 29 mgd during the summer months. Construction would consist of installing additional wells and several new pumps.

3.1.3.4 Alternative 4 – Conservation/Demand Management and Industrial Reuse Alternatives

a. Conservation/Demand Management. This measure consists of implementing the most cost effective conservation/demand management measures from a list of all practical and available conservation measures. Tacoma Water Division analyzed numerous conservation measures to add to their existing conservation program based on estimated water savings and the cost to implement the measure. The measures were divided into four user classes: single family, multi-family, commercial/industrial, and public facilities. Three methods of delivery were evaluated for the single and multi-family user classes – direct installation, hang bag delivery, and direct mail. Each conservation measure was evaluated based on product useful life, cost per device, administrative cost, installation cost, number of units per customer, average water savings, and penetration and retention rates.

b. Industrial Reuse. Two industrial water reuse projects were originally conceived and presented as viable water savings measures in Tacoma Water Division's 1994 Water Reuse Feasibility Study. The first project would use reclaimed water from the county-owned treatment plant to provide up to 5 mgd of water to a Pierce County industry. This first project is scheduled to be implemented and is included as part of the without-project condition as a source of water. The second project consists of providing up to 10 mgd from a city-owned wastewater treatment plant to a paper product industry. Construction for this measure consists of 4,000 feet of 30-inch pipeline needed to deliver the reclaimed water to the identified industry, a water filtration facility, and disinfection and storage facilities at the treatment plant.

3.1.3.5 Alternative 5 – Transfers From Other Systems

a. Alternative 5A – Intertie With Seattle. This measure consists of constructing a water supply pipeline which will connect Seattle and Tacoma. The pipeline will be sized to pass an estimated 40 mgd. At the time this alternative was first conceived it was considered a source of water for Tacoma, with Tacoma purchasing water from Seattle. Further analysis has indicated that while a water supply intertie between Tacoma and Seattle makes sense for sharing of resources in the region and an intertie between Tacoma and Seattle is currently part of the expected without-project condition, Tacoma will be supplying water to Seattle rather than vice versa. As such, this alternative was eliminated from further evaluation.

b. Alternative 5B – Purchase From Auburn. Auburn's supply of water is from wells in the area of the Green River. This alternative would consists of installing additional wells plus constructing a pipeline from the wells. The location of Auburn in the Green River Valley makes it highly likely that hydraulic continuity can be established between the City of Auburn well field and the Green River. Since the Green River is closed to further withdrawal of water during the summer due to low flows, this alternative was eliminated as a viable alternative.

3.1.3.6 Alternative 6 – New Storage and/or Diversion Facilities

a. Alternative 6A – Green River Basin (Smay Creek). Using Smay Creek as a source of supply during the summer would require major dam construction similar to constructing a new Howard Hanson Dam. The environmental problems involved in constructing a new dam would be extensive and so difficult to overcome this alternative was rejected from further consideration as a viable water supply alternative.

b. Alternative 6B – Puyallup River Basin. Development of a new source of M&I water supply from the Puyallup River for use during the summer months would require the construction of a new dam. Minimum instream flows have been established on this river and river water is currently not available above those flows for some periods of each summer. In addition, given the environmental problems associated with construction of any new dam as well as tribal concerns and conflicts associated with a dam on the Puyallup River, construction of this alternative was rejected from further evaluation as a viable water supply alternative.

c. Alternative 6C – Nisqually River Basin. A dam on the Nisqually River would suffer from the same limitations as the Puyallup River. In addition, a major new water supply pipeline would be required to bring the water from the Nisqually River to Tacoma making this a very expensive source of water. Given the limitations of this alternative, it was eliminated from further evaluation.

d. Alternative 6D – Skagit River Basin. This alternative was mentioned in the Reconnaissance Report as being a potential alternative to Howard Hanson Dam. This alternative consists of constructing a new dam on the Skagit River as well as a new pipeline to move the water from the Skagit River to Tacoma. Due to the high cost of this alternative it was not used in the Reconnaissance Report to quantify water supply benefits. Because of environmental problems associated with the construction of any new dam in this region as well as the very high cost of this alternative, it was eliminated from further consideration as an alternative.

3.1.3.7 Alternative 7 – Low Flow Augmentation Alternatives:

a. Alternative 7A – Low Flow Augmentation. This alternative for minimum instream flow was formulated from the most viable quantities and duration of flow from previous scenarios of additional water storage. The minimum instream flow at Palmer would be 300 cfs from March through mid-May, then 200 cfs until mid-September, then increase to 400 cfs from mid-September through the end of October. The 300 cfs quantity was designed to not jeopardize the ability to refill the required storage. The step-down from 300 to 200 cfs was designed to be closely parallel to the water supply diversion so it has a reliability close to 90%. In some drought years, the change from 300 to 200 cfs will occur prior to mid-May. The additional increment of 200 cfs for 1½ months in the fall (to 400 cfs) was treated as a separate block of water. This was a relatively large flow so it was designed to coincide with the arrival of fall precipitation. Modeling shows that the 1½ month duration of 400 cfs in the fall could be accomplished in 77% of the years. In most of the shortage years, the flow augmentation could be delivered to a lower quantity, such as 300 or 250 cfs, or a shorter duration of 400 cfs, such as for one month or a half month. After October, the minimum instream flow returns to 200 cfs. When shortages at the 200 cfs level occurred, they were usually in mid to late November. This alternative has the effect of delaying a block of runoff water from the snowmelt season and returning it to the river in smaller amounts later in the summertime.

b. Alternative 7B – Mimic Natural Hydrology. This alternative uses the same allocations of water storage as the Alternative 7A, but was careful to store and deliver the water in a manner that mimicked the natural runoff hydrology of the river. Instead of using a base flow for refill, the outflow was varied by imposing a refill rate on storage accumulation. A constant storage accumulation rate would cause the outflow to vary with the same pattern as the inflow. The maximum refill rates are shown in the table below. Refill of the existing storage has higher priority and follows the 98% rule curve.

MAXIMUM REFILL RATE FOR ADDITIONAL STORAGE ACCUMULATION

Dates for varying rate	Storage accumulation rate
15 Feb. to 15 April	750 cfs or 1,500 acre-feet/day
16 April to 30 April	300 cfs or 600 acre-feet/day
1 May to 31 May	200 cfs or 400 acre-feet/day

Alternative 7A defined the river condition for low flows, but didn't have any criteria for river flow under average and wet conditions. Alternative 7B included a minimum base flow throughout the refill period in addition to a varying target flow that mimicked a 1-foot stage decline from May 1 through June 30 to protect incubating steelhead eggs. From March 1 to April 30the base flow varied between 900 cfs, 750 cfs, and 575 cfs depending on weather conditions of wet, average, or dry. Likewise, the ending flow from July 1 to July 15 was ramped from the base flow down to 400 cfs for wet and average conditions and 250 cfs for dry conditions. Freshets are scheduled for delivery downstream when storage allows. A freshet is a flow rate of 2,500 cfs at Auburn sustained for a duration of 38 hours. Four freshets are scheduled near the dates of April 1, April 15, May 1 and May 15. If the weather is considered dry, the freshet is cut in half to 1,250 cfs. One freshet near September 1 is scheduled for 700 under all weather conditions. Alternative 7B pays close attention to the instream flows in the MIT/Tacoma Agreement that was not in effect during the formulation of Alternative 7A.

3.1.3.8 Alternative 8 – Water Quality Alternatives

a. Alternative 8A – Dam Temperature Control and Water Quality Improvements in the Lower River with Water Supply. Improve temperature releases from the dam (mimic inflow temperature regime) and other water quality outputs (dissolved oxygen, nutrient dilution from nonpoint sources, algal growth, organics, and saltwater wedge). This measure requires two features: structural improvement of the dam outlet for temperature control and low flow augmentation to increase summer flows in the lower river.

Any HHD downstream fish passage alternative that incorporates a surface withdrawal feature can be used to control dam outflow temperature. The combined flow release from a surface outlet and existing deepwater outlets would blend warmer surface water with cooler deep-water areas. In the majority of years, blended releases from HHD would improve instream temperatures up to 6 miles downstream of the dam. In addition to direct temperature control below HHD, the additional storage for low flow augmentation should help reduce maximum instream temperatures, dilute nonpoint source pollution, and increase-dissolved oxygen in the lower Green River. In the Duwamish River, the additional summer flow releases could also increase the amount of available freshwater estuary habitat. This alternative was carried forward for further evaluation.

b. Alternative 8B – Dam Temperature Control without Water Supply. Same as Alternative 8A but without additional storage of water for M&I and flow augmentation. This alternative was dropped for further consideration as it does not meet the project objective of providing M&I water supply..

3.1.3.9 Alternative 9 – Fish Passage Alternatives:

Any single downstream fish passage measure is dependent on upstream fish passage and vice versa. That is, as restoration measures, downstream fish passage for juvenile salmon and steelhead is inadequate without upstream fish passage. Therefore, downstream fish passage measures through or around HHD must be accompanied by upstream passage for adults around the Tacoma Diversion Dam and HHD to achieve restoration of natural, self-sustaining fish runs.

a. Alternative 9A – Downstream Fish Passage at the Dam with Water Supply. The 221 square miles of watershed above HHD potentially can produce over 1 million juvenile salmon and steelhead smolts. Water withdrawals through the existing deepwater outlets at HHD result in entrapment of most outmigrating juvenile salmon and steelhead. Additional storage of 32, 000 ac-ft will increase maximum dam outlet depths to 107-142 feet. Baseline studies at HHD have shown that up to 97% of the variation in numbers of juvenile migrants (coho salmon smolts) passing HHD can be explained by changes in outflow volume and pool depth. The higher the outflow and shallower the outlet depth the higher the passage rate (r^2=0.97) (Dilley and Wunderlich 1993). A longer term adult survival study confirmed these dam passage studies. For tagged coho salmon smolts planted above HHD Reservoir, almost 100% of adult survival can be explained by differences in dam outflow and outlet depth (r^2=0.99). The highest adult survival rate (6%) occurred for outflow volumes approaching the May 50-percent (median) exceedance flow (1,400 cfs) (see Section 2E, Part 1, Appendix F).

Results from baseline studies at HHD and other high head dams show that successful passage of these spring outmigrants requires a near surface water withdrawal (within the upper 5-30 feet of the water column) that provides sufficient attraction flow: studies at various projects have been inconclusive in identifying a critical threshold flow volume (see discussion in Section 2D, Part 1, Appendix F). Such a facility requires that the surface outlet rise and fall with the filling and drawdown of the reservoir covering a vertical elevation range of 107 feet (1,070 foot pool elevation to 1,177 foot elevation). The FPTC initially recommended that the facility draw and screen up to the 10% exceedance flow during the major juvenile outmigration period in April and May (range from 1,800-2,500 cfs baseline). Later refinements suggested that the median daily flow (50% exceedance, 1,200-1,600 cfs) was the maximum volume any facility could screen and was recommended as the critical design flow for any design alternative considered. Either a multi-port intake, a floating surface screen or a screen with a fish lock would be required to collect and pass these juvenile salmonids downstream through the dam. This alternative was carried forward for further development and evaluation of design alternatives.

b. Alternative 9B – Downstream Fish Passage at the Dam without Water Supply. Existing conservation storage of 25,400 to 30,400 ac-ft results in maximum outlet depths of 77 to 112 feet. Successful passage of juvenile outmigrants will require the surface outlet to rise and fall over a vertical elevation range of 77 feet (1,070 foot pool elevation to 1,147 foot elevation). As described in Alternative 9A, similar downstream passage means would be used. This alternative was eliminated because it did not meet the project objective to provide for a regional water supply and would require the HHD AWS Project to become a single-purpose restoration project.

c. Alternative 9C – Upper Reservoir Downstream Fish Passage with Water Supply. Instead of improving downstream fish passage at the dam a new collection facility would be built upstream of the dam and/or reservoir on one or more major reservoir tributaries. This concept addresses concerns that juvenile salmon and steelhead cannot migrate successfully through the enlarged reservoir with additional storage (5.7 miles long). A similar concept has been applied on the Cowlitz River in southwestern Washington and has been proposed for use in retrofitting existing Corps projects in Oregon. Project features would include one or more collection locations, use of a barrier dam and screening facility, and a means to transport fish such as by truck or in a fish canal. This alternative was carried forward for consideration in combination with Alternative 9A, upstream collection with a dam passage facility.

d. Alternative 9D – Upstream Fish Passage at the Dam with Water Supply. The 221 square miles of watershed above HHD potentially can support from 15,000 to 35,000 adult salmon and steelhead (pre-harvest). In their upstream migration, two migration barriers, the Tacoma Diversion Dam and HHD block these large salmon and steelhead. If successful passage were provided at the Diversion Dam (fish ladder around the dam), HHD would be the next barrier for the adults to traverse. Successful passage of the majority of adults <u>through</u> HHD would require a means to raise the adults (such as a fish lock) from the river below the dam, 1,010 foot elevation, to areas above the dam, 1,070-1,177 foot elevation (low pool to the height of the HHD AWS Project pool). Passage around HHD would require either a fish ladder or an adult fish trap with truck and haul for release above the dam. A fish lock for downstream fish passage (Alternative 9A) could have a dual purpose and provide for upstream adult fish passage. This alternative was eliminated as a single design alternative but was carried forward as a potential dual application of Alternative 9A, fish lock for downstream and upstream fish passage.

e. Alternative 9E – Upstream Fish Passage at the Dam without Water Supply. With less reservoir storage, the vertical elevation of the reservoir pool is lower and under certain passage concepts (fish lock) could result in less passage constraints to providing adult passage. Successful passage of the majority of adults would require dealing with a vertical elevation from 1,010 feet (river level) to 1,147 feet (existing full pool). Similar transport means would be used as described in Alternative 9D,. This alternative was eliminated for the same reasons as Alternative 9B; it does not meet project objective to provide for water supply.

f. Alternative 9F – Remove Existing Dam To provide near natural riverine conditions and total restoration of fish passage (both downstream and upstream), removal of HHD would be required. Either the dam would be removed or a portion breached to recreate the existing Green River channel for unimpeded passage. This alternative was eliminated, as it does not meet HHD AWS Project objectives and would violate existing project purposes for flood control and water conservation (meeting minimum instream flows).

g. Alternative 9G – Trap and Haul Facility at the Tacoma Diversion Dam. As a concept, this alternative is currently being used in several western Washington basins. The Tacoma Diversion Dam is the first complete barrier adult salmon would face in migrating upstream to the Headwaters watershed. A temporary fish ladder and fish trap has been operated at the Diversion since 1991. Since that time, adult steelhead have been captured, trucked and released above the reservoir. Adult salmon are projected to be released into the Upper Watershed beginning in the fall of 2003 or 2004 when the downstream fish passage facility is operational: although an earlier pilot project with limited adult releases is possible to prepare for the planned larger-scale releases in 2004. The Seattle District Corps has built and operated trap and haul facilities at two western Washington projects, Wynoochee and Mud Mountain dam. This measure would have the Corps build and operate a permanent facility either at the Tacoma Dam or at a new location upstream or downstream of the diversion.

Under terms of a mitigation agreement between the City of Tacoma and the MIT, Tacoma is committed to building a permanent fish ladder, collection ponds, and transportation facility at their Diversion Dam. This facility will provide a separate route into a collection facility with holding ponds where adults can be separated for transport either to a supplementation facility or for release above the HHD reservoir. Because of the mitigation agreement providing upstream fish passage, through Tacoma's Diversion Dam and around HHD, this alternative was not carried forward for further evaluation.

h. Alternative 9H – Eliminate Permanent Pool. This alternative considers elimination of the existing conservation storage pool (25,400 ac-ft) to create a "run of the river" project with either no pool or a very minimal pool (turbidity control). Elimination of the conservation pool would theoretically eliminate most barriers to downstream or upstream fish passage. Juvenile fish migrating downstream would have a near-surface outlet while adult salmon and steelhead would have to swim upstream through the existing 900-foot-long tunnel with a modification to the existing gates (or a new tunnel would be required). This alternative was eliminated because it does not meet HHD AWS Project objective of providing M&I water supply and would violate the existing project purpose of meeting minimum instream flows.

3.1.3.10 Alternative 10 – Fish Culture Alternatives

a. Alternative 10A – Increase Existing Hatchery Production. Hatcheries have been used for more than 100 years in attempts to mitigate the effects of human activities on salmon and to replace declining and lost natural populations. In addition they have been used to expand upon natural production to provide additional harvest opportunities. As a result, a major proportion of salmon populations in the Green River now consists of hatchery fish. The purpose of this measure would be to expand existing hatchery programs to provide replacement of lost production in lieu of restoring Upper Green River salmon and steelhead runs, and to mitigate for any adverse impacts to Lower Green River fish from additional storage for water supply. Project features could include 1) expansion of existing hatchery production from Lower Green River facilities; and 2) expansion of the MIT Fish Restoration Facility. This alternative was eliminated for further consideration as does not meet project objective of restoring fish runs above HHD, it is unacceptable to state and federal resource agencies, and it is not consistent with ecosystem restoration guidance or the Basin Restoration Project.

b. Alternative 10B – Permanent Supplementation Programs. Unlike traditional hatchery production where natural production is replaced or enhanced, supplementation is meant to assist in the recovery or maintenance of salmon populations. Integrated planning, management, and operation would be used to minimize impacts to existing natural production and to maximize recovery of populations. This measure would utilize project features constructed to "naturalize" the rearing of juvenile hatchery fish for the life of the HHD AWS Project. Specific examples include 1) creation, maintenance, and stocking of permanent natural rearing facilities such as ponds; and 2) expansion of the MIT Fish Restoration Facility that incorporates natural elements in facility design such as "artificial streams" with low densities of rearing fish. This alternative was eliminated for further consideration as it does not meet project objective of restoring fish runs above HHD, it is not consistent with ecosystem restoration guidance or the Basin Restoration Project, and the City of Tacoma has already committed to building and operating a supplementation program for the Upper Green through the Fish Restoration Facility.

c. **Alternative 10C – Temporary Supplementation Programs.** Unlike current hatchery practices in the Green River, this measure would provide a short-term rearing program to provide additional production of salmon and steelhead to "jump-start" the recovery and restoration of salmon and steelhead to the Upper Green River. This would be a short-term measure and would be meant to complement (not replace) the natural rebuilding of the runs. Project features could include: 1) creation of additional habitat locations where hatchery reared juveniles could be planted for natural rearing; 2) short-term increases in outplanting of smolt ready juveniles; and 3) development of remote site facilities such as egg boxes. This alternative is not carried forward as a distinct measure but will be incorporated into other habitat improvement measures. As noted in Alternative 10B, the Fish Restoration Facility will be the maintained as an existing supplementation program, however additional locations for planting of naturally reared fish could be created.

3.1.3.11 Alternative 11 – Habitat Mitigation/Restoration Alternatives

a. Alternative 11A – Side Channel Improvements. Levees, channel degradation, and controlled flows from HHD have reduced the interaction between floodplains and stream channels in the basin. Many areas of the floodplain have been converted to other uses. This has dramatically reduced the interchange of water and materials between the aquatic and terrestrial systems and has isolated floodplain wetlands. The Basin Analysis estimates that only 10% of the original Duwamish/Green floodplain is still connected to the mainstem and is undeveloped. Of the remaining side channel habitat, the HHD AWS Project could seasonally dewater an additional 8.4 acres. This measure would maintain existing levels of side channel habitat (mitigation) and provide limited improvement (restoration). Project features could include 1) removal of levees to reconnect the floodplain to the main channel; 2) reconnection of relic side channels by lowering the channel inlet or by raising the mainstem water surface; and 3) improve existing side channel by similar means as in (2) or by other improvements such as large wood placement, excavation of new channel areas, gravel placement and riparian plantings. Project areas considered would range from below the Tacoma Diversion Dam (RM 61) to the lower Middle Green River (RM 34). This alternative was carried forward for further development and evaluation.

b. Alternative 11B – Stream and River Improvements.

(1) Alternative 11B1 – Tributary Stream Habitat Restoration. The construction of HHD and filling of the existing conservation pool has resulted in the elimination or degradation of over 8 miles of river and stream habitat. The HHD AWS Project would degrade another 2 to 3 miles of stream habitat above HHD. This habitat represented(s) some of the most productive salmon and steelhead habitat in the Upper Green River. Since dam construction much of the Upper Green River has been logged, with associated degradation of stream habitat, above HHD. While this habitat is degraded from pre-management conditions, it is still considered higher quality habitat or has much greater recovery potential than much of the Lower Green River stream habitat. This alternative will consider various structural and management means to improve the function of existing habitat in streams above HHD. Project features could include 1) replacing culverts that block the movement of juvenile and adult fish; 2) placement of large wood (logs and root wads) and boulders to provide habitat complexity; and 3) use of plantings and thinning to improve riparian habitat along stream corridors. Individual habitat alternatives were developed in plan formulation refinement. This alternative was carried forward for further development and evaluation for areas above the dam.

(2) Alternative 11B2 – Gravel Placement. The disruption of sediment transport from the Upper Green River due to the interception of almost all coarse sediment and gravel by construction and operation of HHD may be causing fundamental changes in the lower mainstem channel and associated habitats. One concern is the elimination of spawning gravels for salmon and steelhead in areas downstream of HHD. Virtual elimination of peak flows (>12,000 cfs at Auburn) and increases in moderate flows (4-12,000 cfs) appear to be causing this condition to continue farther downstream. Overall the channel is down cutting, causing a resultant channel instability which is aggravated by losses of riparian vegetation. This alternative would provide for annual placement of gravel-sized material in areas downstream of the Tacoma Diversion Dam. So that flood protection would not be impacted, total sediment volumes considered would be less than pre-dam natural sediment transport rates. This alternative was carried forward for further development and evaluation.

(3) Alternative 11B3 – Truck and Haul of Large Wood. Just as HHD reservoir stores water and traps sediment, large wood (trees and root wads) is washed into the reservoir and collects in stream channels or on floodplain terraces. This wood would normally be transported further downstream or would stay in place -- providing a variety of hydrologic and biologic functions. Until recently, under project operations and maintenance, the wood was annually collected, stored, and burned. This alternative would involve: 1) collection of the large wood; 2) transport of the wood by truck to below Tacoma Diversion Dam; and 3) placement of the wood in the active channel without anchors so high flows can carry it downstream. This type of collection and replacement of wood below a storage dam is being implemented at least one other western Washington project. This alternative was carried forward for further evaluation.

(4) Alternative 11B4 – Large Woody Debris Management for Fish and Wildlife Habitat. This alternative would utilize large woody debris (LWD), collected during HHD operations, for fish and wildlife habitat restoration projects throughout the basin. This operational measure has been implemented under the existing operations and maintenance program for the dam. The HHD AWS Project would continue this practice. Logs would be set-aside by HHD staff in debris clearing areas for eventual pick-up and transport by resource agency or non-profit groups for use in habitat restoration. This alternative was carried forward for further development and evaluation.

Large woody debris would also be placed in terrestrial habitats to provide additional food and denning places for terrestrial mammals and birds.

c. Alternative 11C – Reservoir Improvements. Improvements to instream habitat within the reservoir are described in Alternative 11B1.

(1) Alternative 11C1 – Create Sub-Impoundments Around Reservoir. This measure would provide wetlands and/or ponds along the reservoir shore for wildlife and fish utilization. Sub-impoundments are designed to flood during high reservoir pool elevations and maintain surface water by containment during reservoir drawdown. Sub-impoundments offer an increase in habitat by trapping and holding water for a longer period of time and by making open water habitat for fish, waterfowl, and amphibians available for longer periods after reservoir drawdown. This alternative was carried forward for further development and evaluation.

(2) Alternative 11C2 – Place Water Tolerant Plants in the Inundation Zone. Under the HHD AWS Project pool raise, increasing the HHD reservoir pool from 1,147 foot elevation to 1,177 foot elevation will inundate 478 acres of terrestrial habitat and 17 acres of stream habitat. This measure is targeted to: (1) maintain plant communities in areas that will be inundated with the additional storage pool; 2) improve and diversify sparsely vegetated emergent plant communities; 3) facilitate transitions from current native plant communities to plant community types that are more tolerant of inundation; 4) stabilize the reservoir inundation zone and reduce wave-action-related erosion along the shoreline; and 5) maintain and restore fish and wildlife habitat. Water-tolerant plants selected must survive short and long periods of inundation, as well as a shortened growing season. Plant types could include: Columbia sedge, inflated sedge, Kellogg sedge, Lyngbye's sedge, bald cypress, Oregon ash, and Pacific willow. Similar aspects of this measure will be implemented in the year 1999 for areas below pool elevation 1,147 feet under the HHD Section 1135 Project. This alternative was carried forward for further development and evaluation.

(3) Alternative 11C3 – Leave Inundated Trees in the Enlarged Storage Pool. In the new inundation zone (1,147 to 1,177 foot elevations) retain existing standing timber to partially maintain wildlife, riparian and instream habitat. As discussed in Alternative 11B1 and 11C2, miles of stream habitat and hundreds of acres of terrestrial habitat will be inundated with an enlarged pool. This habitat will be degraded and much of it will become functionally unusable by target species. Traditionally, the Corps has executed full clearing of all vegetation prior to reservoir filling. Recently, a number of Corps water development projects have left many if not most trees for fish and wildlife habitat (Laufle and Cassidy 1988) . This approach could be used with the HHD AWS Project to maintain fish and wildlife habitat for a period of time and could result in less mitigation. This alternative was carried forward for further evaluation.

d. Alternative 11D – Terrestrial Habitat Improvements above the Riparian Zone.

(1) Alternative IID1 – Accelerate Forest Development to Late Successional Stage. This measure would accelerate the development of late-successional characteristics (large diameter snags and down wood, multi-story canopy, and increased understory cover and diversity) in conifer and mixed forest stands on Tacoma-owned lands near the HHD reservoir to increase the acreage of timber stands managed as late-successional forest habitat in the Upper Green River Watershed. This alternative was carried forward for further development and evaluation.

(2) Alternative 11D2--Elk Pastures. Initial planning efforts targeted forested areas for conversion to pastures to supplement elk forage areas and replace existing foraging areas that would be lost to inundation from the pool raise. Resource agencies expressed concern over further loss of forests, and wondered if pastures couldn't be located elsewhere. The Tacoma Water Division identified power-line rights-of-way as suitable areas for conversion to pastures. Rights-of-way are currently classified mainly as young deciduous, or, in some cases, upland shrub. The rights-of-way are managed for these habitat conditions, as the power companies do not want tall trees growing under the power lines. Thus, they make ideal situations for pastures, not only because trees would be excluded and pastures would be maintained, but also because the existing habitats are not considered to be high quality for any species of wildlife – so that the loss of habitat through conversion to pastures is less than the loss resulting from conversion from a higher quality habitat, such as mature conifer forest. This measure was carried forward for further consideration.

3.1.4 Preliminary Screening of Alternatives

As with all studies, the No Action alternative is carried forward for further discussion.

3.1.4.1 Water Supply Alternatives

Water supply measures were preliminarily screened and either eliminated from further evaluation or were included as potential alternatives to the HHD AWS Project and carried forward for further analysis. Each measure was screened at this stage by considering the preliminary planning criteria. Criteria used to screen alternatives is described above in Paragraphs 3.1.2.2a and b. Using the screening criteria, water supply alternatives eliminated from further evaluation were: Alternative 2B, Additional Storage Without Fish Passage; Alternative 3A, Wells in Lower Puyallup Lowlands; Alternative 3B, Wells in Lower Puyallup Uplands; Alternative 3C, Wells in Clover Creek and/or Chamber Creek Areas; 3D, North Bend Aquifer; Alternative 5A, Intertie With Seattle (this alternative cannot be considered a water supply alternative for Tacoma as they will be supplying water to Seattle – Paragraph 3.1.3.5.a); Alternative 5B, Water Purchase From Auburn; Alternatives 6A, New Storage in Green River Basin (Smay Creek) 6B; Dam on Puyallup River; 6C, Dam on Nisqually River; and 6D, Dam on Skagit River. Reasons for eliminating each of these measures are discussed in each alternative discussion in Paragraph 3.1.3.1.

3.1.4.2 Low Flow Augmentation Alternatives

The two low flow augmentation alternatives, 7A and 7B were screened using the preliminary planning criteria described above in Paragraphs 3.1.2.2a and c. Both alternatives had desirable features for most of the criteria. Criteria that were considered most significant for selecting a preferred alternative are tabulated below.

SIGNIFICANT PLANNING CRITERIA FOR LOW FLOW AUGMENTATION SELECTION

Low Flow Augmentation measures must be:	• acceptable to federal and state resource agencies, tribes, and sponsor. • must address overriding environmental problems. • consistent with existing fish and wildlife management. • cost-effective per unit of output.

Alternative 7B was favored over 7A for all 4 of the significant criteria. Resource agencies and the Muckleshoot Indian Tribe had unanswered questions with Alternative 7A. Alternative 7B addressed overriding environmental problems based on current fish management practices. Costs were not quantified; however, alternative 7B had more predictable and effective outcomes than 7A. Alternative 7B, which mimicked natural hydrology, was carried forward in the planning process for further evaluation.

3.1.4.3 Water Quality Alternatives

Water quality improvement is considered dependent on downstream fish passage improvements. Each measure was screened at this stage by considering the preliminary planning criteria listed above in Paragraphs 3.1.2.2a, b, and c, and were reviewed by the FPTC for consistency with design criteria, and were considered as to whether the alternative could realistically be implemented. The water quality measure eliminated for further consideration was Alternative 8B, Provide Temperature Control at the Dam without Water Supply.

3.1.4.4 Fish Passage Alternatives

Fish passage alternatives were preliminary screened and either eliminated from further evaluation or were included as potential alternatives and carried forward for further analysis. Each measure was screened at this stage by considering the plan formulation criteria listed above, were reviewed by the FPTC for consistency with design criteria, and were considered as to whether the alternative could realistically be implemented. In cooperation with the FPTC, the Seattle District initially developed a list of hydraulic design criteria to evaluate the technical feasibility of downstream fish passage facility concepts. These criteria are listed by facility components, juvenile bypass and screen, and can be found in the FPTC (1990) report.

Fish passage alternatives eliminated from further evaluation were: Alternative 9B, Downstream Fish Passage without Water Supply; Alternative 9E Upstream Fish Passage at Dam without Water Supply; Alternative 9F, Remove Existing Dam; Alternative 9G, Trap and Haul Facility at the Tacoma Diversion Dam; and Alternative 9H, Eliminate Permanent Pool. Reasons for eliminating each of these alternatives are discussed in the write-up of each alternative in Paragraph 3.1. 3.9. Alternative 9D, Upstream Fish Passage at the Dam with Water Supply was not carried forward as a distinct measure, but potential features of this measure (upstream adult passage) could be incorporated into measure 9A, Downstream Fish Passage at the Dam, if the fish lock design were implemented.

3.1.4.5 Fish Culture Alternatives

Fish culture alternatives were preliminarily screened and either eliminated from further evaluation or were included in potential alternatives and carried forward for further analysis. Each alternative was screened by consideration of the criteria listed above. Fish culture measures eliminated from further evaluation were: Alternative 10A, Increase Existing Hatchery Production and Alternative 10B, Permanent Supplementation Programs. Alternative 10C, Temporary Supplementation Programs, was not carried forward as a distinct measure but potential features of this measure will be incorporated into other habitat restoration and mitigation projects.

3.1.4.6 Habitat Mitigation and Restoration Alternatives

Each alternative was screened by consideration of the criteria listed above. Because of the anticipated breadth of the impacts associated with additional storage, there were no habitat mitigation and restoration measures eliminated from further evaluation in the preliminary screening.

3.2 REFINEMENT OF ALTERNATIVES

3.2.1 Refined Plan Formulation Strategy

3.2.1.1 Planning Objectives

The refined water supply objective is consistent with the preliminary planning objective; to provide cost effective and sufficient M&I water supply to meet the water needs of the project sponsor over the life of the project. There was a refinement of the restoration objectives, ecosystem restoration, with a goal to establishing healthy, naturally reproducing, self-sustaining runs of chinook and coho salmon and steelhead trout; and to provide limited habitat restoration for selected ecosystem functions, processes, or structures in the Green River Basin.. This refinement led to three aquatic resource objectives: 1) to have no net loss of lower watershed habitat while maintaining existing anadromous salmonid populations, 2) restore natural, self-sustaining runs of anadromous salmonids in the Headwaters watershed; and 3) restore selected aquatic habitat limiting factors of the Lower watershed.

Refined restoration objective No. 1 is related to mitigation requirements. Storing additional water for water supply and flow augmentation during the spring will impact several features of the Lower Green River including – 1) connection of remaining floodplain habitat areas (side channels) to the mainstem; 2) survival of juvenile fish migrating downstream; and 3) dewatering incubating steelhead eggs. Upper Green River habitat (above HHD) is affected by additional storage, but these impacts are largely unavoidable and require appropriate mitigation. This objective seeks to avoid, minimize, or fully mitigate for any impacts, in the lower watershed, related to storing additional water for M&I and flow augmentation purposes.

Refined restoration objective No. 2 is consistent with the preliminary planning objective of establishing self-sustaining fish runs in the watershed above the dam. Self-sustaining fish runs are defined as a population (species-specific) of salmon or steelhead that exists in sufficient numbers to replace itself through time without supplementation with hatchery fish. The definition of self-sustaining is related to natural reproduction or spawning by each population, it does not refer to the use of fish passage technology to move fish above or below man-made barriers. Identification of the adult numbers required to meet this objective was developed in this phase.

Refined restoration objective No. 3 is consistent with the preliminary planning objective of limited habitat restoration. The limiting factors addressed by habitat restoration projects are: 1) poor connection of the upper and lower watershed by the lack of downstream fish passage at HHD; 2) low flows during summer and fall; 3) poor water quality, due to inability to regulate the temperature of water from the dam; 4) disconnection of floodplain areas to the mainstem; 5) reduction in spring freshets affecting instream (downstream) migration of juvenile salmonids; and 6) lack of quality riparian and stream habitat.

3.2.1.2 Refined Planning Criteria/ Screening Criteria

Water supply criteria remain consistent with preliminary planning criteria, in Paragraphs 3.1.2.2a and b, and were carried forward with one or two exceptions; additional criteria were added to refine mitigation and restoration measures. This additional criteria is described in Paragraphs a and b below.

After the Agency Resolution Process, the Corps and Tacoma began implementing baseline monitoring, in areas downstream of HHD, to develop a database on steelhead spawning, and side channel habitat. In conjunction with this the Corps and Tacoma implemented criteria and actions to evaluate the operation or implementation of the recommended HHD AWS Project phased plan (listed in Paragraph 4.1.3).

a. Water Supply Criteria. Alternative water supply alternatives by themselves or in combination must meet the average summer and/or 4-day peak demands.

b. Mitigation and Restoration Criteria and Assumptions.

(1) To minimize the need for mitigation, all operational and structural means available were used to avoid or minimize impacts of storing additional water for M&I and flow augmentation. A daily hydrologic flow model was used in modeling storage and release of Baseline, Phase I, and Phase II storage water.

(2) Mitigation needs must be addressed prior to development of restoration projects. Selected projects must meet the full mitigation requirement.

(3) Habitat mitigation projects are evaluated by impact areas: 1) side-channel disconnection; 2) riparian and tributary habitat inundation; and 3) terrestrial habitat inundation (wildlife). Impacts and mitigation for downstream migrating fish (lower river) are incorporated in side channel mitigation.

(4) Least-cost alternatives that fulfill identified mitigation requirements were selected first.

(5) Mitigation and restoration projects must be function or process driven.

(6) Mitigation and restoration project sites were developed and selected based on ecosystem or biological need first. However, real estate considerations were integrated in site development and evaluation with use of public lands first, City of Tacoma lands next, and private lands last.

(7) Incremental analysis and evaluation was one tool used to refine and select among mitigation and restoration alternatives. It was not the ultimate criteria for alternative selection. The authority and direction of mitigation and restoration measures includes best professional judgment.

(8) Restoration projects or sites considered addressed specific aquatic habitat limiting factors identified through HHD AWS Project scoping.

(9) A deterministic fish passage model was used to initially evaluate the downstream fish passage alternatives against juvenile fish project survival criteria (95%) and self-sustaining project objective. This model estimated total adult fish run size (pre-harvest numbers) and was used to develop incremental outputs for each alternative. After this, long-term average harvest rates for each species were applied to outputs from each alternative to evaluate which alternative(s) would meet adult spawning escapement goal(s) for each species. The goal for each species is 1) 6,500 adult coho salmon; 2) 1,300 adult steelhead; and 3) 2,300 adult chinook salmon. The model is discussed further in Paragraph 3.2.4.12, above, and is provided in detail in Section 8, Part 1, Appendix F.

(10) In addition to meeting design criteria, fish passage alternatives were assessed based on lessons learned from past project failures and successes in fish passage development. See number (9) above and Paragraph 3.4.12.

(11) If no fish passage alternative can provide 95% project survival, the recommended fish passage alternative must provide project passage survival rates and estimated adult returns that meet or come near the restoration objective of self-sustaining runs. The larger reservoir created by storing an additional 32,000 ac-ft may preclude reaching the target survival rates. The concern over reservoir fish passage over the longer length of reservoir is one reason for the Phased Implementation of the HHD AWS Project. Monitoring will take place before the project is fully implemented (during Phase I) to determine the impact of the larger reservoir on the migrating fish.

(12) The recommended fish passage alternative must meet approval of FPTC and Resource Agency Directors. Through the Agency Resolution Process, directors from NMFS, USFWS, and WDFW gave conditional approval to the HHD AWS Project based on development of a fish passage alternative that met all design criteria.

(13) An ability to screen the 50% exceedance flow (late April through May) through a surface inlet is the most critical design feature for providing successful attraction and entrainment of smolts into any fish passage facility. Other juvenile fish passage projects have consistently shown a poor ability to collect fish whenever the majority of flow is going through outlets other than juvenile collection facilities. The original objective of the FPTC was to pass all instream flows through any fish passage facility, structural constraints limited the maximum volume of the fish passage to 1,200-1,600 cfs (near the 50% exceedance during the major smolt outmigration period). See Paragraph 3.2.4.12 for further discussion.

(14) The development of fish passage alternatives must recognize that the Green River is a heavily urbanized watershed and therefore higher project survival rates and escapements are necessary to reach self-sufficiency. Less than 3% of estuary wetlands and 10% of the historical floodplain remain.

(15) Dam fish passage alternatives must include a surface withdrawal ability to provide for water quality improvements by blending of warmer surface and cooler lower reservoir water.

3.2.1.3 Study Advisory Committee

a. Fish Passage Technical Committee. The FPTC, besides developing fish passage design criteria and interacting with the Corps on concept designs, played a critical role in evaluating a fish passage survival model used in creating outputs for an incremental evaluation of all downstream fish passage alternatives. Initially, the Seattle District developed a deterministic fish passage survival model for nine fish passage alternatives using three Green River fish stocks, coho and chinook salmon, and steelhead. The model was a multiplicative model (each parameter multiplied against the previous parameter) made up of 7 parameters affecting total adult return rates (pre-harvest). An initial incremental analysis was conducted by the Seattle District and reviewed by the FPTC. The FPTC did not agree with outputs from the model and requested that the District revise outputs and add another alternative with new outputs. Following this, during the Agency Resolution Process (Process), the FPTC worked with the Corps to develop a tenth alternative that met all hydraulic design criteria developed by the FPTC (design criteria listed in Section 2D, Part 1, Appendix F). This alternative came closer to meeting the target survival criterion (95%) than any other design for the least cost.

b. Agency Resolution Process. The Corps and Tacoma presented a proposal to the agency directors on February 9, 1996, that described a phased approach to the HHD AWS Project and the commitment by the Corps and Tacoma to implement adaptive management principles and agreements. Agency directors for the state and federal resource agencies gave conditional support to the HHD AWS Project based on this proposal. This conditional support was based on the phased project and development of the FTPC preferred fish passage design. The Muckleshoot Indian Tribe was the one study partner who did not grant conditional acceptance. They remained neutral at this stage in the coordination process.

Under the Agency Resolution Process, the Corps and Tacoma agreed to an adaptive management plan (Plan) for the HHD AWS Project. The key elements of the Plan include experimentation, monitoring and analysis, and synthesis of results, followed by adaptive management practices responsive to the scientific results of those efforts. The HHD AWS Project Adaptive Management Plan involves: 1) phased implementation of increases in project storage volumes, so changes in the ecosystem can be studied with long-term monitoring; 2) incorporation of potential changes in project design and management/operation as we learn from phased implementation studies and monitoring; 3) implementation of changes in program structure if monitoring results and outcomes justify changes; and 4) ongoing coordination with agencies and the MIT throughout the project to ensure that good science is incorporated into management strategies and decision-making.

Four key issues were identified through the Process that were not originally considered in the early Feasibility Study Phase: 1) achievement of self-sustaining runs of salmon and steelhead; 2) connection of flood-plain habitat to the mainstem (side-channel connectivity); 3) steelhead spawning and egg incubation; and 4) instream migration of juvenile salmonids. These issues became the basis for much of the impact analysis and discussion during the later parts of the HHD AWS Project Feasibility Study phase. These issues resulted in the initiation of the Adaptive Management Plan for areas below HHD. Elements of the plan that were implemented include: 1) a side-channel inventory of the lower Green River was conducted; 2) a literature review was completed on instream migration of juvenile salmonids; and 3) a daily flow model for the Green River and the HHD AWS Project was developed. The daily flow model became the basis for all impact analyses for the HHD AWS Project which resulted in identification of fisheries mitigation requirements.

3.2.2 Water Supply Alternatives

Water supply output of HHD is produced during a 153-day period over the summer/fall time frame at 95% reliability. Of this total number of days, 149 days are considered to represent the average summer demand while 4 days during this same period are representative of the 4-day peak period. During this stage of the analysis, the construction cost and average annual costs of each alternative were computed. In addition, the water supply output, measured in millions of gallons of water produced over the 153-day demand period at 95% reliability, of each alternative was computed. Using the average annual cost of each alternative and its output in million of gallons over the 153 day demand period, the cost per million of gallons was computed. The cost per millions of gallons was then used to rank each alternative in order of their cost. Discussed below are the water supply alternatives than were carried forward in this analysis and evaluated in greater detail. Costs of each alternative are based on October, 1997 prices and 7-1/8 percent interest rate.

3.2.2.1 Alternative 2 – Additional Water Supply With Low Flow Augmentation

This alternative was a water supply and low flow augmentation project initially consisting of providing 37,000 ac-ft of storage, from pool elevation 1,141 to elevation 1,177 feet. Since the proposed water supply pool would require juvenile fish to sound to a much greater depth, up to an additional 36 feet, to migrate from the reservoir to the river below and since juvenile fish have difficulty sounding, a fish passage facility was included as the expected method of mitigation.

Since the initial evaluation of this project, the without-project condition has changed at the project site. With the passage of an ecosystem restoration authority, the without-project condition has change to include the addition of a Section 1135 Restoration Project. This project, currently in the process of being implemented, consists of using 5,000 ac-ft of the above 37,000 ac-ft to provide low flow augmentation.. Pool elevation for this 1135 Project will be from elevation 1,141 to 1,147 feet. This change in the without-project condition, reduces the reservoir available for additional low flows. This alternative is described as Alternative 2A in Paragraph 3.3.3, Description of Final Alternatives.

With passage of an ecosystem restoration authority, another at-site alternative was developed which included ecosystem restoration as a project purpose. This project consists of M&I water supply plus the following environmental restoration components: (1) low flow augmentation, (2) fish passage, and (3) habitat improvements. Numerous low flow scenarios, all of which affect the water supply output of the project, were evaluated in a trade off analysis. See Paragraph 3.4, below, for a discussion of low flow augmentation. The goal of the trade off analysis was to try and provide additional water for the fish during the summertime and still be able to meet Tacoma's water supply needs over the 50-year project life. Negotiations finally settled on a project which allocated 9,600 ac-ft of storage to low-flow augmentation and 22,400 ac-ft to M&I water supply. The entire or full project would be developed at the same time. This alternative is described as Alternative 2B in Paragraph 3.3.3.

Another sub-project was developed, through negotiations with state and federal agencies and project sponsor, which would implement the above project in two separate phases. This project is basically the same as measure 2B above but is implemented in two phases. Phase I provides 20,000 ac-ft of water for water supply – from reservoir elevation 1,147 to 1,167 feet. The 1135 Project implemented as part of the without-project condition would continue with 5,000 ac-ft of storage provided for low flow augmentation. Prior to implementation of Phase II, adaptive management would occur which consists of monitoring fish movement across the reservoir and through the fish passage facility with a higher pool. Phase II is expected to be implemented about 5-8 years after Phase I. This phase consists of filling the pool to elevation 1,177 which will provide a total of 22,400 ac-ft for water supply storage and 9,600 ac-ft of additional low flow augmentation. This alternative is described in Section 4 as alternative 2C.

Under existing conditions between the last part of March through June, 25,400 ac-ft of water has historically been stored for flow enhancement. This water is stored in the reservoir between elevation 1,070 and elevation 1,141 feet. An 1135 Project will be in place by the year 2000 and will add an additional 5,000 ac-ft of stored water for low flow augmentation (LFA), initially during drought years, estimated to be 1 year in 5. The frequency of storage of this water can be increased, up to yearly, through adaptive management, under the authority of the 1135 Project. This water will be stored between elevation 1,141 and 1,147 feet. Under existing conditions the maximum summer/fall pool elevation will be 1,147 feet.

In Phase I it is assumed the 5,000 ac-ft of LFA water, authorized in the 1135 Project, will be stored each year, between 1,141 and 1,147 feet. In addition, 20,000 ac-ft of M&I water will be stored during the March through June time frame, for use during the summer/fall, between elevation 1,147 and 1,167 feet.

Under Phase II an additional 9,600 ac-ft of LFA water and 2,400 ac-ft of M&I water will be stored during the March through June time period for use during summer/fall. This storage is between elevation 1,167 and 1,177 feet.

PERFORMANCE OF HANSON STORAGE BY ITEM AND DEVELOPMENT

Item	Existing	Phase I		Phase II	
		Low-Flow	M&I Water	Low-Flow	M&I Water
Incremental Storage (ac-ft)	25,400 plus 5,000 (under 1135 auth.)	30,400 (existing)	20,000	9,600	2,400
Total Storage	30,400	50,400		62,400	
Max Pool Elevation (Ft)	1,147	1,167		1,177	

3.2.2.2 Alternative 3 – Wells

a. Alternative 3e – Tide Flats. This alternative includes installing two additional wells and pumps capable of producing 2.5 mgd each plus constructing 2,000 feet of transmission pipeline needed to convey this water to Tacoma's distribution system. Water supply produced by this alternative during the May-Sept season – or 153 days – is 765 million gallons.

b. Alternative 3f – Lone Star Sand and Gravel. Construction consists of installing a well and pump plus 15,000 feet of transmission pipeline, as well as retrofitting a pump station to achieve a hydraulic gradient of 576 feet.

c. Alternative 3g – South Tacoma Aquifer. Further analysis of this source of water by Tacoma Water Division has resulted in their decision to proceed with implementing this alternative prior to construction of the proposed project. Hence, this alternative is part of the without-project supply of water and has been included as part of Tacoma's existing supply of water. As a result, this measure is no longer an alternative to the HHD AWS Project.

3.2.2.3 Alternative 4 – Conservation/Demand Management and Industrial Reuse

a. Alternative 4A – Conservation/Demand Management. Tacoma Water Division has evaluated numerous conservation/demand management measures ranking them in order of their cost effectiveness. Out of all the alternatives evaluated, Tacoma has put a package together consisting of their most cost effective measures. These measures include: (1) indoor industrial audit – no devices; (2) commercial/industrial ultra low flow toilet rebate; (3) remote irrigation facilities for parks; (4) remote irrigation of school grounds; (5) single-family self-closing hose nozzle – direct mail; (6) ultra low flow toilets in schools; (7) single-family ultra low flow toilet rebate – direct mail; (8) single-family horizontal axis washing machine rebate – direct mail; (9) public building outdoor water audits – direct mail; (10) public schools outdoor water audits – direct mail; (11) commercial/industrial low flow showerhead; (12) public facilities electronic faucets –

direct mail; (13) single-family outdoor faucet auto shutoff – direct mail. Water savings are estimated at 1.3 mgd during the average summer period and 1.8 mgd during the 4-day peak period. Total water savings over the 153-day demand period is 201 million gallons.

b. Alternative 4B – Industrial Reuse. This alternative consists of constructing 4,000 feet of 30-inch water transmission pipeline needed to deliver up to 10 mgd of reclaimed water from a city-owned wastewater treatment plant to the customer, in the paper product industry, plus construction of water filtration, disinfection and storage facilities at the treatment plant.

3.2.2.4 Evaluation of Water Supply Alternatives

In addition to providing water supply by construction improvements to HHD are the remaining viable water supply measures. These measures consist of Alternatives 3e – Wells in the Tide Flats area of Tacoma; 3f – Conservation/Demand Management; 4 – Wells at the Lone Star Sand and Gravel location; and 7 – Industrial Reuse as described above. These alternative water supply measures were used to help quantify the value of water produced by Howard Hanson Dam over the 50-year project life. Without water supply from HHD, these alternative measures would be implemented as the need for additional water occurs with the most cost effective measure implemented first and the least cost effective measure implemented last. With HHD, these measures would not need to be implemented over the 50-year project life and, as such, the cost of these measures would be avoided. This avoided cost represents the value of water supply produced at HHD. If the avoided costs are greater than the separable costs (i.e., costs incurred by adding water supply) associated with water supply, then the addition of water supply at HHD is economically justified.

3.2.3 Low Flow Augmentation Alternatives

3.2.3.1 Alternative 7B –Mimic Natural Hydrology During Refill and Provide Low Flow Augmentation

Alternative 7B was developed to meet or be consistent with three preliminary project objectives: 1) provide a regional M&I water supply; 2) restore upper watershed fish runs; 3) provide limited habitat restoration.

This alternative consists of two components following natural hydrology patterns during spring refill (February 15-June 30) and providing low flow augmentation during the summer and fall (July 1-November 15). The concept of having dam outflow releases follow natural hydrology patterns is an evolution of existing HHD management to adapt to yearly, seasonal and daily changes in physical and biological conditions. Since the mid 1980's, resource agencies and the Corps have been monitoring, evaluating and modeling (under HHD AWS Project or other related projects) various aspects of Green River hydrology patterns and their influence on the habitat use, migration, and survival of juvenile and adult salmon and steelhead. This accumulated knowledge has resulted in the existing project's adaptive management approach to spring refill and outflow releases that seeks to protect existing instream resources while providing for reliability in storing water for summer flow augmentation.

The latest outcome of this adaptive approach has been to model the HHD AWS Project spring refill and outflow release to mimic natural inflow patterns. Under Alternative 7B, a daily flow model was developed that uses several refill rules to meet project objectives for protecting instream resources, meeting existing conservation storage requirements, and providing reliability for storing additional water for M&I and flow augmentation under Phase I and Phase II of the HHD AWS Project. The primary refill rules that were applied include: 1) a maximum refill rate (rate the reservoir is filled or the difference of inflow-outflow) during the main smolt outmigration period, April through May; 2) a minimum baseflow throughout the refill period, February 15-June 30; 3) a stage decline of no more than 1 foot from May 1 to June 30 (to protect incubating steelhead eggs); and 4) maintaining natural freshets or creating artificial freshets in April and May (to speed juvenile migrants downstream). Refill rules for the minimum baseflows and freshet volumes varied for wet, normal and dry years.

The refill rules incorporated all baseline information on juvenile fish migration through the reservoir and dam, instream migration of juvenile fish through the lower river, habitat connection of side channels to the mainstem, and steelhead spawning habitat. A discussion of these refill rules and outputs can be found in Sections 4A and 9, Part 1, Appendix F. These refill rules were applied to an existing database of 32 years (1964-1995) of historic Green River flows. The reliability of storing additional water for M&I and flow augmentation for these modeled years was 91 and 81%, respectively. Table 3-2 shows all Phase II refill and flow augmentation targets.

TABLE 3-2. PHASE II SPRING REFILL AND SUMMER/FALL RELEASE BASEFLOW TARGETS

Seasonal Flow	Baseflow Target	Stage Decline[1]	Low-Flow Targets		
Condition	February 15-April 30	May 1 to June 30	July 1 to Sept-15	Sept 16-30	Oct 1-31
Wet	900 cfs	900-400 cfs	300 cfs	400 cfs	450 cfs
Average	750 cfs	750-400 cfs	300 cfs	300 cfs	400 cfs
Dry	575 cfs	575-250 cfs	250 cfs	250 cfs	350 cfs

1. Stage decline refers to protection of incubating steelhead eggs by allowing no more than a 1 ft stage decline at Auburn from May 1 to June 30.

Since Alternative 7B met or was consistent with all three project objectives, this flow augmentation alternative became the preferred alternative and was carried forward to the Final Plan Formulation Stage.

3.2.4 Fish Passage Alternatives

Ten distinct downstream fish passage alternatives were developed (10% design) for evaluation by incremental analysis, for review by the FPTC, and acceptance by the resource agency directors through the Agency Resolution Process. See Plates 1-50 in Appendix H, Plan Formulation, for drawings of the fish passage alternatives.

3.2.4.1 Alternative 9A1 – Add a Pinch Valve to the Existing 48-inch Bypass Pipe

This alternative consists of only a modification of the existing bypass outlet to provide for more fish friendly outlet conditions through addition of a 4-foot-diameter pinch valve. This alternative met few of the fish passage design criteria, (see 1990, FPTC report entitled *Howard A. Hanson Dam Fish Passage Alternatives for Proposed New Operating Rule Curve*) did not provide temperature control, and was eliminated for further evaluation.

3.2.4.2 Alternative 9A2 – Alternative 9A1 Plus Smoothing of Pipe Curves

This alternative consists of Alternative 9A1 (above) in addition to smoothing the three downstream bends in the existing 4-foot bypass. This alternative, while a slight improvement over 9A1, met few criteria and was eliminated from further evaluation.

3.2.4.3 Alternative 9A3 – Alternative 9A1 and 9A2 Plus Wet Well Chamber in the Existing Tower

This alternative consists of a combination of Alternatives 9A1 and 9A2 (above) in addition to excavation of a wet well chamber within the existing intake tower. This would consist of an extension of the existing bypass intake port from elevation 1,068 feet to elevation 1,140 feet providing near surface collection: with a sliding trash rack and panels in the gate guide slots. This alternative provides for a small surface outlet but did not meet many of the design criteria and was eliminated from further evaluation.

3.2.4.4 Alternative 9A4 – Alternative 9A1, 9A2, and 9A2 Plus Surface Collector on the Existing Tower

This alternative consists of a combination of Alternatives 9A1, 9A2, and 9A3 above in addition to a surface "gulper" collector similar to that used at Green Peter Dam on the Santiam River in Oregon. It would be mounted on the existing intake tower and gate lift hoist structure. Maximum discharge capacity is dependent on pool elevation and bypass pipe: 400-550 cfs. This alternative provides for a surface outlet, meets many design criteria, but fails to meet flow capacity criteria and several other critical design criteria. By not meeting design criteria, and in particular the flow capacity criteria, this alternative did not meet the project passage survival criteria and therefore could not meet the objective of self-sustaining runs. This alternative was selected during an initial incremental evaluation as providing the greatest output for the least-cost but was eliminated following the revision of other design alternatives and to the fish passage model.

3.2.4.5 Alternative 9A5 – New Tower with Single Lock/Single Screen Connected to the Existing Tunnel

This alternative consists of a new intake tower with a single modular incline screen (MIS) and single fish lock. A live box would capture fish within the lock when the lock is being evacuated. Separate open channels would carry flow from the fish bypass and lock evacuation. Flow from the lock eventually combines with the existing flood control tunnel. It has a maximum discharge capacity of 560 cfs. This alternative meets more criteria than Alternative 9A4 but still fails to provide desired attraction flows (flow capacity). It was not incrementally selected or recommended by the FPTC.

3.2.4.6 Alternative 9A6 – New Tower with Single Lock/Single Screen and New Tunnel and Stilling Basin

This alternative consists of a new intake tower same as for Alternative 9A5 above with a single MIS screen and fish lock, except that outflow conduits will be routed through a new tunnel about 2,000 feet long to a portal area downstream of the existing spillway discharge point. It has a maximum discharge capacity of 625 cfs within screen criteria. This alternative meets more criteria than Alternative 9A4, has slightly greater discharge capacity than 9A5 but still fails to provide desired attraction flows (flow capacity). It was not incrementally selected or recommended by the FPTC.

3.2.4.7 Alternative 9A7 – New Tower with Double Lock/Double Screen and New Tunnel and Stilling Basin

This alternative consists of a new intake tower as for Alternative 9A6, except that it uses two intake horns, two MIS screens, and two fish locks. And like Alternative 9A6, the outflow will be routed through a new tunnel to the downstream portal and stilling basin. It has a maximum discharge capacity of 1,250 cfs within screen criteria. This design alternative met all design criteria but was not incrementally selected during the initial or final incremental analysis and evaluation. This alternative was not considered as feasible as the recommended alternative 9A8 due to increased design and operation complexity from two locks.

3.2.4.8 Alternative 9A8 – New Tower with One Enlarged Screen in Single Lock and New Tunnel

This alternative is the preferred alternative and consists of a new intake structure located adjacent to the left side of the existing flood control outlet tower. The fish passage facility would house one enlarged MIS and a single fish lock. Fish would be screened from the attraction flow, fed into the lock chamber and then transported downstream of the dam via a 2-foot-diameter pipe through the existing flood control tunnel and exited into the Green

River. The larger amount of attraction flow would pass through the MIS and be routed through a new tunnel and into the existing flood control tunnel. This alternative meets most of the 39 items of design criteria and in particular meets the critical criteria of screening the 50% exceedance discharge of 1,250 cfs. This alternative was not developed at the time of the initial incremental analysis and evaluation and was therefore not included in that evaluation. It was subsequently developed during the Agency Resolution Process. Based on the results of the fish passage evaluation process and the opinion of the FPTC team of experts, this alternative provides the greatest potential for fish passage success at the least cost than any other alternatives evaluated. As such, this alternative is the FPTC's recommended alternative as well as the politically accepted alternative by the various Agency Directors.

3.2.4.9 Alternative 9B1 – Fish Collector above Reservoir with Truck Transport

The longest reservoir distance smolts must migrate is from the confluence of the mainstem Green River to the dam (4.3 miles at 1,141 feet to 5.7 miles at 1,177 feet). This alternative consists of an upstream collector on the mainstem Green at elevation 1,181 feet. Up to 80% of all potential smolt production in the watershed above HHD occurs above this point. The collector consists of a bank of 4 MIS, a permanent spillway, a seasonal rubber dam (March 15-September 30). Transport would be by truck around the project. A holding facility would be at the collector and release would be at the Palmer Rearing Ponds. The facility was designed for a maximum screening capacity of 2,200 cfs (10% exceedance flow). This design was not reviewed as a single design, it was considered in combination with dam passage alternatives. In the initial incremental analysis, this alternative, when combined with Alternative 8A4 was incrementally justified as the least-cost alternative that nearly met escapement goals under most scenarios.

The FPTC rejected this combination because this alternative (9B1) has major risks associated with it that dam passage does not: trucking fish can increase stress, incidence of predation, disease transmission, and may reduce homing ability of adults. Lastly, even screening the 10% exceedance flow can result in less than desired fish collection efficiency, up to 20% of all smolts can be migrating during these freshets and could pass beyond the facility.

3.2.4.10 Alternative 9B2 – Fish Collector above Reservoir with Flume Transport

This alternative consists of an upstream collector on the mainstem Green at elevation 1,181 feet. The collector consists of a bank of 4 MIS, a permanent spillway, a seasonal rubber dam (March 15-September 30), and open channel around the reservoir using the railroad grade (approx. 5.5 miles) to Bear Creek. MIS meet all screen criteria. This alternative was rejected by incremental analysis and for the same reasons as Alternative 9B1. Transport by flume involves other issues (confinement, increased water temperature, real estate along an active rail line) but was considered a fall-back option should alternative 9A8 prove less than successful.

3.2.4.11 Fish Passage Alternative Combinations

In addition to the 10 single fish passage alternatives described above, combinations of alternatives were evaluated. The concept of combining alternatives was to address passage improvements at the dam with a single fish collector above the reservoir on the mainstem Green River (Alternatives 9B1 or 9B2). This concept addresses limitations that each individual concept is constrained by: 1) even with the best facility at the dam a number of smolts may not reach the dam through an enlarged reservoir; and 2) to collect all fish before they reach the reservoir, fish collectors would be necessary on 3-5 tributaries. Combinations of one dam passage facility (9A1-9A8) with one fish collector (9B1, 9B2) were evaluated. In the initial incremental analysis, Alternative 9B1 when combined with Alternative 9A4 was incrementally justified as the least-cost alternative that met escapement goals under most scenarios. The FPTC rejected this combination as being unnecessary, that a single dam passage improvement, 9A8, should be adequate in providing passage. The combination of having to operate two passage facilities presented additional concerns about operation.

3.2.4.12 Evaluation of Fish Passage Alternatives

Selection of the recommended fish passage facility is based on four areas. 1) scientific understanding of fish passage needs; 2) potential for restoring fish runs in the Green River; 3) technical feasibility and incremental analysis in meeting the restoration objective, and 4) continuity with the Ecosystem Restoration Authority final selection criteria (EC 1105-2-210). Total construction and average annual cost for each fish passage alternative can be found in Appendix B. Discussion of the fish passage model used in the incremental analysis can be found in Section 8, Part 1, Appendix F. A more detailed discussion of the evaluation of fish passage alternatives can be found in Appendix H, Plan Formulation.

a. Scientific Understanding of Fish Passage Needs. Selection of the recommended facility is based on three fundamental methods of scientific understanding of natural systems – experimentation, observation, and deduction. For the past 40 years various fish passage facilities have been tried at high head dams, these could be considered "experiments." These experiments typically overestimated the potential success of the facility and the assessment of productivity (juvenile survival and adult returns) the facility could sustain. Those facilities that are still in use have resulted in reduced natural productivity, with long term declines in fish and either stabilization at a lower population level (using hatchery fish) or die-off (extirpation) of fish runs. Two examples from Corps projects include: 1) Wynoochee Dam which had an experimental multilevel outlet, it is estimated that between 50-65% of the juvenile outmigrants are not "collected" by the outlets and up to 25% of the collected fish are killed during outlet passage (Dunn 1980; Matthews 1980); and 2) Green Peter Dam used a surface collector (a version of alternative 9A4), the collection efficiency of this facility was never greater than 45-55% and the facility has been abandoned (Summit Technology 1995). These experiments have been costly, the Corps is having to revisit both of the above projects (plus several others) to evaluate if they can be retrofitted to provide better survival. In addition to the experiments of past fish passage facilities we have used site-specific experimentation at HHD to identify the passage needs of outmigrating fish. A refill test at the project provided the strongest evidence for the need for high outflow and shallow outlet depths to safely pass fish (Dilley and Wunderlich 1993).

A second fundamental tool in scientific understanding of natural systems is observation. The conditions necessary for good observation results are: 1) a wide range of treatments have been applied; 2) the systems treated were similar to begin with; and 3) the treatments produced different outcomes. For our needs in understanding fish passage at high head dams, we have examples that meet some of these conditions. A number of fish passage facility "experiments" have been tried in the past, mostly between the 1950's to the 1970's. These "experiments" were on similar river systems with similar fish (salmon and steelhead). What is lacking in these treatments are long-term observation, monitoring and evaluation programs to identify facility shortcomings. These "experiments" have usually produced similar outcomes, poor passage survival of fish or in some cases ultimate die-off of natural runs. Without data from observation it is difficult to know the reasons for the lack of success.

The conclusions of the FPTC were: the dam passage facilities either did not provide sufficient attraction flow and did not collect enough juvenile fish (fish collection); or, in one or two places, there was some problem in the reservoir where the fish never came close enough to the dam to be collected by the facility. A comparison of juvenile salmon and steelhead survival through other large reservoirs compared to the HHD AWS Project suggests that the size of the HHD AWS Project reservoir (5.3-5.7 miles full pool total length) should not be a major impediment to most juvenile outmigrants.

Baseline monitoring at HHD produced a specific set of observations on fish passage needs: 1) the higher the outflow the more fish pass the dam; 2) directly tied to No. 1 is the need for a shallow outlet (or intake); 3) under certain conditions the existing low flow bypass (the 48-inch bypass tunnel) can directly kill up to 100% of all fish; and 4) the faster the reservoir is filled the slower fish reach the dam (see Paragraphs 2b.-2e., Part 1, Appendix F). Studies throughout Puget Sound have identified the major outmigration period for salmon and steelhead, April through June, as the critical period when most smolts are present at HHD. In an average year, almost 85% of all smolts in the upper Green River will migrate through HHD between mid-April and late May (see Section 5, Part 1, Appendix F).

The third and last tool used in understanding natural systems is deduction. There is a severe limitation of learning by observation when a "new" problem is presented. There has been little or no experience with the situation we have with HHD where an existing dam (with no passage facilities) is retrofitted to restore historical fish runs at the same time a larger reservoir is created. The issue is, what do we do when we are forced to extrapolate beyond the range of our experience, when we can't experiment because of physical or economic limitations? To extrapolate, we must rely on "general principles" combining historical knowledge about key problems with specific functional knowledge about key processes. A general guiding principle in fish passage is that "fish follow flow". Experiments and baseline monitoring at HHD dam have conclusively shown that more fish pass through the dam and reservoir (and survive) at higher project outflow. What is unknown at HHD is the amount of flow required to meet the required survival rate if we build a new facility. We have limited knowledge because of our inability to specify our initial conditions as well as our inability to test our conceptual model from historical data.

The FPTC applied "fish follow flow" as their guiding principle in the formulation of the design criteria of a surface-oriented fish passage facility that could meet the project restoration objective of a self-sustaining fish runs. The ability to attract and entrain smolts into a passage facility over the greatest range of flows through all pool elevations was the critical biological need the FPTC applied from lessons learned from the failure of other fish passage projects. The flow principle was listed as one of the hydraulic design criteria – "screen all instream flow". Later this was modified to the 50% (median) exceedance flow for April and May, the period of main smolt emigration (85% of all smolts).

b. Potential for restoring fish runs in the Green River. As discussed in Paragraph 1.6.5, the Green River anadromous fish runs have been reduced from 140,000 fish to less than 30,000. The potential for restoring fish runs in the Lower river is severely constrained by urban development and operation of HHD: 97% of estuary wetlands are gone; 90% of the floodplain is no longer flooded on a regular basis; the lower 30 miles of river are largely unusable for spawning and provided limited rearing habitat. In addition, the HHD AWS Project presents additional cumulative effects with storing additional water during spring refill, disconnecting side channel habitat, reducing flows during juvenile salmon outmigration periods, and creating a larger reservoir pool. The reconnection of the Upper river, through combined upstream fish passage by Tacoma and downstream passage by the Corps, is the greatest single measure available for restoring significant fish runs to the Green River basin. The area above the dam represents a large, unused habitat potential with up to 45% of the watershed above HHD (221 square miles) including over 106 miles of stream habitat. The habitat above the dam is not pristine; it has also been degraded from timber harvest, but remains high quality habitat in comparison to most of the Lower river.

The reduced habitat capacity and habitat quality in the Lower river adds to the uncertainty of restoring fish runs in the Upper river. If the Green River watershed were a largely undisturbed river basin, then restoring fish runs above HHD might be accomplished with a smaller (less flow), less costly fish passage facility, with lower passage survival. The FPTC and agencies recognized the reduced system production capacity of the basin and therefore held to a standard of high project fish passage survival (95%).

c. Technical Feasibility and Incremental Analysis. The FPTC used existing fish passage criteria and developed site-specific criteria for HHD based on unique physical and biological aspects of the system obtained from baseline monitoring. They also rigorously applied lessons learned from past applications of fish passage technology on high head dams. The majority of fish passage criteria developed were designed to reduce mortality in the facility itself. There is a solid body of information on the swimming ability of young salmon and the features required to pass them safely through an conduits. There is also solid information on the necessity of providing a facility inlet that is within the depth range of a natural river (hence the term surface collector). What the FPTC couldn't identify from past experiments and monitoring (observations) was the critical flow volume necessary to achieve high collection efficiency. Because of the "fish follow flow" principle, the poor past performance of other passage facilities and the large uncertainty presented with the "new problem" of HHD, the FPTC has pressed the Corps to identify the least cost facility that could provide the greatest flow volume. Throughout the design process the FPTC held to a principle of requiring a facility capable of passing all or most of the flow through a surface inlet.

During the FPTC review of different fish passage facilities, the Corps completed two rounds of incremental analysis and evaluation. The initial round occurred prior to the development of the recommended facility, the final round occurred after development and final costing of the recommended facility.

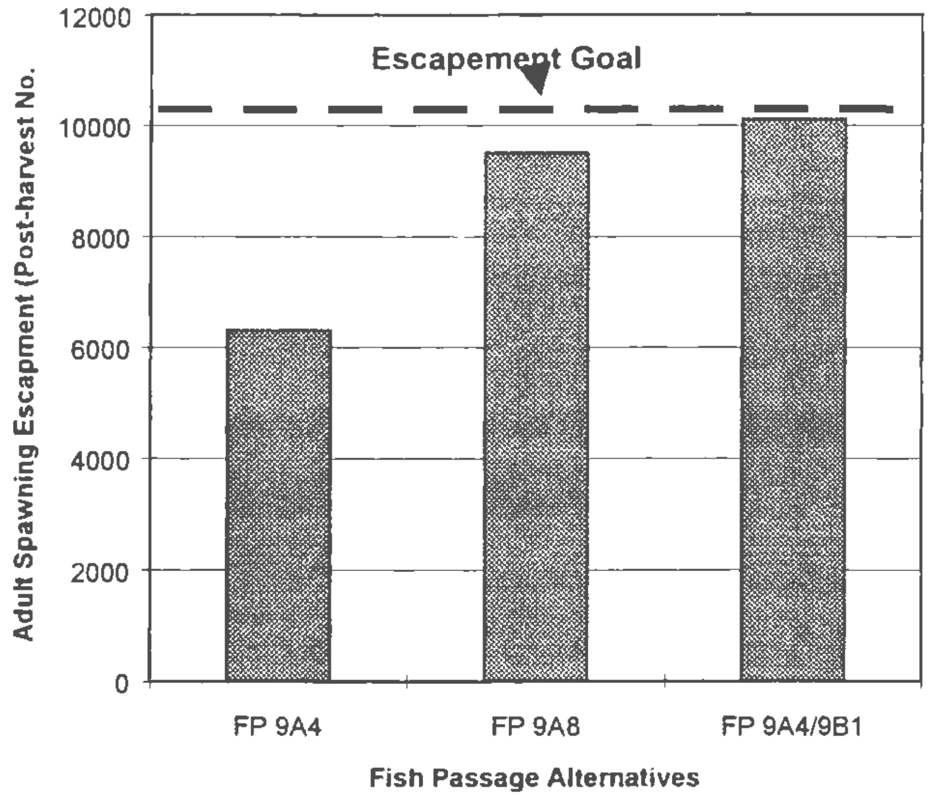
The initial incremental analysis performed by the Seattle District used nine fish passage alternatives and identified two alternatives that met certain design criteria and might be justified as being in the federal interest – 9A4 and 9A4 combined with 9B1. The FPTC reviewed this initial analysis and requested a revision in outputs along with the addition of a tenth alternative, Alternative 9A8. The FPTC rejected outputs developed by the Corps for Alternative 9A4 and the combined 9A4 and 9B1 as being overestimated. They also questioned the concepts and ultimate viability of 9A4 and 9B1. Alternative 9A4 had been previously rejected by the FPTC as not meeting all required design criteria and for providing insufficient attraction flows to pass most smolts (it screens the 95% exceedance flows), therefore it could not even approach requested project survival rates. The concept of upstream fish collection had been rejected early on by the FPTC, but the Seattle District reasserted the need for evaluation based on concerns over reservoir passage from the MIT.

Following FPTC review of the initial incremental analysis, the Corps and Tacoma entered into the Agency Resolution Process with the FPTC and policy appointees from all resource agencies and the MIT. It was during this process that the tenth design alternative, Alternative 9A8, was identified and developed. Alternative 9A8 is a modification and expansion/refinement of Alternative 9A6 Single Lock, MIS, and New Tunnel, and Alternative 9A7, Dual Lock/MIS and New Tunnel. Through several iterations the concept of a single fish lock and a single MIS was modified to meet nearly all hydraulic design criteria developed by the FPTC (hydraulic design criteria listed in Section 2d, Part 1, Appendix F). This design met the critical criterion missing from all alternatives but 9A7 – screening the 50% exceedance flow (1,257 cfs) during the main smolt emigration period in late April and May.

A final incremental analysis and evaluation were completed following development of Alternative 9A8. This analysis incorporated the comments of the FPTC and included

Alternative 9A8. The final list of alternatives that were selected by the model included 9A4, 9A8, and the combination of 9A4/9B1, 9A8/9B1 and 9A8/9B2 (see Table B2-19, Appendix B). The analysis showed the most obvious and largest incremental cost per incremental output percentage increase (286%) falls between 9A8 and 9A8/9B1. Between alternatives 9A4 and 9A8 there is a lesser incremental cost per incremental output ($94) than between A8 and 9A8/9B1 ($350).

After the final incremental analysis identified this range of alternatives, adult harvest rates and in-river survival estimates were applied to the outputs to identify which alternatives meet the restoration objective or adult spawning escapement: 6,500 coho salmon, 2,300 chinook salmon, and 1,300 steelhead (10,100 total). The figure below shows a comparison between the post-harvest output (escapement) of the initially selected fish passage alternatives, 9A4 and the combination 9A4/9B1, with the FTPC recommended fish passage alternative, 9A8. Alternative 9A4 does not meet the escapement goal (by species, 52-69% of goal) and was rejected by the FPTC for not meeting design criteria. Combined Alternative 9A4/9B1 meets the project objective (91-126% of goal) but was rejected by the FPTC and was more expensive than Alternative 9A8 (92-100% of goal). Although Alternative 9A8 does not provide 100% of the Corps escapement goal it is expected that this alternative has the best possibility of meeting any actual state, federal or tribal escapement goal identified in the future. Based on technical feasibility and incremental evaluation, Alternative 9A8 was recommended as the facility being in the federal interest.



Natural Production of Adult Salmon and Steelhead Through Three Fish Passage Alternatives Under Average Harvest Conditions: Initially Selected Alternatives (FP 9A4, and combination FP 9A4/9B1) and Recommended Alternative (FP 9A8).

d. Continuity with Ecosystem Restoration Authority Final Selection Authority. The Corps of Engineers Ecosystem Restoration circular (EC 1105-2-210) provides a set of screening criteria for final selection of restoration plans. These criteria are: 1) acceptability; 2) completeness; 3) efficiency; 4) effectiveness; 5) partnership context; and 6) reasonableness of cost. The recommended fish passage facility is reviewed against each criteria:

- **Acceptability.** *An ecosystem restoration plan (plan) should be acceptable to state and federal resources and local (tribal) government.* Through the Agency Resolution Process the recommended fish passage facility (and HHD AWS Project) has been accepted by Agency Directors from all resource agencies All other facilities are considered unacceptable. The Muckleshoot Tribe has not accepted the HHD AWS Project but is implicitly committed to the recommended facility through the FPTC acceptance.

- **Completeness.** *A plan must provide and account for all necessary investments or other actions needed to ensure the realization of the planned restoration outputs.* The recommended facility is one of only two cost-effective alternatives (second is 9B1/A4) that comes close to meeting to meeting the restoration objective of self-sustaining runs. The restoration objective is consistent with state and federal requirements for management for wild or natural fish production and fits within the King County sponsored Green/Duwamish Ecosystem Restoration study. Because of the uncertainty related to the fish passage facility and the AWS Project impacts, an adaptive management plan has been proposed and is accounted for in the plan.
- **Efficiency.** *An ecosystem restoration plan must represent a cost effective means of addressing the restoration problem or opportunity (cannot be produced more cost-effectively by another institution).* The fish passage problem at HHD can only be addressed by the Corps of Engineers and the City of Tacoma is the only sponsor available who has the means and willingness to cost-share the project.
- **Effectiveness.** *A plan must restore an important ecosystem structure or function to some meaningful degree.* The recommended alternative is the most cost effective facility to nearly meet the function of reconnecting the Upper and Lower watershed. Alternative 9B1/9A8 comes closest to fully meeting this criteria (with least uncertainty) but at a prohibitive cost (see Appendix B for costs).
- **Partnership Context.** *Projects planned in cooperation with other federal agencies, and those agencies having a significant role in implementing the project should receive higher priority than those who do not.* The recommended fish passage facility has been cooperatively planned with all state and federal resource agencies and the MIT. This restoration project makes a significant contribution to local, state, and federal plans for restoration of wild fish runs.
- **Reasonableness of Costs.** *All costs associated with a plan should be considered including whether the benefits to be realized are worth the cost: this will always be a subjective decision and ultimately must rely on experience, reasonable and "common sense."* The FPTC brings a combined 150 years of experience to the evaluation of the fish passage facilities, the resource agency directors and City of Tacoma (sponsor) bring a measure of reasonableness and "common sense", and they all consider the recommended fish passage facility to be worth the cost for the expected benefits.

3.2.4.13 Recommended Fish Passage Alternative and Temperature Control

The recommended fish passage alternative, 9A8, provides for selective withdrawal of surface water and water at a fixed elevation close to the reservoir bottom. The design presented calls for a surface intake horn and MIS screen with a capacity of 400 to 1,250 cfs and a submergence depth for the top of the structure of 5 to 15 feet. The elevation of the intake horn is adjustable with changing reservoir water surface elevation. Meeting temperature targets and providing desired fish passage conditions will require: 1) daily monitoring of outflow temperatures and juvenile fish passage; and 2) close coordination among project personnel and resource agencies.

Historic reservoir inflows and projected outflows were modeled for an earlier fish passage facility design with capacity of 200-610 cfs. Under this outflow capacity, maximum target temperatures (59 F) would be met 70% of the time (22 of 33 years) and state water quality standards (60.8 F) would be met 97% of the time (32 of 33 years). In the study time since this water temperature modeling was completed, the minimum flow capacity was increased from 200 to 400 cfs to meet evolving fish passage screening criteria as requested by resource agencies. The recommended fish passage alternative can be operated for flows as low as 200 cfs, but doing so will probably violate MIS screening criteria. It is unclear if the recommended fish passage facility will meet temperature criteria (at 400 cfs minimum) to precisely the same extent as modeled with the lower minimum flow. During the summer low flow period when outflow releases can fall to below 400 cfs, all outflow from the project will have to go through the surface outlet (to meet project objectives for restoration and successful fish passage) and therefore, could limit use of the deep water outlet to blend flows for temperature control. While this could reduce anticipated benefits somewhat, outflow temperatures will still be greatly improved over existing conditions in most years.

Additional temperature modeling with the revised flow capacity in the final fish passage facility design is recommended. Furthermore, physical modeling of the fish passage facility will more accurately define minimum flows that meet design criteria. These minimum flows could be lower than the estimated minimum of 400 cfs and would provide more flexibility in meeting target temperatures.

3.2.5 Habitat Mitigation/Restoration Alternatives

A list of all aquatic habitat mitigation and restoration projects can be found at the end of Part I, Appendix F, Fish Mitigation and Restoration, Section 8, Appendix Table D-1. A list and description of all terrestrial habitat mitigation and restoration projects can be found in Part 2 of Appendix F, Wildlife Mitigation.

3.2.5.1 Alternative 11A – Side Channel Improvements

Side channel projects below HHD were considered for mitigation and restoration. Mitigation requirements are associated with Phase II storage of 32,000 ac-ft of the HHD AWS Project. Restoration opportunities were related to side channel impacts from original dam construction.

a. Alternative 11A1 – Side Channel Improvements Considered for Mitigation. Six side channel projects were developed and considered for mitigation for areas in the Middle and Upper Green. Mitigation requirement for side channels in the Middle Green River was 6.4 acres; requirement for the Upper Green River was 2 acres. Projects developed and considered were: 1) Mueller Side Channel Improvement, Project No. LVF-01. Mueller side channel is located below Highway 18 at RM 33; 2) Loans Levee Removal and Burns Creek Reconnection, Project No. LVF-03. Loans Levee is located near RM 37; 3) Metzler and O' Grady Connector Side Channel Improvement, Project No. LVF-04.

Metzler and O' Grady are King County Parks near RM 39-40.; 4) Flaming Geyser South: Wetland/Oxbow Reconnection, Project No. LVF-06. Flaming Geyser South is located near RM 44 in a state park; 5) Flaming Geyser North: Cutoff Channel Reconnection, Project No. LVF-07. Flaming Geyser North is located from RM 44-45 in a state park; and 6) Brunner Side Channel Reconnection, Project No. VF-03. Brunner Side Channel is the only project considered for the Upper Green River Basin mitigation requirement; all other projects are in the Middle Green. The five Middle Green River side channel projects were incrementally evaluated. Three of the five projects were selected, LVF-03, LVF-04, and LVF-07, to mitigate for the 6.4 acres impacted there. The Upper Green River Project was selected, but was not incrementally evaluated, as it was the only project developed in the Upper Green River impact area.

b. Alternative 11A2 – Side Channel Improvements Considered for Restoration. One side channel project in the Upper Green River was developed and considered for habitat restoration: Signani Side Channel Reconnection and Restoration, Project No. VF-04. This side channel was impacted during original dam construction when the railroad was re-aligned the channel and associated floodplain was disconnected from the river and the lower end of the side channel was filled in. Restoration of this side channel would open one of only two significant floodplain areas available for improvement between HHD (RM 64.5) and the Middle Green River (RM 45). This project was incrementally analyzed with Alternative 11B1B.

3.2.5.2 Alternative 11B1 – Stream and River Improvements

Stream and river improvements near and above HHD were considered for mitigation and restoration. Mitigation requirements are associated with inundation of streams and nearshore habitat during Phase I and Phase II storage of the HHD AWS Project and are broken into riparian and stream habitat. Restoration opportunities are associated with impacts from original dam construction.

a. Alternative 11B1A – Stream and River Improvements Considered for Mitigation. Riparian habitat mitigation requirements were 79.2 acres in Phase I and 42.4 acres in Phase II. Stream habitat mitigation requirements were 11.2 acres in Phase I and 5.7 acres in Phase II. Eleven riparian and stream habitat projects were developed for evaluation in meeting mitigation requirements from enlarged reservoir storage. These projects are found from the edge of the existing full pool and continue upstream. These projects were:

Riparian and Tributary Mitigation Projects	Project ID[1]
Page Mill Pond and Page Creek Maintenance	VF-05
Side-channel Enhancement, Mainstem and Smay Creek	VF-06
Mainstem and North Fork Channel Maintenance	MS-02, TR-04
Tributary Stream Channel Maintenance	TR-05
Mainstem and Sunday Creek Habitat Enhancement	MS-04,TR-08
Tacoma Wildlands Set-asides in Conservation and Natural Forest Zones	MS-08, TR-09
Lower Bear Creek Stream Restoration	TR-01
Headwaters Culvert Replacement	TR-10

1. Project Identification: VF=valley floor projects; MS=mainstem Green River projects; TR=tributary projects.

These projects were broken into riparian and stream habitat components for incremental analysis and evaluation. Further, these projects were identified for in-reservoir areas and above-reservoir areas. Discussion of assumptions and habitat unit outputs can be found in Section 8, Part 1, Appendix F. Selection of final projects was dependent on meeting the mitigation requirements for riparian and stream habitat areas. Four riparian projects were selected, these projects include maintenance of stream-corridor habitat within the HHD AWS Project inundation zone (13.3 acres) and management of riparian forests to accelerate succession on major streams above the project (108.3 acres). Nine tributary or stream projects were selected to mitigate for 17.4 acres of stream habitat. These projects include maintenance of instream habitat within the inundation zone (8.1 acres) and improvement of habitat above the project (8.8 acres).

b. Alternative 11B1B – Stream and River Improvements Considered for Restoration. The construction of HHD and filling of the existing conversation pool affected almost eight miles of tributary stream and mainstem Green River habitat. Two stream and river improvement projects were developed for meeting limited restoration of mainstem and larger tributaries upstream of HHD. The projects considered were 1) the Howard Hanson Dam Inundation Zone, Project No. MS-01, TR-01 to 03; and 2) Howard Hanson Dam Restoration Zone, Project No. MS-03, TR-06 and 07. These projects were located in two areas -- within the existing inundation zone (1,080-1,141 foot elevation) and above the HHD AWS Project inundation zone (1,177-1,240 feet).

An incremental analysis and evaluation was conducted with the two stream improvement projects combined with the single, side channel restoration project, Alternative 11A2. There was no clear break in the incremental output and cost for each alternative. The HHD Restoration Zone Project was incrementally justified while the HHD Inundation Zone Project was the most costly per output. The Signani Side Channel, 11A2, Project was intermediate in output per cost. This project was included as a second restoration measure (with the HHD Restoration Zone) based on its critical location and function of providing important rearing and spawning habitat.

3.2.5.3 Alternative 11B2 –Sites and Volumes Considered for Placement of Gravel

This is a restoration measure to address affects of reduced spawning gravels in the Lower River. Two areas were considered for annual placement of gravel, the Middle Green River from RM 46 to RM 40, and the Upper Green River from RM 60 to 57. In the Middle Green River four possible placement sites were identified. In the Upper Green River three possible placement sites were identified. A brief evaluation of the hydraulic characteristics of the Upper Green River site showed that gravel placement there would be transitory and largely ineffective without incorporating retention structures. Placement in this area was eliminated from further consideration.

Annual volumes considered for the Lower river were 3,900, 7,800, and 11,700 yd^3. These volumes are based on minimum, median, and maximum sediment transport rates estimated for the Green River (see Part 1, Appendix F, Paragraph 4.b). The least cost level, 3,900 yd^3, was selected as a final restoration measure, This is also the minimum volume considered and while it should have no impact on existing flood protection, monitoring and/or sediment transport modeling will be completed to verify this. This measure is estimated to maintain 400,000 ft^2 of spawning habitat in the Middle Green River over a 50-year period.

a. Alternative 11B3 -- Truck and Haul of Large Wood. This alternative has not yet been discussed in sufficient detail with the HHD AWS sponsor, project operations or resource agencies to be included in the list of selected fish mitigation projects. This alternative will be developed and evaluated more during review of the draft feasibility report.

3.2.5.4 Alternative 11C – Reservoir Improvements Considered for Fish and Wildlife Mitigation

a. Alternative 11C1 – Create Sub-Impoundments Around Reservoir. Sub-impoundments were considered for fish and wildlife habitat. Sub-impoundments directed to fish habitat mitigation are included in one project listed under Alternative 11B1 – Mainstem and North Fork Tributary Maintenance, MS-02 and TR-04. Two sub-impoundments would be created in floodplain areas where the mainstem Green enters the reservoir near 1,160-1,165 foot elevation. In addition, several sub-impoundments will be created just by raising the pool and by overtopping of the abandoned railroad grade. Culverts will be placed in the grade to prevent juvenile fish stranding in these impoundments. Project MS-02/TR-04 was selected as part of the mitigation features for the HHD AWS Project.

In Phase I two sub-impoundments directed to wildlife habitat mitigation are located adjacent to the reservoir – one at the mouth of Cottonwood Creek (wildlife mitigation site #22), the other near the mouth of Gale Creek (wildlife site #27); Phase II would add three sub-impoundments, at wildlife sites #'s 17, 23, and 24. Incremental analysis was useful in selecting sites for each phase, though in fact the final reservoir elevation for each phase played the major role in determining the suitability for each sub-impoundment. The sub-impoundments would require construction of a constructed berm, designed to be overtopped by the full reservoir, but to retain the water for an extended period after the reservoir drops in mid- to late summer. The intent is to provide stable water levels to promote the growth of aquatic plants and encourage nesting and denning by birds, amphibians and mammals. These are included in the wildlife mitigation plan described in Part 2, Appendix F. Culverts or outlet control structures are included to provide for juvenile fish passage.

b. Alternative 11C2 – Place Water Tolerant Plants in the Inundation Zone. Placement of water tolerant plants was considered for fish and wildlife habitat. Placement of plants for fish habitat mitigation is included in projects listed under Alternative IIB1, Mainstem and North Fork Tributary Maintenance, MS-02 and TR-04, and Page Mill Pond and Creek Maintenance, VF-05. These plantings are identified for areas along streams to maintain stream banks. These projects were selected as mitigation features for the AWS Project and should provide 13.3 acres of habitat.

Water tolerant plants directed to wildlife habitat mitigation will be placed in the reservoir inundation zone, mostly within 10 vertical feet of high pool, at wildlife sites #'s 16, 22, 23, 24, and 25; in Phase II, additional sedges will be planted at wildlife sites 11, 22, 23, 24, and 25. Final site selection for each phase was determined by incremental analysis. Approximately 100 acres of sedges will be planted, to replace wetlands that will be drowned by the raised pool, and to provide additional forage to elk during periods of reservoir drawdown. Fish are also expected to benefit from these plants when the reservoir is high. These plantings are described in detail in Appendix F.

c. Alternative 11C3 – Leave Inundated Trees in the Enlarged Storage Pool. In the new inundation zone (1,147 to 1,177 foot elevations) retain existing standing timber to partially maintain wildlife, riparian and instream habitat. This alternative was discussed with the Sponsor (City of Tacoma) and operation personnel Limited clearing will occur in the new inundation zone. Final selection of areas and/or trees will be reviewed by Sponsor and project personnel.

3.2.5.5 Alternative 11D – Terrestrial Habitat Improvements above the Riparian Zone

a. Alternative 11D2. For Phase I, seventy-nine acres of pastures will be established to provide additional forage for elk, to replace the meadow at MacDonald farm that is currently well used, but will be inundated by the raised reservoir. Phase I sites are 1, 2, 5, 7, and 8 (these sites total 106 acres, so will accommodate the planned 79 acres of pastures, even though it is expected that parts of some of the sites may not be suitable for pastures). Ten acres of pastures would be added for Phase II, at wildlife site 3. Incremental analysis was the primary tool used in selecting of sites, though some sites were shifted from Phase I to Phase II, and vice versa, based on professional judgment. Juxtaposition of sites with travel corridors was a primary part of the professional judgment selection criteria. Power-line rights-of-way are the first tier selected for pasture creation, where young deciduous forest and upland shrub habitats would be converted to pastures Pastures will also be created from forested habitat in order to meet the mitigation target for pastures (approximately 8 acres of mature conifer and 55 acres of mature deciduous will be converted to pasture). Pastures will be fertilized and mowed on a regular basis. Pastures are described in detail in Appendix F.

b. Alternative 11D3. Late Successional Forest Management. Several wildlife mitigation sites are selected for the express purpose of accelerating seral stage characteristics such that they will more closely mimic old growth forests more quickly. The intent is to provide habitat for target species such as elk (which utilize old growth forests for thermal cover as well as for forage in severe winters), southern red-backed voles, and pileated woodpeckers. Other species, such as goshawks, black-tailed deer, and pygmy owls should also benefit from this management. Sites were selected on the basis of incremental analysis. In Phase I, wildlife sites 9, 10, 12, 13, 15, 18, 19, and 26 – totaling about 143 acres – were selected for late successional management. In Phase II, this type of management would be conducted at site 14, and expanded at site 26, to total about 65 acres.

3.2.5.6 Evaluation of Mitigation/Restoration Alternatives

Habitat mitigation and restoration alternatives were incrementally analyzed and evaluated and were eliminated from further consideration or were included in the list of final alternatives. Each alternative was also screened by consideration of the refined plan formulation criteria. The final list of viable and cost-effective habitat mitigation and restoration alternatives are broken into fish and wildlife projects. A summary list of all selected fish mitigation and restoration projects is provided in Table 3-3. Total project construction costs for fish habitat mitigation and restoration can be found in Table 1-A of Section 8, Part 1, Appendix F. Total project construction costs for wildlife habitat mitigation are found in Section 4, Part 2, Appendix F.

TABLE 3-3. SUMMARY OF SELECTED FISH MITIGATION AND RESTORATION HABITAT PROJECTS

Project Package Name	Activity Name	Project Number	Mitigation/ Restoration	Location
Howard Hanson Dam Fish Passage	Dam Fish Passage Alternative 4	FP-04	M/R	Howard Hanson Dam, Right Bank, Intake Tower, 1070-1177 ft Elevation
Headwaters Green River Habitat Mitigation	Mainstem and Sunday Creek Habitat Restoration	MS-04	M	Headwaters Mainstem below Sunday Creek Confluence
Headwaters Green River Habitat Mitigation	Tacoma Wildlands Set-asides in Conservation and Natural Forest Zones	MS-08, TR-09	M	Headwaters Floodplain, RM 71.3-80.1, Gale Creek 1240-1280 ft el., N. Fork 1240-1320 ft
Howard Hanson Reservoir Mitigation Zone	Mainstem and North Fork Channel Maintenance	MS-02, TR-04	M	Headwaters and North Fork in New Inundation, 1146-1177 ft Elevation
Howard Hanson Reservoir Mitigation Zone	Tributary Stream Channel Maintenance	TR-05	M	Tributaries to Reservoir in New Inundation, 1146-1177 ft Elevation
Page Mill Pond Mitigation	Page Mill Pond and Page Creek Maintenance	VF-05	M	North Fork Green Floodplain, Left Bank, 1147-1185 ft Elevation
Bear Creek Channel Improvement	Lower Bear Creek Stream Restoration	TR-01	M	Lower Bear Creek, Below HHD at RM 64
Headwaters Green River Habitat Mitigation	Headwaters Culvert Replacement	TR-10	M	Three tributaries in Headwaters Watershed, two small tribs and one large tributary
Middle Green River Side Channel Mitigation	Loans Levee Removal and Burns Creek Reconnection	LVF-03	M	Middle Green River Floodplain, Right Bank, RM 37.9-38.1
Middle Green River Side Channel Mitigation	Metzler and O-grady Connector Side Channel Improvement	LVF-04	M	Middle Green River Floodplain, Left and Right, RM 39-40.2
Middle Green River Side Channel Mitigation	Flaming Geyser North: Cutoff Channel Reconnection	LVF-06	M	Middle Green River Floodplain, Right Bank, RM 44.3
Upper Green River Side Channel Mitigation	Brunner Side-Channel Restoration	VF-03	M	Upper Green River Floodplain, Right Bank, RM 58
Howard Hanson Reservoir Restoration Zone	Mainstem, North Fork and Tributary Restoration	MS-03, TR-06, TR-07	R	Headwaters, North Fork, Reservoir Tributaries, 1177-1240 ft Elevation
Upper Green River Side Channel Restoration	Signani Side-channel Reconnection and Restoration	VF-04	R	Upper Green River Floodplain, Left Bank, RM 58.6-59.6
Mainstem Green River Gravel Nourishment	Middle Green River Gravel Bar Nourishment	LMS-01, LMS-02, LMS-03, LMS-04	R	Middle Green Mainstem, 4 Alternate Locations, RM 40-45

3.3 FORMULATION & EVALUATION OF FINAL ALTERNATIVES

3.3.1 Final Plan Formulation Strategy and Criteria

3.3.1.1 Planning Objectives

The Agency Resolution Process resulted in a dramatic change in HHD AWS Project objectives, in addition to the refined objectives: to provide cost effective and sufficient M&I water supply to meet the water needs of the project sponsor over the life of the project; ecosystem restoration – with a goal to establishing healthy, naturally reproducing, self-sustaining runs of chinook and coho salmon and steelhead trout; to provide limited habitat restoration for selected ecosystem functions, processes, or structures in the Green River Basin; to have no net loss of lower watershed habitat while maintaining existing anadromous salmonid populations; to restore natural, self-sustaining runs of anadromous salmonids in the Headwaters watershed; and to restore selected aquatic habitat limiting factors of the Lower watershed, the final HHD AWS planning objectives now include 1) phased implementation of the project; and 2) adaptive management planning for pre and post-project conditions. Objectives of phased implementation include:

Phase I

- Initiate efforts to establish self-sustaining runs of historical upper Green River anadromous stocks (steelhead, coho salmon, and fall chinook).
- Maximize salmon and steelhead smolt survival through the reservoir and the dam fish passage facility.
- Establish baseline conditions (through inventory and monitoring) for middle and lower Green River anadromous stocks (habitat availability and use, migration/flow survival relationships).

Phase II

- Optimize the (potentially) competing objectives of 1) maximum smolt survival through the project, 2) flow augmentation and municipal water supply, and 3) minimizing impacts to lower watershed fish resources.
- Confirm likelihood of self-sustaining runs of upper Green River anadromous stocks (steelhead, fall chinook and coho salmon).

3.3.1.2 Planning Criteria

Water supply, mitigation and restoration criteria remain consistent with Plan Refinement and are carried for to Final Plan Formulation

3.3.1.3 Agency Resolution Process

The input from other study committees is carried forward from plan refinement but now the Agency Resolution Process has taken pre-eminence in project plan formulation

The conditional acceptance by the resource agency directors included specific provisions that the HHD AWS Project must meet before final project acceptance is authorized. These provisions included implementation of the recommended fish passage alternative, 9A8. Further, these provisions have resulted in the changed project objectives and emphasis on adaptive management. The general understanding of ecosystems by most scientists and resource managers today is that there is a great deal of uncertainty regarding major perturbations to natural systems. This uncertainty was behind the need for Phased Implementation to study the existing system and the changes resulting from successive Phase storage changes.

This uncertainty is also reflected in the FPTC development of the recommended fish passage alternative, Alternative 9A8, New Tower with One Enlarged Screen in Single Lock and New Tunnel and Stilling Basin. This design is a unique application of several project features from lessons learned from past fish passage failures and successes and it includes some inviolate criteria the committee consider necessary for successful fish passage.

3.3.1.4 Water Supply and Restoration Criteria for Phased Storage

a. The Agency Resolution Process proposal stipulated the Phased Implementation of the HHD AWS Project. This stipulation added more specific criteria for evaluating water supply and restoration alternatives.

b. All project restoration alternatives (other than flow augmentation) are implemented immediately in Phase I. Mitigation alternatives are implemented prior to implementation of additional water storage: Phase I alternatives are completed prior to Phase I and Phase II alternatives prior to Phase II.

c. To provide for successful fish passage, structural improvements and changes in reservoir operations are necessary.

d. On a daily basis, adaptive management to protect instream resources has higher priority during spring refill than additional storage. To avoid and minimize impacts to the resource base, refill rules were developed – this affects the timing and reliability of storage.

e. Existing storage has higher priority than additional water storage.

f. **Refill operations were targeted to mimic natural hydrology patterns with specific refill rules developed including:**

(1) minimum baseflows;
(2) maximum fill rates; and
(3) use of artificial freshets

g. **Minimum instream flow targets for additional storage flow augmentation are revised over state mandated minimums.** Tacoma must meet these flows prior to additional storage or diversion of water. The MIT/Tacoma mitigation agreement developed these new, higher minimum flows (see Paragraph 1.6.2).

h. **A daily flow model incorporating all baseline data from HHD AWS Project studies and utilizing refill rules was used to evaluate the Phased Implementation storage alternative for refill reliability and impact analysis.**

3.3.2 Description of Final Alternatives

Four reservoir storage alternatives are considered as final alternatives to provide M&I water supply and ecosystem restoration improvements on the Green River. These alternatives are: No Action; single purpose water supply with increased conservation storage of 22,400 ac-ft for M&I water supply and fish passage as mitigation; and immediate full development of the HHD ASW Project with ecosystem restoration with increased storage of 22,400 ac-ft for M&I water supply and 9,600 ac-ft for LFA. The preferred alternative is phased storage of M&I and low flow augmentation water with ecosystem restoration. The preferred alternative is broken into two storage phases: Phase I is immediate storage of 20,000 ac-ft (SSWR) for M&I water supply and Phase II is future, additional storage of 2,400 ac-ft for M&I water supply and 9,600 ac-ft for LFA. A list of the pertinent features for each of the final four alternatives is provided in Table 3-4.

3.3.2.1 Alternative 1 – No Action

The No Action Alternative represents the without-project condition and is the most likely condition expected to exist in the future in the absence of the proposed project, including any known changes in law or public policy. Following are the expected without-project conditions assumed to exist without the proposed Howard Hanson Dam Additional Water Storage Project. This condition assumes neither water supply or restoration at this project are implemented.

TABLE 3-4. FINAL WATER SUPPLY ALTERNATIVES AND ECOSYSTEM RESTORATION.

ALTERNATIVES	No Action	Single Purpose Water Supply with Fish Passage as Mitigation	Full Development with Environmental Restoration	PREFERRED ALTERNATIVE: Phased Development with Environmental Restoration
SSWR Withdrawal (i.e., 100 cfs whenever instream flows are satisfied)	Yes	Yes	Yes	**Phase 1: Not during active spring-time storage; Yes other times Phase 2: Yes**
RESERVOIR STORAGE CHANGE				
Pool Elevation (feet MSL)	1141 normal 1147 drought	1164 normal 1169 drought	1177	**Phase 1: 1167 Phase 2: 1177**
Total Storage (acre feet)	25,400 normal 30,400 drought	47,800 normal 52,800 drought	62,400	**Phase 1: 50,400 Phase II: 62,400**
LOW FLOW AUGMENTATION (LFA)				
Existing LFA (acre feet)	25,400	25,400	25,400	**25,400**
Section 1135 (acre feet)	5,000 drought years	5,000 drought years	5,000 every year	**Phase 1: 5,000 every year Phase 2: 5,000 every year**
Additional LFA (acre feet)	None	None	9,600	**Phase 1: None Phase 2: 9,600**
MUNICIPAL AND INDUSTRIAL WATER SUPPLY STORAGE				
M&I storage (acre feet)	None	22,400	22,400	**Phase 1: 20,000 (SSWR only) Phase 2: 22,400**
ECOSYSTEM RESTORATION (FISH PASSAGE AND HABITAT RESTORATION)				
Downstream Fish Passage	No	Yes Green Peter "Gulper" (9A4)	Yes MIS with new tower & lock (9A8)	**Yes MIS with new tower & lock (9A8)**
Upstream Fish Passage	Yes Likely to be discontinued without successful downstream passage	Yes Likely to be discontinued without successful downstream passage	Yes	**Yes**
Habitat Restoration	None	None	Yes	**Phase 1: Yes Phase 2: None**

a. Water Supply. The without-project condition assumes the following conditions:

(1) Implementation of Tacoma's Second Supply Water Right, which allow an additional 100 cfs of water to be diverted at the Tacoma diversion structure, and construction of Tacoma's Pipeline No. 5 (P5) will occur prior to project year one of 2003. P5 is a water transmission line that will run from Tacoma's water diversion structure located just downstream of Howard Hanson Dam through several communities in south King County and on to Tacoma. Construction of this pipeline is not contingent on the AWS Project and is scheduled to be completed by year 2001. This line will be used to transport water from the proposed project to Tacoma, and several south King County service areas in need of additional water. However, due to the requirement by the State and in an agreement with the Muckleshoot Tribe for prescribed minimum flows in the river below Tacoma's diversion, without the project Tacoma would be precluded from drawing their total allocation of water from the river at many times during the summer and fall due to low flows.

(2) Additional new ground water wells will be drilled to augment the existing water supply. These wells will not be able to provide for Tacoma's total requirements and will be required under with-project conditions also.

(3) Tacoma investigated implementation of a proposed artificial recharge project. The project is not feasible until greater groundwater withdrawals occur in the South King County aquifer.

(4) Tacoma is investigating the use of recycled water, using non-potable water from the sewage treatment plant in industrial applications

(5) Construction and completion of a water supply intertie between Tacoma and Seattle water systems with a peak capacity of 25-40 mgd, and

(6) Water conservation and non-structural measures have been instituted, to include:

- required use of low-flush toilets and low-flow showerheads in new and remodeled residential construction;
- conservation pricing – seasonal water rate increases for residential and wholesale customers.

The above measures will not provide adequate water to supply Tacoma's demands beyond the next 30 years.

b. Fish Passage. The outlet works at HHD were designed to pass water, for flood control and flow enhancement, not fish. When HHD was constructed in the early 1960's there were no migrating fish runs in the upper river, the Tacoma Diversion Dam provided a physical barrier separating the upper river from the lower river preventing upmigration of adult fish past the diversion. In the 1980's resource agencies and the MIT began planting juvenile steelhead, coho, and chinook in the upper river above HHD. Since there is no provisions for fish passage at the dam the water and outmigrating fish are passed from the reservoir through the two regulating outlets; the 48-inch bypass, elevation 1,069 feet and the 19-foot tunnel, elevation 1,035 feet, controlled by two 12-foot radial gates to the river below. The survival rate for outmigrating fish is low approximately 5-25% and is expected to stay that way under the No Action alternative.

Adult wild steelhead returning to spawn are presently collected at the Tacoma Diversion Dam and transported to the reservoir. Adult salmon are projected to be released into the Upper Watershed beginning in the fall of 2003 or 2004 when the downstream fish passage facility is operational, although an earlier pilot project with limited adult releases is possible to prepare for the planned larger-scale releases in 2004. The City of Tacoma in an agreement with MIT will be constructing a fish ladder above the Diversion Dam but will continue to trap and haul adult returning fish at the Diversion Dam for transport to the reservoir. This is a Without-Project/No Action condition and operation will be consistent and unchanged in the with- and without-project conditions.

c. Ecosystem Restoration. When attempting to migrate downstream, juvenile salmon and steelhead would continue to be passed through the existing bypass system at the dam suffering high mortality in the process. Trapping of adult salmon and steelhead below the dam with transport and release above the dam will continue for all alternatives considered. Without project condition assumes the proposed 1135 restoration project, which provides 5,000 ac-ft of storage for low flow augmentation, is in place. Initially, this additional storage will take place in drought years, approximately 1 in 5 years, but through adaptive management the frequency of that storage can be increased to every year. Available habitat would remain as is.

(d) Water Quality. The existing project dramatically alters water temperature in the river section immediately downstream of the dam. With the existing outflow ports, withdrawal of water occurs well below the thermocline during the temperature stratified period. The result is that early summer reservoir outflows are significantly colder than the unregulated river would be. Once the cold water below the thermocline is depleted, usually in the first half of August, the outflow temperature increases dramatically. The result is that late summer and early fall outflows are significantly warmer than the unregulated river would be. Under the existing project, the downstream river often exceeds state water quality standards in the fall.

The existing project adequately meets state water quality objectives for turbidity.

3.3.2.2 Alternative 2A – Additional (Single Purpose) Water Supply With Fish Passage for Mitigation

a. Water Supply. An additional 22,400 ac-ft of water will be stored raising the water surface elevation to a maximum pool elevation of 1,169 feet. This would provide

Tacoma's additional water needs for the next 35-45 years. Additional water rights would be required for this alternative. Under this alternative, Tacoma would continue withdrawal of SSWR water whenever instream flows are satisfied.

b. Fish Passage Facilities. This would consist of modifications to the existing intake tower to add a surface level fish passage, similar to the Green Peter Dam "gulper," as mitigation for the increased depth of the reservoir. Since the existing tunnels would continue to be used for fish passage it is not expected that survival would be greatly increased over present conditions. Out migrating fish would still be subject to injury and descaling due to high flow velocities and abrasion along the tunnel walls.

Adult returning wild fish would continue to be trapped at the Tacoma Diversion Dam and hauled for release in the reservoir as discussed in Paragraph 3.3.3.1 b. above. This would be true for all of the final alternatives considered.

c. Project Operations. The project would operate in a fashion similar to the present, however, 100 cfs (approximately 65 mgd) would be available from storage to supply Tacoma's SSWR water demands during the summer and fall. Storage of Section 1135 LFA water would continue in drought years with pool elevation of 1164 ft (47,800 ac-ft) in normal years and 1169 ft (52,800 ac-ft) in drought years.

d. Mitigation Alternatives. The additional pool length coupled with the increased depth and the need for the fish to sound an additional 30 feet to exit the reservoir at full pool make modifications to the existing intake tower, a surface level collector, necessary to maintain fish runs at the current levels. Other mitigation involving construction of new habitat, to make up for that lost due to the greater height of the pool, would take place in and along the reservoir and tributary streams. This is a "single purpose" alternative to increase water supply. It does not address environmental restoration and therefore, was subsequently dropped from further consideration.

(e) Water Quality. Water temperature problems downstream of the dam that result from the existing low elevation outlets would be exacerbated with this alternative. Earlier refill of the reservoir each year, combined with greater depth and larger surface area would produce a more developed thermocline. Early summer release temperatures would be even colder than existing conditions; fall temperatures would be even warmer.

Earlier refill of the reservoir each year would not significantly impact the project's ability to meet state water quality objectives for turbidity.

3.3.2.3 Alternative 2B – Immediate Full Development of Water Supply and Environmental Restoration with Fish Passage

a. Water Supply. An additional 22,400 ac-ft of M&I water and 9,600 ac-ft of low flow augmentation would be stored in the spring for release during the summer and fall. Tacoma's SSWR of 100 cfs would be diverted at all times during the year, except when minimum flows could not be maintained. Additional water rights would be needed for this alternative. The water surface elevation under this alternative would be 1,177 feet

b. Fish Passage Facilities. The proposed fish collection facility (Plates 29-35) would be a new structure that is intended to pass migrating juvenile fish downstream through Howard Hanson Dam (see Appendix A for design details). It is not intended to pass migrating adult fish upstream through the dam. The adult fish would continue to be trapped below the dam and transported for release above the dam. The main features of the fish passage facility are:

- a new intake tower,
- a wet-well,
- a floating fish collector,
- a fish lock,
- a discharge conduit, and
- a fish transport pipeline.

c. Project Operations. Currently, the entire Green River flow must pass through the existing outlet works intake structure. Upon completion of the new facility, which will be located adjacent to the existing outlet works, flows will pass through either the existing intake structure or the new fish passage facility. The new fish passage facility will be designed to pass the 50% exceedance flow.

Essentially, this facility will operate as a lock. The fish are collected into the fish lock by a floating fish collector located in the wet-well, just upstream of the fish lock. The fish collector houses a modular-inclined screen that allows 95% of the entering flow to pass through it, while preventing the fish from passing through it. The remaining 5% of the flow "washes" the fish across the modular-inclined screen into a flume that deposits the fish into the fish lock. When a sufficient number of fish are collected, the water level in the fish lock is lowered to a predetermined elevation, and the remaining quantity of water and fish are then discharged as a unit through the fish transport pipeline to the Green River just below the existing stilling basin.

d. 1135 Project Operations. The storage of 5,000 ac-ft of water, for low flow augmentation (LFA), initially in drought years is assumed to be stored every year by the time the HHD AWS Project is implemented.

e. Mitigation Alternatives. The new fish passage facility would be both for water supply and low flow mitigation, to maintain the existing level of fish, and for restoration to increase the level of return to allow self-sustaining fish runs.

Habitat improvements would also be required to mitigate for the loss of existing habitat as the pool is raised. Four riparian projects were selected to mitigate for 120 acres of riparian habitat area inundated by the pool raise. These projects include maintenance of stream-corridor habitat within the inundation pool (13.3 acres) and management of riparian forests to accelerate succession on major streams above the project (108.3 acres) for a total of 121.6 acres. Project types include: leaving trees in the inundation pool rather than clearing (not counted as a listed project); planting of water-tolerant vegetation; reserve of riparian forests at 5 acres to 1 acre impacted; and intensified forest management – thinning and planting. The mitigation impact amount was dependent on defining the riparian area, the definition was provided from the Tacoma Forest Land Management Plan.

Nine tributary or stream projects were selected to mitigate for 17.4 acres of stream habitat area inundated by the pool raise. These projects include maintenance of in-stream habitat within the inundation pool (8.1 acres) and improvement of habitat in streams above the project (8.8 acres) for a total of 16.9 acres. These projects do not equal the total 17.4 acre mitigation requirement, but additional compensation can be found through leaving trees in the inundation zone or under the two habitat restoration projects above and below the project. Stream habitat mitigation project types include: placement of large structures (boulders or logs) to increase habitat complexity; replacement of culverts reconnecting tributary habitat; creation of side-channel or pond habitat through excavation. (See Table 3-3.)

f. Environmental Restoration Alternatives

(1) Fish Passage. The main environmental restoration feature of the project is the proposed fish passage. When environmental restoration was added as a project objective the choice of a fish passage changed from one that provided mitigation only to one that provided mitigation and restoration. It is expected that the proposed fish passage will allow a 95% survival rate of juveniles migrating through it. This is the survival rate considered necessary to accomplish the goal of a self-sustaining fish run. Habitat restoration alternatives upstream of HHD are dependent on providing adequate fish passage downstream through the dam.

(2) Low Flow Augmentation. This alternative provides 9,600 ac-ft of additional storage water for low flow augmentation. The flow targets at Auburn vary from 900 cfs to 250 cfs depending on calendar dates and seasonal weather conditions of wet, average, and dry. Details were described earlier in this report under "Alternative 7B – Mimic Natural Hydrology During Refill and Provide Low Flow Augmentation".

(3) Habitat Alternatives. The disruption of sediment transport from the Headwaters watershed due to the interception of almost all course sediment (including gravel) by the original construction of HHD may be causing fundamental changes in the mainstem channel and associated habitats of the Upper to Lower Green River. Gravel nourishment could be used to replenish areas presently deficient of salmon and steelhead spawning-sized sediments and slow or stop the downstream extent of streambed armoring. To implement this measure, monitoring or sediment transport modeling will be required to evaluate the long-term impacts of this restoration measure. It is expected that 3,900 square yards of gravel nourishment should maintain 400,00 square feet of spawning habitat in the Middle Green River

In addition to gravel nourishment, two habitat restoration projects were selected to address original impacts of dam construction and pool inundation that impacted over 8 miles of stream and side-channel habitat. One project is a side-channel reconnection in the Upper Green River (below HHD) that will restore up to 3.2 acres of off-channel habitat and the other is 3.5 miles of river and stream habitat improvement in tributaries above the inundation pool (from 1,177 to 1,240 foot elevation) These projects will interact with the fish passage restoration facility and should help accelerate re-establishment of Headwaters and Upper Green River salmon and steelhead populations.

g. Water Quality. Improved water temperature in the river downstream of the dam would be a benefit of this alternative. Water temperatures problems associated with the existing project would be eliminated or significantly reduced in nearly all years. Early summer release temperatures would follow the natural river temperatures. In the fall, blending of water from above and below the thermocline would allow the project to meet State water quality standards in most years.

Earlier refill of the reservoir each year would not negatively impact the project's ability to meet State water quality objectives for turbidity.

3.3.2.4 Alternative 2C – Phased Development of Water Supply with Fish Passage and Environmental Restoration

a. Phase I Development

(1) Water Supply. An additional 20,000 ac-ft of M&I water would be stored in the spring for release during the summer and fall to supply 100 cfs of Tacoma's SSWR water. The water surface elevation under this alternative would be 1,167 feet.

(2) Fish Passage Facilities. The fish passage facility would be the same as in Alternative 2B above. See sheets 29 – 35.

(3) Project Operations. Under this plan the SSWR water that Tacoma would be allowed to divert during the winter and spring would be stored in the reservoir for release in the summer/fall when the need for the water is greater and the river flows are lower. It is assumed storage of 5,000 ac-ft of water, for low flow augmentation, authorized in the 1135 Project would be stored every year. Adaptive management will be used to minimize the impacts of the HHD AWS Project. Through adaptive management the operation of the HHD can be modified to provide protection and/or compensation to prevent steelhead redd and egg desiccation by 1) reducing freshet volume, and 2) increasing instream flows at the end of the spring refill period during June.

(4) Mitigation Alternatives. Under this Alternative the riparian habitat mitigation would remain the same as in Alternative 2B, would be phased with 79.2 acres being improved in Phase I. The stream habitat mitigation would remain as in Alternative 2B, but would also be phased with 11.2 acres of improvements implemented in Phase I.

(5) Environmental Restoration Alternatives.

(a) Low Flow Augmentation. This alternative contains no additional low flow augmentation in Phase I. Without-project conditions will continue for instream flow. The existing storage will insure a flow of 110 cfs at Palmer. An attempt will be made to follow baseflow levels and release artificial freshets as identified in the adaptive management flow modeling exercise; however, the reliability of attaining the target operations would not be very high without additional storage.

(b) Habitat Alternatives. Habitat restoration alternatives will be the same as in Alternative 2B. All habitat restoration alternatives will be implemented in Phase I.

(6) Water Quality. This alternative would have water quality benefits similar to those of Alternative 2B.

b. Phase II Development. Phase I is expected to last approximately 5-8 years. During that time the effects of Phase I of the HHD AWS Project on the environment and on the fish runs will be monitored and adaptive management alternatives will be used to minimize the impacts of the project.

(1) Water Supply. An additional 2,400 ac-ft of M&I water would be stored along with 9,600 ac-ft of storage for LFA, for a total of 32,000 ac-ft of water under Phase I and Phase II. The water surface elevation in Phase II would be 1,177 feet. During the refill period 32,000 ac-ft of water would be stored behind HHD, in addition, during this time, up to 65 mgd of water would be withdrawn through pipeline 5. This withdrawal of additional water would require new water rights and would be subject to the greater of State or MIT/Tacoma Agreement instream flows.

(2) Fish Passage Facility. The fish passage facility will be completed in Phase I.

(3) Project Operations. Phase II operation is the same as Alternative 2B.

(4) 1135 Project Operations. The water for low flow augmentation (LFA) would continue to be stored every year.

(5) Additional Mitigation Alternatives. Phase II includes an additional 42.4 acres of riparian mitigation and 5.7 additional acres of stream habitat mitigation. Once Phase II was completed it would be the same as Alternative 2B.

(6) Additional Restoration Alternatives. In Phase II, 9,600 ac-ft of additional water will be stored for low flow augmentation. Operation of this storage will be the same as described in Alternative 2B.

(7) Water Quality. This alternative would have water quality benefits Phase I in addition to the low flow augmentation (LFA) of Phase II. LFA provides a slightly deeper, faster moving river that would remain cooler for a further stretch downstream of the dam than under existing conditions.

3.3.3 Comparative Evaluation of Final Alternatives: Criteria

3.3.3.1 General

In formulating a plan to meet the final planning objectives, a number of planning criteria were considered. These criteria were used to screen and evaluate alternative plans and to measure each plans contribution to the national economic development (NED), environmental quality (EQ), and regional development (RD) and other social effects (OSE) accounts from the Water Resource Council's "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" of March 1993. Not all of the criteria are compatible and no plan could fully satisfy all of them. However, the recommended plan comes closest to satisfying all of them. Applicable planning criteria for the study is presented in the following paragraphs under the account to which they are primarily related.

3.3.3.2 National Economic Development

For this multiple-purpose project the NED criteria was used to help formulate plans which meet the NED objective of developing maximum net benefits to the nation. This particular project is unique given it is a dual purpose project where one project purpose places a value on the benefits in dollars (water supply) while the other project purpose benefit is quantified in non-dollar values (ecosystem restoration). As a result, the typical maximization of net benefits (benefits minus costs) is not possible and other criteria must be used. For this project, one of the economic criteria used to evaluate alternative projects was to implement the least cost measure that would achieve the goal of each project purpose. The goal of water supply was to implement the least cost way of meeting future water demands over the 50-year life of the project. Water supply benefits must also exceed the separable water supply costs. For ecosystem restoration, the goal was to achieve the least cost way of producing self-sustaining runs of salmon and steelhead. Self-sustaining runs are those which do not have to be supplemented with hatchery fish. Other NED criteria are listed below.

- The period of analysis for this study includes a 50-year period from 2003 to 2053.
- Project Costs and dollar quantified benefits are in October 1997 prices. Project interest rate is 7 and 1/8 percent.

- Water supply and habitat measures cannot adversely impact existing project purposes for flood control and water conservation storage for minimum instream flows. Existing storage has higher priority than additional water storage.
- Water supply and Restoration measures must be in the Sponsors best interest.
- Value of water supply benefits is based on the least-cost water supply alternatives to HHD.
- Output of water supply measures is measured at 95% reliability and provides the same water quality as HHD.
- The water supply source must be available, not just speculative.
- Water supply measures must meet the average summer and/or 4-day peak demands,
- Fish passage measures must meet design criteria provided by an independent technical committee.
- Restoration measures must be consistent with the Ecosystem Restoration Guidance.
- Restoration measures must be consistent with HHD AWS Project objectives of 1) providing an acceptable level of water supply; 2) restoring anadromous fish above HHD; and 3) restoring selected ecosystem processes or functions.
- Restoration strategies and measures must be consistent with existing fish and wildlife management.
- The project is managed adaptively, but for planning purposes Phase I is assumed to last 5 to 8 years. This should be considered a reasonable period of time for meeting project performance objectives for Phase I and to determine through monitoring and evaluation if Phase II can be implemented.
- All operational and structural means available were used to avoid or minimize impacts of storing additional water for M&I and flow augmentation.
- Mitigation needs addressed prior to development of restoration projects.
- Least-cost alternatives that fulfill identified mitigation requirements were selected first.
- Cost effective incremental cost analysis was used to help refine and select between mitigation and restoration alternatives.

3.3.3.3 Environmental Quality Criteria

The EQ criteria are used to evaluate the effects of alternative plans on the EQ account, which displays non-monetary effects on significant natural and cultural resources. The EQ criteria include those imposed by federal, state, local and tribal regulations, and those uniquely related to the HHD AWS Project area and the Green River. The significant environmental resources of this area are described in this DFR/EIS and Appendix F. The pertinent EQ criteria are as follows:

- Protect and restore critical ecosystem functions, processes and/or target fish and wildlife habitats in the study area.
- Restore self-sustaining runs of salmon and steelhead to the Upper Green River
- Protect, and where possible, assist in the recovery of any threatened or endangered species in the study and their critical habitat.

- Protect and restore water quality in the study area.
- Preserve or salvage significant historic and prehistoric cultural resource sites affected by potential project construction or effects in accordance with the Historic Preservation Act of 1966; the Reservoir Salvage Act of 1960, as amended by Public Law 93-291; EO 11593; and the Archaeological Resources Protection Act of 1977
- Protect, and where possible, enhance recreational values within the study area.
- Water supply measures must avoid any overriding environmental problems.
- The water supply measure must not adversely affect water quality conditions: turbidity, dissolved oxygen, temperature, and saltwater intrusion.
- Wells must not be in hydraulic continuity with existing surface water.
- Water supply measures must not adversely affect minimum in-stream flows.
- Restoration measures must address overriding environmental problems, in particular, identified and accepted aquatic habitat limiting factors.
- The restoration project area is limited.
- To provide for successful fish passage, structural improvements and changes in reservoir operations are necessary.
- On a daily basis, adaptive management to protect instream resources has higher priority during spring refill than additional storage.
- Refill operations were targeted to mimic natural hydrology patterns with specific refill rules developed including: 1) minimum baseflows; 2) maximum fill rates; and 3) use of artificial freshets.
- Minimum instream flow targets for additional storage flow augmentation are revised, and higher, than state mandated minimums.
- Habitat mitigation projects are evaluated by impact areas: 1) side-channel disconnection; 2) riparian and tributary habitat inundation; and 3) terrestrial habitat inundation (wildlife).
- Mitigation and restoration projects must be ecosystem function or process driven
- Mitigation and restoration project sites were developed and selected based on ecosystem or biological need first.
- Restoration projects or sites considered addressed specific aquatic habitat limiting factors identified through HHD AWS scoping.
- If no fish passage alternative can provide 95% project survival, the recommended fish passage alternative must provide project passage survival rates and estimated adult returns that meet or come near the restoration objective of self-sustaining runs.
- In addition to meeting design criteria, fish passage alternatives are to be assessed based on lessons learned from past project failures and successes in fish passage development.
- The recommended fish passage alternative must meet approval of FPTC and Resource Agency Directors.
- Fish passage alternatives recognize that the Green River is a heavily urbanized watershed and therefore higher project survival rates and escapements are necessary to reach self-sufficiency.

- Dam fish passage alternatives must include a surface withdrawal ability to provide for water quality improvements by blending of warmer surface and cooler lower reservoir water.
- An ability to screen the 50% exceedance flow (late April through May) through a surface inlet is the most critical design feature for providing successful attraction and entrainment of smolts into any fish passage facility.

3.3.3.4 Impacts to and/or Effects on Existing Project Operation

a. Flood Control. All alternatives have had the same flood control space and operational requirement. This includes the conditions within the Phase I and Phase II implementations. Flood control procedures may include a warning to water and land resource managers during flood events when certain features constructed around the reservoir area are likely to be inundated. However, the presence of these features (or lack of) did not influence the selection of the preferred alternative. Both Phase I and Phase II include refill operations that start as early as mid-February. Flood control operations have a higher priority function than refill operations, so the refill would be interrupted and evacuated when a flood forecast is immanent. After a flood event, river flows are still high and biological functions are usually interrupted (unintentionally), so an accelerated refill schedule could likely be imposed to regain the space that was earlier evacuated. A similar situation could occur in the fall season. The flood control zone could have about a quarter of its space occupied by the conservation storage. The immanent occurrence of fall rains is predictable by meteorological and satellite photo observations. The weather transition marks the end of the low-flow season. There still would be space in the river channel to plan the evacuation of surplus conservation storage. Water and biological resource managers would coordinate the magnitude and duration of reservoir releases into the Green River. The requirement to refill the conservation space for the potential continuation of low flows after the first rain is a possibility that would be considered during real-time observations of the transition season.

b. Right Abutment Seepage. The right abutment is a short, sharp, narrow rock ridge dividing the present and ancestral Green River valleys. The rock is hydrothermally altered and weaker than most of the rock forming the left abutment. The complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the standpoint of hydrogeology. Basically, at least two major aquifers are present with the possibility that others exist.

Seepage through the right abutment of the dam and its effect on the stability of the downstream right bank slope of the dam have been a basis for continued exploration and studies since the dam became operational in December 1961. The last formal document addressing these issues was a report titled "Post Flood Report, Howard A. Hanson Dam." dated April 1997.

In February 1965, when the pool briefly reached elevation 1,161.8 feet, a spring appeared on the downstream right abutment at elevation 1,134 feet, approximately 460 feet downstream from the dam axis. The spring area was blanketed by a gravel fill, and a crib wall was constructed to support the gravel. In 1968, to improve seepage control, a 640-foot-long concrete lined drainage tunnel was constructed into the right abutment at elevation 1,100 feet, 200 feet downstream of the dam axis.

Since that time there have been four major flood pools that exceeded elevation 1,160 feet. The first flood occurred on December 5, 1975 with a peak of 1,175.8 feet. The second flood peaked at 1,173.6 feet on December 4, 1977. The third flood peaked at 1,167.2 feet on December 1, 1995. The fourth occurred on February 10, 1996 with a peak of 1,183.2 feet. During each of these events increased seepage has been noted.

From studies performed to date, it is apparent that some form of corrective actions must be incorporated into the design of the HHD AWS Project to mitigate for the effects of the higher pool. Several alternatives have been developed and analyzed to address reduction of seepage through the right abutment (see Appendix E, Geotechnical Considerations).

The recommended plan proposes that consolidation grouting be done locally to reduce the seepage through the right abutment. This would consist of a series of borings (assumed to be on 3-foot centers and two rows at this time) drilled approximately 10 feet into bedrock for a total length of drilling of about 25,510 feet to facilitate placement of grout. Grouting (estimated at about 7,420 cubic yards) would be performed under very low pressures to reduce the chance of hydro-fracturing the abutment materials.

During the Feasibility Study, consideration was given to raising the pool to 1,177 feet for an extended period of time to allow us to better determine the effects of the higher pool, but this was unacceptable to the regulatory agencies. Either during PED or early in construction, depending on approval of the agencies, a test pool raise will be conducted to determine if more aggressive measures will be needed to control right abutment seepage.

c. Turbidity and Temperature Control

(1) Temperature. Any additional water supply alternative without fish passage will result in outflow temperatures exceeding desired target temperatures and state mandated temperature requirements (60.8^{0}F maximum) in most years. The existing project with a single low elevation outlet results in colder than natural releases in the early summer and warmer than natural releases during mid summer through early fall. Without the fish passage facility, additional water supply would exacerbate this situation Additional water supply with the recommended fish passage alternative can result in a blending of outflow from warmer surface waters with the cooler deeper outlets.

By maximizing surface withdrawal through the fish passage facility during the spring and early summer cool water storage is maximized for use in the later summer and fall. The fish passage facility surface outflow tends to track natural inflow temperature until the reservoir stores a significant amount of heat. Blending of surface and deeper water would occur sometime in July. After this time, meeting temperature requirements could restrict the use of the fish passage facility, or conversely, meeting fish passage criteria could result in possible violation of state temperature requirements. To address these constraints daily monitoring of outflow temperatures and fish passage would be required as would close coordination with resource agency biologists.

(2) Turbidity. Any of the final project alternatives would require beginning spring refill 5-6 weeks earlier than current operation of the reservoir, increasing the likelihood of storing water from high turbidity events. Historic records show that March inflow turbidity is no higher than April inflow turbidity and that suspended sediments tend to settle from the water column within a few days. Under any HHD AWS alternative, high turbidity flows stored in the reservoir would be more frequent, however, the effect on outflow turbidity would be minor and short-lived, no different than under current operation. An enlarged reservoir would cause small and localized bank instability during initial inundation of the conservation pool resulting in insignificant effects on turbidity (Eckerlin, October 1995). The reservoir recently filled for flood control to the elevation of the proposed conservation pool with only temporary impacts to outflow turbidity.

Selective removal of trees is expected prior to inundation with the first additional storage conservation pool. Although the final amount of tree removal has not been identified, removal may decrease bank stability and will be one criterion in assessing the final clearing plan.

3.3.3.5 Operation & Maintenance

The selected alternative will shift the focus of the operation of the project from the existing intake to the new fish passage facility. Except during floods and maintenance closures, the new facility will be used to control the flow. Because stoplogs must be installed or removed to match the pool elevation, significantly more labor is involved in raising or lowering the pool, particularly during the spring impoundment, when the pool rises rapidly for 3 ½ months. Also, whenever the main gates are used in conjunction with the fish passage gate, project personnel will adjust the gates in time consuming incremental adjustments to maintain the correct combined flow. The new facility also will contain more equipment for the project personnel to maintain in addition to the equipment in the existing intake structure.

3.3.3.6 Funding and Budget

It is expected that the PED phase of this project will begin in approximately the last quarter of calendar year 1998 and will take approximately 3½ years. Construction will take approximately 3½ years with completion of Phase I construction in 2004. Construction phase will begin in 2001 and will overlap the PED phase of the project. This will allow construction of the mitigation features, except for the new tower and fish passage, and a test pool raise while design of the tower and fish passage is completed.

The cost of PED is estimated to be approximately $8.3, in 1997 dollars. The federal share of the PED costs is 75% with the non-federal sponsor contributing the other 25%.

The cost of construction is estimated to be approximately $66.4, in 1997 dollars, including required monitoring. The federal share of the construction cost is 65% of the cost attributable to ecosystem restoration. The non-federal share of construction is 100% of the costs attributable to M&I water supply and 35% of the costs associated with ecosystem restoration. See Section 4.11 for more detail.

3.3.4 Designation of Alternative Plans

3.3.4.1 National Economic Development

Based on the NED criteria presented in Paragraph 4.3.2 (National Economic Development), the NED plan is primarily based on implementing the most cost efficient plan that would achieve the goal of each project purpose. The NED plan is Alternative 2C described in Paragraph 4.2.4. This plan will provide 22,400 acre-feet of storage or 48 mgd over the 153-day summer/fall demand period at 95% reliability and will also provide 9,600 acre-feet of storage for low flow augmentation during the summer or an additional 39 cfs at 78% reliability over a 123-day summer/fall period. In addition, the NED plan will provide a fish passage facility determined to be the least cost alternative of meeting the restoration goal of establishing self-sustaining wild runs of chinook, coho and steelhead in the upper watershed above HHD.

3.3.4.2 Least Environmentally Damaging

Alternative 9F is the least environmentally damaging of the alternatives considered. To provide near natural riverine conditions and total restoration of fish passage (both downstream and upstream), removal of HHD would be required. Either the dam would be removed or a portion breached to recreate the existing Green River channel for unimpeded passage. This alternative was eliminated, as it does not meet AWS Project objectives and would violate existing project purposes for flood control and water conservation (meeting minimum instream flows).

3.3.4.3 Preferred (Tentatively Recommended) Plan

The recommended plan is Alternative 2C – Phased Development of Water Supply with Fish Passage and Environmental Restoration, described in Paragraph 4.2.4. This plan is also the NED plan and meets the NED planning objectives to: (1) provide cost effective and sufficient M&I water supply to meet the water needs of the project sponsor over the life of the project; (2) provide ecosystem restoration, with a goal to establish healthy, naturally reproducing, self-sustaining runs of chinook and coho salmon and steelhead trout in the Upper Green River watershed above HHD; and (3) provide limited habitat restoration for selected ecosystem functions, processes or structures in the Green River Basin.

SECTION 4. RECOMMENDED PLAN

4.1 RECOMMENDED PLAN DESCRIPTION

In 1994, as a result of a change in federal policy, the project purpose was expanded from water supply to water supply and environmental restoration. This significantly affected the overall outlook on the additional water storage project, as now project features could be looked at as restoration opportunities, not just mitigation.

The recommended plan includes raising the level of the reservoir to provide 22,400 acre-feet (ac-ft) of storage for Municipal and Industrial (M&I) water supply, and 9,600 ac-ft of storage for low flow augmentation, habitat improvements, and a new downstream fish passage facility at Howard Hanson Dam as environmental restoration measures. Also included are mitigation measures required due to the pool raise.

Upstream migrating wild adult salmon and steelhead will be caught at the Tacoma Diversion Dam and transported upstream and released in, or upstream of, the reservoir. The handling of the returning fish is considered a without-project condition.

In February 1996, in response to agencies and Muckleshoot Indian Tribe (MIT) concerns, the project implementation was broken into two phases. This was done to isolate the concern for impacts to in reservoir fish migration and effects of storing water during the spring. In breaking down the implementation into two phases and committing to an adaptive management approach to operating the project, four key resource agencies (NMFS, WDOE, USFWS, and WDFW) conditionally accepted Phase I of a two-phase project implementation proposal. Additional letters were received in November 1997, from the Office of the Governor of Washington State, NMFS, WDOE, USFWS, WDFW, and Trout Unlimited, conditionally supporting approval and funding of Phase I on the project these letters are included in Appendix I. Acceptance was based on 20,000 ac-ft water supply storage, fish passage facility, and various reservoir habitat improvements being implemented as Phase I. Their acceptance of Phase II, storage of an additional 2,400 ac-ft of M&I water plus 9,600 ac-ft of low flow augmentation water, will be based upon successful performance of Phase I and the Corps' ability to demonstrate that Phase II project impacts can be overcome.

4.1.1 Phase I

Phase I includes all structural features, all mitigation features required for raising the pool to elevation 1,167 feet, and all environmental restoration features except low flow augmentation.

a. Structural Features. Structural features are required to provide a fish passage facility for environmental restoration and mitigation for the pool raise. At this level of investigation, it is assumed that the features of the fish collection facility can be constructed using normal construction techniques and practices familiar to contractors doing business in the Pacific Northwest region

A three-dimensional rendering of the fish passage facility is shown in Figure 4-1. A plan view of the dam, lower reservoir, and fish collection facility are shown in Plates 29, 30 and 31. A cross-section of the facility and wet-well structure is shown in Plates 32 and 33 and Figure 4-2. A cross-sectional view of discharge conduit and intake tower is shown in Plates 34 and 35 and Figure 4-3. The location of the cofferdam and limit of forebay excavation is shown in Plate 35. Figure 4-4 shows an artistic rendering of the proposed facility superimposed on a photograph of the HHD lower reservoir area. Plates and figures are found at the end of this report.

(1) New Tower. The new intake tower will be located to the left of the existing intake tower. The new intake tower will house the gate chamber, vent shaft, and access shaft. The gate chamber is about 30 feet by 20 feet in plan, has a base elevation of 1,035 feet, and an upper elevation of about 1,085 feet. It will house a single radial gate and operating hydraulic actuator. A guide slot for the emergency tractor gate for the attraction water discharge will be located just upstream of the radial gate.

The gate chamber and tower will be monolithically constructed of normal weight reinforced concrete structure.

(2) Fish Collection and Transport Facility. The proposed fish passage facility is a new structure that is intended to pass migrating juvenile fish downstream through Howard Hanson Dam. It is not intended to pass migrating adult fish upstream through the dam. The returning wild adult fish will be trapped at Tacoma's Diversion Dam and hauled to the reservoir, a without-project condition. The main features of the fish collection facility are:

(a) A Wet-Well. The wet-well structure is a 105-foot-long by 30-foot-wide by 150-foot-deep open-end box structure. Approximately 105 to 115 feet of the structure will be embedded in rock. The structure has a top elevation of 1,185 feet and a floor elevation of 1,035 feet. The upstream end, or intake horn, of the wet-well structure is flared to a width of about 45 feet, and the right edge abuts the left side of the existing intake tower trashrack structure. The floating trashrack is attached at the flared end of the wet-well structure

(b) A Floating Fish Collector. The fish collector assembly is, essentially, a floating container for a modular inclined screen. The modular-inclined screen (MIS) will be mounted in the center of the collector housing, and will have hinges along its center of rotation that attach it to the housing framework. The MIS is held in position by hydraulic actuators, and may be rotated to allow accumulated debris to be washed off of the screen.

Various instrument sensors will be installed to monitor water flow and debris accumulation. The purpose of the MIS system is to safely separate the fish from the majority of the flow. The screen will allow most of the water to pass into the wet well while the fish and a small portion, approximately 5%, of the water will be diverted to the fish chamber. The screen is of special construction to prevent injuries to the fish as they slide along it.

(c) A Fish Lock. The fish lock structure is a 35-foot-long by 30-foot-wide by 135-foot-deep closed-end box structure. Approximately 90 to 100 feet of the structure will be embedded in rock. The structure has a top elevation of 1,185 feet and a floor elevation of 1,049 feet. It is to be constructed monolithically with the wet-well structure. The common wall that separates the fish lock from the wet-well will contain the guide slot for the stoplog set that serves the same purpose. Integral with the right-hand wall is to be the guide slot for the fish lock regulating well stoplog set and floating weir. This vertical slot will have a full height screen, made of the same wedge-wire fabric as the MIS, to prevent fish from entering the regulation well. At the bottom of the fish lock is a full-coverage fish screen, made of the same wedge-wire fabric as the MIS. This screen will be sloped to funnel fish into the fish transport pipe inlet at the base of the right-hand wall. A removable steel framework and grating will be installed on top of the fish lock structure to provide a work deck for safety, operation, and maintenance functions.

(d) A Discharge Conduit. The discharge conduit is a new tunnel that connects the new wet-well structure to the existing outlet works tunnel. The new conduit is to be designed to pass flows ranging from 400 to 1,600 cubic feet per second (cfs), although under normal operating conditions a maximum flow of 1,250 cfs will be used, as high flows are accompanied by velocities which are unacceptably high from a smolt survival standpoint. These flows will be regulated by a radial gate. Upstream of the gate, the flow regime is pressurized, and downstream of the gate the flow will be open-channel.

The new conduit will enter the existing flood control tunnel just downstream of the location of the existing splitter wall. It will enter the existing tunnel with a floor elevation of about 1,034 feet (the existing tunnel's floor elevation is about 1,023 feet at this point so that the exit opening will be above the flow line in the flood control tunnel at all flood control operating conditions). The new conduit begins at the downstream end of the wet-well structure, with a base elevation that matches the wet-well base elevation of 1,035 feet, and has an alignment that is parallel with the new wet-well centerline. Although its alignment is presently shown on the drawings as turning 90 degrees toward the existing facility, the conduit will be realigned during PED (pre-construction engineering and design) to eliminate this curvature upstream of the control gate.

(e) A Fish Transport Pipeline. The fish transport pipeline is a 24-inch-diameter steel pipe that will run continuously from the fish lock to the Green River at an appropriate location downstream from the flood control tunnel stilling basin to provide acceptable entrance conditions back into the river. This pipeline will be suspended along the roof of the new discharge conduit and along the crown of the existing outlet works tunnel. The pipeline will be attached to the tunnel crown with a suitable anchor bolt and saddle assembly. At the present time, it is envisioned that the fish transport pipeline will be supported along the right-hand side of the stilling basin, in the vicinity of the existing 48 - inch bypass line.

(f) PED Changes to Fish Collection and Transport Facility. Some revisions to the recommended plan presented in this Feasibility Report will be accomplished during PED to ensure or improve upon safe operation, acceptable fish passage performance and/or hydraulic performance. The most significant of these revisions involve the fish collection and transport facility, and include:

- The attraction flow outlet conduit between the wet-well and the existing flood control tunnel will be realigned to eliminate the horizontal curve which is presently shown upstream from the outlet conduit control gate.

- The emergency gate for the wet-well outlet conduit will be provided with an independent air supply source. The present design does not provide for air supply to the emergency gate which would present an operational problem if the gate is needed to close the outlet conduit under flow conditions.

- Separate pipes will be provided for fish transportation and lock drainage downstream from the fish lock. The present design uses one pipe to serve both purposes which requires two separate bifurcations which create a potential for fish injury.

- The fish transportation pipe will be extended downstream well beyond the flood control stilling basin. The present design places fish back into the river in the stilling basin. Because the stilling basin presents a likely location for predators and high turbulence, etc., placing the juvenile fish in the stilling basin creates a high potential for injury to the fish.

(3) New Buildings. Four new buildings, or additional to existing buildings, are proposed as part of the fish collection facility. These are: an administration building, a maintenance building, a monitoring building, and a generator building. If a new administration building is found to be more cost effective that adding to the existing building, then the existing administration building will be demolished.

A maintenance building is required to provide a ventilated, heated and secure workspace for routine maintenance and repair work. This building would also provide space for the storage of tools, spare parts, and maintenance supplies.

The monitoring building is a small building or trailer that will be located immediately downstream of the dam and will house the downstream fish monitoring equipment.

The generator building will house the emergency generator which will provide back-up power to the new fish passage facility.

(4) Right Bank Seepage Remediation. The rock on the right abutment is hydrothermally altered and weaker than most of the rock forming the left abutment. The complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the standpoint of hydrogeology.

Seepage through the right abutment of the dam and its effect on the stability of the downstream right bank slope of the dam have been a basis for continued exploration and studies since the dam became operational in December 1961. The most recent document addressing these issues was a report titled, *Post Flood Report, Howard A. Hanson Dam*, dated 8 April 1997.

In February 1965, when the pool briefly reached elevation 1,161.8 feet, a spring appeared 460 feet downstream of the dam axis on the right abutment at elevation 1,134 feet. The spring area was blanketed with gravel fill and a crib wall was constructed to support the gravel. In 1968, a 640-foot-long concrete lined drainage tunnel (adit) was constructed into the right abutment at elevation 1,100 feet to improve seepage control. The tunnel is located 200 feet downstream of the dam axis.

Since the initial filling of the reservoir there have been four major flood pools that exceeded elevation 1,160 feet. The first flood occurred on December 5, 1975, with a peak of 1,175.8 feet. The second flood peaked at 1,173.6 feet on December 4, 1977. The third flood peaked at 1,167.2 feet on December 1, 1995. The fourth and maximum to date occurred on February 10, 1996, with a peak of 1,183.2 feet. During each of these events significant seepage has been recorded.

From studies performed to date, it is apparent that some form of corrective actions must be incorporated into the design of the Additional Water Storage (AWS) project to mitigate for the effects of the higher sustained conservation pool. Several alternatives have been developed and analyzed to address reduction of seepage through the right abutment. (See Appendix E, Geotechnical Considerations.)

The recommended plan proposes that consolidation (injection) grouting be done between the right abutment and the dam embankment to reduce seepage through the right abutment. (See Figure E-9 in Appendix E, Geotechnical Considerations, for location of the proposed grouting.) This would consist of a series of borings (assumed to be on 3-foot centers and two rows at this time) drilled approximately ten feet into bedrock for a total length of drilling of about 25,500 lineal feet to facilitate placement of grout. Grouting, estimated at about 7,420 cubic yards, would be performed under very low pressures to reduce the chance of hydrofracturing the abutment materials.

During the Feasibility Study, consideration was given to raising the pool to 1,177 feet for an extended period of time to allow the U.S. Army Corps of Engineers (USACE; the Corps) to better determine the effects of the higher pool, but this was deemed unacceptable to the regulatory agencies. Therefore, the test pool must be accomplished during construction for two reasons: first, the test pool will be preceded by grouting the area between the right abutment and the embankment and second mitigation for the pool raise will have to be done, as much of the existing vegitation is expected to be impacted by having the pool up for a long enough period to to obtain needed inforamtion. The test pool is needed in order to monitor groundwater conditions in the right abutment and to design and construct an appropriate modification to the seepage control measures currently in existence, if necessary. Requirements for a test pool are as follows:

1) It is known that precipitation effects the groundwater regime of the upper aquifer, therefore, the test pool will be conducted under conditions of a normal summer conservation pool.

2) The test pool will be conducted in a staged manner; i.e. the pool will be raised in approximately 10-foot increments, allowing time for instruments to stabilize before the initiation step. It is estimated that the test pool will take about three months to accomplish.

3) A complete analysis of the data will follow the completion of the test pool, which is expected to take approximately two months to complete. The design of any new seepage control feature or modification to the existing seepage control features will commence after completion of the analysis.

Additional right bank seepage corrective actions may be necessary once the test pool has been conducted. Cost of these measures may ultimately limit the final pool raise elevation to something less than 1,177 feet.

(5) New Access Bridge. An access bridge will provide vehicle, utility, and personnel access to the new facility. It will have a deck width of about 20 feet and will connect to the exiting intake tower access bridge with an expansion joint. As this bridge will approach the existing bridge at an unusual angle, it is anticipated that the new bridge will be a free-standing structure and will not be supported by the existing bridge.

At this time, the bridge is envisioned to be a concrete structure.

b. Changes in Water Storage. An additional 20,000 ac-ft of M&I water will be stored in the spring for release during the summer and fall to supply up to 100 cfs (65 mgd) for Tacoma's second supply water rights. The water surface elevation under this alternative would be 1,167 feet. Tacoma will not divert second diversion rights water during the spring reservoir refill, but will allow it to be stored for use in summer and fall when there is a greater need for the water. It is assumed that the 5,000 ac-ft of water stored for low flow augmentation, initially during drought years under the 1135 project, will be stored every year, through adaptive management, by the time Phase I is implemented

c. Mitigation Features. The new fish passage facility would be both for mitigation, to maintain the existing level of fish escapement, and for restoration to increase the level of return to allow a self-sustaining run.

Habitat improvements would also be required to mitigate for the loss of existing habitat as the pool is raised. Four riparian projects were selected to mitigate for 120 acres of riparian habitat area inundated by the pool raise. These projects include maintenance of stream-corridor habitat within the inundation pool (13.3 acres) and management of riparian forests to accelerate succession on major streams above the project (108.3 acres) for a total of 121.6 acres. Project types include: leaving trees in the inundation pool rather than clearing (not counted as a listed project); planting of water-tolerant vegetation; reserving riparian forests at a ratio of 5 acres reserved to 1 acre impacted; and intensified forest management – thinning and planting. The mitigation impact amount was dependent on defining the riparian area, the definition was provided from the Tacoma Forest Land Management Plan. Riparian habitat mitigation will be phased with 79.2 acres being improved in Phase I to mitigate for the higher pool elevation of 1,167 feet.

Nine tributary or stream projects were selected to mitigate for 17.4 acres of stream habitat area inundated by the pool raise. These projects include maintenance of in-stream habitat within the inundation pool (8.1 acres) and improvement of habitat in streams above the project (8.8 acres) for a total of 16.9 acres. These projects do not equal the total 17.4 acre mitigation requirement, but additional compensation can be found by leaving trees in the inundation zone or under the two habitat restoration projects above and below the project. Stream habitat mitigation project types include: placement of large structures (boulders or logs) to increase habitat complexity; replacement of culverts reconnecting tributary habitat; creation of side-channel or pond habitat through excavation. The stream habitat mitigation will also be phased with 11.2 acres of improvements in Phase I.

d. Environmental Restoration Features. The main environmental restoration feature of the project is the proposed fish passage. When environmental restoration was added as a project objective the choice of a fish passage facility changed from one that provided mitigation only to one that provided mitigation and restoration. The goal of the proposed fish facility passage is to allow a 95% survival rate of juveniles migrating through it. This is the survival rate considered necessary to accomplish the goal of a self-sustaining fish run. Habitat restoration measures upstream of HHD are dependent on providing adequate fish passage through the dam.

The disruption of sediment transport from the Headwaters watershed due to the interception of almost all course sediment (including gravel) by the original construction of HHD may be causing fundamental changes in the mainstem channel and associated habitats of the Upper to Lower Green River. Gravel nourishment will be used to replenish areas presently deficient of salmon and steelhead spawning-sized sediments and slow or stop the downstream extent of streambed armoring. To implement this measure, monitoring and/or sediment transport modeling will be required to evaluate the long-term impacts of this restoration measure. It is expected that 3,900 cubic yards of gravel nourishment should maintain 400,000 square feet of spawning habitat in the Middle Green River.

In addition to gravel nourishment, two habitat restoration projects were selected to address original impacts of dam construction and pool inundation that impacted over 8 miles of stream and side-channel habitat. One project is a side-channel reconnection in the Upper Green River (below HHD) that will restore up to 3.2 acres of off-channel habitat and the other is 3.5 miles of river and stream habitat improvement in tributaries above the inundation pool (from 1,177 to 1,240 foot elevation). These projects will interact with the fish passage restoration facility and should help accelerate re-establishment of Headwaters and Upper Green River salmon and steelhead populations.

4.1.2 Phase II

Phase I is expected to last approximately 5-8 years. During that time the effects of the project on the environment and on the fish runs will be monitored and adaptive management measures used to minimize the impacts of the project. Implementation of Phase II would be contingent upon acceptance by the regulatory agencies and the MIT.

a. Changes in Water Storage. An additional 2,400 ac-ft of M&I water would be stored along with 9,600 ac-ft of storage for LFA, for a total of 32,000 ac-ft of water under Phase I and Phase II. The water surface elevation in Phase II would be 1,177 feet. During the refill period 32,000 ac-ft of water would be stored behind HHD, in addition, during this time, up to 65 mgd of water would be withdrawn through pipeline 5. This withdrawal of additional water would require new water rights and would be subject to the greater of State or Muckleshoot/Tacoma Agreement instream flows

b. Additional Mitigation Features. Phase II includes an additional 42.4 acres of riparian mitigation and 5.7 additional acres of stream habitat mitigation, to mitigate for the pool rise from 1,167 feet to 1,177 feet and complete the mitigation outlined in Paragraph 4.1.1c above.

4.2 HYDROLOGIC CONSIDERATIONS

4.2.1 Basin Description

The Green River basin is located in the southern portion of King County, Washington. The Green River flow west and north from the Cascade Mountains 60 miles to join with the Black River forming the Duwamish River. The Duwamish River empties into Elliott

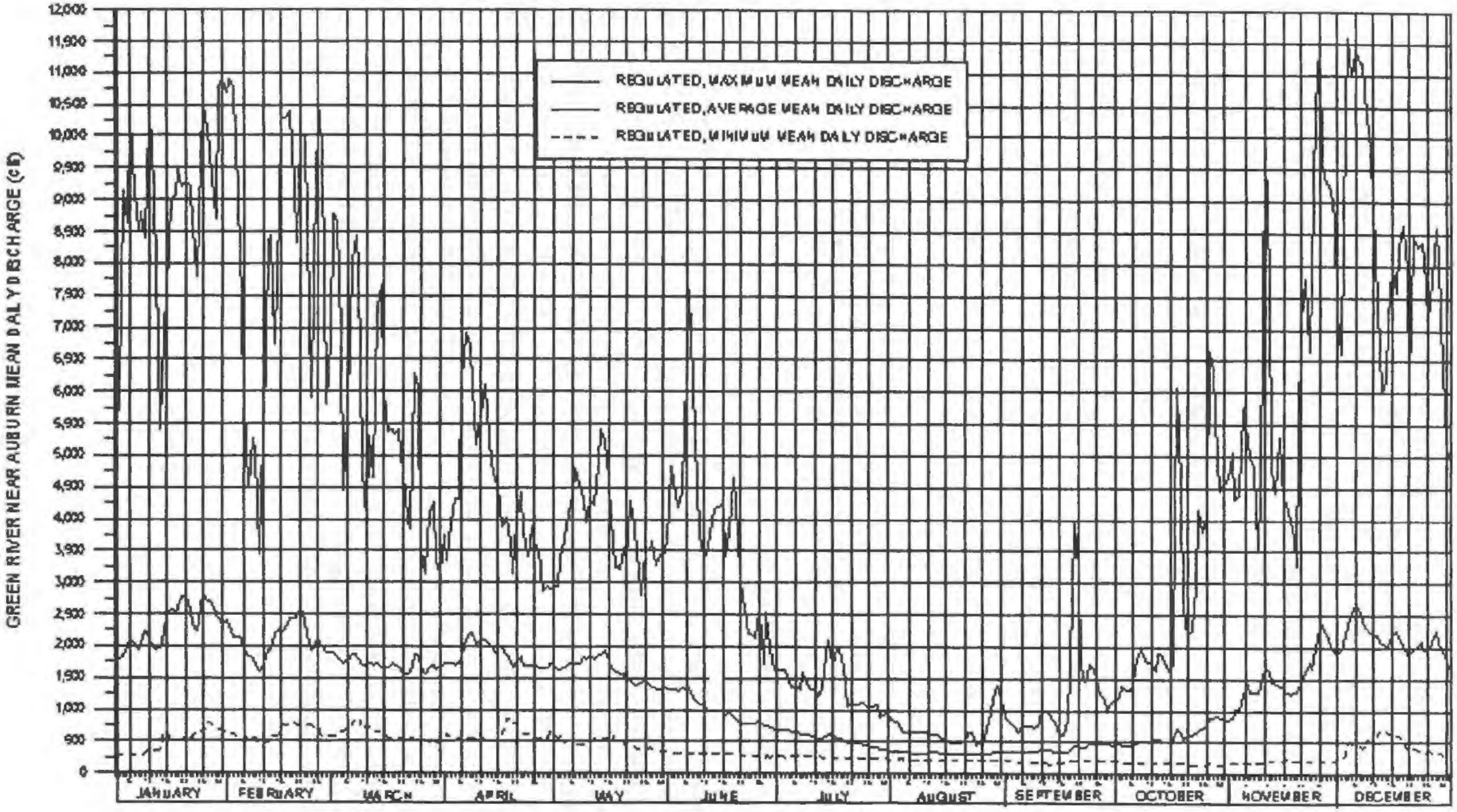
Bay in Puget Sound 12 miles further downstream. Green River water is used for a variety of purposes. The river is the main source of supply for the City of Tacoma municipal and industrial purposes. The City of Tacoma built and maintains a water supply diversion dam at RM 61. There are 6 active streamgages where the U.S. Geological Survey records stream flows. The table below provides the locations of the streamgages. The relatively high average discharge per square mile in the vicinity of the dam site makes this a more efficient location for water supply than the other locations.

STREAMGAGE LOCATIONS AND AVERAGE DISCHARGE

Location	River Mile	Square Mile Area	Average Discharge	Avg. Disch. per Sq. Mile
HHD Reservoir above the dam	64.5	220	n/a	
Below HHD Reservoir	63.8	221	1008	4.6
At Purification Plant, near Palmer (near diversion site)	60.3	231	1067	4.6
Newaukum Creek near Black Diamond	0.8	27.4	60.4	2.2
Big Soos Creek near Auburn	0.9	66.7	126	1.9
Green River near Auburn	32	399	1439	3.6

4.2.2 Existing Streamflow and Storage

Green River hydrology is characterized by high winter flows and low summer flows. During winter months, when the potential for flooding is greatest, Howard Hanson Dam is operated to control flooding. Beginning in early spring, the reservoir is allowed to gradually rise to provide storage of the spring runoff for augmentation of the arrival of low flows in the summer. Since 1962, flows in the lower Green River have been regulated by the reservoir at HHD. To provide a general understanding of the lower Green River hydrology, the regulated maximum, average and minimum daily flows for a 1-year period have been summarized into the hydrograph shown below. Storage operations occur generally in April or May during the slight bulge in the runoff that reflects snowmelt from the mountains. Low flow augmentation occurs during the low period in August and September. The April-May runoff season is also the prime season for juvenile salmon outmigration. Additional storage during operation of the recommended plan will be gained from runoff during the last part of February and March.



HHD Regulated Discharges (Green River near Auburn)

Regulated, Maximum Mean Daily Discharge (top)
Regulated, Average Mean Daily Discharge (middle)
Regulated, Minimum Mean Daily Discharge (bottom)

Throughout the years that HHD reservoir has been in operation, many downstream changes have occurred in area land use, recreation, fisheries, resource allocation, and environmental awareness All of these external influences have resulted in operational changes and manipulations, primarily manifested in the refill timing of the conservation pool and instream flow needs. This information will be included in future refill operations with the recommended plan so as to minimize any adverse impacts to the biological resources due to a change in the hydrology.

4.2.3 Tacoma's Water Supply Pipeline Projects

The City of Tacoma's diversion dam was built at river mile (RM) 61, which is 3.5 miles downstream of HHD. This diversion is the source of Tacoma's First Supply Water Right diversion. The diversion consists of a pipeline (Pipeline No. 1) that carries water from the diversion dam south and west to Tacoma (see Figure 1-2). The pipeline has a capacity of 112 cfs (72 mgd). Tacoma is in the process of constructing another pipeline (Pipeline No. 5) from the diversion towards Tacoma over a more northerly route by way of south King County and Federal Way. New pipeline 5 will carry Tacoma's Second Supply Water Right (SSWR) and have a discharge capacity of 100 cfs (65 mgd). The operation of the SSWR diversion is subject to conditions specified in an agreement between Tacoma and the Muckleshoot Indian Tribe.

The Muckleshoot/Tacoma Mitigation Agreement developed new and higher minimum flows (at Auburn) than the Washington State Department of Ecology (WDOE) requirements. For any particular year, instream flows are set by the summer month conditions, beginning on July 1. The summer month flow conditions as stated in the Agreement are: "For Wet years, the minimum continuous instream flow shall be 350 cfs. For Wet to Average years, the minimum continuous instream flow shall be 300 cfs. For Average to Dry years, the minimum continuous instream flow shall be 250 cfs. For Drought years, the minimum continuous instream flow shall range from 250 to 225 cfs, depending on the severity of the drought." Flows at Auburn must be at or above these requirements before Tacoma can divert water for their Second Supply Water Right project.

4.2.4 Low Flow Augmentation

Beginning around April, the reservoir begins to fill to a maximum pool elevation of 1,141 feet to provide summer and early fall flow augmentation. The 1,141 pool level impounds 25,400 acre-feet (ac-ft) with a surface area of 732 acres. This storage volume has a 98% reliability for maintaining a minimum instream flow of 110 cfs at the Palmer, below Tacoma's water supply intake. The existing storage volume and minimum flows are barely sufficient to provide for instream passage of adult salmon during low flow years and are insufficient to keep steelhead eggs watered. The Washington Department of Ecology and Muckleshoot Indian Tribe completed an instream flow study that identified and recommended much higher instream flows than what HHD reservoir provides. In addition to the instream flow study, the Tacoma/Muckleshoot Agreement stipulated a higher instream flow requirement for Tacoma prior to their diversion of Second Supply water (see paragraph above).

The HHD Section 1135 project is scheduled to be implemented in 1999 to provide greater reliability in meeting the existing minimum flow and the Muckleshoot/Tacoma negotiated flows. The Section 1135 project provides for an additional 5,000 ac-ft of storage (30,400 ac-ft total) for flow augmentation under an adaptive management approach. This water is currently targeted for use in a drought year that is estimated to occur once every 5 years on the average, but through adaptive management may be stored up to every year and used for low flow augmentation The storage provides enough water for maintenance of minimum instream flows of 250 cfs at Auburn.

4.2.5 Potential Additional Storage

The recommended plan consists of providing an additional 32,000 ac-ft for the purposes of water supply (22,400 ac-ft) and an increase in the low flow augmentation from 110 cfs to 200 cfs (9,600 ac-ft). The summer pool elevation would go from the existing project summer conservation storage at elevation 1,147 feet to elevation 1,177 feet.

4.2.6 Allocation of Additional Storage

Numerous flow scenarios, all of which affect the water supply output of the project, were evaluated based on the amount of water available for water supply diversion, low flow augmentation, and habitat improvements. Evaluations of water supply and low flow augmentation finally settled on a project which allocated the 32,000 ac-ft of "additional" storage space into 22,400 ac-ft to M&I water supply and 9,600 ac-ft of storage to low flow augmentation.

a. Phase I. Through negotiations with state and federal agencies and the project sponsor, a sub-project was developed which would implement the additional storage project in two separate phases. Phase I provides 20,000 ac-ft of storage for the water supply purpose. The elevation change would be from 1,147 to 1,167 feet. The 1135 project, implemented as part of the "without-project" condition, raised the pool by 5,000 ac-ft from elevation 1,141 to elevation 1,147 feet. There is no additional storage for the low flow purpose until Phase II. Prior to implementation of Phase II, adaptive management would occur which includes monitoring fish movement across the reservoir and through the fish passage facility with a higher pool.

b. Phase II. Phase II consists of a pool to elevation 1,177 which will provide an additional 2,400 ac-ft of M&I water supply storage and 9,600 ac-ft of storage for low flow augmentation.

4.2.7 Downstream Flow Deliveries

Rules developed during a simulation of Green River discharges with a daily flow model will be applied to the operation of the additional storage. Refill rules were developed to meet project objectives for protecting instream resources, meeting existing conservation storage requirements, and providing reliability for storing additional water for M&I and low flow augmentation under Phases I and II. The primary refill rules include:

- a maximum refill rate for the accumulation of storage during the main smolt outmigration period, April through May,
- a minimum base flow throughout the refill period, 15 February – 30 June.
- a stage decline of no more than 1 foot from 1 May to 30 June to protect incubating steelhead eggs, and
- maintaining natural freshets or creating artificial freshets in April and May to speed juvenile migrants downstream.

The refill and flow augmentation targets are shown in more detail in the following table

PHASE II SPRING REFILL AND SUMMER/FALL BASEFLOW TARGETS

Seasonal Flow Condition	Baseflow Target 15 Feb. to 30 April	Stage Decline 1 May to 30 June	Low – Flow Targets		
			1 July to 15 September	16-30 September	1-31 October
Wet	900 cfs	900-400 cfs	300 cfs	400 cfs	450 cfs
Average	750 cfs	750-400 cfs	300 cfs	300 cfs	400 cfs
Dry	575 cfs	575-250 cfs	250 cfs	250 cfs	350 cfs

4.2.8 Fish Passage Flows

The fish passage structure has an operating flow range that varies between a range of 400 cfs for a minimum and 1,600 cfs as a maximum. The target design flow was approximately 1,200 cfs which is the 50% exceedance flow for April and May when the rate of juvenile outmigration was at a maximum.

4.3 WATER QUALITY CONSIDERATIONS

4.3.1 Temperature Analysis

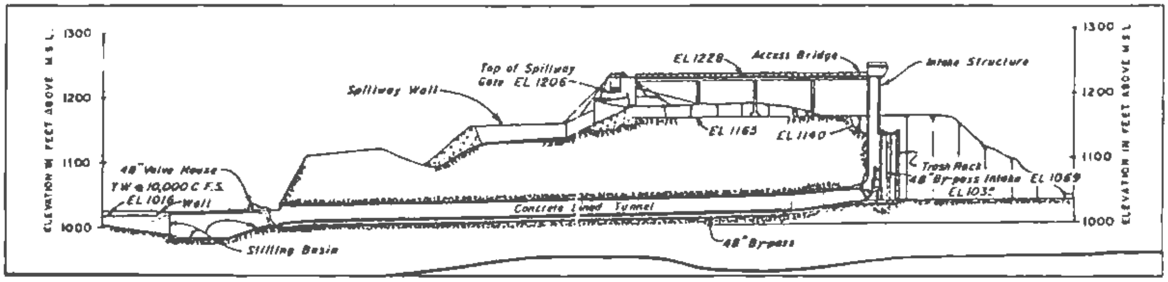
The existing, fixed outlet gates do not allow selective withdrawal of reservoir water form a particular zone within the reservoir. The recommended plan calls for a fish passage horn that can be used to control the outflow temperature from the dam. The combined flow release from a surface outlet and existing deep water outlets would blend warmer surface water with cooler deep-water areas. In the majority of years, blended releases from Howard Hanson Dam would improve instream temperatures up to 6 miles downstream of the dam. In addition to direct temperature control below HHD, the additional storage for low flow augmentation should help reduce maximum instream temperatures, dilute nonpoint source pollution, and increase dissolved oxygen in the lower Green River In the Duwamish River, the additional summer flow releases could also increase the amount of available freshwater estuary habitat.

By maximizing surface withdrawal through the fish passage facility during the spring and early summer, storage of cool water is maximized for use in the later summer and fall. The fish passage facility surface outflow tends to track natural inflow temperature until the reservoir stores a significant amount of heat. Blending the surface and deeper water would occur sometime in July. After this time, meeting temperature requirements could restrict the use of the fish passage facility; or conversely, meeting the fish passage criteria could result in the violation of state temperature requirements. To address this potential conflict, daily monitoring of outflow temperatures and fish passage would be required as would close coordination with resource agency biologists.

4.3.2 Turbidity Analysis

The recommended plan requires that the spring refill process be initiated 5-6 weeks earlier than the current operation of the reservoir. This increases the likelihood of storing water from high turbidity events. Historic records show that March inflow turbidity is no greater than April inflow turbidity and that suspended sediments tend to settle from the water column within a few days. The incidence of turbid water being stored in the reservoir would therefore become more frequent; however, the effect on outflow turbidity would be minor and short-lived The result would be no different than under the current operation. An enlarged reservoir would cause small and localized bank instability during initial inundation of the conservation pool resulting in insignificant effects on turbidity (Eckerlin, 1995). The reservoir has recently filled for flood control to the elevation of the proposed conservation pool with only temporary impacts observed to the outflow turbidity. Selective removal of trees is expected prior to inundation with the first additional storage conservation pool. The removal activity may decrease bank stability and will be one of the criteria in assessing the final reservoir clearing plan.

4.4 HYDRAULIC DESIGN



4.4.1 Hydraulic Design Considerations

The overall hydraulic considerations used in design of the fish passage facility were to minimize injury to downstream migrating fish and not impact safe operation or change the elevation-discharge relationships of the existing projects flood control outlet works and spillway. A detailed discussion of the specific hydraulic design of the various features of the fish passage facility is included in Part 2 of Appendix D of this report. A committee (the FPTC) of five regionally and nationally recognized federal agency and private experts in the field of anadromous fish passage was established to assist in this design and resolution of the numerous fish passage issues associated with design of an acceptable fish passage facility.

4.4.2 Hydraulic Design Criteria

The fish passage facility is designed to operate for fish passage through a pool range of 1,070 feet to 1,177 feet and with a discharge of 400 cfs to 1,250 cfs. Discharges less than 400 cfs can be accommodated through the facility although fish attraction conditions may be less than optimal. The fish passage facility may be shut down, and not operational, during at least part of the winter flood season (approximately 1 October through 31 March). Specific hydraulic criteria used in design of the facility are included in Section 2, Part 2 of Appendix D. The specific criteria and guidance used in this design have been established by the National Marine Fisheries Service (NMFS) and the State of Washington Department of Fish and Wildlife (WDFW). This criteria has been developed over the past years through research and operating experience at numerous adult and juvenile passage facilities, both large and small, and represents present state-of-the-art knowledge regarding requirements for safe passage of fish.

4.4.3 Hydraulic Model Studies

The hydraulic design presented in this report will be verified in final design (PED) through the use of at least three separate physical models. The results of the model studies will be presented in a separate Feature Design Memorandum and in a final model study report Following is a summary of the various physical models which will be used for final design

a. A 1 . 50 scale general model of the forebay will be used to evaluate the general approach flow conditions to the fish passage facility and to evaluate any impacts of the fish passage facility on the pool elevation versus discharge capability of the spillway The spillway testing is required because the existing spillway was never model studied and the proposed fish passage facility structure will be located in the approach channel to the spillway. This model will be sized and constructed to test various locations of the fish passage facility if necessary to either improve fish passage approach conditions or eliminate spillway performance impacts.

b. A 1 : 25 scale model of the fish passage facility wet-well, attraction flow outlet conduit, and upstream 250 feet (approximate) of the existing flood control outlet tunnel will be constructed to evaluate flow conditions and assist in final design of the attraction flow water conveyance features of the facility. This model will be constructed to evaluate the near field flow conditions in the approach to the fish passage structure and to complete detailed design of the confluence area between the flood control outlet tunnel and the fish passage facility attraction flow outlet conduit.

c. A 1 · 8 scale model of the fish passage facility collector horn, modular inclined screen (MIS), fish transport pipe between the MIS and the fish lock and a sufficient portion of the wet well chamber to reproduce flow lines through the MIS will be used to obtain detailed, localized hydraulic conditions (i.e., velocities, head losses, etc.) adjacent to the screen. This model is required to verify, or fine-tune the design sufficiently to ensure, that the flow conditions on this type of screen will meet the criteria established for safe fish passage.

4.4.4 Construction Considerations

No additional water conveyance features for diversion of flow will be required for construction. The existing flood control outlet works will be utilized to pass water during construction of the fish passage facility. The connection between the fish passage facility attraction flow outlet conduit and the flood control tunnel will be made in the dry during the summer period when the existing low flow bypass is operating. Connection of the existing low flow bypass pipe under the floor of the flood control tunnel and the low flow bypass pipe from the fish passage facility will require the construction of a relatively low-height divider wall structure downstream from the existing splitter wall in the flood control tunnel. This connection, which will also be made in the summer low flow period, will be used to confine the flow through the left hand side (looking downstream) of the flood control tunnel and divert water around the right hand side of the tunnel where the connection will be made.

4.5 GEOTECHNICAL CONSIDERATIONS

4.5.1 Project Geology

a. Geologic, Tectonic, and Seismic Settings. Howard A. Hanson Dam was constructed across a narrow rock gorge located between an upstream extensively glaciated valley and a downstream unglaciated rock canyon cut predominantly in volcanic rocks. The location of the dam was selected based on topography and the fact it had to be downstream of the confluence of the Green and North Fork rivers for hydrologic reasons, but far enough above the City of Tacoma headworks to minimize impact on that facility. The present gorge beneath the dam was cut as a result of river blockage by a massive slide off the northeast valley wall. The preslide Green River Channel is located over 1,000 feet northeast of the right abutment of HHD. (See Appendix E, plate E-1.)

The present North Cascade Range was uplifted during the Late Tertiary by a series of complex folds and faults. One such fault was the Green River fault. Between the area of the dam and mountain front, the Green River exploits the fault zone and parallels its trace. The dam lies in Seismic Zone 3 which corresponds to a seismic coefficient of 0.10 for the lateral earthquake force. The dam has had a design earthquake analysis that identifies dynamic earthquake motions and response – *Earthquake Analysis of Howard Hanson Dam*, Design Memorandum No. 26, 1983. Results of the analysis indicated that the gate tower was deficient and would not withstand the maximum design earthquake at the project site. The Corps has completed construction of structural modifications to remedy this situation.

b. Pre-Construction and Subsequent Explorations. During initial exploration for the dam a total of 65 exploratory core and churn drill borings were drilled in the spillway, intake channel, stilling basin, tunnel, right and left abutments, and riverbed between 1947 and 1958. Seepage through the right abutment of the dam and its effect on the stability of the downstream right bank slope have been a basis for continued exploration since the dam became operational in December 1961. To date there are 72 automated piezometers in the right abutment for measuring right abutment seepage.

In early 1994 five core borings were drilled in the left abutment to determine feasibility for a fish facility structure to be located several hundred feet upstream of the existing gate tower. In December 1995 the upstream tower site and tunnel configuration were significantly scaled back to reduce costs. A site was picked on the right side of the existing gate tower, but because of poor foundation conditions described in the 1963 Construction Foundation Report, the site had to be moved again. The final site is on the left side of the existing gate tower. A single core boring was drilled in May 1996 to affirm the feasibility of the newest site. In June 1996, the proposed tunnel transition alignment was reoriented because of the high possibility that roof failure would occur during excavation of the very long transition into the left wall of the existing diversion tunnel. The new tunnel transition will enter the existing left sluiceway at nearly a right angle thereby shortening the distance of transition excavation. In mid January 1998, the fish passage facility was moved to its final feasibility location, this time 25 feet south to provide room for siting the cofferdam on the rock slope adjacent to the existing gate tower

c. Dam Site Geology. The project lies within a series of Tertiary age volcanic rocks dipping 35° southeast. The volcanic rocks are composed of andesite and basalt flows, tuffs, and breccia that are so faulted, sheared and hydrothermally altered that few mappable structures and stratigraphic patterns are seen. The left abutment bedrock is hard to moderately hard, except in the hydrothermally altered zones where the rock is generally soft. Bedrock in the left abutment is moderately to intensely fractured. A few faults and shear zones were mapped in the canyon walls and inside the diversion tunnel during project construction. The dominant trends are east-west and southeast-northwest. The right abutment, at the dam, is a short, sharp, narrow rock ridge dividing the present and ancestral Green River valleys. Bedrock rises steeply to elevation 1,150 feet, then drops away to elevation 850 feet into the ancestral valley. Landslide materials rest on the right abutment bedrock surface as well as fluvial and lacustrine deposits. The slide surface rises northeastward to elevation 1,300 feet. (See Plate E-4 in Appendix E for the bedrock topography beneath the project.)

Groundwater occurs in both abutments of the dam. In the right abutment at least two distinct aquifers have been found in the overburden. A semi-impervious blanket, consisting of a compacted sand and gravel core covered by a rock shell, was placed on the upstream right abutment as part of the original construction to control seepage. A 640-foot-long concrete-lined drainage tunnel with drainage wells was added in 1968 to collect water in the upper aquifer and to lower the piezometric surface. On the left abutment minor seepage has been observed from the hillside located south of the existing gate tower and moderate seepage was experienced during excavation for the diversion tunnel. The single exploration boring drilled in 1996 at the fish facility site encountered water under moderate pressure a few feet beneath the proposed foundation grade. Water flowed from the boring out onto the ground surface at a rate of 40 gallons per minute for six days before the artesian zone was finally cemented.

d. Additional Exploration and Testing Needed in PED. Approximately 25 shallow rotary/diamond core borings (deepest to be 200 feet) are planned during PED for determining overburden thickness, presence of ground water, in situ rock properties and obtaining rock core for laboratory strength tests. Exploratory borings will be drilled for the cofferdam, intake channel, fish passage facility, portal, tunnel and its transition into the sluice and possibly the right abutment of the dam. Where practical borings will be photographed with a down hole camera to distinguish fracture patterns. Two inclinometer borings are planned at Charley Creek, located about one mile upstream of the dam. Additional exploration may be needed regarding right abutment seepage concerns.

4.5.2 Reservoir Slope Stability

a. Reservoir Area Landslides. The reservoir extends seven miles eastward up the Green River Valley and four miles northerly up the North Fork Valley. Reservoir slopes are primarily alpine glacial sediments and weathered volcanic rocks. Slope stability has not been a serious problem since water was first impounded to the conservation pool at elevation 1,141 feet in December 1961. Zones of current and potential instability have been identified and are discussed in Appendix E.

Wave erosion and bank groundwater seepage account for the majority of landslides along the reservoir shoreline. Most are of the common overburden slip-off type. Only one pre-reservoir slide of appreciable magnitude has been documented in Corps of Engineers literature. This is the Charley Creek landslide briefly discussed in Design Memorandum 19, Supplement No. 1. The Charley Creek landslide was buttressed at its toe. Since filling and operating of the reservoir, one significant landslide has occurred. This was a rotational failure in early December 1995 following a period of intense rainfall. The area above the slide had been loaded with rock and soil debris over many years. The waste debris was from an area just upstream. The rotational slide occurred 1.7 miles upstream of the dam at the downstream end of a rock canyon. The City of Tacoma performed necessary grading to reduce risk of future slope failure for this area.

b. Additional Water Storage Effect on Reservoir Slopes. The reservoir rim between elevations 1,170 feet and 1,210 feet will be impacted by the proposed additional water storage project. Minor bank calving, slip-off sliding, and raveling will be experienced early in the pool raise, but will pose no threat to operation of the project. Multiple slumping episodes are anticipated within bedded silts and clays, but should have minimal effect on turbidity. Even though portions of the shoreline are very steep, landslides of damaging magnitude are not anticipated. Large scale landslides and slumps in sand and gravel deposits and laminated silt and clay beds are anticipated along the west slope of Charley Creek. Because of a history of sliding in this area and the proximity of the nearby railroad bridge, two inclinometers are planned for the head wall area of the Charley Creek landslide. Inclinometers will be closely monitored for the first few years of higher pool operation.

4.5.3 Right Abutment Seepage Concerns

a. Seepage Analysis. Complex geologic conditions in the right abutment have created a complicated reservoir seepage problem. Basically, two major aquifers are present with the possibility that others exist. The lower aquifer with base elevation of about elevation 1,000 feet is found within the buried valley's alluvial materials. The upper aquifer with approximate base elevation of 1,065 feet is found in glacial and landslide materials.

Engineering Pamphlet, EP 1130-2-500 was reviewed to determine the appropriateness of applying the contained criteria to this project for a Risk-based analysis. The following

Chapters and Appendixes referenced confirm that a Risk-based analysis for this project is not appropriate.

1) Chapter 3: The proposed seepage control work for the right abutment should not be considered rehabilitation because it would be unnecessary without the additional water storage project. The dam and right abutment are reliable and efficient in their present condition with the current conservation pool level.

2) Appendix B (B-3. d. (1) (d)): The proposed seepage control work is not due to deterioration or degradation in service level.

3) Appendix B (B-3. e. (3) (a)): Alternatives have been developed, but are totally dependent on the reaction of the right abutment to a sustained pool raise.

4) Appendix B (B-3. F. (1) (b)): Failure scenario for this project poses an imminent threat to public safety with a complete dam failure being the worst case.

5) Appendix H: This appendix refers specifically to Hydropower rehabilitation. Howard Hanson Dam is a flood control/water supply dam.

A test pool must be accomplished during construction for two reasons: (1) The test pool will be preceded by grouting the area between the drainage tunnel and the embankment. (2) Mitigation for the pool raise will have to be done. (See Appendix E for test pool requirements.)

b. Stability Analysis. Stability analyses during design for the upstream and downstream slopes were performed using the "UTEXAS3 Slope-Stability Program." These analyses showed a minimum factor of safety of 1.41 and 1.25 for two sections through the downstream slope. The upstream slope in the blanketed area had a minimum factor of safety of 1.91 with a pool at elevation 1,080 feet, and a minimum factor of safety of 1.60 under assumed draw-down conditions. The upstream slope in the random fill area had a minimum factor of safety of 1.67 with a pool at elevation 1,120 feet and a minimum factor of safety under draw-down conditions of 1.30.

c. Corrective Action. As evidenced by the relatively low Factors of Safety derived from this study and the previous seepage studies performed to date, some form of corrective actions to reduce seepage through the right abutment will be necessary. Alternatives considered in this report include: extending the existing drainage tunnel length about 200 feet and adding more relief wells; drilling horizontal and inclined drains from the end of the existing tunnel; constructing a seepage cutoff wall, and consolidation (injection) grouting. The last alternative would reduce seepage through the right abutment by providing a positive cutoff between the right abutment and the axis of the dam (see Figure E-9, Appendix E). It would consist of a series of borings drilled into bedrock. Grout would be injected through sleeve grout pipes installed in the borings. Additional right bank seepage corrective actions may be necessary once the pool raise has been completed Cost of the repairs may ultimately limit the final pool raise to something less than elevation 1,177 feet

4.5.4 Foundation Treatments for Existing Project Elements

The existing 460-foot-long intake channel is an open rock cut, leading to the gate tower and diversion tunnel. Drain holes and rock bolts were systematically installed as rock was excavated for both the gate tower and intake channel. At the gate tower the finished floor of the channel is at elevation 1,035 feet with a bottom width of 40 feet. The existing tunnel portal is 40 feet by 40 feet in size, with a flat roof section through the 35-foot-long transition. This design required an elaborate support structure to hold the flat roof consisting of 24-inch I-beams on 18-inch centers. The right side of the gate tower excavation was revised during construction from 2V on 1H because of the poor quality of the rock. A soft zone of pyroclastic andesite on the right wall of the gate tower carries into the right side of the upstream tunnel transition section, across the floor of the tunnel and disappears into the left wall at the downstream end of the transition section. Considerable ground water flow was experienced from the left wall during tunnel advancement. After placing the concrete lining, a grout collar was installed in the foundation rock for a depth of 20 feet and was carried 90 feet downstream from the upstream portal area. The 19-foot-diameter tunnel was driven through extremely variable volcanic rock. Light loads were experienced even though much of the supported sections were in interstratified soft andesitic pyroclastic rocks and denser basalt and felsite rocks. One-third of the tunnel was self-supporting where it was driven through moderately hard, irregularly jointed andesite.

4.5.5 Geotechnical Design

a. General. The various elements of geotechnical design involve remedial work to control seepage through the right abutment of the dam and for construction of the proposed fish passage facility which will include: a) strengthening of the rock abutments for the cofferdam; b) fish facility slot excavation and slope support; c) excavation of the new tunnel and support; and d) intake channel and slope support. The proposed fish passage facility site was opted very late in the study after several alternatives were evaluated. Time and money restrictions did not allow for subsurface geotechnical exploration at the selected fish structure site, therefore, subsurface conditions are mostly unknown, except for some information in the 1963 Construction Foundation Report.

b. Design Criteria. Designs for the surface excavations and tunnels were based on empirical guidelines in EM 1110-2-2901, "Tunnels and Shafts in Rock". Maximum cut slopes in rock for the fish passage facility structure will be limited to 10V on 1H while for the intake channel , where the rock is anticipated to be much poorer quality, the cut slopes will be limited to 4V on 1H and will have a 5-foot-wide bench every 20 feet of slope height. Controlled blasting will be used to minimize overbreak and reduce the vibrations acting on existing structures. Vibration velocity will be less than 4 inches per second on existing concrete and 2 inches per second or less on newly placed concrete. Permanent measures such as shotcrete, drains, and rock bolts will be used for slope stability for both features. Temporary and permanent chain link mesh are also planned for personnel safety.

The Rock Mass Rating (RMR) system in EM 1110-2-2901 (1978) was used for cursory tunnel analysis for the feasibility study. The RMR system is based on a set of case histories of relatively large tunnels excavated using blasting. New EM 1110-2-2901 (1997) guidance emphasizes tunnel excavation by mechanical means in lieu of drill and blast methods especially where existing concrete structures are in close proximity. For the feasibility study both the light load blasting method and mining by mechanical methods, such as roadheader equipment appear workable. Advantages of mechanical methods include less disturbance to the rock outside the excavation prism, which may mean reduced support requirements. Excavation methods will be researched thoroughly in the PED phase. During the geotechnical exploration program which will occur early in the PED phase emphasis will be placed on performing essential tests such as thin section analysis, hardness tests, and density, porosity, compressive, and tensile strength tests. These tests and others will be helpful in predicting mechanical excavator performance.

Rock reinforcement in critical tunnel areas will be by tensioned rock bolts, fiber reinforced shotcrete, and steel sets or steel liner. Rock bolts and cement grout will be employed to strengthen the tunnel transition into the sluice and to control groundwater. No blasting excavation will be authorized beneath the sluices, excavation will be only by mechanical means.

c. Bedrock Properties. Left abutment bedrock consists of a variety of igneous rock types with unit weights ranging from 150 to 172 pounds per cubic foot. (See Appendix E for laboratory test results.) Bedrock has closely and widely spaced fractures depending on location. Evidence of prehistoric movement is recorded by gouge and slickensides on fault surfaces exposed in local rock outcrops. The RQD for the single 1996 core boring drilled some 70 feet northwest of the existing gate tower shows rock of good quality. Fracture spacing in the boring ranges from a tenth of a foot to 18 feet.

d. Dewatering. Groundwater under moderate pressure will be encountered during excavation for the fish passage facility and tunnel, therefore two-inch-diameter drains drilled into rock on pattern are planned in the backslope of the fish facility excavation and within the tunnel excavation. Seepage dewatering will be maintained during excavation and construction as conditions dictate. In addition to the rock drains, systematic grout hole drilling and pressure grouting may be necessary around the bottom of the fish facility exploration especially between elevations 1,015 and 1,035 feet.

e. Cofferdam. The south rock wall of the existing intake channel extending from the gate structure to approximately 100 feet upstream will compose part of the proposed cofferdam system. (See Appendix A, Design, for the planned cofferdam configuration and cofferdam abutment reinforcement scheme. Also see Plates E-15 and E-16 for as-built reinforcement in the existing south wall.) The cofferdam abutments will be reinforced with post-tensioned cable tendons extending from the ground surface to approximately 35 feet beneath the base of the cofferdam. The tendons will be installed within a series of closely spaced 6-inch diameter vertical borings and grouted full length. In addition to the tendons the abutments will be strengthened with heavy duty Dywidag bolts. Short rod extensometers will be used to measure rock deformation. The rock between the cofferdam abutments will also be left intact and will be grouted to ensure a water tight condition. Construction for the cofferdam will be complicated by a confined work area adjacent to the operating outlet works.

f. Fish Structure and New Intake Tower. Overburden, consisting of silty, sandy gravel with numerous cobbles and boulders, on the upslope (south) side of the wet well/lock varies in thickness from several feet to possibly 30 feet. A design slope of 1V on 2H with toe resting on a rock bench 5 to 10 feet from the neatline excavation should allow sufficient room for construction of a temporary barrier fence to catch debris that might otherwise slough into the excavation. Conventional drill and blast methods can be used to excavate a deep cut or slot in the rock. For ease of construction, the near vertical slopes will have 24-inch setbacks for normal air track drills. The volcanic stratigraphy is very irregular with soft hydrothermally altered zones of incompetent rock. Adequate exploration data is unavailable; therefore slope protection was conservatively designed with the following conditions assumed: a) joint planes paralleling the excavation cutslope could result in planar sliding and b) intersecting joint planes may form wedges capable of sliding out of the slope. Inclinometers and extensometers will be used to measure rock deformation. Since water conveyance channels require permanent protection against rock falls, all exposed rock surfaces will be permanently covered with chain-link mesh. Concrete retaining walls will contain weep holes to prevent buildup of water pressure.

g. Portal and New Conduit. Tunnel portals are particularly sensitive to rock conditions even when much is known about rock quality and structure. For this reason the portal for the new conduit has been conservatively designed to include strengthening of the crown with untensioned rock bolts, shotcrete, and steel mesh prior to turnunder. Rock removal in the upstream portal area will be by the drilling and blasting method. The portal will be strengthened with one or more steel sets as mining advances. Consolidation grouting will be accomplished and drains drilled and installed as needed to control water pressure. Deformation monitoring will be used to provide early warning of potential instability and as a check on the adequacy of installed support. The instruments will be installed during the early stages of the work to optimize their value.

Based on documentation for the existing diversion tunnel, rock quality and hardness vary with rock type and location. During construction of the existing diversion tunnel the natural state of stress of the rock was affected resulting in redistribution of stresses and displacements within the surrounding rock, therefore considerable local variation in degree of fracturing is predicted. Rock is anticipated to vary from massive and intact at the proposed tower portal to crushed and altered at the proposed transition. Also, excessively sheared and chemically deteriorated rock may be encountered. The crown and left wall of the existing diversion tunnel will be pre-supported by consolidation grouting for a distance of 40 feet beyond the existing concrete liner to strengthen in place rock. Pattern rock bolts will be installed in the crown. Rock load is predicted to change erratically from point to point within this reach, therefore steel sets are also planned. Blasting will not be permitted beneath the sluiceway, so rock removal will be through mechanical methods such as a hydrohammer.

h. Intake Channel. In the existing upstream intake channel, rock varies from intensely brecciated to moderately fractured. There are three main joint sets exposed in the channel. Intersecting sets show no adverse wedge failure problems, however, some of the larger fractures display slickensides and gouge material more than 2-inches wide. Most of the channel widening excavation will be in rock. Systematic drilling and controlled blasting procedures will be employed to prevent damage to final cut slopes and grades. Rock slopes 2V on 1H or steeper will be presplit.

i. Disposal of Excavated Materials. Materials from excavated areas will be placed in designated areas for disposal or used as borrow. All excavated rock from tunnel mining and from the upstream intake channel widening should be considered waste material. Hydrothermally altered materials destined for disposal will require testing for leachable metals and other suspect specific compounds.

4.5.6 Construction Materials

During construction of the dam and ancillary structures concrete aggregate was shipped from a source in Steilacoom, Washington because local sources were unsuitable due to a high percentage of soft particles. The use of existing ready-mix company pits in nearby vicinities for fish facility related work will require investigations prior to final design. During original project construction the rocks produced from the excavation of the spillway cut, tunnel, forebay, and intake channel were intended to be used as rock fill for the embankment dam, but because the rock weathered so severely within the stockpile, a new off site rock source had to be obtained. Since rock need is minimal several commercial rock quarries within 20 miles of the site may be used to supply rock. Rock testing and approval will be required.

4.6 STRUCTURAL CONSIDERATIONS

At this level of investigation, it is assumed that the features of HHD AWS facility can be constructed using normal construction techniques and practices familiar to contractors doing business in the Pacific Northwest region. See Appendix A, Design, for more detail

A cofferdam will be constructed to elevation 1,150 feet which will allow construction behind it during March through October. During the flood control season, November through February, it is estimated that the cofferdam would overtop with a 10 year flood, although with close control of outflows the overtopping could be controlled to a greater extent If a 10 year event is forecast the contractor will be notified so he may remove his equipment and backflood the construction site to minimize impact.

4.7 MITIGATION FEATURES

Mitigation is required for the impacts from increasing the reservoir storage pool volume and inundating stream and forest habitat as well as for downstream impacts from decreasing instream flows during spring refill. Mitigation feature are grouped by impact area and watershed location: 1) construction and monitoring of the fish passage facility; 2) flow management; 3) habitat improvements for fish; and 4) habitat improvements for wildlife.

4.7.1 Fish Passage Facility

After the initial selection of fish passage facility alternative 9A4, the FPTC felt there was enough concern about passing smolts through the enlarged reservoir and collection at the dam that they requested maximizing the outflow capacity of facility. Following this, the fish passage facility was increased in size from a maximum 400-550 cfs outflow volume at surface withdrawal (5 to 20 feet) to 400-1250 cfs: the original design was constrained by the size of the existing bypass pipe and head of the reservoir. The new screened outflow (within criteria) represents up to 300% increase in total flow volume. The FPTC recommended the maximum expansion of the facility to provide for capacity to pass surface flows to assist in reservoir outmigration of smolts.

a. Outmigrant Monitoring and Evaluation During Operation. For coho, steelhead, and chinook, 15 years of outmigrant monitoring is required (discussed in Section 2g, Part 1, Appendix F). Cost is shared by mitigation and restoration. A sampling station, hydroacoustic (sonar) monitoring, and PIT-tag (a miniature tag used for fish 2 inches and larger) release and evaluation are proposed.

b. Predator Monitoring and Evaluation During Operation. Beginning in 1998, PED phase, 2 years of Baseline monitoring of predator abundance in the reservoir is proposed. This is a preventive measure to insure successful outmigration of chinook outmigrants (the smallest outmigrants). In combination with PIT-tag and hydroacoustic monitoring and evaluation, monitoring of predators would continue during Phase I and II. If there is an increase in overall abundance in response to outmigrant presence a selective predator removal program can be initiated. The predator removal program must be coordinated through the City of Tacoma, and cooperating resource agencies.

4.7.2 Flow Adjustments

A series of flow adjustments are proposed to minimize impacts to juvenile salmon migrating through the reservoir and the lower river. These adjustments are meant to mimic the natural flow patterns that are expected during the juvenile outmigration period in spring and early summer.

a. Maximum Refill Rates. A maximum refill rate (rate the reservoir is filled or the difference of inflow-outflow) is proposed for each phase of the HHD AWS project. A fill rate limit was already implemented under the AWS project hydrologic modeling (see Section 9, Part 1, Appendix F). The fill rates varied by phase: Phase I had maximum rates in March of 400 cfs per day, in April of 300 cfs per day, and in May of 200 cfs per day; Phase II had maximum rates only in late April at 300 cfs per day, and in May of 200 cfs per day. Even with the maximum fill rates, there are less protected times when smolts outmigrate, especially any early migrants in March or early April in Phase II. Our empirical data has only looked at travel times when fill was up to 400 cfs per day. Monitoring during the first years of the AWS project operation are considered essential to identify the range of fill rates affecting juvenile outmigration (reservoir travel time) and ultimately survival. This monitoring should provide the needed information to adapt the AWS project to maximize smolt survival through the HHD project.

b. Natural and Artificial Freshets. Another project operation or management tool for mitigation of potential reservoir and Lower River smolt mortality is the use of increased outflows or artificial freshets. In the past few years under existing operation, the Corps has "captured" natural spring freshets (high flow events) to guarantee the 98% reliability of filling the pool to maintain instream flows throughout the low flow season. The capture of freshets results in a flat or constant outflow with an associated high refill rate that is presumed to have a very negative effect on juvenile outmigration survival. The use of natural and artificial freshets during spring and late summer is proposed for Phase I and Phase II of the AWS project. During Phase I, two freshets would be released in May to improve the survival of Upper (smolts migrating through the reservoir) and Lower River smolts migrating to the ocean. During Phase II, two to four freshets would be released in April and May.

c. Downstream Temperature Improvements. By maximizing surface withdrawal through the fish passage facility during the spring and early summer cool water storage is maximized for use in the later summer and fall. The fish passage facility surface outflow tends to track natural inflow temperature until the reservoir stores a significant amount of heat. In the majority of years, releases from HHD would improve instream temperatures up to 6 miles downstream of the dam (discussed in Part 3 of Appendix D) meeting maximum target temperature criteria, 59°F, 70% of the time (which is more restrictive than existing water quality criteria, 60.8°F). Blending of surface and deeper water would occur sometime in July. After this time, meeting temperature requirements could restrict the use of the fish passage facility, or conversely, meeting fish passage criteria could result in violation of state temperature requirements. To address these constraints daily monitoring of outflow temperatures and fish passage would be required as would close coordination with resource agency biologists. In addition, flow augmentation during Phase II should slightly improve downstream temperatures by 1) deepening the channel, 2) increasing water velocities, and 3) increasing inter-gravel flow.

d. Turbidity Effects. Any of the final project alternatives would require beginning spring refill 5-6 weeks earlier than current operation of the reservoir, increasing the likelihood of storing water from high turbidity events. Historic records show that March inflow turbidity is no higher than April inflow turbidity and that suspended sediments tend to settle from the water column within a few days. Under any AWS alternative, high turbidity flows stored in the reservoir would be more frequent, however, the effect on outflow turbidity would be minor and short-lived, no different than under current operation. An enlarged reservoir would cause small and localized bank instability during initial inundation of the conservation pool resulting in insignificant effects on turbidity. The reservoir has recently filled for flood control to the elevation of the proposed conservation pool with only temporary impacts to outflow turbidity. Selective removal of trees is expected prior to inundation with the first additional storage conservation pool. Although the final amount of tree removal has not been identified, removal may decrease bank stability and will be one criteria in assessing the final clearing plan.

4.7.3 Habitat Mitigation Measures

This management measure has two components, stream channel and riparian habitat maintenance, and stream channel and riparian habitat improvements. Several components of stream channel and riparian habitat maintenance and habitat improvement and have been identified and organized by impact issue and watershed area. Impact issues and watershed location are 1) reservoir survival of outmigrating juvenile salmonids and riparian and tributary habitat inundation in the reservoir, in-reservoir areas in the Headwaters watershed; 2) Middle and Upper Green River side-channel connection and downstream outmigrant survival, lower watershed below the dam; and 3) Middle and Upper Green River steelhead spawning and egg incubation, lower watershed below the dam. Mitigation features developed to compensate for these unavoidable adverse impacts are discussed by issue/area. Project numbers identify the habitat mitigation (or restoration) site: FP=fish passage; MS= mainstem Green River above RM 47; LMS=lower mainstem Green River below RM 47; TR=tributary streams; VF=valley floor of the Green River above RM 47; LVF=lower valley floor below RM 47.

The location of fish mitigation sites in the Lower Watershed and Upper Watersheds is shown in Figures 4-5 and 4-6, respectively. The location of wildlife mitigation sites around HHD is shown in Figure 4-7. Referenced figures can be found at the end of this report.

a. **Side Channel Improvements.** **{Alt. 11A}** Levees, channel degradation, and controlled flows from HHD have reduced the interaction between floodplains and stream channels in the basin. Many areas of the floodplain have been converted to other uses. This has dramatically reduced the interchange of water and materials between the aquatic and terrestrial systems and has isolated floodplain wetlands. The Basin Analysis estimates that only 10% of the original Duwamish/Green floodplain is still flooded on a regular basis and is undeveloped. Of the remaining side channel habitat, Phase II of the AWS project could seasonally dewater an additional 8.4 acres (see Section 6, Part 1, Appendix F). To mitigate for this impact a variety of mitigation features have been developed to maintain existing levels of side channel habitat. Project features could include 1) removal of levee(s) to reconnect the floodplain to the main channel; 2) reconnection of relic side channels by lowering the channel inlet or by raising the mainstem water surface; and 3) improve existing side channel by similar means as in (2) or by other improvements such as large wood placement, excavation of new channel areas, gravel placement and riparian plantings. Project areas considered would range from below the Tacoma Diversion Dam (RM 61) to the lower Middle Green River (RM 34).

(1) Site LVF-03: Green RM38 & Lower Burns Creek. This project provides for mitigation of side-channel habitat dewatered in the Middle Green River during spring refill. This project would reconnect and improve up to 2.8 acres of side-channel habitat. An isolated levee along the mainstem river at RM 37.9-38.2 would be removed (replaced with a set-back levee) allowing the river to reclaim the historic floodplain. The relic side channel would be improved and a nearby tributary, Burns Creek, would be re-aligned to follow its historic connection with the floodplain.

(2) Site LVF-04: O-grady and Metzler Parks. This project provides for mitigation of side-channel habitat dewatered in the Middle Green River during spring refill. This project would reconnect and improve of 2.1 acres of Middle Green River side-channel habitat, 4.81 acres baseline, 2.1 additional acres with mitigation, by increasing the complexity and connectivity of two major side channels located on the right bank (Metzler Park) and left bank (O' Grady Park). The existing channels would be improved by addition of large woody debris, use of debris jams to raise the mainstem water surface to create a more permanent side channel/river connection and by improving a ground-water tributary channel (in O' Grady Park).

(3) Site LVF-06: Flaming Geyser Park. This project provides for mitigation of side-channel habitat dewatered in the Middle Green River during spring refill. The project would reconnect and improve up to 3.75 acres of side-channel habitat: 2.4 acres baseline and 2.35 additional acres with mitigation. Under the concept plan for the Basin Study (Green/Duwamish Basin Restoration Plan), an existing side channel and an existing spring-fed stream would be reconnected through excavation of an old cutoff channel. The existing and new channels would be enhanced through addition of large woody debris and providing stable water source (spring-fed stream).

(4) Site VF-03: "Brunner Slough". This project provides for mitigation of side-channel habitat dewatered in the Upper Green River during spring refill. This project would reconnect and improve up to 2.8 acres of side-channel habitat to quality fish habitat. This side-channel became disconnected from the Green River due to reduced peak flows from HHD and isolation of upstream meander on south side of river from construction of railroad and pipeline berm. Reconnection and improvement of the side channel would be accomplished by excavation of the old channel, diverting flow from the mainstem Green to allow natural scour and excavation of the old channel; addition of large woody debris for habitat complexity, and redirect a small tributary that formerly flowed into this channel.

b. Riparian and Stream Improvements. {Alt. 11B1 and 11C3}. The AWS project will degrade riparian (forest habitat along streams) and stream (in-channel) habitat around the existing storage pool. There will be 2.9 miles of stream and riparian inundated by the enlarged storage pool during Phase I and II. The total riparian habitat loss, acres of quality and quantify, is 79 acres in Phase I and 42 acres in Phase II for a total of 121 acres. The total stream habitat loss is 11.5 acres in Phase I and 5.9 acres in Phase II for a total of 17.4 acres. This habitat represented(s) some of the most productive salmon and steelhead habitat in the Upper Green River. This measure considers different structural and management mitigation features to maintain and improve the function of existing habitat in streams and riparian above HHD. Project features include 1) use of plantings and thinning to improve riparian habitat along stream corridors; 2) replacing culverts that block the movement of juvenile and adult fish; 3) placement of large wood (logs and rootwads) and boulders to provide habitat complexity; and 4) excavation of floodplain areas to create new channels and ponds.

(1) Riparian Habitat – In Reservoir. As partial mitigation for 121 acres of riparian habitat inundated by the pool raise, 79 acres Phase I and 42 acres in Phase II, a series of actions would be implemented. In the new inundation zone (1147 to 1177 foot elevation): 1) retain existing standing timber to partially maintain wildlife, riparian and instream habitat (overlaps with stream habitat); 2) maintain riparian habitat through planting of water tolerant riparian zone vegetation; and 3) maintain reservoir perimeter vegetation by planting of water tolerant vegetation.

(a) Site VF-05: Page Mill Pond and Page Creek. The project site is the floodplain of the North Fork Green River (1147 to 1185 foot elevation) and includes a pond (Page Mill) and creek. This project would maintain and improve an existing wetland pond complex that lies within and above the enlarged storage pool. A series of smaller ponds would be developed within the floodplain of the existing wetland/pond complex. Native wetland plants would be planted above the new storage pool and inundation tolerant plants would be planted within the new pool.

(b) Site MS-02: Green River. Project location is RM. 69-70, upper Green River from full pool (elev. 1146 feet) to full additional pool elevation (1167 foot Phase I and 1177 foot Phase II). This project would provide partial maintenance of up to 7,000 lineal feet of mainstem river riparian habitat. Partial mitigation for riparian areas would be accomplished by 1) retention of existing trees along the riparian zones; and 2) plantings in bare areas in/and along stream channels with inundation tolerant grasses, forbs, trees and aquatic plants.

(c) Site TR-04: North Fork Green River. Project location is North Fork Green from full pool (elev. 1146 feet to additional pool elevation (1177 feet). This project would provide partial maintenance of up to 3,000 lineal feet of large tributary riparian habitat using similar features described in MS-02.

(2) Riparian Habitat – Above Reservoir. In-reservoir mitigation features provide partial maintenance of habitat quantity and quality, additional features above the reservoir are required to compensate for habitat in-reservoir projects can't address.

(a) Site MS-08: The project location is the mainstem Green River valley floor RM 71.3-80.1, beginning at elevation 1240 feet (at the upper edge of restoration project MS-03). This partial mitigation feature (and including TR-09, a linked project) is a set-aside of riparian forest reserve (managed solely for fish and wildlife habitat) on lands owned and managed by Tacoma Water Department in the Upper Green. The mitigation area on the mainstem Green includes stream buffers of 200 feet and protects a total riparian area of 400 acres. Within the set-aside areas are two hot-spots of biodiversity, the only remaining old-growth area along the mainstem Green, approximately 20 acres of Sitka spruce, and a large unsurveyed wetland area (recently identified, US Forest Service 1996). This forest reserve area would has 210 acres as natural forest (no management) and would include prescriptions to improve riparian habitat including 1) selective thinning (90 total acres) of riparian zones to open forest canopy, improve tree growth, and to drop habitat logs for aquatic and terrestrial habitat; and 2) planting of evergreen species, cedar, hemlock and spruce (50/acre for 100 total acres).

(b) Site TR-09: This is a continuation of the riparian forest reservoir (MS-08) for two tributaries of HHD reservoir. The project location is on Tacoma Forest Lands along Gale Creek (8.3 acres) from elevation 1240 to 1280 feet and the North Fork Green (31.7 acres) from elevation 1240 to 1320 foot elevation. Riparian buffers of 150 feet would be managed solely for fish and wildlife with prescriptions described in MS-08.

(3) Stream Habitat – In Reservoir. As partial mitigation for 17.4 acres of stream habitat inundated by the pool raise, 11.5 acres Phase I and 5.9 acres in Phase II, a series of actions would be implemented. In the new inundation zone (1147 to 1177 foot elevation): 1) retain existing standing timber to partially maintain instream habitat (this overlaps with riparian habitat); 2) maintain existing instream habitat through placement of large structural elements; and 3) enhance reservoir habitat by creation of sub-impoundments and addition of floating debris.

(a) Site VF-05: Page Mill Pond and Creek. The project site is the same as described under riparian habitat. A series of new, smaller ponds would be created and large woody debris would be added to the ponds and existing stream channel

(b) Site MS-02: Green River. Project location same as described above in MS-02-riparian habitat project. This project seeks to maintain instream and bank habitat along the mainstem Green River in the new inundation pool. Project features include 1) placement of large structural elements to contain the existing channel (boulders); 2) addition of large woody debris (anchored to the structures or embedded into the riverbank) to create limited cover for fish; 3) excavation of sub-impoundments/ponds, side-channel habitat and dendrites; 4) placement of floating islands in selected areas around reservoir; and 5) barrier removal with culvert replacement (in railroad berm) and grade realignment where necessary.

(c) Site TR-04: North Fork Green River. The project site is the same as described above in TR-04 riparian habitat project. The project has the same features as MS-02-stream habitat project but does not include culvert replacement.

(d) Site TR-01: Lower Bear Creek. The project site is the lower 3,000 feet of Bear Creek, a large tributary that enters the Green River just below HHD, at RM 63. This project would improve the stream channel by adding boulder or logs and includes limited excavation to recreate meanders or backwater habitats.

(e) Site TR-05: The project sites are tributaries of the reservoir including Charley, Gale, Cottonwood and McDonald Creeks. This project would provide partial maintenance of large and small tributary habitat. Habitat maintenance features include those listed in MS-02 but do not include floodplain excavation.

(4) Stream Habitat – Above Reservoir. Several project concepts were developed for areas above the enlarged reservoir, these were: 1) improve fish passage to one or more tributaries by replacing impassable culverts; 2) improve selected areas of mainstem and large tributary instream habitat through placement of large woody debris or boulders; and 3) replacement of the mainstem Green River into its historic channel.

(a) Site MS-08: The project site is the mainstem Green River valley floor RM 71.3-80.1, beginning at elevation 1240 feet. Management prescriptions within the protected area to improve fish and wildlife habitat include: 1) riparian improvements discussed above; and 2) addition of large keystone trees (60 feet or greater, 4-foot-diameter rootwad attached) at one 2-3 trees cluster/half-mile of mainstem to act as collection points for additional debris and to improve channel diversity -- pools, gravel collection, side channels.

(b) Site TR-09: The project site is on Gale Creek from elevation 1240 to 1280 feet and the North Fork Green from elevation 1240 to 1320 feet. Management prescriptions include 1) riparian improvements discussed above; and 2) placement of one cluster of keystone logs in the North Fork channel.

(c) Site TR-10: Headwaters Culvert Replacement. Three tributaries of the Upper Green River would have existing culverts replaced to provide passage for juvenile and adult salmon and steelhead. A culvert inventory has been proposed for the Upper Green River (either MIT or WDFW) and will identify locations on two small tributaries and one large tributary for culvert replacement.

(d) Site MS-04: Mainstem Channel Replacement. The project site is the mainstem river near the Lester Airport between RM 83 and 84. This project would return the river to its historic channel by diverting the river with a one or more series of debris jams/flow deflectors and by excavating excess sediments. Currently, the river has abandoned its historical channel and begun eroding the old Lester airstrip and the mainline road adjacent to the river. This land is owned by Washington State Department of Transportation. During summer low flow period the new exposed, braided channel has high stream temperatures with no pool volume and low width/depth ratio presenting a potential barrier to introduction of adult anadromous salmonids.

c. Wildlife Habitat Mitigation. The wildlife mitigation plan that follows is dynamic. Though the principal components (pastures, late-successional forest habitat management, etc.) would remain as the foundation of the plan, certain details of the plan will change through design, site manipulations, and construction. For example, the actual acreage of pasture on various sites may be different after construction than that described in the following sections. Site 1, for example, may end up being 16 acres due to topographic relief that doesn't allow development of pasture on the entire site; in this case, additional acreage would be sought at other sites. In the worst case, if there were not enough acreage on the sites selected for Phase I, one or more sites selected for Phase II would be selected to provide all acreage required to meet full mitigation targets for Phase I. Other details that may change may be in the application of fertilizer, or the amount of tilling and re-seeding that is done per site. Such changes would not affect the attainment of full mitigation; rather they would affect the manner in which full mitigation is achieved.

(1) Phase I Mitigation.

(a) Elk Forage Habitat. Pastures would be created requiring intensive management (fertilizing annually, and 25% of pasture tilled and re-seeded annually). All pastures would be similarly managed. All sites are on Tacoma Public Utilities land, unless otherwise noted. The location of wildlife mitigation sites around HHD is shown in Figure 4-7. Referenced figures can be found at the end of this report.

The following list includes sites managed exclusively to provide grazing areas for elk.

Site 1 An 18 acre site, to be constructed on a BPA right-of-way to the west of North Fork Green River. Currently in vegetation classes FDY (young deciduous forest) and G (grassland).

Site 2 Same as Site 1, except that pasture would cover 45 acres.

Site 5 Expansion of existing pasture (Baldi Field), on a raised bench above and to the northwest of MacDonald Farm (originally part of MacDonald Farm). Pasture is currently about 14 acres; would expand to 18 acres by removing forest patches that have established in the center of the pasture, and by expanding pasture into existing forest around the edges.

Site 7 East of and adjacent to Site 6, also an 11 acre pasture, in the Puget Sound Energy (PSE) right-of-way, and including similar forest habitat.

Site 8 Southeast of Site 7, partially in PSPL right-of-way, otherwise on TPU lands. The entire site is young deciduous forest, with a small amount of grassland. The site would be converted to a pasture 14 acres in size.

(b) Upland Forest Habitat. The following sites are on mature conifer, or mixed forest lands, where the goal is to utilize certain forest practices that promote conditions found in late successional and old growth forests. These conditions include down timber, snags, and openings in the canopy that allow light to reach the forest floor, and thereby promote the growth of ground covers and shrubs. In addition, areas with high densities of trees would be thinned to leave a low density stand of larger trees, which again allows additional light to reach the forest floor.

Site 9 A mature deciduous forest in the Conservation Zone, on the south side of the reservoir west of Charlie Creek. Ten acres would be managed.

Site 10 Also ten acres, and on the south side, but west of Charley Creek, in the Natural Zone, and composed of mixed forest.

Site 12 A 10 acre site, also on the south side of the reservoir, at the extreme upstream limit of the pool raise. This site contains primarily mature deciduous forest, with a small amount of mature conifer forest, overlapping both the Natural and Conservation Zones.

Site 13 A 10 acre patch of mostly mixed forest, with some deciduous forest, adjacent to MacDonald Field, in the Natural Zone.

Site 15 A 15 acre site comprised almost entirely of mixed forest, with a small component of conifer forest, north of Baldi Field. This site is in the Conservation Zone.

Site 18 A five acre patch adjacent to and upslope from Site 13, consisting mainly of mature deciduous forest, with smaller amounts of mixed and mature conifer forests. This site is in the Natural Zone.

Site 19 A six acre site comprised of mature conifer and mixed forests in the Conservation Zone, located northeast of MacDonald Field.

Site 26 Forest Lands identified by TPU for late successional management. Fifty acres would be managed specifically as mitigation for the Phase I pool raise.

The site is east of the North Fork Green River and extends south from TPU Northern Property line of Section 15 T21NR8E to Piling Creek.

(c) **Wetland and Riparian Habitat.** These are currently wetlands which would be inundated by the pool raise, and would be modified so as to enable them to continue to exist as wetlands following the pool raise. The modification would primarily be in the form of a subimpoundment at Sites 22 and 27, and planting of sedges adapted to extreme depths and duration of inundation.

Wetland Habitat

Site 16 This site is on the south side of the reservoir, near the Burlington Northern Railroad Bridge #17. This site is currently 100% mature deciduous forest that would be inundated by the pool raise, and the trees would die. Sedges would be planted to provide a forage area on the south side of the reservoir. The site is about 10 acres in size.

Site 22 This site and the next three sites are within the inundation zone of the reservoir, and would be planted to sedges that can tolerate deep water and short growing seasons, to replace the loss of existing marshes, which would not survive the inundation. Site 22 is at the mouth of Cottonwood Creek, and would cover about 5 acres.

Site 23 At the site known as "Cedar Swamp", west of Baldi Field. This site would cover about 10 acres in Phase I.

Site 24 This site includes the pasture and adjacent wet meadows of MacDonald Field. It is hoped that 30 acres of sedges could be planted at this site.

Site 25 This site is located between the mouths of MacDonald Creek and Gale Creek. The site would result in 5 acres of sedge meadow.

Riparian Habitat

Site 22 Phase II pool would inundate a portion of the mouth of Cottonwood Creek; a three acre subimpoundment would be created, which would include plantings of willows and Oregon ash, and installation of nest boxes and large woody debris.

Site 27 A wall-based channel supported wetland created in part by the construction of a railroad bed many years ago. A subimpoundment would be constructed, which would consist of raising the railroad berm sufficiently to maintain water levels at the higher pool elevation of the new water supply project. Wetland plants and trees would be planted to replace those lost to inundation, and nest boxes and large woody debris would be installed. The subimpoundment would cover 5 acres.

(2) Phase II Mitigation

(a) Elk Forage Habitat. As in Phase I, pastures would be created requiring intensive management (fertilizing annually, and 25% of pasture tilled and re-seeded annually). All pastures, except for Site 17, would be similarly managed. Sites not on power company rights-of-way are all on Tacoma Public Utilities land, unless otherwise noted. The following list includes sites managed exclusively to provide grazing areas for elk.

Site 3 Same as Sites 1 and 2, on 15 acres east of the North Fork Green River, one mile north of MacDonald Farm.

Site 11 Adjacent and west and slightly higher elevation than Site 16, this 5-acre site is comprised of mature deciduous and mixed forests.

Sites 23, 24, and 25 Phase II pool raise would inundate additional acreage above each of these sedge meadows. Sedges would be planted above the Phase I plantings to form continuous sedge meadow habitat up to the upper Phase II reservoir level. The three sites combined would add another 18 acres of sedge meadow to the reservoir area.

(b) Upland Forest Habitat. One 65 acres of late successional forest management would be added to the mitigation plan for Phase II. This includes 15 acres on Site 14, and 50 acres on Site 26 (see Paragraph 4.07 (3) (ii) and Figure 5 in Appendix F2, Wildlife, for locations of these sites).

Site 14 Comprised of 15 acres of mature conifer and mixed forest stands, east of and upslope from Site 23 (Cedar Swamp area), and northwest of Baldi Field. The site is in the Conservation Zone.

Site 26 For Phase II mitigation, fifty acres would be added to the fifty already being managed for Phase I. The Phase II site extends east of the reservoir from Piling Creek and extending south and east to Gale Creek. Both parcels (Phase I and II) are spread over all three management zones (Natural, Conservation, and Commercial

(c) Wetland and Riparian Habitat. Subimpoundments would be constructed at three sites to utilize Phase II higher reservoir for wooded wetland creation. Woody plants would be planted at a third site.

Site 17 A relatively complex area of pasture, fruit trees, woodlands, and wetlands at the Koss Field homestead. The created pocket wetlands would cover about 9 acres, and would follow existing wall-based channels, with interspersed ponds to hold water during and following the pool raise. Aquatic plants and trees would be planted, and nest boxes and large woody debris would be installed. A one acre subimpoundment would be created, which would include plantings of Oregon ash, Pacific willow, Sitka willow, and red-osier dogwood, and the installation of nest boxes and large woody debris.

Site 23 Willows and Oregon ash would be planted on a level bench, just below the high Phase II reservoir level, in the "Cedar Swamp" area.

Site 24 A six acre sub-impoundment would be created at MacDonald Creek. Pacific and Sitka willows, Oregon ash, and red-osier dogwood would be planted along with aquatic and emergent herbaceous vegetation. Woody debris and nest boxes would be installed.

4.7.4 Mitigation Monitoring

Scientific monitoring of the elk pastures, wetlands, and in-reservoir restoration measures will be performed to assure successful establishment of plants and use of sites by wildlife. Monitoring of the growth of trees, shrubs, and sedges would occur in years 1, 2, 5, and 10 following planting. Details of the monitoring plan are given in Annex IV of Appendix F2, Wildlife.

Monitoring of fish mitigation and restoration features will also be performed in years 1, 2, 5, and 10 following establishment of these features. Details of fish monitoring are found in Appendix F1, Fish Restoration and Mitigation.

4.8 ENVIRONMENTAL RESTORATION FEATURES

The objective of this measure is to address impacts from the original construction and operation of HHD. The location of ecosystem restoration sites (fish restoration) in the Lower Watershed and Upper Watersheds is shown in Figures 4-5 and 4-6, respectively. Referenced figures can be found at the end of this report.

4.8.1 Side Channel Improvements

In addition to the habitat loss from the dam and reservoir (see below), there was a large left-bank side-channel, RM 59.4 to 58.8, impacted during re-alignment of the railroad grade during dam construction. This side-channel, and the accompanying side-channel on the right bank, represent the largest floodplain area between end the Middle Green, RM 46, to HHD at RM 64.5. The lower 1,000 feet of channel of a left bank, major mainstem side-channel was filled, channelized, and disconnected by Corps during construction of Howard Hanson Dam and re-alignment of the BNR railroad in 1960 and 1961. Average channel width in 1940 had been 75-125 ft, in 1995 width is estimated at 10 to 15 feet. The original culvert or bridge was replaced with a 48 in culvert. During construction in 1960-61, when the channel was filled and temporarily cut-off from the Green River, over 1,000 adult salmon were trapped in the channel (L. Signani, Army Corps of Engineers, personal communication 1995).

a. Site VF-04: The project site is the left bank of Green River between RM 58.8-59.4. This restoration feature would restore up to 3.4 acres of side-channel habitat to quality fish habitat which was lost due to isolation from the river, channelization, and filling by the Corps during realignment of BNR Railroad during construction of HHD. This would be accomplished in the slough channel through 1) excavation of fill material; 2) replacement of a 48-inch culvert with one or two 16-foot culverts; 3) addition of large woody debris and excavation in the floodplain to restore habitat complexity; and 4) diversion of 35 cfs flow from the Green River to provide additional water for the entire channel length.

4.8.2 Tributary Stream Improvements

Stream habitat projects were identified to restore a portion of the 7.7 miles of anadromous fish stream habitat lost from construction of the original dam and inundation of streams by the existing pool (up to the 1141 foot pool elevation). The total habitat area affected by construction and filling of the existing HHD reservoir was approximately 56 acres of instream habitat.

a. Site MS-03: This project would restore and improve 8,000 lineal feet of mainstem and valley floor habitat of the Green River in areas adjacent to the raised pool 1177 feet and up to elevation 1240 feet. Features of the project include several treatments: 1) addition of structural elements (large woody debris or boulders) to increase pool depth, sediment routing, and instream cover, bank stability and channel confinement; and 2) restoration or creation of off-channel habitat (side channels or meanders); and 3) implementation of the Tacoma Forest Plan 200 foot Natural Zone riparian buffer widths.

b. Site TR-06: This project would restore and improve 4,000 lineal feet of main channel and valley floor habitat of North Fork Green in areas adjacent to the raised pool 1177 feet and up to elevation 1240 feet. Treatments are similar to those discussed in MS-03.

c. Site TR-07: The project site selected areas of the main channel of several tributaries of HHD Reservoir including Charley, Gale, McDonald, Cottonwood, Piling, and 3 unnamed tributaries from elevation 1177 feet to elevation 1240 feet. Treatments are similar to those discussed in MS-03.

4.8.3 Gravel Placement

Gravel nourishment was identified as a necessary feature to maintain mainstem spawning habitat in the Lower Green River. This project would provide 3900 yd^3 of screened, gravel-sized material to the Middle Green River just below the Green River Gorge beginning near RM 45-46. The gravel would maintain an increment of existing spawning habitat in the Middle Green River and could help maintain and proposed side channel habitat mitigation projects (LVF-04, and LVF-06 and numerous Green/Duwamish Basin Restoration Projects). Because of the reduction in peak flows (with decreased sediment transport ability), gravel nourishment in the Flaming Geyser area is limited and will not equal the annual transport rate for the river (estimated range 3,900-11,700 cu yd^3/year, Section 4D). The replacement value for this project is approximately 50% of the median estimated loss of sediment. A second potential nourishment area was identified below the Tacoma Diversion Dam (MS-05, 06, and 07, described in Appendix) but was not selected Gravel source would come from a nearby commercial gravel pit 2-3 miles from 2 of the 4 alternative sites. Gravel to be placed just within the active channel, to be moved by high flows.

a. Sites LMS-01, LMS-02, LMS-03, and LMS-04: Four alternate gravel placement sites are proposed. These are conceptual sites and are found between RM 40 to 46. These sites are from 4-8 miles from a nearby gravel quarry. Access to river at the uppermost placement sites (LMS-03 and 04) may come from a 1500-foot extension of Washington State Department of Parks access road on north bank or from the eastern end of the Flaming Geyser State Park access road. Monitoring is discussed in Section 4, Part 1, Appendix F.

4.8.4 Large Woody Debris Management

Large woody debris would be stockpiled in a convenient location that would also not interfere with project operations, for the purpose of placement in habitats at a later date. The existing debris holding areas would appear to be logical locations for this purpose.

The placement of large woody debris will require some care, so as not to impede maneuverability of animals or people. The best locations for placement of large woody debris (especially stumps and logs) are adjacent to existing or created wetlands or subimpoundments, to provide hiding places for amphibians and small mammals. Large snags would be placed in young forests that are lacking in cavities; a small number of stumps and logs could also benefit animals in forests lacking in structural diversity.

Small mammals, such as Boreal red-backed vole (*Clethrionomys gapperi*), deer mouse (*Peromyscus maniculatus*), and Townsend's chipmunk (*Eutamias townsendi*) all utilize fallen logs as runways, shelters, and a food resource. Decaying wood attracts numerous invertebrates, which provide additional food for animals that eat them. Oregon salamanders (*Ensatina eschscholtzi oregonensis*) hide and make nests under fallen logs, and red-legged (*Rana aurora*) and Cascades (*R. cascadae*) frogs may lay their eggs in tiny pools in the tops of stumps.

Aside from the benefits stated above, the temporary storage of the debris also provides temporary homes for many small mammals and birds, as well as perches for hawks and other birds.

4.9 REAL ESTATE

The HHD Additional Water Storage Project involves approximately 2,132.40 acres of land for initial construction of this federally assisted project. The current plan is for construction to take place in two phases. Phase I pool raise and mitigation sites are to contour elevation 1,167 feet. The Phase II pool raise, fish and wildlife mitigation and restoration sites are to contour elevation 1,177 feet. The non-federal sponsor can currently demonstrate fee ownership of 1,153.27 acres fee for fish and wildlife mitigation and restoration sites, and pool raise area.

Before advertisement for construction, the non-federal sponsor will make all lands, other than USACE owned lands, necessary for the project available to the federal government by a Certification of Lands and Authorization For Entry (see Appendix G, Real Estate Assessment, Exhibit C) and Attorney's Certificate (see Appendix G, Real Estate Assessment, Exhibit D). The non-federal sponsor will provide the Corps, within 60 days after authorization of entry for construction, supporting LERRD credit documentation, including credit appraisals for lands made available for the project.

The non-federal sponsor has land acquisition experience and is fully capable of acquiring any lands necessary for the project. (See Appendix G, Real Estate Assessment, Exhibit B for the Assessment of the Local Sponsor's Real Estate Acquisition Capability document.).

Provided below is a baseline cost estimate for the land value, non-federal sponsor land acquisition expenses, and federal review and assistance costs by phases.

TABLE G-5-1 - PHASE I

Lands and Damages	$1,216,000
Non-federal Sponsor's Costs	120,000
Federal Review and Assistance Costs	45,000
Subtotal	$1,381,000
Contingency 20%	$276,000
TOTAL PHASE I	$ 1,657,000

TABLE G-5-2 - PHASE II

Lands and Damages	$1,861,000
Non-federal Sponsor's Costs	$32,000
Federal Review and Assistance Costs	$16,000
Subtotal	$1,909,000
Contingency 20%	$382,000
TOTAL PHASE II	$2,291,000
GRAND TOTAL PHASE I & II	$3,948,000

4.10 DESIGN AND CONSTRUCTION SCHEDULE

It is expected that the PED phase of this project will begin in approximately the last quarter of calendar year 1998 and will take approximately 3½ years. Construction will take approximately 3½ years with completion of Phase I construction in 2004. Construction phase will begin in 2001 and will overlap the PED phase of the project. This will allow construction of the mitigation features, except for the new tower and fish passage, and a test pool raise while design of the tower and fish passage is completed.

4.10.1 Pre-construction Engineering and Design (PED)

During the PED phase plans and specifications, for the project, will be completed, this includes all structural and habitat features. In PED there are several other additional items to be completed they include, but are not limited to, the following items.

a. Design Memorandums Required. A Feature Design Memorandum is planned for the new tower and fish passage facility. Included in this document will be an analysis of the geotechnical exploration to be completed for the new tower. Also the results of the hydraulic model testing and the design of the tower and fish passage to approximately the 35% level.

b. Hydraulic Model Tests. At present it is anticipated that three model physical studies will be required. They will be done at approximately the 35% design level.

c. Foundation Exploration. Foundation exploration and evaluation of the data obtained will be required for the design of the new tower, fish passage, and tunnel. This effort will begin 1998 at the beginning of the PED phase.

4.10.2 Phase I Construction/Implementation

a. Plans and Specifications. Work on the plans and specifications for Phase I, to be completed in PED, will begin late in 1998 and will continue through 2001. It is expected that design will be broken down into three main sections: 1) Design of the new tower and fish passage facility; 2) design of the support buildings; and 3) design of habitat mitigation and restoration features. See Paragraph 4.11 for estimated schedule and costs of PED

b. Construction. Construction of Phase I is expected to begin in the summer of 2000 with completion of construction in 2004. See Paragraph 4.11 for estimated costs and schedule for construction.

4.10.3 Phase II Construction/Implementation

This document does not request authorization to proceed to Phase II plans and specifications or construction. As a result of negotiations with the resource agencies and the MIT it was agreed that Phase II would be delayed until the environmental impacts of Phase I could be determined and evaluated. At this time it is estimated that will take 5-8 years from the time that Phase I is implemented.

4.11 PROJECT CONSTRUCTION COST ESTIMATE

See the following table and GANTT chart for the estimated schedule and cost breakdown of the PED and construction phases of this project.

4.12 OPERATION AND MAINTENANCE

4.12.1 Considerations and Concerns

During the planned pool raise 15 February to 1 June, the new facility will pass up to 1250 cfs. The main gates will pass flow in excess of 1250 cfs. As the pool rises, gates in both the old intake and the new fish passage will have to be adjusted to maintain flows through the two structures. One stop log set will be placed for every 10-foot rise in pool elevation. In the early days of the pool raise, a stop log set will be placed about once every 8 hours. The fish chamber will be cleared whenever it reaches capacity, the frequency of which has not been determined by current studies.

TOTAL - ALL CONTRACTS — TOTAL PROJECT COST SUMMARY

BASED ON 35% DESIGN DATED 14 JULY 1997 AND OCTOBER 1997 DOLLARS

PROJECT: HOWARD HANSON DAM FISH PASSAGE

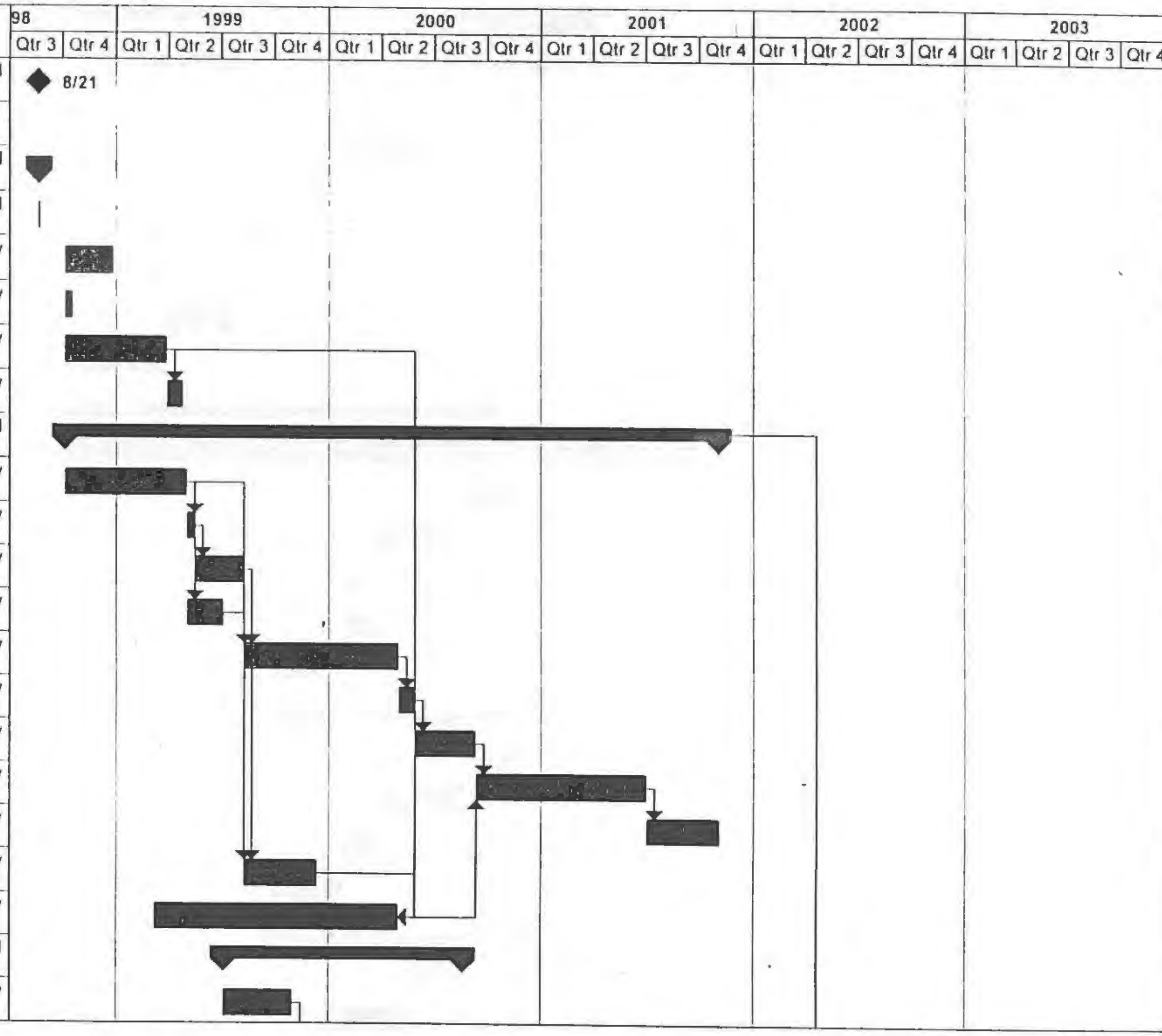
LOCATION: HOWARD HANSON DAM, WASHINGTON

CURRENT MCACES ESTIMATE PREPARED: Jan 98

EFFECTIVE PRICING LEVEL: Oct 97

ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)										
04	DAMS					check	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2007 =
04.03	OUTLET WORKS					sum									
04.03.01	MOB, DEMOB & PREPARATORY WORK	820	164	20.0%	984	984				325	659				
04.03.03	CARE AND DIVERSION OF WATER					0									
04.03.01.02	COFFER DAM	3,503	701	20.0%	4,204	4,204					4,204				
04.03.03	PERMANENT ACCESS ROADS AND PARKI	2,002	400	20.0%	2,402	2,402				2,402					
04.03.05	BRIDGE	220	44	20.0%	264	264						264			
04.03.09	BUILDINGS	1,856	371	20.0%	2,227	2,227				557		1,670			
04.03.10	EARTHWORK FOR STRUCTURES	2,666	533	20.0%	3,199	3,199					2,111	1,088			
04.03.11	FOUNDATION WORK	2,010	402	20.0%	2,412	2,412						2,412			
04.03.12	SEEPAGE CONTROL					0									
04.03.12.1	CONSOLIDATION GROUTING	3,035	607	20.0%	3,642	3,642				3,642					
04.03.12.2	ADIT EXTENSION	724	145	20.0%	869	869				869					
04.03.12.3	FEEDER WELLS	249	50	20.1%	299	299				299					
04.03.12.4	HORIZONTAL DRAINS	375	75	20.0%	450	450				450					
04.03.12.5	PRESSURE GAGE	2	0	0.0%	2	2				2					
04.03.12.6	RE-PERFORATE FEEDER WELLS	21	4	19.0%	25	25				25					
04.03.12.7	ROCK BLANKET	2,500	500	20.0%	3,000	3,000						3,000			
04.03.29	APPROACH AND OUTLET CHANNELS	1,413	283	20.0%	1,696	1,696					1,696				
04.03.54	OUTLET PORTAL AND STILLING BASIN	75	15	20.0%	90	90					90				
04.03.55	TUNNEL AND CONDUIT	1,518	304	20.0%	1,822	1,822						1,822			
04.03.56	INTAKE STRUCTURE	6,846	1,369	20.0%	8,215	8,215						8,215			
04.03.57	INTAKE GATES AND EQUIPMENT	3,400	680	20.0%	4,080	4,080						3,060	1,020		
04.03.99	ELECTRICAL	1,314	263	20.0%	1,577	1,577						520	1,057		
04.03.99	CRANE	3,261	652	20.0%	3,913	3,913					3,913				
		37,810	7,562		45,372	45,372			0	8,571	12,673	22,051	2,077		0
06	FISH AND WILDLIFE FACILITIES														
06.03	WILDLIFE FACILITIES AND SANCTUARY					check	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	2007 ==>
06.03.99	WILDLIFE HABITAT MITIGATION					sum									
	PHASE 1	1,154	231	20.0%	1,385	1,385				1,385					
	PHASE 2	828	166	20.0%	994	994									994
06.03.99	FISH HABITAT MITIGATION					0									
	PHASE 1	779	156	20.0%	935	935				935					
	PHASE 2	1,603	321	20.0%	1,924	1,924									1,924
	FISH HABITAT RESTORATION PHASE 1	1,217	243	20.0%	1,460	1,459					487	486	486		
		5,581	1,117		6,698	6,698			0	2,321	487	486	486		2,918
	TOTAL CONSTRUCTION COST	$43,391	$8,679	20.0%	$52,070	52,070	$0	$0	$0	$10,892	$13,160	$22,537	$2,563	$0	$2,918
01	LANDS AND DAMAGES						FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	2007 ==>
	PHASE I	1,381	276	20.0%	1,657	1,657			830	827					
	PHASE II	1,909	382	20.0%	2,291	2,291									2,291
30	PLANNING, ENGINEERING AND DESIGN (P	6,950	1,390	20.0%	8,340	8,340	20	2,310	4,200	1,420	390				
31	CONSTRUCTION MANAGEMENT	3,471	694	20.0%	4,165	4,165				1,041	1,041	1,833	250		
	TOTAL PROJECT COSTS	$57,102	$11,421	20.0%	$68,523	68,523	$20	$2,310	$5,030	$14,180	$14,591	$24,370	$2,813	$0	$5,209
	MONITORING	5,153	1,031	20.0%	6,184	6,184				412	412	412	412	412	4,124
	TOTAL PROJECT COSTS PLUS MONITORI	62,255	12,452	40%	74,707	74,707	20	2,310	5,030	14,592	15,003	24,782	3,225	412	9,333
							FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	2007 ==>

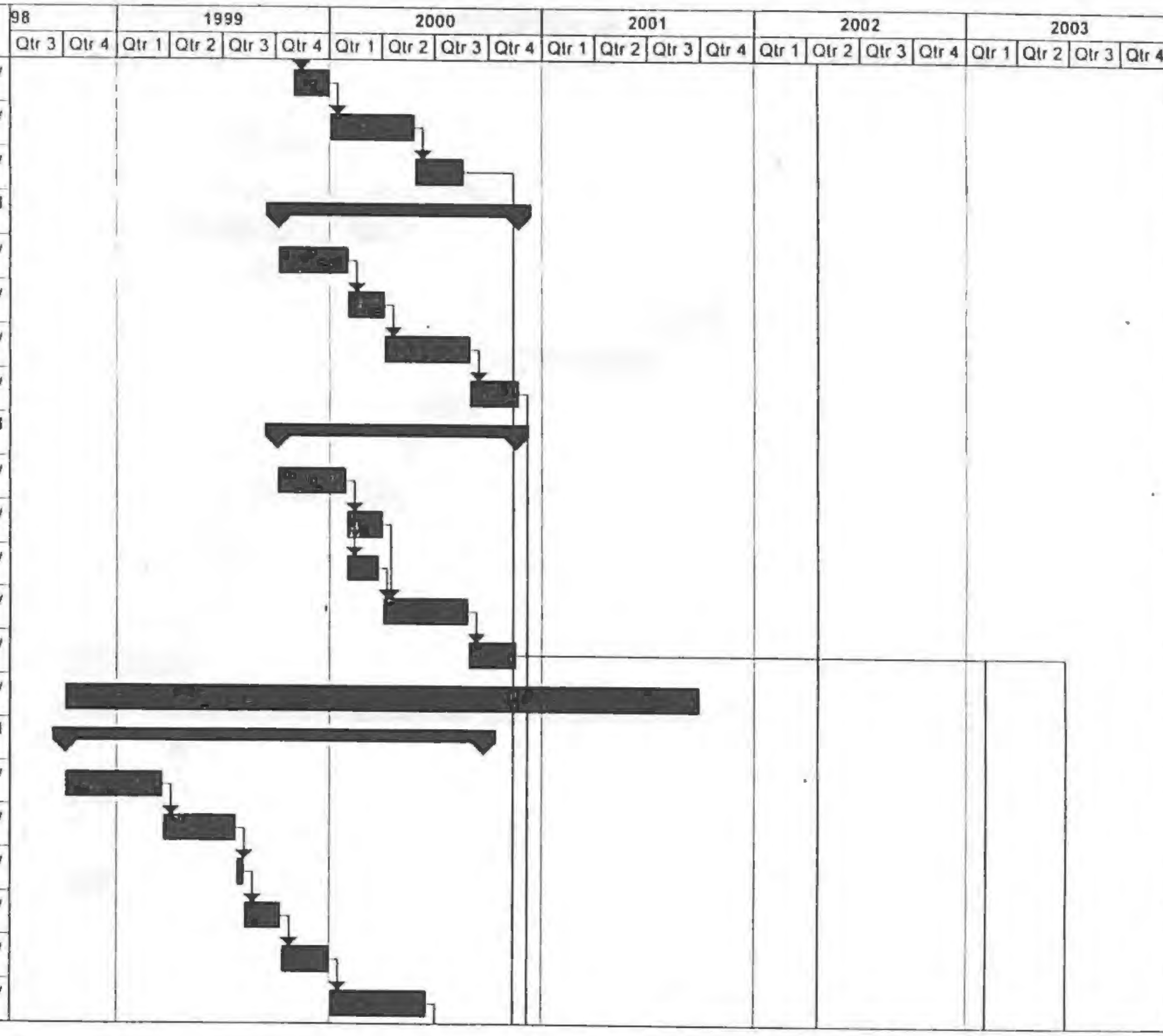
ID	Task Name	Duration
1	DESIGN PHASE	0d
2		
3	PED START	1d
4	Sign Cost Share Agreement	1d
5	Survey for tower	12w
6	Survey for buildings	2w
7	GT Exploration for tower	25w
8	GT Exploration for buildings	4w
9	Tower	805d
10	30% Design Tower	30w
11	Cost Est Tower	2w
12	30% Design Review	12w
13	VE Study	9w
14	65% Design tower	38w
15	65% Cost Estimate tower	4w
16	65% Design Review	15w
17	Final Design/Cost Est tower	42w
18	Final Design Review	18w
19	Model Studies	18w
20	Feature Design Memo - Tower	60w
21	Rt Abutment Seepage Control	295d
22	Prelim Design/Cost Est Seep	17w



Project: HHD AWS PED & Constructi
Date: Mon 4/6/98

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone	◆	Rolled Up Milestone	◇		

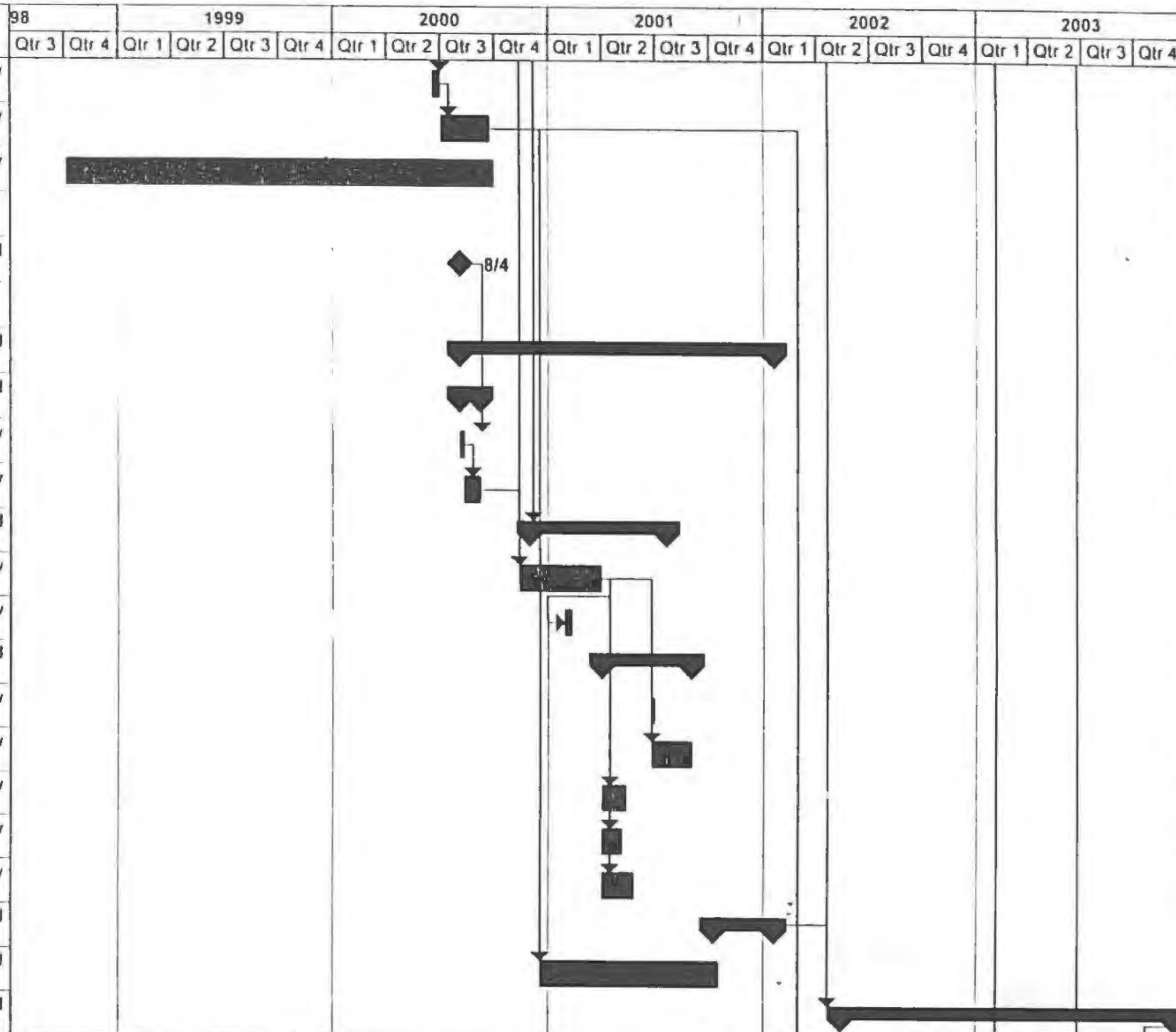
ID	Task Name	Duration
23	Prelim Review Rt Abt Seep C	9w
24	Final Design/Cost Est Seep C	21w
25	Final Review Rt Abt Seep Cnt	12w
26	**Road and Bridge Design**	295d
27	Prelim Design/Cost Est Rd &	17w
28	Prelim Review Road & Bridge	9w
29	Final Design/Cost Est Rd &	21w
30	Final Review Road & Bridge	12w
31	**Building Design**	295d
32	Prelim Design/Cost Est Bldg	17w
33	Prelim ReviewBldgs	9w
34	VE Bldgs	8w
35	Final Design/Cost Est Bldgs	21w
36	Final ReviewBldgs	12w
37	Environmental Studies	156w
38	**Mitigation/Restoration Site Desi**	515d
39	Survey Mit/Rest Sites	24w
40	Prelim Design Mit/Rest Sites	18w
41	Prelim Cost Est Mit/rest Sites	2w
42	Prelim Design Mit/Rest Revie	9w
43	VE Mit/Rest Sites	12w
44	Final Design Mit/Rest Sites	24w



Project: HHD AWS PED & Constructi
Date: Mon 4/6/98

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress

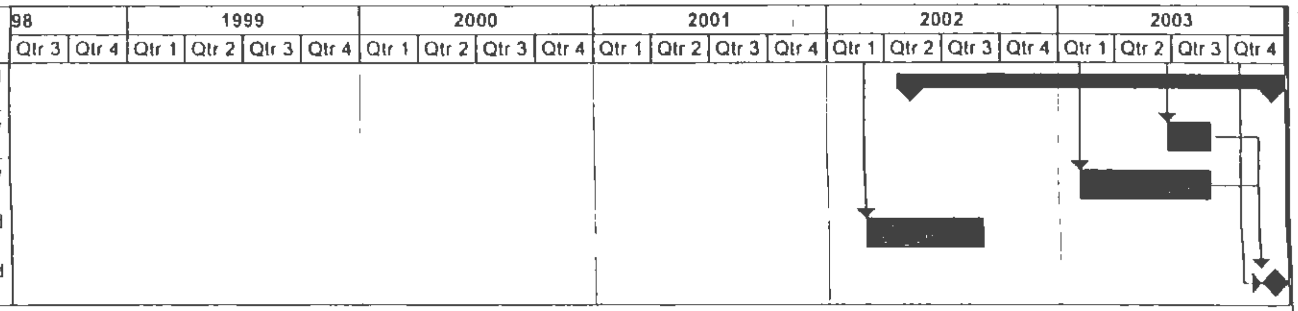
ID	Task Name	Duration
45	Final Cost Est Mit/Rest Sites	2w
46	Final Design Mit/Rest Review	12w
47	Obtain Real Estate	104w
48		
49	PROJECT CONSTRUCTION PHA	0d
50		
51	CONSTRUCTION PHASE I	381d
52	Project Office	25d
53	Mobilization	1w
54	Construction	4w
55	Access Road	166d
64	Consolidation Grouting	20w
65	Re-perforate Feeder Wells	2w
66	ADD'L RIGHT BANK SEEPA	110d
67	Pressure Gage	1w
68	Adit Extension	10w
69	Seepage Adit Feeder We	6w
70	Horizontal Drains	5w
71	Rock Blanket	8w
72	Cofferdam	75d
77	Habitat Mitigation, 1167' Pool	217d
78	CONSTRUCTION FISH PASSAG	413d



Project: HHD AWS PED & Constructi
Date: Mon 4/6/98

Task | Summary | Rolled Up Progress
Progress | Rolled Up Task
Milestone | Rolled Up Milestone

ID	Task Name	Duration
79	Fish Collector	413d
141	Maintenance Building	10w
142	Administration Building	30w
143	Habitat Restoration	131d
144	PROJECT COMPLETION	0d



Project: HHD AWS PED & Constructi
Date: Mon 4/6/98

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress

The pool raise will also be a period of intense activity for the floating habitat, as anchors and cables will require attention to position the islands High pool will also allow project personnel to float new logs into position near the floating habitat, but attaching the new logs will be done while the islands are on the ground.

During full pool and about the first 10 feet of drawdown, no stoplogs will be moved, and the fish passage will pass the entire flow Should the flow exceed 1250 cfs, the main gates will be used to pass the excess flow. While dam personnel will not need to move stoplogs during this phase, any required manual fish lock operation will continue.

During the summer drawdown, the fish passage facility will control the flow, which normally will not exceed 1250 cfs. Dam personnel will remove stoplogs at the rate of approximately once every two weeks, and perform maintenance operations on upland habitat sites. New logs for the floating islands will be floated to the islands during high pool.

During the winter flood season, the reservoir is at its lowest level and the fish outmigration is also at its lowest rate. This is the only opportunity for major maintenance, but it is also the coldest time of winter. Except during maintenance and high pools, the fish passage will remain in operation to pass any winter outmigration, but low numbers of fish should allow fully automated operation of the fish discharge feature. Because winter flow levels may exceed 1250 cfs, the main gates will be used frequently in addition to the fish passage gate, and stoplogs will be installed during some flood events to maintain fish passage operation. Winter may be the only time to perform maintenance on the floating habitat sites, as they will be on the ground while the pool is down.

4.12.2 Required Increase in Staffing

Stoplog operation requires three persons. The fish discharge procedure will be automated, but may require occasional manual operation during peak outmigration. Habitat maintenance will typically require three to four man crews.

For 3½ months from 15 February to 1 June, the high activity rate at the fish passage facility will require up to 11 additional personnel to operate the gates, stoplogs, and fish discharge equipment. Coordinating the main gates and the fish passage gate is sufficiently time consuming to require additional staffing. The additional staff will work three shifts per day, generally three persons per shift. The rate of pool fill during this period and the rate of outmigration requires operation through the night. The design team will examine controlling the pool fill so as to eliminate the third shift by preventing the need for nighttime stop log installations. The pool raise staffing equates to 5 FTE.

During the summer and fall months, stoplog changes will not be so frequent, and pool elevation can be managed to allow stoplog operation during the day shift. Personnel will be needed to remove the stoplogs, but will not be needed full time. Assuming that the outflow does not exceed 1250 cfs, the fish passage gate will control the flow and the main gates will not be needed. Therefore flow control will not require staffing above current levels. However, three man crews will be required for the occasional stop log removal. Upland habitat maintenance will be scheduled for this time. The total staffing for these months equates to 3 FTE.

During the winter months of December, January, and the first half of February, the water quality pool is maintained. This is the lowest reservoir level of the year, but is also the peak flood season. Any maintenance needed on the MIS system will have to be performed during this season. Operations personnel are concerned that low temperatures and generally poor weather conditions will hamper maintenance efforts. To continue fish passage operation during a moderate flood event, a crew would be needed to install and remove the stoplogs. The winter staffing equates to 1 FTE.

The total staffing required for the new structure is 9 FTE. Included in this is less than ¼ FTE required for the additional trap and haul of adult fish around HHD. Trap and haul is a without-project condition. Adult returning fish are trapped at Tacoma's Diversion Dam both for transportation around HHD and for hatchery use. Increased numbers of returning fish are expected once the project is implemented so there will be an increase in the number of trips required to transport fish around HHD.

4.12.3 Cost of Operation and Maintenance

At 25.02/hr (WG -10/3), 9 FTE will cost $468,374 per year.

4.13 ECONOMIC ANALYSIS

4.13.1 Benefit Evaluation

a. Problems and Needs. In order to help meet the increasing summer M&I water needs of Pierce and South King Counties as well as Seattle, the proposed project will add up to 48 mgd of "summer" (May/June-September/October) M&I water supply. The proposed project will also provide ecosystem restoration with the intent of restoring "self sustaining" runs of anadromous fish runs in the upper Green River above Howard Hanson Dam. Self sustaining runs are defined as fish runs which do not require supplementation of hatchery fish to maintain the run. Restoration measures consist of providing: (1) a fish passage facility which will significantly improve the success of juvenile salmon and steelhead locating and passing from the reservoir to the river below the dam in their migration to the ocean, (2) an additional 9,600 ac-ft of low flow augmentation storage, and (3) several fish habitat improvement measures.

(1) Water Supply. Tacoma Water defines summer water demands as consisting of both an average demand per million gallons of water per day (mgd) over the May-September time frame (average summer) plus peak demands in mgd over a 4-day peak period during the summer Based on the medium growth water demand forecast, compared to the without-project supply of M&I water, the average summer demand for M&I water in the greater Tacoma service area is expected to exceed the without-project summer supply of M&I water by project year one of 2003. The 4-day peak demand (discussed in Appendix H, Paragraph 2.6.5), which also occurs in the summer, is expected to exceed the without-project 4-day peak supply of water shortly after project year one. As a result, Tacoma Water Department is in need of a new source(s) of summer water supply sufficient to meet both the average summer and 4-day peak demands for future M&I water.

(2) Ecosystem Restoration. From an ecosystem standpoint, construction of Howard Hanson Dam caused several significant impacts to anadromous fish in the Green. One major impact was caused by disconnecting the prime habitat areas found in the headwaters of the Green River from the downstream Green River Basin. In an attempt to utilize the prime fish habitat in the upper watershed, salmon and steelhead have been reestablished (planted) above the dam. However, juvenile fish trying to pass from the reservoir to the river below the dam in their migration to the ocean, have difficulty finding the outlet works in the dam and when they do they must pass through the existing fish unfriendly by-pass system. Because they must sound up to 70 feet, depending on the species, 80-95% of these juvenile fish either cannot find the fish outlet and perish in the reservoir as juveniles or if they do fine the outlet, do not survive the passage to the river below the dam.[1]

Other significant impacts to the river as a result of Howard Hanson Dam include: (1) reduced amount of fish habitat in both the Green River and its tributaries (2) reduced water quality and peak flows downstream of the dam and (3) elimination of sediment transport of gravel in the river below the dam which is needed for successful spawning of salmon and steelhead. All of these factors have contributed to declining salmon and steelhead runs in the Green River to the point where the runs are no longer self sustaining and must be supplemented with hatchery fish. In fact, chinook runs in rivers of Puget Sound have declined to the point where they are "likely to become endangered" based on a risk assessment of Washington salmonid stocks by the National Marine Fisheries Service as presented in their "Draft Ecosystem Impact Statement of the State of Washington Wild Salmon Policy", table 11, page 62, dated April, 1997.

b. Ecosystem Restoration Goal. The ecosystem problems on the Green River have resulted in steady declining runs of anadromous salmon and steelhead fish coupled with a severe inability to attract and successfully pass juvenile salmon and steelhead from the HHD reservoir to the river downstream. The goal of the restoration project is of paramount importance in determining the various measures available to help solve identified problems. ER1105-2-210, dated June, 1995 states that "the goal of restoration is to return the environmental study area to as near a natural condition as is justified and

[1] Based on a 5-year (season) study of monitoring juvenile fish passage through Howard Hanson Dam.

technically feasible." For this project, the restoration goal is: to restore and maintain naturally reproducing and self sustaining runs of historical species of anadromous fish found in the upper Green River above HHD Self sustaining runs are those which do not have to be supplemented with hatchery fish to maintain the run. While the output of the proposed project will not return the Green River to its "natural condition", it does attempt to develop fish runs which maintain themselves naturally (i.e., without the use of hatchery produced fish).

c. Benefit Methodology. Benefits produced from this multiple purpose project consist of M&I water supply and ecosystem restoration. Following is a discussion of benefit methodologies used to quantify water supply outputs and evaluate ecosystem restoration.

(1) Water Supply. Economic evaluation of the proposed water supply storage project at HHD was conducted in accordance with Policy and Planning Guidance (ER1105-2-100), dated 28 December 1990.

Water supply benefits are based on: (1) the need for additional water supply, (2) the timing of that need and (3) society's willingness to pay for the increased output of water supply. Where the price of water reflects marginal cost pricing, that price is to be used to measure willingness to pay. Where marginal cost pricing is not used, willingness to pay is estimated based on the cost of the water supply alternative(s) most likely to be implemented in the absence of the proposed project. The most likely alternative(s) are usually the least cost alternative(s) available to the utility. In other words, using this methodology, the value of M&I water supplied by the proposed project is estimated based on the avoided costs of not needing to construct the least cost alternatives to the proposed project. Since Tacoma uses average cost pricing of water rather than marginal cost pricing, water supply benefits were estimated using the most likely alternative methodology.

(2) Ecosystem Restoration. The evaluation of ecosystem restoration was performed in accordance with Engineering Circular 1105-2-210, dated 1 June 1995, "Ecosystem Restoration In The Civil Works Program". The economic evaluation of ecosystem restoration measures for fish passage and habitat improvements were performed using a cost effectiveness and incremental cost per incremental output analysis. The level of low flow augmentation to be provided was determined based on a negotiated [2] trade off analysis between low flow augmentation and M&I water supply which considered the benefits of low flow augmentation versus the benefits of water supply. The number of expected returning adults in the with-project condition assume that the proposed low flow augmentation is implemented. Except for low flow augmentation and gravel placement in river, primary restoration benefits were quantified in terms of number of returning adult salmon and steelhead. Secondary benefits of each measure were also incorporated into the analysis. Gravel placement was measured using square feet of gravel coverage.

[2] Negotiated between project sponsor, federal and state resource agencies and Corps of Engineers.

d. Water Supply Benefits. Water supply benefits are based on the cost of implementing the most likely alternative(s) in the absence of the proposed water supply project, which could be used to provide the same quantity of water in demand at the same reliability and quality as the proposed project. The proposed additional water storage project consists of two phases. The first phase (Phase I) is between years 2003 and 2008. During this time period the proposed project will have the capability of producing 42 mgd over the May-September time frame at 95% reliability. Phase II is assumed to begin in year 2008 and extends to the end of the project life or 2053. During this phase the proposed project will have the capability of producing 48 mgd at 95% reliability over the same time period.

Water supply benefits over time are limited to the amount of water deficit in a given year or water supplied by the proposed project, whichever is less. That is, if the forecast water supply deficits are projected to be 10 mgd in year 2005, 20 mgd in year 2010 and 30 mgd in year 2020, but the proposed project can supply a maximum of 30 mgd, then water supply benefits in year 2005 and 2010 would be limited to 10 mgd and 20 mgd respectively. Benefits for the full 30 mgd supplied by the project, can not be claimed until year 2020, the year the deficits reach 30 mgd. If, however, supply deficits exceed 30 mgd, the value of water supply benefits could not exceed the project output of 30 mgd.

The value of M&I water supplied by the proposed project is computed by identifying those least cost water supply alternatives which would be implemented if the proposed project is not constructed. The City of Tacoma Water Division has identified all of their without-project water supply alternatives which are *realistically available to them over the foreseeable future.*

Water supply benefits were computed for both the average summer day and 4-day peak demand periods and were limited to the output provided by the proposed project or the projected deficit, whichever is lower. That is, based on a 95% reliability, Howard Hanson Dam, in Phase II, will provide 48 mgd during the May-September time frame. Therefore, water supply benefits for the average summer day and 4-day peak are limited to the project output of 48 mgd or the projected deficit, whichever is lower. Computation of the water supply benefits associated with average summer day and 4-day peak demand periods are in tables B2-11 and B2-12 of Appendix B respectively. As shown in these tables, cumulative present worth water supply benefits total **$19,267,000** ($18,729,000 + $538,000) which when levelized over the 50-year project life at 7-1/8 percent interest represents an average annual benefit of **$1,418,000**.

e. Ecosystem Restoration Benefits. The economic evaluation of ecosystem restoration is performed by comparing the economic cost to implement, operate and maintain ecosystem measures to the outputs gaining as a result of the ecosystem measures. While the cost of these measures can be measured like the cost of any other project purpose, there is currently no acceptable way to measure the value of the outputs in monetary terms (except for those fish which are produced by the project and subsequently harvested).

Therefore, a traditional benefit-cost ratio for this part of the project cannot be determined. When benefits are not measured in dollars, a cost effectiveness and incremental cost analysis offers the next best approach to evaluate plan alternatives. While this analysis will not necessarily identify a unique or optimal solution, it will provide a mechanism to help decision makers allocate financial resources more efficiently and avoid the selection of economically irrational restoration measures. The results of the analysis allows decision makers to progressively compare alternative levels of ecosystem outputs and be able to ask if the next level of ecosystem output is worth its monetary cost.

The restoration projects include fish passage measures, habitat restoration and low flow augmentation measures. Fish passage as well as habitat restoration measures were evaluated through use of cost effective and incremental cost analyses. Low flow augmentation was determined through negotiations between the sponsor, tribe, resource agencies and the Corps. The recommended fish passage facility consists of constructing a new intake tower with a single enlarged modular incline screen with a single fish lock. A live box would capture fish within the lock when the lock is evacuated. Outflow would be routed through a new tunnel and stilling basin. An attenuation chamber would be provided at the tunnel outlet. Maximum discharge capacity would be 1,250 cfs. This facility is estimated to produce 23,381 returning adult salmon and steelhead before harvest. This facility is the least cost fish passage measure which meets the restoration goal of establishing self sustaining runs of wild salmon and steelhead. Harvest of fish produced by this facility could continue at the long term harvest rates of 55% for chinook, 70% for coho and 35% for steelhead.

The recommended habitat improvements consist of (1) creating a slough on the south side of the Green River below Tacoma's water supply diversion structure, (2) improving river channels in the upper watershed between pool elevations 1177 and 1240 feet, and (3) placing 3,900 cubic yards of spawning gravel in the Green River new the town of Palmer, WA.. The recommended low flow project was determined based on a negotiated trade off analysis between water supply and low flow augmentation. This project consists of providing 9,600 ac-ft of storage which will produce an additional 39 cfs at 78% reliability over a 123-day summer/fall period. These restoration actions will also help produce additional returning adults to the upper watershed.

Specific and detailed information on the water supply analysis as well as the restoration analyses used to determine the recommended plan is presented in Appendix B.

4.13.2 Project Cost Sharing

a. Construction and Investment Costs. Project first costs consist of construction cost. Major construction items consist of modification to the outlet works to include lands, intake tower, intake gates and equipment, seepage control, foundation work, access road, mitigation measures, and restoration and mitigation monitoring. Total construction costs are estimated to be $74,707,000 in October 1997 prices. Investment costs include construction costs plus interest during construction (IDC). IDC was computed by compounding interest over the construction period at 7-1/8 percent interest and is estimated at $5,500,000. Shown below is a summary of project construction and investment costs.

b. Annual Costs. Estimated annual costs are based on investment costs levelized over the 50-year economic life of the project at 7-1/8 percent interest. The estimated incremental increase in annual operation and maintenance costs associated with the proposed project are also included. Shown below are the estimated annual costs of the proposed project.

Construction Cost	$74,707,000
Interest During Construction	5,500,000
Investment Cost	$80,207,000
Average Annual Costs	
Interest and Amortization (50-Yrs @ 7-3/8%)	$5,904,000
Operation and Maintenance	468,000
Total Annual Cost	$6,372,000

c. Cost Allocation. While the proposed project does not affect the outputs of the existing project, the project does add two additional project purposes; both with different cost sharing requirements. As project sponsor, Tacoma Public Utilities is responsible for paying 100% of the construction, operation, maintenance and replacement costs allocable to water supply and 35% of the construction and 100% of the operation, maintenance and replacement costs allocable to ecosystem restoration (except for monitoring associated with returning adults). As a result, a preliminary allocation of the proposed project costs is necessary. This preliminary cost allocation establishes a basis for determining the proportion of project costs which are assigned to the project purposes of M&I water supply and ecosystem restoration. In addition, cost allocable to water supply and restoration were further broken out between Phase I and Phase II costs. A final cost allocation will be prepared after construction and audit is completed.

Since ecosystem restoration benefits are not quantified in dollar terms, the normal separable cost-remaining benefits cost allocation methodology cannot be used. As a result, a modified use of facilities cost allocation method was developed and used for allocating costs (except labor costs associated with monitoring restoration and mitigation facilities) of the proposed project. The cost allocation methodology used for this project has been approved by the Corps' Northwest Division as well as Headquarters and consists of determining the separable costs allocable to each project purpose and then allocating the remaining joint use costs (all were identified as associated with fish passage facility) based on the height of the fish passage facility. In addition, a separate cost allocation was used to allocate the labor costs associated with monitoring the restoration and mitigation sites. Specific details on how these costs were allocated between each project purpose are in Appendix B. Furthermore, in accordance with current requirements when an existing project is used to produce a revenue generating project purpose, a share of the existing project costs are to be allocated to that purpose. As a result, a share of construction costs associated with the existing HHD project were allocated to the purpose of water supply. Specific information on how these costs were determined can be found in Appendix B.

The results of the preliminary allocation of total estimated construction costs for the existing project including monitoring costs as well as a share of the existing project construction costs show that $18,510,000 is allocable to water supply and $56,398,000 is allocable to ecosystem restoration. Table 4-1 summarizes the proposed project cost allocation results. See Appendix B for a specific determination on how the allocation of costs were determined.

TABLE 4-1
HOWARD HANSON DAM WATER SUPPLY AND ECOSYSTEM RESTORATION PROJECT
COST ALLOCATION SUMMARY
(October 1997 Prices)

	M&I Water Supply	Ecosystem Restoration
Separable Cost	$15,011,000	$39,083,000
Remaining Joint Costs	2,164,000	12,265,000
Allocation of New Project Construction Costs w/o Monitoring	$17,175,000	$51,348,000
Labor Costs - Monitoring	1,134,000	5,050,000
Share of Existing Project	201,000	0
Total Allocation		**$18,510,000**
		$56,398,000

d. Cost Sharing Computations. All costs (construction, operation, maintenance and replacement costs) allocated to water supply are considered non-federal costs and are the responsibility of the project sponsor. For ecosystem restoration, construction costs including labor costs for monitoring (except for monitoring of returning adults) are shared 65% federal and 35% non-federal. The proposed cost sharing of labor cost for monitoring returning adults is one-third Corps, one-third sponsor and one-third resource agencies.

Operations and maintenance requirements are the responsibility of the non-federal project sponsor. In addition, the cost sharing formula requires the local sponsor to repay a portion of the existing project when storage is being added to an existing project *for the purpose of M&I water supply*. The sponsors share of the existing project cost was computed in accordance with ER1105-2-100, paragraph 4-32e, with an adjustment to reflect the number of months during the year Howard Hanson Dam is used to provide water supply storage. In this case, water supply storage will be provided during the May through September season or 5 month during the year. Therefore, the sponsor's share of the existing project was adjusted accordingly (5/12 = 42%). The sponsor's estimated share of existing project used for water supply totals $201,000. See Appendix B for the computation of sponsor's share of the existing project used for water supply.

e. Construction Costs. Shown below in Table 4-2 are the estimated federal and non-federal construction cost sharing requirements. Costs sharing numbers are in 1997 prices as well as to the mid point of construction or full funded dollars. Based on a full funded construction cost estimate of $84,000,000, 48.5%, or $40,740,000 is the federal share and 51.5% or $43,260,000 is the non-federal sponsor share.

TABLE 4-2
HOWARD HANSON DAM WATER SUPPLY AND ECOSYSTEM RESTORATION PROJECT
FEDERAL AND NON-FEDERAL SHARE OF CONSTRUCTION COSTS
(Costs in Oct 1997 Prices and Full Funded)

	COST SHARING BY PROJECT PURPOSE		
PROPOSED PROJECT	FEDERAL	NON-FEDERAL	TOTAL
WATER SUPPLY	$0.0	$18,510,000	$18,510,000
ECOSYSTEM RESTORATION	$36,284,000	$20,114,000	$56,398,000
TOTAL COST-PROPOSED PROJECT (97 Prices)	$36,284,000	$38,624,000	$74,908,000
ALLOCATED SHARE IN PERCENT	48.5%	51.5%	100.0%
FULL FUNDED SHARE	**$40,740,000**	**$43,260,000**	**$84,000,000**
LESS: NON-CASH LANDS	0	2,346,000	2,346,000
CASH REQUIREMENT	**$40,740,000**	**$40,904,000**	**$81,644,000**

Table 4-2 shows the estimated share of full funded construction costs, including the cash share for the project sponsor and federal government. These construction costs include costs for both Phase I and Phase II of the project. The estimated construction cost incurred in each phase of the project is shown in Table 4-3. Except for an estimated $100,000 associated with Phase II of the fish passage facility, all other Phase II costs will be expended when Phase II is implemented. Phase II fish passage costs will be expended during Phase I.

TABLE 4-3
ESTIMATED CONSTRUCTION COST EXPENDITURES BY PHASES

	PHASE I	PHASE II
Construction Costs	**$79,240,000** [3]	**$4,726,000**

f. Operation and Maintenance. Based on October 1997 prices, average annual operation and maintenance costs are estimated to be $468,000 per year of which $100,000 is associated with implementation of Phase II. All operation and maintenance costs are the responsibility of the project sponsor.

4.15 FUTURE FUNDING AND BUDGETING BY FISCAL YEAR

4.15.1 General Investigation

a. Federal. The pre-construction engineering and design (PED) phase of this project is scheduled to begin late in calendar year 1998 and continue through the end of 2001. The estimated cost of PED is $8.4 million and includes extensive goetechnical site exploration and model studies of the new tower and fish passage. The federal share is 75% of the PED costs. See Paragraph 4.11 for cost breakdown by year.

b. Non-Federal. The non-federal share is 25% of the PED costs. See Paragraph 4.11 for cost breakdown by year.

4.15.2 Construction General

a. Federal. The federal share of the construction is 65% of the cost attributable to ecosystem restoration. See Paragraph 4.11 for cost breakdown by year.

[3] Includes $90,000 for Phase II fish passage facility expended during Phase I.

b. Non-Federal. The non-federal share is 100% of the cost of construction attributable to M&I water and 35% of the cost of ecosystem restoration. See Paragraph 4.11 for cost breakdown by year.

4.15.3 Operation and Maintenance

a. Federal. All O&M costs are the responsibility of the non-federal sponsor.

b. Non-Federal All O&M costs are the responsibility of the non-federal sponsor.

SECTION 5. AFFECTED ENVIRONMENT

5.1 GENERAL

For this Draft Feasibility Study Report/EIS, the Region of Influence (ROI) is defined as the HHD reservoir and associated lands above the dam to an elevation of 1,240 feet; the mainstem Green/Duwamish River and lands within one mile of the river; and the associated tributaries to the Green River. For purposes of describing existing conditions and impacts, Sections 4, 5, and 6 are divided into the Upper (above HHD) and the Lower (below HHD) Watersheds. The prominence of HHD within the watershed, as well as differences in habitats and level of development above and below the dam, justify this division. Exceptions to this include the discussions of aquatic habitat and fisheries, which are a dominant concern in the watershed and are thus covered in more detail. These discussions are divided into river reaches.

Information used in this portion of the report was collected from existing published materials including but not limited to: *Howard A. Hanson Dam, Draft Environmental Impact Statement for Operation and Maintenance (USACE 1995); Howard Hanson Dam, Section 1135 Fish & Wildlife Restoration Project, Final Project Modification Report/Environmental Assessment (USACE and Tacoma Public Utilities 1996); and, Green/Duwamish River Basin General Investigation Ecosystem Restoration Study, Reconnaissance Phase(USACE 1996).* This document includes the project feasibility results and assumes the implementation of the Section 1135 recommendations and the construction of Tacoma's Second Supply Water Right (SSWR) pipeline (Pipeline No. 5).

5.1.1 Geography

HHD is southeast of Seattle on the upper reaches of the Green River at Eagle Gorge. The dam is 64.5 miles from the mouth of the river at Elliott Bay. It is one of the largest river flowing out of the Cascades and has supplied drinking water to the region since the mid-1800s. It is one of the most industrialized and developed watersheds in the region because of its proximity to the industrial center of Seattle. The river provides water access for cargo and commercial shipping to this second largest port on the west coast.

Early development in the region was focused in the Green/Duwamish watershed, starting near present-day Seattle and extending up the valley. The rate and type of development were related to distance from Seattle and corresponding topography. Land utilization has been heaviest in the lower floodplain (from approx. RM 30 to the outlet), where agricultural and rural development were the primary uses early in the century. These areas have become increasingly developed for industrial use in the past four decades. Upriver, both agriculture and industrial development have been limited by increasingly steep topography and distance from shipping ports. Before the construction of HHD in 1962, development in the Upper Watershed was limited to logging, construction of the Northern Pacific Railroad, and a few small settlements associated with the railroad. The Upper Watershed is presently closed to the public and is undeveloped except for HHD and the railroad. Logging activities are still the principal enterprise in the upper watershed.

5.1.2 Aesthetics

The Upper Watershed contains relatively high aesthetic value because it is mostly undeveloped and forested. The dam structure is located in the steep-walled Eagle Gorge canyon, which is dominated by visually impressive bedrock benches and ledges. The surrounding hillsides are in various stages of second-growth forest and clearcuts. While this area is relatively scenic, it is generally not accessible to the public because it is located in the closed City of Tacoma watershed.

From HHD to the Tacoma Diversion the scenery remains relatively high in visual appeal due to the paucity of development and river manipulation. While the prevalence of clearcuts on the landscape detracts somewhat from the visual quality, the river follows a basically natural course in this area. Like the Upper Watershed, this area is within the Tacoma watershed and is closed to the public. Palmer-Kanaskat State Park, just downstream from the Tacoma Diversion (RM 60), is a popular public park featuring high-quality scenery and recreational value.

The river enters the exceptionally scenic Green River Gorge just downstream of the Park. The Gorge is roughly 13 miles long, 500 to 1,000 feet wide, and up to 300 feet deep. It has very high visual appeal due to its exposed bedrock ledges, waterfalls and springs. Below the Gorge, Flaming Geyser State Park boasts another highly scenic river reach, characterized by a wider, more meandering section of river. The Green River remains a broad, low gradient river as it flows west through farmland. It has high to moderate aesthetic appeal within this pastoral landscape. While some riparian vegetation has been removed to facilitate farming, the river still meanders within its floodplain in this location, and it retains a pleasant, natural appearance.

As the Green River approaches Auburn (RM 30.5), it becomes increasingly leveed and revetted. While this stretch of river retains a sinuous path characteristic of the historic low-gradient river, increasing human manipulation diminishes its natural character. Aesthetic value is moderate to low and continues to decrease with downstream distance. By Kent (RM 23), the river flows through an increasingly urbanized landscape and is channelized and almost entirely devoid of riparian vegetation. While there are a few areas of calm water and overgrown banks that are visually appealing, the overall visual quality of the area is low. As the river enters Tukwila and becomes the Duwamish River (RM 11), it is increasingly channelized and surrounded by industrial and commercial development. At RM 5.5 it is dredged for use by commercial vessels. The aesthetic quality of the river is very low as it approaches Elliot Bay because of the scarcity of riparian vegetation, degraded water quality, and heavy marine traffic.

5.1.3 Climate/Weather

HHD and the Green/Duwamish watershed are under the influence of a maritime climate typical of the west side of the Cascade Mountains. Mild temperatures and heavy precipitation, mostly rain, which falls primarily between the months of October and April, characterize this climate. Winters are generally wet and mild while summers are cool and dry. At higher elevations in the watershed, mean temperatures are lower and winter precipitation is more likely to fall as snow. Temperatures in the lower part of the watershed range from a mean high of 76° F in July to a mean low of 32° F in January. Near HHD, mean temperatures typically range from a high of 72.5 ° F in July to a low of 27.5° F in January. Annual precipitation at Seattle-Tacoma International Airport in the lower portion of the basin is approximately 39 inches. At Stampede Pass, above the Upper Watershed, the average annual precipitation is over 92 inches, much of which falls as snow.

5.1.4 Socioeconomic Overview

The Green/Duwamish River valley was among the first areas of Puget Sound extensively settled by Euro-American immigrants. As early as 1850, homesteads and settlements were appearing in the middle and lower sub-basin near present-day Tukwila and Kent. The early Euro-American settlers encountered a vigorous native culture that had lived in the valley and along the shores of the estuary for centuries: fishing, hunting, cultivating, and gathering foodstuffs. The new inhabitants immediately set about altering the landscape to fit their particular needs. The results of those alterations, many of which continue today, loom large in the present life of the river. Table 1 identifies some specific events and results of changes to the river and riparian zone in the latter half of the 19th century and into the 20th century.

The Green/Duwamish River is the major feature in the watershed. Since the 1850'a, development has historically centered on the river and floodplain, where there are now several major population centers. These cities and towns supply the services and commercial needs of the surrounding area, which still remains somewhat rural and agricultural. This is especially true upstream from Auburn (RM 32). In the 1960's, with construction of HHD and provisions for flood protection, the predominately agricultural area in the Lower Watershed shifted to high intensity commercial and industrial use, especially below RM 28. Population growth continues at a relative high rate in the Lower Watershed, bringing with it the additional commercial and public services development and transportation infrastructure to accommodate these increases. Several large employers have also moved into the region within the last ten years, supplying the jobs and economic incentives for these population increases.

TABLE 5-1. CHRONOLOGY OF EVENTS IN THE GREEN-DUWAMISH RIVER BASIN BETWEEN 185-1997

Date	Event	Result
1850	Oregon Donation Land Act	Land granted to settlers after 5 years homesteading
1851	First Euro-American settlers arrive in the Duwamish area	Land clearing begins - three claims filed
1852	Livestock introduced into Green River valley	Grazing begins on land
1853	Extension of Land Act through 1855	Seventeen claims filed along the river
1854	First road built in King County	Road built through the river valley
1855-58	Removal of debris from river for navigational purposes.	Elimination of LWD habitat
1855-56	Indian Wars	Settlers move to Seattle for protection - settlement slows
1856	Land clearing resumes	Duwamish area gardens planted, orchards established, timber cutting begins
1858	Drainage Laws	County passes laws permitting ditches for drainage, swamp land drainage begins
1862	Homestead Act	Settlement of territory encouraged
1866	Population of valley starts to grow in earnest	Displacement of Native Americans
1867	First railroad bridge built across Black River	Local railroad construction begins in DGB
1870	277 settlers living in valley	Displacement of Native Americans
1870s	Major railroads build lines	Pace of logging increases in Green/Duwamish River watershed
1875	Channel Improvement Act	County road funds used for improvement of rivers
1880-1910	Extensive logging occurs in the watershed	Extensive road and railroad construction
1883	RR bridge built across White River	Northern Pacific Railroad constructs east/west line through Green River valley
1893	Great Northern Railroad develops lines in north/south direction in valley	Increases population of basin
1895	Drainage District Act	County Drainage Districts formed
1895	Duwamish East Waterway construction begins	East Duwamish Waterway dredged and used for Harbor Island fill
1902	Green River Hatchery	State operated Green River Hatchery opens on Soos Creek
1901-04	Hydraulic sluicing of Beacon Hill	Fill placed in the intertidal area of the Duwamish River to raise land and decrease flooding potential
1906	Major flooding in rivers during fall and winter	Log jam on lower White River forces flood water into the Puyallup River

Date	Event	Result
1902-27	Interurban Electric railway	Interurban rail eclipses riverboat travel
1910	Tacoma Water Diversion authorized	City of Tacoma Green River Diversion Dam construction is begun for municipal water
1911	White River Diversion	White River completely diverted to Puyallup River to reduce flooding problems
1913	Tacoma Water Diversion completed	Water diverted from Green River, complete blockage to upstream migration of fish
1916	Black and Cedar Rivers diverted from Green/Duwamish River	Ship Canal cut to Lake Union draining Lake Washington to Puget Sound. Reduced flooding in Green/Duwamish Basin
1917	East/West Duwamish Waterways finished	Dredging of channel completed, 2.2 square miles of Duwamish intertidal area filled, flooding reduced
1919	Private and county levees built to protect lowlands from flooding	Encouraged more productive agricultural use
1931	Installation of first stream gauge at Palmer	Begin to acquire river flow data
1959	One of the largest floods on record (28,000 cfs at Auburn)	Significant property damage
1960s	Extensive levee building by local and federal government	Channelization of the river
1963	Howard Hanson Dam completed	Reduces maximum flow of Green River to 12,000 cfs at Auburn to reduce flooding
1977	Tacoma completed their North Fork Valley well fields	Allows Tacoma to provide water during periods of high turbidity or low flows in the river
1980	Washington State Department of Ecology establishes instream flows at Palmer and Auburn	All but eliminates any future river diversions during periods of low flows
1995	Tacoma and Muckleshoot Agreement for future off-stream or diversions and instream flows	Further protection of fisheries resources during low flow periods
1996	Corps completes a Section 1135 Environmental Assessment for additional water supply at HHD for low flow augmentation	Further protection of fisheries resources during low flow periods
1997	Corps completes the Reconnaissance Report for the Green-Duwmaish Ecosystem Restoration Study and begins Feasibility Phase	Proposed project has restoration features that complement the HHD AWS Project

5.2 SOCIOECONOMIC RESOURCES

5.2.1 Population/Demographics

The Green/Duwamish River system lies wholly within King County, which includes the largest population center in the state. The watershed is bounded on the west by Kittitas County and on the north by the Cedar River watershed. The southern boundary is north of Pierce County. The Upper Watershed is within the Mt. Baker-Snoqualmie National Forest and City of Tacoma Watershed, and public access is prohibited.

No settlements currently exist in the Upper Watershed, and there are no population data that directly correspond to the project area. Population data used in this section were developed from published sources, primarily the King County Annual Growth Report (1996) and the Washington State Yearbook (PSI 1996).

Within the Lower Watershed are King County unincorporated areas, the cities of Seattle, Tukwila, Kent, Auburn, and Enumclaw, and numerous small towns and communities. The City of Seattle is the largest jurisdiction (population 534,700 in 1996) and is mostly outside the project area. The second largest jurisdiction is the unincorporated area, with a population of 431,910 (1996). The expansion of cities into formerly unincorporated areas was the most significant growth trend in King County in 1995, and was apparent in the Lower Watershed project area.

Below RM 46, the Green River system passes through two geographical areas, the Enumclaw Community Planning Area, and the Eastside/Green River Valley Area. The Enumclaw Community Planning Area is contained totally within the Lower Watershed, while the Eastside/Green River Valley Area extends east of the Lower Watershed and includes data for such population centers as Bellevue, Kirkland, and Mercer Island.
The Enumclaw Community Planning Area includes the City of Enumclaw, a portion of the City of Auburn, and unincorporated lands including a substantial part of the Muckleshoot Indian Reservation. The population of this area was estimated to be 25,300 in 1995, a 16% increase from 1990. This compares to population increases of approximately 18% in the periods from 1970- 1980 and 1980-1990. While the population of Enumclaw has increased 42% since 1990, the populations of Auburn and the unincorporated areas increased by only 9%.

The Eastside/Green River Valley Area encompasses fifteen cities, including parts of Kent, Auburn, and Tukwila. Due to recent annexations and incorporations, less than 2% of the population lives in unincorporated areas. The population was estimated to be 247,900 in 1995, an increase of 5% since 1990. Growth has slowed dramatically since the periods between 1970-1980 and 1980-1990, when 15% population increases were observed. Caution should be used when interpreting these data for the project area, since the Eastside/Green River Valley Area includes large populations outside of the Lower Watershed.

Several large population centers are on or near the Green River. For cities like Kent and Auburn the Green River system is an integral part of the cityscape. Other smaller cities, towns, and communities are clearly affected by activities in the river system. Historic population changes are shown in Table 5-2.

TABLE 5-2. POPULATION FOR SELECTED CITIES IN THE GREEN RIVER WATERSHED

City	1980	1990	1996	% Growth, 1980-1990	% Growth, 1990-1996
Auburn	26,417	33,102	36,130	25	9
Black Diamond	1,170	1,422	2,010	22	41
Enumclaw	5,427	7,227	10,260	33	42
Kent	23,152	37,920	60,380	64	59
Tukwila	3,578	11,874	14,880	232	25

Source: King County Annual Growth Report.

City population changes resulted from incorporations, annexations, immigration, and natural increases. Kent's large population increase from 1990 to 1996, for example, is primarily due to the annexation of the areas surrounding Lake Meridian. While migration represented the largest proportion of growth to the area in the late 1980's, local births represent the majority of the recent growth.

The median household income in King County in 1994 was estimated to be $48,100. This represents a 5% drop in real wages since 1991. Real wages in the county have declined since 1992, while employment rates have accelerated. The economic base of King County is entrenched in the finance and services, manufacturing, wholesale, and retail sectors.

5.2.2 Housing

No housing is available in the Upper Watershed. Housing statistics are not available for the entire Lower Watershed, but are available for selected cities (see Table 5-3).

TABLE 5-3. HOUSING STATISTICS

City	Households (1990)	Total Housing Units (1995)	Median House Value (1990)	Median Rental (1990)	% Change Average House Sale, '90-'94	% Change Average Rental, '90-'94
Auburn	13,357	14,314	$91,500	$398	13	12
Black Diamond	541	748	83,200	341	12	12
Enumclaw	2,936	3,983	86,100	392	22	15
Kent	16,246	20,087	107,100	458	13	9
Tukwila	5,639	7,589	93,900	433	10	12

Source: King County Annual Growth Report.

A recent increase in formal plat applications in King County indicates that residential construction will increase in the future. In 1995, the number of plats applied for increased by 30% from the preceding year. The majority of residential permit activity is in the cities, where it is chiefly multi-family. In contrast, most of the new residential units being constructed in unincorporated King County are single-family units. Seattle leads King County cities in residential permits, issuing 1,567 since 1990. The City of Kent ranks second with permits for 649 units.

Data for King County also show that home ownership rates have been falling since 1980, as real wages have not kept pace with housing price increases. For households in the lowest income categories, there were 47% fewer affordable housing units than households in 1990. Home ownership is also not an affordable housing option for households with typical renter incomes. In 1994, there was a 50% gap between what a median renter could afford to pay for a house and the median price of resale homes, and the affordability gap continues to widen.

5.2.3 Utilities and Public Services

Utility and services are not available in the Upper Watershed. Electrical power is transmitted from Eastern Washington over Stampede Pass and through the Upper Watershed and project area, providing power to areas of Western Washington. The electrical transmission includes powerlines and powerline rights of way (ROW's) which transit the north and south sides of the project area. These ROW's are annually maintained by brushing of trees and vegetation by the respective utility. The Lower Watershed includes a network of fire, water, sewer, and school districts. The project area includes nine fire districts, seven water districts, five sewer districts, and six school districts. Sewer and water are not available upstream of Auburn, while fire and school districts are present up to the City of Tacoma Watershed boundary.

5.2.4 Transportation

Within the Upper Watershed, the primary existing transportation network consists of logging roads. In addition, Burlington Northern Santa Fe Railroad (BNSF) has an active rail line that provides access to points east via Stampede Pass. BNSF reactivated this rail line in December of 1996 and is currently running one train in each direction seven days a week. Future plans include running up to ten trains per day in each direction. Intermodal rail traffic is expected to continue to increase in the area. The Puget Sound Regional Council reports a significant increase in regional freight movement, and notes that the "region has become a major international center for waterborne commerce" that will require identifying better ways to transport goods and services throughout the region (PSRC 1995).

Freeways, arterials, and the Green River waterway serve the Lower Watershed. Interstate Highways 5 and 405 provide access to Seattle to the north and Olympia and Oregon to the south. Interstate 90, located north and east part of the watershed provides access to Seattle to the west and Cle Elum and other points east. State Routes (SR) 18, 165, and 410 are located north, west, and south, respectively, of HHD.

Traffic counts were not conducted for this project. Traffic data were obtained from the Washington State Department of Transportation (WSDOT). Average annual daily traffic volumes (ADTs) along I-5 east of the project area are 54,000 at SR 507 in Tacoma and 156,000 just south of I-405. This represents an increase of approximately 30% and 10%, respectively, from 1990 to 1993. ADTs at the intersection of SR 410 and Mud Mountain Road are 3,200 representing an increase of 6% since 1990. For SR 18, ADTs at the intersection with I-90 are 6,800 representing an increase of 70% since 1990, and at its intersection with I-5, ADTs are 67,000, representing an increase of 26% during the same period. The increase in ADTs is consistent with the growth and development that has steadily occurred throughout King County. King County population has increased 18% between 1986 and 1994. This growth coupled with the decrease in transit ridership in the county has significantly contributed to the increase of ADTs. In addition, the 1990 Census reported that 74% of all work trips in the County were single occupant vehicle trips as compared with 9% for transit.

King County Department of Metropolitan Services (Metro) provide very limited service to the Lower Watershed. According to Metro, the low density residential population along with the dominant agricultural uses are a challenge to service in the Green River valley area, and residents of the area travel long distances to work (King County 1995). There are several Metro Routes along I-5, I-405, and I-90. Metro Routes provide access between Southcenter and Auburn as well as between Enumclaw, Black Diamond and Maple Valley. Park and Ride facilities are located in Auburn, the Southcenter area, and Renton.

5.2.5 Recreation

The Upper Watershed is basically undeveloped and closed to public access within lands owned by the City of Tacoma. Some recreational hunting is permitted annually in this area Public access is available and recreational use is quite heavy on national forest lands to the east of the City of Tacoma's lands. Activities that typically occur on these lands include hunting, fishing, berry picking, sightseeing, and snowmobiling. This area sees its heaviest use between August and March. Dispersed camping occurs throughout the year: overnight camping is allowed east of Friday Creek. Some private lands in the Upper Watershed could be opened to the public in the future.

The area below HHD (RM 64 - 44) is a regional recreational resource of particular value. Several state parks provide direct access to the river for activities such as fishing, floating, canoeing, kayaking, and hiking. The Green River Gorge, located just downstream of

Palmer-Kanaskat State Park, is of particular interest to private and commercial kayakers and rafters. The bedrock ledges and boulders that dominate the Gorge cause large hydraulics that offer premier whitewater recreational opportunities during high flows. Recreational boating opportunities on the river are reduced during spring refill from reduced flows but improved during the summer because of low flow augmentation from HHD.

Flaming Geyser State Park is located just downstream of the Gorge, at RM 44. This park offers access to the exceptional scenery along the river and is a popular fishing spot. A moderate whitewater run is located from the Park downstream to Whitney Bridge Park, RM 41.2. As in the Green River Gorge, the recreational boating opportunities in this section of river are limited by dam-controlled water flows. Other state parks located along the Green River within the Lower Watershed include Metzler State Park (RM 40), O'Grady State Park (RM 39), and Narrows Parks (RM 32.9).

King County, local municipalities, and state and federal agencies maintain a system of parks near the Duwamish River. Existing facilities include numerous municipal parks, golf courses, picnic facilities, and the Interurban Trail.

5.3 GEOLOGY

5.3.1 Land Forms - General

Upper Watershed

The project lies within a series of western Cascade Tertiary volcanic rocks deposited 35 to 50 million years ago. These rocks are predominantly andesite flows, andesitic tuffs, and breccias with subordinate amounts of basalt and basaltic, pyroclastic, and felsitic rocks (HWA 1993).

Prior to the last Ice Age, the channel was located northwest of its present location. As continental glaciers from the south met alpine glaciers from the west, ice sheets and moraines blocked the North Fork of the Green River Valley. A lake was formed in the valley, and water eventually formed a new outlet near the HHD location. The Upper Watershed area includes terraces formed in the underlying lava and bedrock by glacial scouring, as well as lacustrine terraces formed when the ancestral lake level was stable. Many locations of bedrock outcrop also exist. The exposed bedrock is largely granite, basalt, or andesite (USDA 1992).

Slopes in the upper basin are highly variable but can be quite steep, especially in the upper reaches. The potential for erosion hazard is high or severe on many soils where the slopes are greater than 30%. These soils often slump or slide in rainy periods after vegetation has been removed. In some locations the depth of the soil is less than 40 inches to either bedrock or an impermeable layer such as till or a leached mineral layer (USDA 1992).

Lower Watershed

The Green River Gorge is cut through the sandstone and mudstone of the Puget Group, a series of soft and erodable rock units. Downstream of the Gorge, the Green River travels through glacial outwash and alluvium deposited during the most recent advance of continental glaciers in the area (from 15,000 to 18,000 years ago). In the lower part of the watershed, volcanic deposits have been contributed to the valley floor from events such as the massive Osceola iceflow from Mt. Rainier approximately 5,000 years ago. Marine deposits have also been contributed from waters that extended up the Duwamish Valley to the present-day City of Auburn near the time the glaciers were retreating. Since the retreat of glaciation, the Green River has been carving out a floodplain from these sedimentary, volcanic, and glacial deposits.

5.3.2 Engineering and Design Considerations

The dam is a zoned embankment 235 feet high, with a 500-foot-long crest at elevation 1,228 feet. Because of the high permeability of portions of the material in the right abutment, a 560-foot-long semi-impervious blanket was placed on the upstream side to minimize seepage. Construction of the dam, including spillway and stilling basin, intake tower, outlet works, and low flow bypass, was completed between 1959 and 1962. The project also required relocation of 13 miles of the Northern Pacific mainline railroad, mostly on the left valley wall, and construction of three major bridges.

The first significant flood pool, which briefly attained elevation 1,161.9 feet, occurred in February 1965. At that time, a spring abruptly broke out at elevation 1,134 feet about 350 feet downstream from the downstream right abutment toe. A gravel blanket supported by a crib wall controlled the spring. In 1968, a drainage tunnel was constructed at elevation 1,100 feet and extending 650 feet into the mountainside. Twelve relief wells were drilled to intersect and extend 20 feet below the tunnel floor. This system appears to have adequately controlled abutment leakage during the flood pools experienced to date.

Dam safety instrumentation has been installed within the dam embankment and abutments. The instrumentation data are monitored regularly. The instruments are maintained and upgraded as required..

Corps policy in dam design is that dams capable of placing human life and property at risk of causing a catastrophe should they fail, are to be designed to safely handle a Probable Maximum Flood (PMF) inflow computed from the Probable Maximum Precipitation (PMP) over the water shed upstream from the dam. The PMP criteria for HHD was recently updated by the National Oceanic Atmospheric Administration, National Weather Service from the PMP values used at the time of original design of HHD. A review, evaluation and analysis of as-built data and hydraulic conditions associated with the revised PMP criteria indicated that no significant modifications of existing features at HHD were required to prevent catastrophic failure due to PMP events.

The maximum pool levels reached to date were 1,168.0 feet on December 1, 1995 and 1,183.2 feet on February 10, 1996 under flood conditions. The flood control design event pool elevation of 1,206 feet has not been reached during past dam operation.

5.3.3 Dam Seismic Safety

The Corps performed seismic analyses of the dam and intake tower. Results of the analyses indicated that the dam will withstand the maximum design earthquake, but the Intake tower required structural modification. These modifications were completed in 1997.

The Corps performs routine inspections, instrumentation data monitoring and analysis, Dam Safety Training, and formal Periodic Inspections (PI) by dam design expert engineers. The most recent PI report is dated April 1996, and includes a summary of project history, detailed descriptions of project facilities, data analysis, inspection findings and recommendations. The PI report concluded that HHD is safe for continued operations.

5.4 AIR QUALITY AND NOISE

No air quality or noise monitoring is regularly conducted in the Upper Watershed, but the undeveloped nature of the area makes pollution problems unlikely. While limited information is available for the specific Lower Watershed project area, air quality monitoring stations are located along the Duwamish River in Seattle, and in Enumclaw and Kent. Sampling locations in Seattle measure particulate matter, sulfur dioxide, total suspended particles and lead. The Enumclaw station measures ozone, and the Kent station measures particulate matter (PSAPCA 1995).

Air quality in the Puget Sound region has increased substantially since 1980. The number of good air quality days in Seattle in 1984 was 315, a 77% increase from 1980. No unhealthful days were recorded in 1994, compared to 18 in 1980. Federal standards for sulfur dioxide, lead, and nitrogen dioxide were met in the entire Puget Sound region from 1990 to 1994, but the Region was out of compliance with the standards for carbon monoxide, particulate matter, and ozone in specific areas. Two of the three-recorded exceedances of the ozone standard were at the Enumclaw monitoring station. The Kent station recorded a generally steady decrease in particulate matter values between 1990 and 1994 (PSAPCA 1995).

5.5 LAND USE

Lands in the Upper Watershed and downstream to the Tacoma Diversion dam is managed by the City of Tacoma as a municipal watershed. Use designations within the project area include a Natural Management Zone buffer around the reservoir, and Conservation and Commercial Management Zones at slightly higher elevations. Natural Management zones are managed for protection of old growth forests and fish and wildlife habitat. No timber harvest is conducted. Conservation Management zones are managed to maintain or improve the health and vigor of the vegetative layer for fish and wildlife habitat. Regulated timber harvests may be conducted to maintain or enhance wildlife habitat. In Commercial Management zones, forest management is directed at producing merchantable timber. This zone has the highest rate of timber production (Tacoma Public Utilities 1996).

From the Diversion dam to Flaming Geyser State Park, dominant land uses are forestry and rural residential, with some mining. Between the Park and Auburn the land is primarily zoned for rural residential and agriculture, with some inclusions of parks, mining, and urban land use (King County 1994). Horse and cattle ranches are common, as are small farms and communities.

In Auburn, local land uses include suburban or urban residential and light industrial use (King County 1994). Downstream of Auburn, land use becomes increasingly industrial, from light industry in Kent to the heavily industrialized Duwamish River area near Elliot Bay.

5.6 CULTURAL RESOURCES

5.6.1 Pre-History

Several groups of people historically inhabited the Green River valley, including the Skopamish, Sko-pabsh, Skopeamish, Niskap, Neccope, Nescope and Nooscope. These people spoke the Southern Lushootseed language (Suttles and Lane 1990) and are related to the present-day Duwamish, Suquamish and Muckleshoot Indian tribes (USFS 1987). The project area contains a variety of resources related to prehistoric Native American hunter-fisher-gatherer activities. As of 1986, it was estimated that 36% of the Green River channel had been systematically investigated for prehistoric cultural resources, with the majority of investigations situated in the coastal and lowland zones.

Upper Watershed

An archeological survey of the Upper Watershed area was conducted in 1996 for the Corps, Seattle District, to provide baseline information on cultural resources in the anticipated area of the raised reservoir. The survey identified only one prehistoric hunter-gatherer resource, an isolated cryptocrystalline silica flake most likely related to hunting or hide-working activities. Several historic artifacts were identified (LAAS 1996; see Historical, below).

In 1985 and 1986, Benson and Moura surveyed selected areas within the upper Green River watershed and identified 14 prehistoric or hunter-gatherer sites, all but one clustered at the confluence of the Green River and the North Fork of the Green River. Artifacts recovered spanned a period of approximately 8,000 years (Benson and Moura 1986). While none of these sites fall within the project area of this EIS, their presence nearby indicates a long history of hunter-gatherer use of the area (LAAS 1996).

Several other cultural resource surveys have been conducted near the project area. Two small lithic scatters and a berry processing and hunting site (Mule Spring Site) were recorded in the uplands southeast of Howard Hanson Reservoir (Hedlund et al 1978; Northwest Archaeological Associates 1995). The Mule Spring Site dates from 5000 B.P. (before present) to the historic period and excavations provided information on large-scale berry processing in an upland environment. Archeological explorations in the Chester Morse Lake vicinity, north of the project area, uncovered nine hunter-fisher-gatherer sites on the contemporary lake margin. This site provides information on the types of resources that might be expected in the HHD area (LAAS 1996).

Lower Watershed

In the Lower Watershed, historic, geologic, and ethnographic literature indicates there are several areas with a high probability for cultural resources along the banks of the Green River, especially at confluences with other rivers and streams and where the shoreline is undisturbed. One of the more significant investigations in the Duwamish River basin is the Duwamish No. 1 Site (Lorenz et al. 1976) near Elliot Bay. This site is believed to have been occupied between A.D. 600 and 1600. The Sbabadid Site, located near Renton, consists of two separate intact winter village sites (Chatters 1981). One site associated with the Duwamish Indians was occupied between 1790 and 1825 and the other between 1850 and 1856. The Tualdad Altu Site, also located near the present City of Renton, is between the Duwamish and Black Rivers. This site consists of the remnants of a long house situated on a tidal flat dating to the 4th century (Chatters 1988).

5.6.2 Historical

Beginning approximately 250 years B.P. (before present), articles of European manufacture begin to appear in the archeological record. At this time, early explorers recorded the extensive Native American trade networks established between the coast, along the major drainages and across the Cascades. The mid-1830's brought Euro-American fur-traders west across the mountains. Established wagon routes facilitated the subsequent flow of settlers into Western Washington during the mid-1840's. The initial Euro-American settlement and subsequent development of the Green/Duwamish River basin was integrally related to logging, mining, railroad construction and agriculture. The first permanent Euro-American settlement in what was to later become King County was recorded along the Duwamish River.

Upper Watershed

Larson Anthropological/ Archaeological Services identified four historic sites within the proposed pool raise area during their 1995 and 1996 surveys. These included several sites that had been previously recorded by Benson and Moura (1986) and Hedlund et al (1978). The sites, consisting of the remnants of a lumber mill, logging camps and homesteads, were assessed as not eligible for the National Register because of extensive damage due to river erosion and historic and recent razing and demolition activities (LAAS 1996). Northwest Archaeological Associates (l993) surveyed areas southeast of Howard Hanson Dam as part of a US Forest Service land exchange project and recorded several historic trails in the vicinity.

Lower Watershed

The Green River floodplain was surveyed by for the Tacoma's proposed pipeline 5 (Tacoma Public Utilities l995). Six historic sites were located including a tunnel and railroad features, none of which were considered eligible for the National Register.

Other historic resources in the Lower Watershed, especially within urbanized areas, are well documented throughout the region. Documentation including contemporary accounts, maps, public records, and local historical organizations and individuals have preserved photographs.

5.7 NATIVE AMERICAN RELATIONSHIPS AND ISSUES

The Muckleshoot Tribe and the Suquamish Tribe are involved on many levels with the Green/Duwamish River system. The northern section of the Muckleshoot reservation lies within the river floodplain area affected by the HHD project. The Tribe planning department administers land use and environmental policy within the boundaries of the reservation. The Tribe has co-management responsibilities with the State of Washington for fisheries resources within its usual and accustomed fishing areas, which include the Green River basin. The Suquamish Tribe shares in this co-management within the Duwamish estuary. Fishing, hunting, gathering of native plant material, and access to the river, wetlands, and forests of the basin provide essential economic and spiritual sustenance to the Muckleshoot and Suquamish people (USFS 1996).

5.8 WATER RESOURCES

5.8.1 Surface Water

The Green River is the prominent hydrologic feature in the project area. The river is fed by fall and winter rainfall throughout the basin, along with spring snowmelt in the Upper Watershed. The tributaries throughout the basin collect surface waters and direct them into the mainstem of the Green River. The flow regime of the Green/Duwamish River generally follows that of other west slope Cascade Range rivers with a characteristic seasonal double peak indicating the effect of winter rainfall and a spring peak from combined rainfall and snowmelt.

Floods in the Green/Duwamish River are generally the result of warm rainstorms during the months from October to March. Runoff may be augmented by rain-on-snow events during the early winter. Highest flows generally occur in December or January, declining through March with a subsequent snowmelt peak in April or May.

With the construction of HHD in 1962, sufficient storage was provided to control the Green/Duwamish River flows to bankfull (approximately 12,000 cfs) at the US Geological Service (USGS) flow gage at Auburn. The dam provides flood protection up to the 100-year event. Flood events that once scoured the river and inundated the adjacent flood plain no longer occur, and large, channel altering flows have an extremely low probability of occurrence.

Upper Watershed

The reservoir (conservation pool) extends approximately seven miles eastward from the dam along the main river channel and four miles northward along the North Fork of the Green River. The reservoir is normally maintained at approximately 1,070 feet from the end of October to the end of March to provide flood control storage. Beginning in approximately April the reservoir is filled to a maximum pool elevation of 1,141 feet. At this conservation pool level, the reservoir impounds 25,400 acre-ft and covers 732 acres.

Forty-eight tributaries enter the system above HHD, feeding both the main stem and the reservoir. Large tributaries include the North Fork of the Green River, and Piling, Gale, Charley, Friday, Sunday, Snow, Smay, Champion, Sawmill, Tacoma, Twin Camp, and Rock Creeks. These lie in the snow zone and exhibit seasonal, bimodal discharge peaks indicative of increased flows due to fall rain and spring snowmelt.

Lower Watershed

In the Lower Watershed, precipitation and surface runoff into the river are supplemented by inputs from major tributaries, including Newaukum Creek, Soos Creek, and Mill Creek.

These streams do not lie in the snow zone and typically have a single runoff peak in December or January.

Newaukum Creek joins the Green River near Black Diamond. Summer flows in Newaukum Creek have been declining over the past four decades. After comparing the relative decline in precipitation to the declines in mean annual flow, Washington Department of Ecology (WDOE) concluded that the declining flows in Soos Creek were not caused by declining precipitation, but rather by groundwater withdrawals (King County 1996a). Increases in impervious surface areas in the watershed resulting from urbanization have also probably reduced summer flows. Projections for urbanization in the sub-basin suggest that impacts from additional impervious areas will be of growing concern.

The Soos Creek system consists of Big Soos Creek and approximately 25 tributaries. The system has over 60 miles of streams and drains an area of nearly 70 square miles. Heavily wooded riparian corridors interspersed with pastures and increasing residential development characterize the upper sections of Big Soos Creek. Existing development in the basin ranges from rural to high-density urban. A number of flow-related problems have been associated with the increasing urban development. As the amount of impervious surface in the Soos Creek sub-basin continues to increase, peak flood flows have also increased and flow alternative has diminished. Along with high winter flood flows, low summer flows have also been observed. With increasing impervious surface, less water is captured and stored in the sub-basin's wetlands and aquifers, reducing water supplies for the summer flows.

The Mill Creek and Mullen Slough drainages cover a combined area of about 22 square miles on the west side of the Green River. This sub-basin extends into portions of the Cities of Kent, Auburn, Federal Way, and Algona, in addition to unincorporated parts of King County. The sub-basin covers three different types of drainage areas; the very flat Green River valley floor, the steep slopes along the western edge of the valley, and the rolling upland plateau on which the principal headwater tributaries are formed. Runoff from the upland plateau flows down to the Green River valley floor in a series of steep well-incised ravines. At the valley floor, watercourses flatten and flow north through the Green River valley via Mill Creek to the Green River. A complex network of low-gradient ditches drains the valley floor itself and agricultural drains, which contribute further flows to the mainstreams of Mill Creek. Contributions of flow to Mill Creek from the valley floor have increased dramatically in recent years as a result of increased development.

Under current conditions, flooding in the lowest reaches of Mill Creek and Mullen Slough is controlled by backwater effects from the Green River. High flows on the Green River can result in the inundation of up to about 900 acres of agricultural land in the Mill Creek/Mullen Slough sub-basin.

5.8.2 Ground water

A significant portion of the snowmelt and rainfall within the Green River Basin infiltrates downward to become ground water. When water table levels exceed surface water levels, ground water discharges into the Green River and its tributaries, supplying most of the river flow in late summer through winter. This is particularly true in the upper basin, including the section within the Upper Watershed study area. Conversely, when water levels in the river are higher than the water table, the river loses water to ground water aquifers This situation is more likely in the Lower Watershed.

Upper Watershed

The Upper Watershed is mantled by volcanic and sedimentary rocks, which are too fine-grained or too highly altered to yield much ground water. This area acts primarily as a ground water discharge system, contributing water to the Green River when river levels exceed ground water levels (WDOE 1995).

At the dam, the complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the point of hydrology. At least two major aquifers are present with the possibility that others may exist. The lower aquifer with base elevation about 1,000 ft is found within the buried valley's alluvial materials. The upper aquifer, at base elevation 1065 ft, is found in glacial and landslide materials. Pervious zones in the overlying glacial and slide materials form the upper aquifer, the probable source of the seepage problem on the downstream slope of the right abutment. Aquifer recharge is by precipitation runoff and by direct communication with the reservoir.

Lower Watershed

The Upper part of the Lower Watershed (east of Palmer) is similar geologically to the Upper Watershed, and does not yield significant amounts of ground water. West of Palmer, thick glacial and alluvial deposits form aquifers with high water yields. The 1989 King County Ground Water Management Plan divides the western half of the Lower Watershed into four hydrogeologic sub-areas. These include the Covington Upland, Des Moines Upland, Federal Way Upland, and Green River Valley (SKCGWAC 1989).

The Covington Upland is drained by Soos Creek. It contains five principal aquifers, with the highest ground water elevations within the Black Diamond and Lake Youngs areas. This sub-area receives ground water recharge from the Lake Youngs reservoir, and discharges ground water primarily to the Cedar and Green rivers. The Des Moines Upland and Federal Way Upland occupy the north and south halves, respectively, of the upland drift plain bounded by the Green River on the east and Puget Sound on the west. This sub-area also contains five principal aquifers, which discharge either to Puget Sound or to the Green/Duwamish River. The Green River Valley separates the Covington

Upland from the Des Moines and Federal Way uplands, and contains two primary aquifers (SKCGWAC 1989).

Water level declines have been observed in aquifers in the Covington, Des Moines, and Federal Way Uplands (SKCGWAC 1989). In addition, preliminary results from a 1989 King County study concluded that pumping even from deep aquifers in the region produces significant impacts on surface water bodies within the Green River basin (WDOE 1995).

5.8.3 Water Management

Upper Watershed

Management of the water resources at HHD is under the jurisdiction of the Corps' Hydrology and Hydraulics Branch in the Seattle District office. During the winter storm season the project is essentially empty while snowpack accumulates in the Upper Watershed. The storage pool is drawn down to accommodate the flood storage in the fall and provide the maximum level of flood protection. During this period, HHD passes natural inflows and the river fluctuates in a near-natural state unless flood conditions occur

Periodically, warmer coastal winter storms melt a portion of the snowpack, which dramatically increases runoff in the Upper Watershed. In this case, outflows from the project are regulated to control the flood flows and provide protection for downstream areas by limiting discharge to 12,000 cfs as measured at the Auburn USGS river gage. After flood conditions subside, water is released from HHD using the same discharge control at Auburn.

Beginning in early spring, conservation storage commences at HHD. Under the present system, conservation storage begins in April or May and continues until the pool level of 1,141 feet elevation is attained. Stored water is used for low-flow augmentation during the summer drought months. Unless there is an abnormally low level of late summer and fall precipitation, conservation storage is generally depleted in October of each year, when the drawdown process begins again. In abnormally dry years, conservation storage maybe required to supplement streamflows into December.

Many factors are involved in the development of the yearly water control plan. The issues of maximizing water quality below the project; managing instream flows below HHD in relation to fisheries; predicting future weather patterns; and insuring that water is available during summer low flow conditions must be considered during refill operations. To accomplish this, the Hydrology and Hydraulics Branch relies on coordination between its staff, other Corps branches, and other agencies managing public resources and representing river users. Since 1987, the Hydrology and Hydraulics Branch and the Environmental Resources Section of the Corps' Seattle District office have conducted regular meetings with representatives from the Washington Department of Fish and Wildlife (WDFW); the City of Tacoma; the US Fish and Wildlife Service (USFWS); the Muckleshoot Indian Tribe; whitewater rafters; and occasionally Trout Unlimited to determine the yearly water budget and refill strategy. During these meetings all parties share information and reach a general consensus about the upcoming or current water control plan.

Decisions pertaining to how and when to refill the project are of particular concern. At refill time, the Water Management Section is responsible for balancing both present demands and future needs through the water year. Refill must occur at a rate to allow for sufficient instream flows below the project for fish production, recreation, and other water users. Prior to 1992, outmigration of smolts received a higher priority. Since 1992, during the early spring, the primary issue concerning refill rates deals with impacts to fisheries, particularly impacts to wild steelhead production. When instream flows are reduced during the spring refill, the potential exists for steelhead redds to be dewatered, resulting in egg mortality and reducing the available spawning habitat. Any species has the potential to be affected by dewatering; however, wild steelhead in the Green River are especially susceptible since the peak spawning period coincides with the most favorable conditions to begin refilling the project.

The refill plan must also consider other impacts related to downramping rates and timing. Side channels and edgewaters, inundated at higher water levels, may be isolated from the main river. Several species, particularly chum and coho salmon, favor side channels and edgewaters as spawning and rearing habitats. Sufficiently high quality rearing habitat is critical for the growth and development of juvenile salmon. As instream flows are decreased during refill, these areas are no longer available and juvenile fish already using these areas may be stranded, trapped in isolated pockets of pooled water. Most of these fish will die unless they are repatriated with the main river. Stranding is a natural process along most rivers as water levels decrease during the spring and summer. This issue is a concern on the Green River during refill because spring flows are reduced to lower levels and at a faster rate than would naturally occur. The decreases occur at an important time for rearing fish.

Since the time of the original authorization, priorities have changed in the watershed (such as the social and economic importance of recreational uses and balancing Upper and Lower Watershed fisheries) and new information is available about the life cycle and habitat needs of many fish species. Additional considerations that were not in place when the project was authorized have also been placed on the river, such as balancing tribal rights and development pressure. The new information and the new demands on the Green River now play an important role in current water management decisions. The role of water management is simplified late in the fall when the project converts again from conservation storage to flood storage until the spring.

Lower Watershed

Below HHD, many users compete for Green/Duwamish basin surface and ground water resources. WDOE has issued a total of 860 consumptive water rights in the Lower Watershed, with municipal-domestic consumption the primary use. Irrigation is also an important use in the agricultural Auburn valley. An additional 52 nonconsumptive surface water rights have been issued for such uses as fish propagation, hydroelectric power generation, and recreation (WDOE 1995).

The total quantity of surface water allocated by rights and claims within the Green/Duwamish basin is 640.1 cubic feet per second (cfs), with 57% of rights issued to municipalities (WDOE 1995). The City of Tacoma is the largest municipal user, presently diverting up to 112 cfs of surface water from the Green River at its diversion facility at RM 61. Tacoma filed a water right claim in 1971 for a maximum of 400 cfs. An additional 100 cfs diversion was granted to Tacoma by WDOE in 1985, subject to minimum instream flows. Use of this diversion right is pending construction of the Second Supply Pipeline.

Rights and claims in the Lower Watershed allocate a total of 446 cfs of ground water. Some 76% of ground water rights are allocated to municipalities, with the City of Tacoma being the largest municipal user. Tacoma has a ground water permit of 139.3 cfs. There are 54 pending ground water applications on file with WDOE, requesting a total of 121.2 cfs. Forty-two of these are for municipal use, and twelve are for ground water withdrawals downstream of the Auburn gage (WDOE 1995).

Tacoma also operates a well field in the North Fork Green River, above HHD. This wellfield has a 111 cfs capacity and is used to replace a portion of the surface water withdrawn from the Green River during periods of high turbidity.

5.8.4 Water Quality

Upper Watershed

Water quality in the Upper Watershed has the highest rating based on the Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201). The state has classified the mainstem and tributaries of the Upper Watershed as Class "AA" (extraordinary) (WDOE 1989). The specific criteria for water quality parameters are meant to define the type and level of human induced impacts to the system and do not necessarily define natural conditions. The Corps conducts water quality monitoring within the Upper Watershed, and these data were used to describe existing conditions in the Upper Watershed.

Discharges into the Upper Watershed portion of the river are prohibited by the state. The City of Tacoma draws water from the Green River at their diversion facility in the Lower

Watershed. However, almost all of the water withdrawn from the river at the diversion dam originates in the Upper Watershed. The parameters of concern for the Upper Watershed were identified in a 1985 study commissioned by King County and include temperature, dissolved oxygen (DO), turbidity, and fecal coliform (King County 1985).

a. Temperature

Water temperatures throughout the Upper Watershed are cool. Even in the summer inflows are generally below 60° F. However, inflows to the Project above 60° F degrees occur in most years. Such periods are generally brief and do not appear to greatly affect reservoir temperatures. The water column in the reservoir during summer conservation storage is generally stable and stratified. Temperatures in the lower levels of the reservoir during the summer are cool, between 50° and 55° F. This may be 10 °F below average inflows and 15° F below surface temperatures during the same time period (WDOE 1989). Surface temperatures fluctuate more than lower layer temperatures and reservoir stratification is generally weaker than in natural lakes (USACE 1988). The 48-inch bypass pipe is located below the level of typical reservoir stratification. As a result, releases from the Project during the early summer are usually below expected natural temperatures. As the cool water is depleted later in the summer and into the fall, releases from the project are higher than expected natural temperatures. This higher than natural temperatures can adversely affect salmon spawning behavior and may artificially accelerate development of developing salmon eggs.

b. Dissolved Oxygen (DO)

DO levels in clean waters are inversely related to temperature. Low DO levels have the highest potential to occur during periods of high temperatures. Low DO levels limit biologic respiration potentials and may be a limiting factor in some instances. Because temperatures remain generally cool and stable within the Upper Watershed, DO levels are more stable. The low level of stratification noted in the reservoir allows DO to disperse to the bottom layers. The reservoir is oligotrophic with no significant algae blooms or macrophytes that might decay and result in low DO. There have been no recorded observations in the Upper Watershed where DO has fallen below the standard for Class "AA" waters (9.5 mg/l), although there has been little sampling in the Upper Watershed.

c. Turbidity

Turbidity is the only water quality parameter that seasonally exceeds standards in the Upper Watershed (USCOE 1995). Periods of high turbidity are generally associated with winter storms and snow melt. Extensive logging in the upper basin has increased turbidity and suspended sediment levels due to the removal of vegetative buffer along the streams and disturbance to surface soils. The construction of logging roads has increased the sediment load of large winter and spring runoff events.

The US Forest Service (USFS) has estimated that 824 miles of roads exist in the upper Green River basin (USFS 1996). Approximately 34.5 miles of road have been decommissioned. Roads, especially older roads, can contribute significant quantities of sediments to the streams and the upper Green River. Plum Creek estimated that the main road along the upper river contributes over 150 tons/year of sediment to the upper Green River (Plum Creek 1996). Additionally, roads on steep slopes can cause mass wasting events, which may cause large debris flows into streambeds. Suspended sediment in upper basin streams eventually enters the Howard Hanson Reservoir. While studies have shown no net accretion of sediment in the reservoir, it is likely that larger, heavier particles settle in the reservoir while smaller particles are carried downstream of the dam.

d. Fecal Coliform

Restricted development in the upper Green River Basin results in no significant human fecal coliform sources. Animal fecal coliform sources in the upper basin are limited to wildlife populations in the immediate vicinity of the mainstem and tributaries.

e. Metals and Toxics

The National Water-Quality Assessment Program (NAQWA) is a US Geological Survey program begun to study water quality within waters of the United States. The Puget Sound Basin, and the Green River Basin, is one of 15 water quality study units started in 1994. Sampling in the Upper Watershed at Twin Camps Creek includes benthic sediments and tissues from resident fish, including sculpins. Heavy metals such as arsenic, lead and zinc have been identified in preliminary results from these sediment and tissue samples. The source of these heavy metals is unclear as there has been limited resource development in the area besides timber management.

Lower Watershed

Several sources indicate that the Green River has sufficient water quality throughout the Lower Watershed to support current water uses of the river (King County 1995a; USFWS 1986). The section of the Green River from HHD to Flaming Geyser State Park (RM 42) is classified as "AA" (extraordinary). From Flaming Geyser State Park to the Duwamish waterway (RM 11), the river is classified as Class "A" (excellent), and within the Duwamish waterway it is classified as Class "B" (good) (WDOE 1989). Nevertheless, the Green River was included on WDOE's 1994 list of "troubled waterbodies" for temperature, DO, fecal coliform, and mercury. Water quality may be limiting to the beneficial uses of the river during certain times of the year, particularly in areas below Auburn (WDOE 1989).

Monitoring within the Lower Watershed is conducted by King County Metro. Parameters presented here were identified in a 1985 study commissioned by King County, and include metals and toxics in addition to the parameters discussed for the Upper Watershed (King

County 1985). Additional information on temperature in the river was provided by a study commissioned by the Muckleshoot Tribe in 1992 (Caldwell and Associates 1994).

a. Temperature

Caldwell and Associates (1994) studied temperatures between HHD and RM 12. Between HHD and the Tacoma diversion dam, summer water temperatures averaged 57-65° F. It was noted that water temperatures at the Tacoma diversion were found to be independent of HHD outfall temperatures. Between RM 45 and 13, maximum temperatures between 72.5 and 75° F were observed in the summer months. Metro and WDOE have also measured numerous instances of high water temperatures in the lower Green/Duwamish River, particularly at water quality stations located immediately upstream from the junction of the Green River with the Duwamish Waterway.
The Washington State criteria for Class A waters exclude temperatures greater than 64.4° F for freshwater. Water temperatures above 60° F are limiting for cool water adapted fish such as salmon and steelhead, in combination with other potentially limiting water quality parameters (such as low DO). Elevated temperatures may result in algal blooms, especially below Kent and in the Duwamish Waterway. It is also thought that high water temperatures affect the movement of migrating adult salmonids (typically spring and summer chinook), particularly during July, August and early September (Caldwell and Associates 1994).

High temperatures in the Lower Watershed probably result from solar heating of the river during summer low flow periods. The factors responsible for this warming include the extensive paved areas in the watershed that exacerbate diminished groundwater recharge, low summer flows, and lack of shade along the lower river. In addition, the present system of levies confines the river to a wide, shallow channel that contributes to high water temperatures during low flow periods.

b. Dissolved Oxygen (DO)

Levels of DO are generally satisfactory to support the fisheries resource within the river. However, samples collected by Metro in the lower Green River show a few occasions where DO levels were measured below state Class "A" criterion (WDOE 1989). Low DO can impair successful migration by fish (USFWS 1986) and may affect reproductive success, especially during periods when eggs and hatchlings are within the gravel strata. Fish kills in the Duwamish Waterway and the Green River below Kent are not uncommon and may be a result of low DO levels (WDFW and Washington State Treaty Indian Tribes, 1994).

c. Turbidity

Turbidity is not generally limiting to fish through most of the Lower Watershed, though it may limit other uses such as water supply and recreation. Turbidity is of greatest concern during flood events when river waters may be too turbid for use by Tacoma Public Utilities. When this occurs, Tacoma uses secondary sources until turbidity levels fall to acceptable levels. Siltation resulting from suspended solids occurs in some sections of the river Siltation may clog spawning gravels reducing the amount of available spawning habitat. Siltation of redds lowers intragravel DO levels and may restrict egg development.

d. Fecal Coliform

Water quality standards for fecal coliform are frequently exceeded in parts of the Lower Watershed. The state water quality standard established for fecal coliform was exceeded 204 times during the period from July 1987 to January 1992 in the lower Green/Duwamish River basin, including tributaries (WDOE 1995). Livestock access to streams is thought to be the primary cause of high fecal coliform levels, and exceedances are most common during significant storm events when storm runoff washes fecal material from agricultural lands and paved urban areas (King County 1985). In addition, the functional lifespans of the septic systems for some of the early developments along the river have been exceeded. As a result, failing septic systems may be contributing to the elevated coliform levels measured between Auburn and Kent (King County 1994a).

e. Metals and Toxics

Heavy metal levels, particularly copper, lead, iron, mercury, and cadmium, are of concern throughout the Lower Watershed. WDOE has measured levels of mercury, copper, lead, and zinc above state established standards in the Duwamish waterway (WDOE 1995). One source of mercury was the Renton Treatment Plant, which discharged waste water into the Black River/Springbrook Creek until 1987. An additional source of metals into the river may be leachate from the now closed Kent Highlands Landfill (King County 1978).

Toxic contaminants have been identified in bottom sediments and surface water in the Lower Watershed. Chemical testing of bottom sediments in the lower 5 miles of the Duwamish revealed contamination by oil and grease, sulfides, pesticides, and polyaromatic hydrocarbons (PCBs) (NOAA 1981). More recently, WDOE cited excursions beyond criteria in sediment for PCBs and polyaromatic hydrocarbons (PAH's) (WDOE 1996). Runoff from agricultural and developed areas within the watershed are thought to be a major source of toxics contamination in the Lower Watershed. Potential contamination sources are also common along industrialized sections of the lower river. This section of the river is part of the EPA's *Elliott Bay Toxics Action Plan* and other programs designing remediation and source control activities for toxic contaminants.

5.9 ECOSYSTEM DESCRIPTION AND FUNCTION

5.9.1 Terrestrial Resources

a. General Vegetation

The Green/Duwamish basin is located in the Southern Cascades physiographic province (Franklin and Dyrness 1973). The watershed is located primarily in the Tsuga heterophylla zone, which is dominated by climax western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) forests and sub-climax Douglas fir (*Pseudotsuga menziesii*) forests. Although western hemlock is the potential climax species in this zone, Douglas fir forests cover large areas of the landscape due to this species' ability to dominate stands that develop following disturbance, such as clearcut logging practices. Hardwoods are not dominant in the zone except in riparian areas, where common species include black cottonwood (*Populus balsamifera*) and red alder (*Alnus rubra*).

Within the project area, the landscape has been altered by widespread disturbance including land clearing for agriculture and industry, logging, and dam construction

Upper Watershed

The Upper Watershed is in the western hemlock vegetation zone, which is the most extensive zone in western Washington. In this region Douglas fir is the most widespread and common subclimax species. Deciduous trees such as red alder and big-leaf maple (*Acer macrophyllum*) often occur immediately following disturbance in many parts of this zone. While topography, aspect, geology, soil, and available groundwater all influence vegetation occurrence at the local level (micro-climate), disturbance has probably been the most significant factor in the occurrence of much of the vegetation within the Upper Watershed. Timber harvest activities have resulted in the predominance of second-growth, even-aged coniferous stands on the steep slopes that typically surround the reservoir above elevation 1,220 feet. The oldest stands are 60 to 80 years old. Douglas fir is the dominant tree species, but western hemlock and western red cedar are also present.

Deciduous forests comprised of red alder, big-leaf maple, and black cottonwood dominate the lowest elevations adjacent to Howard Hanson Reservoir, below elevation 1,220 feet. Lesser amounts of mixed coniferous-deciduous forest occur in scattered locations throughout the Upper Watershed (USACE 1985).

Conditions created by the presence of steep slopes and fluctuating water levels render the majority of the shoreline around the reservoir unsuitable to support extensive riparian or wetland communities. The result is a lacustrine environment bordered abruptly by upland coniferous and deciduous forest. The presence of an unvegetated shoreline of varying width is a common occurrence that results when the reservoir is drawn down. Riparian and wetland vegetation is primarily limited to a few locations where low gradient topography occurs adjacent to the reservoir and along the tributary streams that flow into the reservoir. One relatively large concentration of sedge and grass wetland meadow occurs in the vicinity of the McDonald Farm site located on the northern shore of the reservoir.

Lower Watershed

The Lower Watershed, from HHD to the Auburn gauging station, includes two distinct geographic areas. The upstream segment flows through steeper terrain where the river is flanked by forested slopes. This segment extends approximately 15 river miles downstream from HHD and includes the Green River Gorge. The river channel is relatively narrow and steep which results in faster flows compared to areas further downstream. The remaining downstream river segment flows through a relatively wide flood plain valley. Agricultural land dominates the adjacent flood plain areas. Steep forested slopes border the flood plain further from the river.

The Lower Watershed is dominated by second-growth Douglas fir on the forested slopes near the river. The forested habitats of the Lower Watershed are similar in composition to the forested habitats in the Upper Watershed. Virtually no late successional forest exists in the Lower Watershed. Pasture and cropland are the dominant cover types in the agricultural areas further downstream. Because the topography is flatter and the river fluctuations are not as severe in the Lower Watershed, riparian and wetland habitats are more common than in the Upper Watershed. Riparian deciduous forest is common immediately adjacent to the river. Wetland habitat is most prevalent in the lower segments where the river is flanked by floodplain.

The Lower Watershed is influenced more by human activities than the Upper Watershed. Timber harvest, development, agricultural activities, and recreational use are the primary activities that influence habitat conditions. In general, human activity and land use intensity increase in the downstream direction.

b. Wetlands

Upper Watershed

Six wetland types covering 327 acres have been identified in the Upper Watershed below elevation 1,220 feet. Identified wetland types include forested swamp, shrub swamp, emergent marsh, moss, mudflat, river bed, and open water.

Forested swamp occurs along the banks and gravel bars of the HHD reservoir just below the upland deciduous forest. These receive water both from high river flows (overflow) and from small streams that enter backwater sloughs. Some of the small streams originate from hillside springs and thus provide a year-round source of cool surface water. Black cottonwood and red alder are the dominant overstory species. Willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), salmonberry (*Rubus spectabilis*), water parsley (*Oenanthe sarmentosa*), and coltsfoot (*Petasites frigidus*) dominate the shrub and herbaceous layers.

Shrub swamp is located in small patches adjacent to, and slightly above, the emergent marsh wetlands. These are almost entirely associated with summer high reservoir levels. The shrub swamps consist almost entirely of dense willow thickets.

Emergent marsh is the most common wetland community in the vicinity of the reservoir, occurring most often below the filled pool elevation of 1,141 feet. These areas are dominated by woolgrass (*Scirpus cyperinus*), soft rush (*Juncus effusus*), creeping bentgrass (*Agrostis alba*), and creeping buttercup (*Ranunculus repens*) depending on the elevation. Elk graze many of these areas regularly and the vegetation remains cropped as a result. A relatively large area of emergent marsh occurs at the McDonald farm site.

Moss dominated wetlands occur below the elevation of the emergent marsh. These areas are typically inundated from about June through August. Patches of creeping bentgrass and creeping buttercup are occasionally present.

Unvegetated mudflats occupy lower elevations around the perimeter of the reservoir. These areas are exposed up to six months during the lowest reservoir pool levels. Implementation of the Section 1135 Fish and Wildlife Restoration Project will increase the conservation pool level from 1,141 to 1,147 feet above mean sea level (MSL). This pool raise will likely decrease the amount of emergent marsh below 1,141 feet. Section 1135 enhancement measures include planting sedges from below 1141 feet MSL to 1,147 feet MSL. Impact analysis for the Additional Storage Project assumes 85 acres of emergent wetland in the upper reservoir area.

Lower Watershed

Few wetlands occur in the upper portion of the Lower Watershed (from HHD down through the Green River Gorge) because of the steep topography that confines the river to a definite channel. The wetlands are primarily restricted to a few relatively small flat areas adjacent to the river, and are mostly scrub-shrub and forested. Because of the predominately steep surrounding slopes, development has not encroached on these wetland areas to the extent it has further downstream in the floodplain.

About two thirds of the wetlands in the Lower Watershed are adjacent to the river and within the main channel. Scrub-shrub wetlands are most common, but forested and emergent wetlands also occur. Most of the remaining wetlands occur on the wide floodplain area at the lower end of the Lower Watershed (below the Green River Gorge). Emergent wetlands are most common in the floodplain areas, but scrub-shrub and forested wetlands are also present.

c. Wildlife

Upper Watershed

Wildlife present in the vicinity of the Upper Watershed include common species associated with lowland coniferous and deciduous forests of western Washington. Because the upland forests in the project area consist primarily of younger stands, wildlife primarily associated with late successional forests are expected to be uncommon or absent from the area.

A variety of forest dwelling mammals, including herbivores, carnivores, rodents, lagomorphs (rabbits and hares), and insectivores are expected to occur in the Upper Watershed. The most visible mammals include Rocky Mountain elk (*Cervus elaphus nelsoni*) and black-tailed deer (*Odocoileus hemionus*). Cougar (*Felis concolor*) are also numerous.

Passerines (perching birds), raptors (birds of prey), waterfowl, upland gamebirds, and shorebirds occupy the various habitats of the Upper Watershed. Raptors occuring in the basin include bald eagle (*Haliaeetus leucocephalus*), red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), sharp-shinned hawk (*Accipiter striatus*), osprey (*Pandion haliaetus*) and several species of owls. Waterfowl species that may nest near the reservoir include great blue heron (*Ardea herodias*), Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), wood duck (*Aix sponsa*), harlequin duck (*Histrionicus histrionicus*), hooded mergansers (*Lophodytes cucullatus*) and common merganser (*Mergus merganser*). Common loons (*Gavia immer*) have been observed nested on the reservoir since the early 1990's. The reservoir is utilized during the winter by common goldeneye (*Bucephala clangula*), ring-necked duck (*Aythya collaris*), and bufflehead (*Bucephala albeola*).

Because of the migratory tendencies of many birds, their populations typically fluctuate throughout the year in any given location. The Upper Watershed is no exception. Passerines are typically more common during the nesting season in spring and early summer. Waterfowl populations are highest in winter when up to 200 ducks have been observed on the reservoir at one time. Populations of resident birds, such as many raptors and upland gamebirds, remain more constant.

Common amphibians and reptiles associated with forests, wetlands, and riparian areas of western Washington also live in the Upper Watershed.

Lower Watershed

Wildlife occurrence in the upstream portion of the Lower Watershed is similar to that of the Upper Watershed. However, because of an increase in human activity below the public restricted portion of the watershed, populations of wildlife most sensitive to human disturbance, such as elk and cougar, are generally lower. Further downstream where forest habitat decreases and agricultural land dominates, wildlife composition shifts to a predominance of species associated with agricultural and edge habitat. Because of the increase in human activity and predominance of disturbed habitats in the downstream areas, wildlife inhabiting these areas are typically adaptable to a variety of habitats and have more tolerance to disturbance than the species in the more secluded forest habitat of the Upper Watershed.

Significant Species

Mammals

Rocky Mountain Elk

Following the extirpation of native Roosevelt elk from the west slope of the Cascade Range by the early 1900's, Rocky Mountain elk were introduced at two locations in King County. Since those introductions, Rocky Mountain elk have increased in number and have expanded their range along the west slope of the Cascades. Restricted public access and limited hunting in the Upper Watershed, along with favorable habitat conditions have contributed to the establishment of a significant herd of Rocky Mountain elk in the vicinity. At present, the WDFW estimates that 590 to 650 head of elk occupy the watershed throughout the year. Areas around Howard Hanson Reservoir provide high quality wintering habitat and calving grounds for the elk. The habitat in the vicinity of the McDonald farm is heavily used throughout the year by the elk. Because of less favorable habitat conditions below the dam, elk occurrence is considerably reduced in the Lower Watershed.

Special permits for a limited elk harvest allowed in the watershed are highly sought after by recreational hunters because of the high success rate and the large number of mature bulls present. A tribal subsistence hunt is also permitted in the watershed for Native Americans associated with the Muckleshoot Indian Tribe.

Black-tailed Deer

Although no recent population surveys have been completed for black-tailed deer in the watershed, their numbers are estimated to be similar to black-tailed deer populations in surrounding areas. A special permit limited hunt is also allowed for black-tailed deer in the watershed. Although this hunt generally does not receive as high acclaim as the special elk hunt, permits for this hunt are highly sought after. Although the overall population may be comparable to similar areas nearby, the limited hunting allowed in the watershed likely contributes to a relatively high ratio of mature bucks. As with the elk, the limited amount of land where hunting is allowed in the Lower Watershed reduces the significance of this species as a game animal in this area.

Cougar

The WDFW is involved in a study of cougars in the vicinity of the Cedar and Green River watersheds. Preliminary estimates of 25 to 35 cougars in the Green River watershed have been reported by the WDFW. Hunting restrictions, limited human access, and the large, stable elk herd in the watershed are believed to be significant factors contributing to this healthy population of cougars. The WDFW study indicates that the range and movement of cougars coincides with the range and movement of the elk. The population of cougars in the watershed is believed to be a stronghold for the species that contributes to the stability of populations in surrounding areas. Since elk primarily reside within the Upper Watershed, cougar populations in the Lower Watershed are presumed to be low to non-existent.

Raptors

Northern Goshawk

The northern goshawk (*Accipiter gentilis*) is a federal candidate species for listing as threatened or endangered. This species requires mature forests for assisting and foraging. Habitat conditions in the Upper Watershed are marginally suitable for goshawk nesting, and goshawks have been infrequently documented within the Upper Watershed project area. No goshawks have been documented in the Lower Watershed.

Osprey

In the Upper Watershed, one osprey nest is documented within one mile of the reservoir. Osprey feed primarily on fish, therefore, the Green River and HHD reservoir provide potential primary hunting areas for these birds. Seven osprey nests are located in the Lower Watershed just downstream from HHD. Five are in the section from the Green River Gorge upstream to HHD and the other two are below the Gorge. All nests are located close to the river.

Waterfowl

Harlequin Duck

The harlequin duck is a federal candidate species for listing as threatened or endangered. Harlequin duck breeding areas have been documented in the free flowing portions of the Green River in the upper portion of the Lower Watershed, and in some tributary streams immediately above HHD reservoir.

Common Loon

Common loons typically nest on large secluded lakes surrounded by forested habitats. Common loons have nested on Eagle Lake located about one mile northeast of HHD reservoir. A pair of common loons were present on HHD reservoir during the 1991, 1992, and 1993 nesting seasons following placement of nesting platforms by the WDFW in 1993. This pair finally nested during the 1994 and 1995 seasons (two attempts in 1995), but the nesting attempts were unsuccessful. The nesting platforms were placed too late in the season in 1996, and the loons made no attempt to nest. In 1997, the pair nested again, laid two eggs, both of which hatched. At least on chick survived through summer. Other common loons have been observed on the reservoir during migration. Since no large bodies of water exist in the Lower Watershed, common loons are not expected to occur in this vicinity.

Threatened and Endangered Species

Flora

The US Fish and Wildlife Service or Washington Department of Fish and Wildlife identified no threatened, endangered, or sensitive plant species as possibly occurring in the vicinity of the reservoir (USFWS 1996; WDFW 1996). The Washington State Department of Natural Resources (WDNR) Natural Heritage Information System identified fringed pinesap (*Pleuricospora fimbriolata*), a state Sensitive Species, as occurring in the vicinity of the Upper Watershed (WDNR 1996).

Fauna

A list provided by USFWS (1996) of proposed and listed threatened and endangered species identifies bald eagle (*Haliaeetus leucocephalus*), gray wolf (*Canis lupus*), grizzly bear (*Ursus arctos*), marbled murrelet (*Brachyramphus marmoratus marmoratus*), and northern spotted owl (*Strix occidentalis caurina*) as possibly occurring within a two-mile radius of the HHD reservoir. The gray wolf is currently listed as federally endangered. The other four species are currently listed as federal threatened.

Bald Eagle Bald eagles have been observed every month of the year near HHD reservoir; however, they are most common during the winter months. No more than four eagles have been observed at one time during any season. The large number of waterfowl present during the winter on the reservoir are probably an important prey source. No recent nesting activity has been confirmed in the Upper Watershed , but one adult and one sub-adult were observed during the 1994 nesting season, and again during the 1996 nesting season. One bald eagle nesting territory is located in the Lower Watershed. This territory was last active during the 1993 nesting season. Mid-winter eagle surveys conducted by the WDFW from 1984 through 1989 indicate that wintering bald eagle occurrence is similar in the Upper and Lower Watersheds.

Gray Wolf
No gray wolves have been observed in the project area. The closest known surveys to be conducted for gray wolves have been in selected areas on Huckleberry Ridge between the Green River and White River drainages in 1993. During these surveys, no wolves were heard and evidence of wolf use of the area was not observed.

Grizzly Bear

No grizzly bear or sign of grizzly bear has been reported in the project area. The closest reported sighting of grizzly bears have been 12 miles from the reservoir. Grizzlies have large home ranges with ranges as large as 1,004 square miles reported. Grizzly bears usually move down to lower elevations after emerging from their high elevation denning areas between March and May. Grizzly bears forage in areas that support emergent vegetation in the spring such as south-facing chutes and shrubfields. They feed in higher elevations as the season progresses.

Marbled Murrelet

Marbled murrelets typically inhabit shallow marine waters and nest in mature old growth trees. While murrelets have been found in Washington up to 52 miles inland, 90% of sightings occur within 40 miles of marine waters. An informal assessment of potential murrelet nesting habitat conducted by the WDFW, USFWS, and Corps, resulted in the determination that little potential nesting habitat occurs in the vicinity of HHD reservoir. Surveys conducted during the 1994 nesting season near HHD resulted in no murrelet detection. Murrelets are unlikely to be found in the Lower Watershed due to lack of habitat requirements, and no surveys have been conducted here.

Northern Spotted Owl

Because spotted owls are typically associated with late successional forests, habitat conditions in the Upper Watershed are less than optimal. Spotted owl surveys conducted by the DNR during the 1993 and 1994 nesting seasons resulted in no spotted owl detection in the vicinity of the reservoir in the Upper Watershed. One historic nesting location exists within about one mile from the reservoir. Spotted owl activity has not been detected at this site during the surveys conducted the past two nesting seasons and the site is presumed inactive. Spotted owls have been documented in several locations within the Green River watershed above the Upper Watershed project boundaries out of the range of influence of the operation of HHD. Spotted owls are not expected in the Lower Watershed because of the dearth of late successional forests, and no surveys have been conducted here.

5.9.2 Aquatic Resources

a. Aquatic Habitat

The Green River provides habitat for fish, invertebrates, and numerous other aquatic species. Channel width, streambed gradient, and bottom substrate are important indicators of habitat quality. Number and size of tributaries may also be important for fish and other species.

Upper Watershed

Headwaters Sub-basin RM 64.5 to RM 88

The width of the main stem Green River in the Upper Watershed varies considerably and depends on the elevation of the reservoir. Most of the channel within the Project, RM 64.5 to 69, is inundated during the full conservation pool, a total of 7.7 miles of stream and mainstem habitat. Approximately one mile is inundated year-round by maintenance of the turbidity pool. Streambed gradient is gradual within the reservoir area. The removal of riparian vegetation and large woody debris within the reservoir has resulted in degraded instream habitats including a loss of pool area and pool quality. Bottom substrates in the upper reaches of the Project area are primarily gravels and cobbles. Near-surface bottom substrates in the lower reservoir, especially immediately above HHD, are finer. This area is where most of the siltation in the reservoir occurs. Substrates in the project are generally unstable in relation to biologic value. Substrate stability is affected by changes in pool elevation and bedload shifts during periods of high flows. Lastly, the long-periods of pool inundation change the characteristics of the naturally free-flowing stream habitats to more lake-like conditions with increased water depths including – changes in water temperature, reduced water velocities, and reductions in dissolved oxygen.

Steep walled valleys and mountainous terrain generally limit stream widths from the upper extent of the Project (RM 69) to the headwaters of the Green River (RM 88). Average widths of the mainstem area ranges from between 25 to 85 feet at low flow. Larger tributaries range in width from 10 to 40 feet. As expected, stream width decreases as streambed grade increases. Much tributary stream habitat in the upper Green River is fast running cascades with few pools. Bottom substrates are generally coarse consisting of boulders and large rubble. Stream gradient decreases and gravels are more prevalent in areas closer to the Project. In total, the mainstem and tributary systems include over 260 linear stream miles. About 106 miles are accessible and 78 miles are probably useable by fish; however, fish passage between these systems and the main stem is often limited by natural and constructed (culverts) barriers close to their confluence with the Green River. Tributaries are generally small first or second order streams.

Lower Watershed

Diversion Dam Reach RM 64.5 to 61,0

The section of the Green River from HHD (RM 64.5) to the Tacoma Diversion Dam (RM 61.0) covers 3.5 river miles and mostly flows through Eagle Gorge. This section of river includes the outlet works of HHD and the Tacoma Diversion Dam. The only riverside development in this section are the dam works, the mainline road, and the remnants of the old railroad line. This area is restricted to public access at the City of Tacoma's gate just below the Diversion Dam. River widths within Eagle Gorge are from 100 feet to 150 feet. Stream gradient is moderate with several steep sections including one cascade that could present a low-flow barrier to upstream migrating fish. Bottom substrates are primarily boulders, large rubble, and cobbles. Gravels and smaller cobbles suitable for spawning are limited because of sediment storage behind HHD. One large tributary, Bear Creek, enters the Green River just below HHD at RM 63.5.

Upper Green River Sub-basin RM 61.0 to 46.5

The section of the Green River from the Tacoma Diversion Dam (RM 61) to RM 46.5 covers 15 river miles and flows through several topographic areas. This section of river includes the Green River Gorge, Flaming Geyser State Park, and the outlet works below the Tacoma Diversion Dam. Riverside development in this area varies from rural in the lower sections to restricted access forested watershed within Tacoma's controlled areas above the diversion dam. Within the Green River Gorge the river is limited to a width ranging from only 100 feet to 200 feet, especially for the 12 miles within the Gorge. Stream gradient in this section is moderate and maintains natural mountain stream characteristics. Bottom substrates are primarily boulders, large rubble, and cobbles especially in the vicinity of Kanasket (RM 61to RM 56). Gravels and smaller cobbles suitable for spawning are limited to short riffles and at the tailcrest of pools. No large tributaries enter the river in this section. Over twenty-five first and second order tributaries are present, mostly above the Green River Gorge.

Middle Green River Sub-basin RM 46.5 to 33.8

The Green River above Auburn includes 16 miles of river from the Green River Gorge (RM 46.5) to the city. Most of this section is within unincorporated King County. Streamside development is less urban and stream bank vegetation is better established compared to lower sections, although diking and active flood control measures are in place in some areas (RM 38 through RM 30). Stream width averages 150 feet, but width is extremely variable and reflects the general form of the surrounding valley. Valley width ranges from 200 feet at the base of the Green River Gorge to approximately a mile at Auburn. Stream gradient is slight in this area with about 0.1% change within the 16 mile reach. Bottom substrates are primarily gravels and cobbles. Gravel composition is generally considered excellent for fish use. The lower gradient of this section affords good pool-riffle composition with many glides, side channels, and channel-split areas favored by several salmonid species for spawning and rearing. Several tributaries enter the river in this section. Tributaries include Big Soos Creek, Newaukum Creek, Burns Creek, Crisp Creek, and eight small, unnamed streams. These systems, in addition to several smaller unnamed streams, provide over 90 linear miles of stream habitat.

Lower Green River Sub-basinRM 33.8 to 11

The Green - Duwamish system near Kent includes 19 miles of river from Auburn (RM 33.8) to the confluence of the Black River near Tukwila (RM 11). Development along the banks of the river in this section is generally urban, though not typically water dependent. Stream widths range from 100 to 200 feet and the path of the river is more natural; less influenced by channelization. Levees, dikes, and rip-rapped banks are maintained to control flooding and limit stream bank erosion. From the Black River to Kent (RM 26), bottom substrates are similar to the lower section; however larger rubble and boulders provide a slightly more diverse habitat structure. The channel is not dredged in this area. From Kent to Auburn stream gradient increases and substrates are generally compacted gravels. Seven tributaries and several drainage ditches enter the Green River in this section. Of these only Hill Creek, draining Lake Dolloff, is a major tributary.

*Duwamish Waterway RM 11-0*The lower part of the Green - Duwamish system is known as the Duwamish Waterway. The Waterway includes the Green River from its confluence with the Black River near Tukwila (RM 11) to its mouth at Elliott Bay (RM 0). Stream widths range from 150 feet at RM 11 to 1,000 feet at the mouth. Levees and dikes generally control widths. The lower five miles of the river are under tidal influence and stream flow velocities generally dissipate in this area. River bottom substrates are generally soft silt and mud. The lower five miles are dredged periodically to facilitate shipping. The Black River and one small tributary enter the Duwamish Waterway in this section.

b. Fish

Overview

Over 30 fish species inhabit the Green River, including both resident and anadromous stocks. Resident fishes such as cutthroat trout, mountain whitefish, and sculpin are present in both the Upper and Lower watersheds. Anadromous stocks were once present throughout the entire basin, but they are currently limited to the river system below the Tacoma dam diversion, except where they are stocked or released in the Upper Watershed. For planning purposes, this EIS focuses on anadromous fish species. Protection of anadromous salmonids with stream-type early life histories, such as coho, steelhead and sea-run cutthroat trout, was assumed to provide adequate protection for resident fish species.

Eight anadromous salmonid species historically or currently use the Green River system. These native species include chinook, coho, chum and sockeye salmon *(Oncorhynchus tshawytscha, O. kisutch, O. keta, O. nerka*), steelhead and sea-run cutthroat trout (*O. mykiss, O. clarki clarki*), Dolly Varden and bull trout (char; *Salvelinus malma, S. confluentus*). Races of salmon and steelhead historically or currently present include spring, summer, and fall chinook, winter and summer steelhead. Additional information on life-history types and stock status is discussed in Part 1, Appendix F, Section 5, Downstream Migration of Anadromous Salmonids Through the Lower Green River.

Management

Federal, state, and tribal agencies manage Green River fisheries and fish habitat with cooperation from the Corps. Wild salmon and steelhead stocks are augmented with plants from several regional hatcheries. The Green River Hatchery operated by the WDFW is the most significant facility, with important additional contributions from the Muckleshoot Tribe and smaller WDFW facilities.

Stocking is an important component of anadromous fisheries management in the Green River system. Anadromous stocks were re-introduced into the Upper Watershed beginning in 1982. Past yearly fish harvests and escapement goals within the region were based on hatchery supported stocks. However, recent fisheries practices have supported the removal of non-native stocks from hatchery programs and current escapement goals for winter steelhead and summer/fall chinook are based on wild fish returns.

The separation between wild and hatchery stocks is notable because even though hatchery and wild stocks may be the same species, they are managed differently. Hatchery stocks typically can support a higher level of exploitation (harvest) than wild fish because of lower mortality in early life stages, different (and often less restrictive) habitat needs, and different migration timing. Some researchers feel that the introduction of hatchery fish, especially those originating from other river systems and/or those whose natural cycle has been altered by hatchery practices, can influence the genetic health and fitness of wild stocks. This occurs when hatchery-bred fish reproduce naturally with wild fish.

State sponsored steelhead production is formally managed by the WDFW. The WDFW rears winter steelhead for the Green River at its South Tacoma facility from Chambers Creek stock. Summer steelhead plants are reared at the Skamania hatchery and originate from Washougal and Klickitat River stocks.

Description of fisheries resources by river reach

Upper Watershed

Headwaters Sub-basin RM 64.5-88

Returning anadromous fish have no access to the Upper Watershed because the Tacoma diversion dam blocked the natural upstream migration of anadromous salmonids since 1921. Fish stocking in this Upper Watershed first occurred in 1982. Since 1992, a small pilot program has been undertaken to trap returning adult steelhead at the Tacoma Diversion and release them above the Project to spawn naturally in the upper Green River and its tributary streams. Juvenile anadromous salmonids, particularly chinook, coho, and steelhead have been stocked in the streams of the Upper Watershed in order to utilize natural rearing habitat above HHD. Chinook and steelhead are generally stocked in the main stem, North Fork, and larger tributaries. Coho are stocked in most accessible streams.

Various surveys by the USFWS, US Forest Service, and other public and private land owners have investigated resident fish use in the reservoir and Upper Watershed. Documented fish include resident rainbow trout, cutthroat trout, mountain whitefish and sculpins. Brook trout were identified in Page Creek, a tributary to the North Fork Green

River. Resident trout populations are composed of stream rearing and possible lake and reservoir dwelling strains. Stream rearing fish live out their entire life cycle in the small tributary streams of the Upper Watershed. Lake rearing fish reside primarily in isolated alpine lakes while reservoir rearing fish use the mainstem and reservoir area, spawning in larger tributary streams.

Lower Watershed

Diversion Dam Reach RM 64.5 to 61.0

Surveys by the Army Corps of Engineers and the City of Tacoma show that resident rainbow and cutthroat trout use this river reach for spawning and rearing. This reach contains excellent pool habitat for adult and juvenile trout rearing but appears to be limited by suitable spawning gravels. Bear Creek, the one large tributary found in this section, has good riparian areas but has a migration barrier near RM 0.7 at the road crossing. The stream at this point flows over a bedrock outcropping with water depths too low for larger resident trout or larger anadromous fish to be able to cross. Use of he mainstem reach by naturally spawned anadromous fish (salmon, steelhead, cutthroat, char, lamprey) is blocked by the Tacoma Diversion Dam. Juvenile fish planted above HHD and in Bear Creek may use this section of river throughout the year. Juvenile steelhead and chinook salmon have been observed during the low flow season.

Upper Green River Sub-basin RM 46.5-61.0

WDFW spawning surveys show that chinook, coho, and steelhead use parts of this sub-basin for spawning; however, this section generally contains more rearing habitat than spawning habitat. Rearing habitat is generally limited to the main channel and small tributaries. The WDFW maintains two fish production facilities; one on Icy Creek, near the bottom of the Green River Gorge, that has produced fall chinook and coho over the past ten years; and a second at Palmer, that produces steelhead. No other fish production facilities are located upstream. Resident fish are represented by those cold water species adapted to swifter mountain streams, including trout, whitefish, and sculpins.

Middle Green River Sub-basin RM 33.8-46.5

WDFW spawning surveys (1987-1993) show that this sub-basin supports the highest density of natural spawning activity by anadromous salmonids (as indicated by redd counts). This section of river is the most important section for chinook, steelhead, coho, and chum production in the entire basin. Steelhead and chinook also spawn in Big Soos and Newaukum Creeks. Chum spawning in off channel areas and in Burns and Crisp Creek. Coho spawn and rear in the main river and most tributaries, especially the smaller streams. In addition to natural production, this area contains the bulk of the hatchery plants within the basin. The Green River Hatchery run by the WDFW on Big Soos Creek has been in operation since the early 1900's. Other hatcheries include WDFW rearing ponds on Crisp Creek and a facility operated by the Muckleshoot Indian Tribe. Resident trout, whitefish, sculpins, and other indigenous species are likely common in this section.

Lower Green River Sub-basinRM 11-33.8
This section of the Green River serves as a corridor for anadromous fish species during migration, for access to upstream spawning areas, and for spawning. The section from Kent to Auburn contains many riffles with good salmonid spawning habitat. WDFW spawning surveys show that chinook are more likely than chum or coho to use spawning habitat in this area. Steelhead may also use this area for spawning. This section also provides rearing habitat for both anadromous and resident species. In addition to anadromous fish use, warm water freshwater species are more common in this section of stream than those areas further upstream or downstream.

Duwamish Waterway (RM 11-0)
The Waterway serves as the portal to the marine environments of Puget Sound, the Strait of Juan de Fuca, and the Pacific Ocean. All anadromous fish species use this eleven mile section of the river during some part of their life cycle. Anadromous fish include all races of chinook, coho, and chum salmon, steelhead and cutthroat trout, Dolly Varden char, longfin and surf smelt, and river lamprey. Several other species are likely to use this portion of the river, particularly those species common to brackish or marine environments including starry flounder, hybrid sole, English sole, Pacific tomcod, Pacific snakebelly, shiner perch, and pile perch.

The lower section contains limited wetland and estuary habitat, important natal and rearing habitat for many fish species. Spawning of salmon and steelhead is constrained in this portion of the main river; however, spawning does frequently occur in the tributaries. The Black River sub-basin including Springbrook Creek, Mill Creek, and several tributaries, is known to contain a significant quantity of spawning and rearing habitat.

c. Threatened and Endangered species

The USFWS lists two aquatic candidate threatened species, the spotted frog (*Rana pretiosa*) and the bull trout (*Salvelinus confluentus*), that could occur in the project area (USFWS 1996).

NMFS lists one aquatic species proposed for threatened status, Puget Sound chinook salmon (*Oncorhynchus tshawytscha*), in the project area (NMFS 1998): on February 26, 1998, the NFMS proposed that the Puget Sound Evolutionary Significant Unit (ESU) for chinook salmon be listed as threatened, final listing (or nonlisting) will be formally decided 12-18 months after the date of the proposal.

<u>Spotted Frog</u>
The Lower Watershed lies within the historic range of the spotted frog. Sightings in Thurston County are the only confirmed observations of spotted frogs in 23 years in western Washington lowlands. Within the Green/Duwamish River basin, perennial water sources with adjacent emergent vegetation could provide suitable spotted frog habitat. Nevertheless, due to the rare documented occurrence of the spotted frog in western

Washington lowlands, the spotted frog is not expected to occur in the project area. A survey for amphibians was conducted along the margin of the reservoir I 1997. Eggs of red-legged frogs (*Rana aurora*) were found. No other species of amphibian was detected during the survey.

Bull Trout

Historically, bull trout were found in the thousands in the middle Green River (USACE 1986). Their historic occurrence in the upper Green River has not been verified. The USFS conducted recent surveys in the upper Green River Basin and several tributaries including Sunday Creek and Pioneer Creek, and found no evidence of bull trout (USACE 1996). Plum Creek Timber Company has also completed surveys in other upper Green River tributaries with no verification of bull trout presence (Plum Creek 1996). The habitat in these areas was considered somewhat degraded due to past timber harvests. Stream temperatures in the survey area may also be warmer than temperatures required by bull trout in the late summer (Goetz 1989, USFS 1994). Bull trout were last reported in the Green River in 1964 and in the Duwamish River in 1994 (USACE 1996).

Chinook Salmon

Historically, chinook salmon were found in the lower and middle Green River in the ten's of thousands: 55,000 were counted during spawner surveys in the late 1930s and early 1940s (USACE 1996). There is limited documentation for their presence and abundance in the upper Green River. Historical information on the Headwaters anadromous fish assemblage and the potential number of returning adults comes from trapping of adults (from hatchery egg take) at the Tacoma Diversion Dam in the early part of the century. Grette and Salo (1986) reported that historical escapement estimates ranged from 150 to 300 spring chinook. The authors researched Washington Department of Game records and concluded that harvest and seasonal blockages below the trap could have resulted in underestimates of total chinook returns.

The WDFW completed a stock status report in 1993 and concluded that at that time chinook salmon in the Green River were considered healthy; determination under the Endangered Species Act may be different. A Genetic Stock Inventory (GSI) sample of various parts of the river was conducted in the fall of 1997, this sample will be analyzed to determine what parts of the Green River population may still contain segments of wild Green River chinook salmon. This analysis could be important in establishing the final assessment of the Green River stock as wild, wild and hatchery, or hatchery which could affect their protection and recovery if Puget Sound chinook salmon are listed as a threatened species. Currently, natural spawner escapement to the lower river is 5800 adults. Most of the natural spawning occurs in the mainstem river between RM 28 up to RM 60 at the Tacoma Diversion Dam. Rearing of Lower Watershed spawned juveniles occurs from RM 60 all the way to the mouth of the river. Dam and reservoir operations that affect flow releases and sediment transport also affect life stages of chinook from adult upstream migration, to spawning and egg incubation, fry emergence, juvenile rearing and, lastly, to juvenile (smolt) migration to the ocean.

No spawner escapement goal has been established for the Upper Watershed by WDFW or the Muckleshoot Tribe, however, for planning purposes the Corps has estimated a potential escapement of 2300 adults. Since 1982, juvenile chinook salmon have been outplanted throughout the upper Green River from lower Green River hatchery brood stock. As part of the without-project condition, it is assumed that the Fish Restoration Facility (FRF) is in place and that the upstream trucking and release of adult chinook has begun (see Paragraph1.6.3). Chinook salmon juveniles rear in the reservoir and larger tributaries above the reservoir and migrate through the reservoir and dam. It is presumed that adult chinook salmon will be released in or near the reservoir and that spawning could occur in the inundation area or more likely in the mainstem and larger tributaries above this zone.

Restoration of chinook salmon to the upper Green River is dependent on project features and operations and on a number exogenous factors, including – climactic conditions, habitat quantity and quality above the project, successful operation of the FRF and upstream adult transport, lower river habitat quantity and quality, and ultimately adequate numbers of naturally spawning adults which are determined by ocean rearing conditions and fish harvest levels. Project features that can affect chinook salmon, primarily juveniles, include the operation of the fish passage facility, the size (Phase I or II pool) and rate of refill of the reservoir, the presence and abundance of terrestrial, avian or aquatic predators, and the frequency, timing, and size of freshet releases (natural or artificial), and low flow augmentation.

SECTION 6. ENVIRONMENTAL AND SOCIOECONOMIC CONSEQUENCES

6.1 INTRODUCTION

The potential adverse and beneficial consequences of the construction and operation of single purpose water supply and the full and phased alternatives with environmental restoration are described in this section, along with possible mitigation measures. Study of this proposed action has been supported and encouraged by Congressional representatives, federal and state fishery agencies, and regional and local water supply agencies because of the long-term benefits to fish and water supply. The impacts from each alternative are evaluated side by side under each element of the environment. Efforts to avoid and minimize impacts, which shaped the proposed alternatives, are also described under each element of the environment. The phased development with full environmental restoration is the Corps' and local sponsor's preferred alternative based on economic and environmental considerations.

6.1.1 Matrix Summary or Impacts on Alternatives

Table 6-1 summarizes impacts of each alternative discussed in the following Paragraphs 6.2 to 6.9. Note the impacts listed in Table 6-1 do not line up directly with the Paragraph titles that follow. Refer to Paragraph 3.3.2 for a description of the final alternatives. Table 3-4 provides a comparison of major project features by alternative. In this section's discussion, the alternatives' names are shortened as follows:

Full Name of Alternative	Shortened Name of Alternative
No Action	No Action
Additional Municipal and Industrial Water Supply with Fish Passage for Mitigation (pool elevation 1169 ft)	Single Purpose Water Supply
Immediate Full Development of Water Supply with Environmental Restoration (pool elevation 1177 ft)	Full Development with Environmental Restoration
Preferred Alternative: Phased Development of Water Supply with Environmental Restoration (pool elevation in Phase I 1167 ft; Phase II – 1177 ft)	Preferred Alternative: Phased Development with Environmental Restoration

TABLE 6-1. HOWARD HANSON DAM ADDITIONAL WATER STORAGE PROJECT IMPACT SUMMARY CHART

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
FLUVIAL PROCESSES				
Channel Morphology	No change – the mainstem channel continues to downcut further isolating floodplain due to entrapment of sediments behind HHD and reduced peak flows	No change – the mainstem channel continues to downcut further isolating the floodplain due to entrapment of sediments behind HHD and reduced peak flows	Implementation of gravel nourishment and adaptive management to attempt reinitiating sediment transport from HHD reduces rate of channel degradation potentially maintaining the bed surface elevation in the Middle Green River and marginally maintaining connection to the floodplain	Implementation of gravel nourishment and adaptive management to attempt reinitiating sediment transport from HHD reduces rate of channel degradation potentially maintaining the bed surface elevation in the Middle Green River and marginally maintaining connection to the floodplain
Sediment and Organic Matter Transport	No change - gravel would be trapped behind the Dam; large wood would be removed from the reservoir; adult salmon would not be released to Upper Watershed	Little change – gravel would continue to be trapped behind the dam; large wood would be removed from the reservoir; limited no. of adult salmon released to Upper Watershed	Implementation of gravel nourish-ment in Middle Green; adaptive management to attempt gravel transport through dam; large wood transported below Diversion Dam; up to 9000 salmon released above HHD	Implementation of gravel nourish-ment in Middle Green; adaptive management to attempt gravel transport through dam; large wood transported below Diversion Dam; up to 9000 salmon released above HHD
WATER QUALITY				
Turbidity-Long Term	No change	Minor turbidity episodes reduced or eliminated as initial sliding events subside	Minor turbidity episodes reduced or eliminated as initial sliding events subside	Phase I – minor turbidity episodes reduced or eliminated as initial sliding events subside; additional minor events as Phase II pool is initiated but eventually reduced or eliminated
Turbidity-Short Term	No change– turbidity episodes occur regularly	Minor turbidity increases due to sliding would last several days during the first few years of operation	Minor turbidity increases due to sliding would last several days during the first few years of operation	Minor turbidity increases due to sliding would last several days during the first few years of operation in Phase I followed by similar increases during early Phase II
Temperature (Immediately below HHD)	No change–early summer warmer than natural; late summer/fall warmer than natural	Water temperatures would mimic natural trends; summer/ fall releases would see a large improvement from 3-10 miles downstream.	Water temperatures would mimic natural trends – summer and fall releases would see a large improvement from 3-10 miles downstream.	Water temperatures would mimic natural trends – summer and fall releases would see a large improvement from 3-10 miles downstream.
Drinking Water Quality	No change	Application of fertilizer to mitigation sites near the reservoir could result in local effects on water quality	Application of fertilizer to mitigation sites near the reservoir could result in localized effects on water quality	Application of fertilizer to mitigation sites near the reservoir could result in localized effects on water quality

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
WATER QUANTITY				
Instream Flow Volumes (cfs): Below Tacoma Diversion Dam				
Winter (Nov 1-Feb 15)	No change	No change	No change	Phase I No change Phase II No change
Spring (Feb 16-June 30)	No change	Reduced due to M&I water storage over and above current SSWR diversion	Reduced due to M&I water storage over and above current SSWR diversion	Phase I Volume unchanged (only storing SSWR); timing improved Phase II Reduced due to M&I storage over and above Phase I SSWR storage
Summer and Early Fall (Jul 1-Oct 31)	No change	No change	Improved	Phase I Improved non-drought years Phase II Improved
FISHERIES				
Restoration Potential in the Upper Watershed and Lower Watershed Population Status				
Chum	Chum salmon were not historically found in the U. Watershed; no change in Lower Watershed	L. Watershed – Reduced	L. Watershed – Reduced	Lower Watershed Phase I – Neutral Phase II – Reduction without mitigation
Sockeye	Sockeye salmon were not historically found in the U. Watershed; no change in Lower Watershed	L. Watershed – Reduced	L. Watershed – Reduced	Lower Watershed Phase I – Neutral to Improved Phase II – Reduction without mitigation
Chinook	Chinook planting would likely cease and no adults would be released in the U. Watershed; no change in L. Watershed	U. Watershed – Improved but questionable chance of self-sustaining runs L. Watershed – Reduced	U. Watershed – Improved over single purpose but still questionable for self-sustaining runs L. Watershed – Neutral to Reduced	U. Watershed – Phase I moderate chance of self-sustaining; Phase II questionable chance of self-sustaining L. Watershed – Phase I improved; Phase II – Neutral to Reduced
Coho	Coho salmon planting would likely cease; no adults would be released in the U. Watershed; no change in L. Watershed	U. Watershed – Improved but low to moderate chance of self-sustaining runs L. Watershed – Reduced	U. Watershed – Improved over single purpose but still moderate chance for self-sustaining runs L. Watershed – Neutral to Reduced	U. Watershed – Phase I self-sustaining likely; Phase II moderate chance of self-sustaining L. Watershed – Phase I improved; Phase II -- Neutral to Reduced

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
Steelhead	Steelhead planting would likely cease; no adults would be released in the U. Watershed; no change in L. Watershed	U. Watershed -- Improved but low to moderate chance of self-sustaining runs L. Watershed – Reduced	U. Watershed -- Improved over single purpose but still moderate chance for self-sustaining runs L. Watershed – Neutral to Reduced	U. Watershed – Phase I likely self-sustaining; Phase II moderate chance of self-sustaining L. Watershed – Phase I improved; Phase II – Neutral to Reduced
Resident Trout Populations	No change - no future food source from salmon; trout below dam would continue to experience exacerbated temperatures regime	Reduced production above dam from pool raise increase below dam from more natural temperatures	Neutral to increase above dam from pool raise/removal but offset by habitat improvement and increased prey base further upstream; increased production below dam from improved water temperatures	Neutral to increase above dam from pool raise/removal but offset by habitat improvement and increased prey base further upstream; increase below dam from improved water temperatures and prey base
Habitat Restoration, Impacts and Fish Passage				
Spawning Gravel Habitat Restoration	No change – gravels are trapped behind dam; degradation of Middle Green River habitat cont. further downstream	No change – gravels are trapped behind dam; degradation of Middle Green River habitat continues further downstream	Implementation of gravel nourishment in Middle Green with 3900 cu yd/year; adaptive management to attempt gravel transport through dam	Implementation of gravel nourishment in Middle Green with 3900 cu yd/year; adaptive management to attempt gravel transport through dam
Side Channel Habitat Restoration and Impacts	No change – main channel continues downcutting potentially isolating Middle Green River habitat	Downcutting of main channel continues; additional water storage dewaters several acres of habitat during spring refill	Downcutting is reduced by addition of gravels in Middle Green; attempt reinitiating of sediment transport; a side-channel is restored at Kanaskat; additional storage dewaters up to 8.4 acres of habitat during refill	Phase I – downcutting is reduced by gravel nourishment; attempt reinitiating sediment movement at dam a large side-channel is restored at Kanaskat; adaptive management increases useable habitat by 1.0 acre during spring refill Phase II – see Full Development
Instream Habitat Restoration	No change – river/stream habitat above/below HHD lacking in large wood and quality pools	No change – river and stream habitat above and below HHD lacking in large wood and quality pools	Implementation of addition of large wood and boulders to streams/rivers above HHD; transport of large wood to below Diversion Dam	Phase I - Implementation of large wood and boulders to streams/rivers above HHD; transport of large wood to below Diversion Dam Phase II – continues Phase I

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
Riparian and Instream Habitat Impacts	No change -- no pool raise occurs	Pool raise to 1169 ft inundates 80+ acres of riparian habitat and 12+ acres of stream habitat; mitigation projects are found throughout the Upper Watershed	Pool raise to 1177 ft inundates 121 acres of riparian habitat and 17.4 acres of stream habitat; mitigation projects are found throughout the Upper Watershed	Phase I - Pool raise to 1167 ft inundates 79.2 acres of riparian habitat and 11.5 acres of stream habitat Phase II -- pool raise to 1177 ft additional 42.3 acres of riparian and 5.9 acres of stream habitat
Reservoir and Dam Fish Passage	No surface outlet at dam, survival rates are so low hatchery planting of juvenile fish likely discontinued; release of adult steelhead is likely discontinued	Improved surface outlet but less than 60% dam survival; adults released in U. Watershed hatchery supplementation necessary throughout life of the project	State-of-the-art surface outlet; juvenile salmon survival reduced due to size of 62,000 ac-ft reservoir; adult salmon and steelhead released in U. Watershed for natural spawning; chinook may require supplementation	Phase I -- State-of-the-art surface outlet; juvenile salmon survival higher than Phase II from smaller reservoir volume; adult salmon and steelhead released for natural spawning; less likely chinook require supplementation Phase II -- see Full Development
WILDLIFE AND VEGETATION				
Inundation Zone	no change--no loss in habitats	281 acres inundated; loss of inundated habitat would be mitigated	442 acres inundated; loss of inundated habitat would be mitigated	281 acres inundated in Phase I; 161 acres inundated in Phase II; loss of inundated habitat would be mitigated separately in each phase
Terrestrial Wildlife	no change--no effect on wildlife populations	mitigation focuses on elk, red-backed vole, pileated woodpecker, and wood duck	mitigation focuses on elk, red-backed vole, pileated woodpecker, and wood duck	mitigation focuses on elk, red-backed vole, pileated woodpecker, and wood duck
Wetlands	no change--wetlands would remain unaltered	loss of 90 acres of sedge meadows replaced by 69 acres of sedge meadows; loss of 7 acres of forested wetland replaced by 8 acres of forested wetland	loss of 111 acres of sedge meadows would be replaced by 87 acres of sedge meadows; loss of 12 acres of forested wetland replaced by 15 acres of forested wetland	loss of 90 acres of sedge meadows and 7 acres of forested wetland in Phase I, replaced by 69 acres of sedge meadows and 8 acres of for. wet. resp.; loss of 21 acres of sedge meadows and 5 acres of for. wet. in Phase II replaced by 18 acres of sedge meadows and 7 acres of for. wet., respectively
Threatened and Endangered Wildlife Species	no change--species would not be affected	bald eagles, spotted owls, marbled murrelets, grizzly bears, and gray wolves would not likely be adversely affected	bald eagles, spotted owls, marbled murrelets, grizzly bears. and gray wolves not likely to be adversely affected: bald eagles likely to benefit from restoration of salmon runs	bald eagles, bald eagles, spotted owls, marbled murrelets, grizzly bears. and bears, and gray wolves not likely to be affected: bald eagles likely to benefit from restoration of salmon runs

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
LAND USE & RECREATION				
Land Use	near project: no change is expected region: growth and land development is slowed	near project: expansion of fish and wildlife habitat lands region: growth and land development proceed at rates defined by Growth Management Act	near project: expansion of fish and wildlife habitat lands region: growth and land development proceed at rates defined by Growth Management Act	near project: expansion of fish and wildlife habitat lands region: growth and land development proceed at rates defined by Growth Management Act
Recreation	no change in land use recreational opportunities	white-water boating could be compromised by alterations in frequency and timing of outflows released from HHD	white-water boating could be improved by alterations in frequency and timing of outflows released from HHD	Phase I –white-water boating could see an improvement in the frequency and timing of spring high flow events from HHD; Phase II see the Full Development Alt.
CULTURAL RESOURCES				
Coordination with Native American Tribes	may affect existing agreements for operation of HHD, and long-term relationship with Muckleshoot Tribe	may affect existing agreements for operation of HHD, and long-term relationship with Muckleshoot Tribe	may affect existing agreements for operation of HHD, and long-term relationship with Muckleshoot Tribe	agreement with Muckleshoot Tribe based on understanding this alternative would be implemented. No effect to Tribal coordination anticipated
Historic	no effect on historic or pre-historic properties	historic sites would be inundated; no mitigation for these sites is necessary	historic sites would be inundated; no mitigation for these sites is necessary	historic sites would be inundated; no mitigation for these sites is necessary
SOCIOECONOMIC				
Fisheries	no change--fish runs will continue to decline	lack of habitat restoration & smaller fish passage facility reduces likelihood of salmon restoration	implementation of fish flows, upstream plants of adult spawners, and downstream fish passage over the dam, will help to restore fish runs in the Green River	implementation of fish flows, upstream plants of adult spawners, and downstream fish passage over the dam, will help to restore fish runs in the Green River
Logging Road over HHD	no change in current operation	road over dam currently used by timber companies would be closed, access to are available from other routes south side of watershed	road over dam currently used by timber companies would be closed, access to lands is still are available from other routes south side of watershed	road over dam currently used by timber companies would be closed, access to lands is still are available from other routes south side of watershed
Non-clearing of trees in Inundation Zone	no trees would be cut except for some trees in TPU's commercial zone	limited to no clearing would be conducted; trees would die and become snags for wildlife	limited to no clearing would be conducted; trees would die and become snags for wildlife	limited to no clearing would be conducted; trees would die and become snags for wildlife

ALTERNATIVES	No Action	Additional Municipal and Industrial Water Supply With Fish Passage for Mitigation (pool elevation to 1169')	Immediate Full Development of Water Supply With Environmental Restoration (pool elevation 1177')	PREFERRED ALTERNATIVE Phased Development of Water Supply With Environmental Restoration (pool elevation in Phase I-1167'; Phase II-1177')
Employment	no change near project; region may see reduced employment if alternative water supply is not available	new jobs would be created for construction and maintenance of project facilities; regional employment would proceed at rates defined by growth management	a greater number jobs than in the previous alternative would be created for project construction and maintenance regional employment would proceed at rates defined by growth management	new jobs would be created for construction and maintenance of project; additional jobs would be created in future years to construct Phase II; regional employment would proceed at rates defined by growth management
Railroad Effects	no effect on railroads	pool raise inundates bridge footings & supports but does not affect structural access would be required across tracks to reach mitigation sites	pool raise inundates bridge footings & supports but does not affect structural integrity; access would be required across tracks to reach mitigation sites	pool raise inundates bridge footings & supports but does not affect structural integrity; access would be required across tracks to reach mitigation sites
Electric Power Company Rights-of-way (ROW's)	no change	some wildlife mitigation sites would be placed in ROW's	some wildlife mitigation sites would be placed in ROW's	some wildlife mitigation sites would be placed in ROW's
ECOSYSTEM				
Number of Runs with "Moderate to Likely" Restoration Potential	0	0	2	Phase I – 3 Phase II – 2

6.1.2 Test Pool

A test pool would be conducted prior to project construction to evaluate the potential effects on dam and bank stability. The test pool would be filled in accordance with the rule curve developed for the preferred alternative. The test pool would result in the same environmental effects as the those briefly described in Table 6-1, and described in more detail throughout Section 6. As the test pool is considered to be part of the project (it would be conducted for any of the alternatives, except for the no action alternative), mitigation for the test pool will be incorporated into the overall project mitigation.

6.2 SOCIOECONOMIC RESOURCES

6.2.1 Population/Demographics

a. No Action Alternative

The no action alternative without future project construction would result in no change in existing population or employment opportunities near the dam. There is an obvious need for M&I water supply in Pierce and King County. If additional water storage does not occur, other alternatives would either be more costly, or would likely have a greater environmental impact increasing water supply costs to area residents. In selected areas of King County, if additional water storage is not available, other sources are currently unavailable and may remain available into the future, resulting in fewer employment opportunities and slower population growth in these areas.

b. Single Purpose Water Supply Alternative

The single purpose water supply alternative would result in the creation of new jobs for construction and maintenance of the project facilities. As part of the pool raise from 1147 to 1169 ft, forest lands (trees) surrounding the reservoir will be inundated. To provide mitigation, these trees will be left to provide habitat for wildlife and fish; alternatively these trees would have otherwise provided revenue and short-term employment. Outside the project area, by providing storage of 22,400 ac-ft for M&I water supply, this alternative would result in an increase in population growth and employment opportunities in selected areas of the county by providing a reliable, reasonably priced source of water.

c. Full Development Alternative With Environmental Restoration

The full development with environmental restoration alternative would result in creation of a greater number of jobs for construction and maintenance of project facilities than the single purpose alternative. This alternative will also result in a greater number of inundated trees around the reservoir that otherwise could have provided timber revenues. Outside the project area, this alternative would probably result in a slightly lower population and employment increase relative to the single purpose alternative because of the full development water cost is higher from additional investments in environmental restoration.

d. Preferred Alternative: Phased Development With Environmental Restoration

The phased development with environmental restoration alternative would result in the creation of a similar number of jobs for construction and maintenance of project facilities as the full development alternative. The loss of revenue from the leave of inundated trees would be less in Phase I, than the full development alternative, but would be equivalent in Phase II. Outside the project area, in Phase I, this alternative would produce fewer jobs and would probably result in slower population growth than the single purpose or full development alternatives. This is because Phase I storage is 2,400 ac-ft less than either of the other two water supply alternatives. In Phase II, this alternative would result in population growth and employment equivalent to the full development alternative.

6.2.2 Housing

a. No Action Alternative

The no action alternative would result in no change to existing housing opportunities near the project. Opportunities for housing in areas in South King County, Seattle, and East King County would be reduced under this alternative. The Department of Ecology has limited future surface and ground water withdrawals from areas of South (Soos Creek watershed) and East King County (Sammamish Plateau) and the lack of a reasonable source of future water supply will result in reduced or no future development in these and other areas in the county. The increased cost of water supply from other sources would result in higher property taxes and utility rates resulting in fewer homes at higher prices throughout King County, including Seattle.

b. Single Purpose Water Supply Alternative

The single purpose water supply alternative would result in an increase in the number of homes near the project. These homes would provide housing for the increased number of permanent and seasonal employees required to run the project for water supply. Opportunities for housing in areas in South King County, Seattle, and East King County would be maintained or improved under this alternative. The additional water available from this alternative would provide a reasonably priced source of water for areas of South and East King County and thus enable development to proceed, within constraints of the Growth Management Act, in areas of the county currently without an available future water supply.

c. Full Development Alternative With Environmental Restoration

The full development with environmental restoration alternative would result in a slightly higher number of homes near the project relative to the single purpose alternative. These homes would provide housing for the increased number of permanent and seasonal employees required to run the project for additional purposes of water supply and restoration. Opportunities for housing in areas in South King County, Seattle, and East King County would be nearly equivalent to the single purpose water supply alternative; water supply storage volumes for the two alternatives are the same but the cost of water would be higher due to additional project investment in environmental restoration.

d. Preferred Alternative: Phased Development With Environmental Restoration

The phased development with environmental restoration alternative would probably result in a similar number of houses near the project relative to the full development alternative. These homes would provide housing for the increased number of permanent and seasonal employees required to run the project for additional purposes of water supply and restoration. In Phase I, opportunities for housing in areas in South King County, Seattle, and East King County would be less than either the single purpose or full development alternatives: storage in Phase I is limited to storing Second Supply water which is 22,400 ac-ft less than the other two water supply alternatives. In Phase II, housing opportunities in King County would be equivalent to the full development alternative.

6.2.3 Utilities and Public Services

a. No Action Alternative

The no action alternative would result in no change to existing utilities and public services around the project area and for areas in the Lower Watershed.

b. Single Purpose Water Supply Alternative

The single purpose waters supply alternative would result in no change to existing utilities and public services around the project area and for areas in the Lower Watershed. Some wildlife mitigation sites would be placed in electrical power company ROW's resulting in a change in vegetation management in these corridors.

c. Full Development Alternative With Environmental Restoration

The full development with environmental restoration alternative would result in no change to existing utilities and public services around the project area and for areas in the Lower Watershed. Some wildlife mitigation sites would be placed in electrical power company ROW's resulting in a change in vegetation management in these corridors.

d. Preferred Alternative: Phased Development With Environmental Restoration

The full development with environmental restoration alternative would result in no change to existing utilities and public services around the project area and for areas in the Lower Watershed. Some wildlife mitigation sites would be placed in electrical power company ROW's resulting in a change in vegetation management in these corridors.

6.2.4 Transportation

a. No Action Alternative

The no action alternative will not change the existing transportation networks above, near or below the dam.

b. Single Purpose Water Supply Alternative

The single purpose water supply alternative would require that the existing road over the dam be closed to non-project related vehicles. Currently this road is used by timber companies to access their properties and to haul timber. Closing of this road will not impact the companies' ability to access the south side of the watershed as other roads are available. The pool raise from 1147 ft to 1169 ft would inundate railroad bridge footings and structures, but would not affect structural integrity of the bridge, and would limit access to selected mitigation projects at full pool. Access to these sites would require additional crossings of the railroad. The slight increase in the number of adult salmon and steelhead released in the Upper Watershed would result in a very small increase in traffic along the mainline road from the Diversion Dam to areas above the reservoir by state and tribal fisheries trucks. No change to existing road or railroad traffic is expected below the Tacoma Diversion Dam.

c. Full Development Alternative With Environmental Restoration

The full development with environmental restoration alternative would require that the existing road over the dam be closed to non-project related vehicles. Currently this road is used by timber companies to access their properties and to haul timber. Closing of this road will not limit the companies' ability to access the south side of the watershed as other roads are available. The pool raise from 1147 ft to 1177 ft would inundate railroad bridge footings and structures, but would not affect the structural integrity of the bridge, and would limit access to selected mitigation projects at full pool. Access to these sites would require additional crossings of the railroad. The large increase in the number of adult salmon and steelhead released in the Upper Watershed would result in a limited increase in traffic along the mainline road from the Diversion Dam to areas above the reservoir by state and tribal fisheries trucks. A one week increase in existing road traffic is expected between HHD to the area just below the Tacoma Diversion Dam during hauling of large woody debris from the reservoir to the river in the Palmer/Kanaskat area. In the Lower

Watershed there would be a seasonal increase in truck traffic between Black Diamond and Flaming Geyser State Park as dump trucks haul gravel for placement in the Green River.

d. Preferred Alternative: Phased Development With Environmental Restoration

The phased development with environmental restoration alternative would require that the existing road over the dam be closed to non-project related vehicles. Currently this road is used by timber companies to access their properties and to haul timber. Closing of this road will not limit the companies' ability to access the south side of the watershed as other roads are available. During both phases, the pool raise from 1147 ft to 1167 ft and 1177 ft would inundate railroad bridge footings and structures, but would not affect the structural integrity of the bridge, and would limit access to selected mitigation projects at full pool. Access to these sites would require additional crossings of the railroad. The large increase in the number of adult salmon and steelhead released in the Upper Watershed would result in a limited increase in traffic along the mainline road from the Diversion Dam to areas above the reservoir by state and tribal fisheries trucks. A one week increase in existing road traffic is expected between HHD to the area just below the Tacoma Diversion Dam during hauling of large woody debris from the reservoir to the river in the Palmer/Kanaskat area. In the Lower Watershed there would be a seasonal increase in truck traffic between Black Diamond and Flaming Geyser State Park as dump trucks haul gravel for placement in the Green River.

6.2.5 Recreation

a. No Action Alternative

Under the no action alternative the Upper Watershed would remain undeveloped and closed to public access within the City of Tacoma watershed. Recreational fishing and hunting opportunities would be limited to the highest elevation areas of the watershed, on US Forest Service lands. The Lower Watershed could see reduced recreational fishing opportunities if anadromous fish runs continue to decline because of continued habitat degradation and isolation of the Upper Watershed above HHD. Flow releases from HHD would be unchanged with existing whitewater and casual boating opportunities.

b. Single Purpose Water Supply Alternative

Under the single purpose water supply alternative the Upper Watershed would remain undeveloped and closed to public access within the City of Tacoma watershed. Recreational fishing opportunities would be slightly improved on national forest lands above the Tacoma lands with the increased number of spawning adult salmon and steelhead released in the Upper Watershed: these runs would not be self-sustaining but would require continued hatchery plants of juvenile fish. Bird and wildlife viewing opportunities could improve as a result of expected increases in the numbers of bald eagles, hawks, bear and other wildlife that would come to the river to feed on the salmon carcasses. Recreational hunting of elk would remain unchanged or could decrease slightly if mitigation features are unsuccessful.

The Lower Watershed would have little or no improvement in recreational fishing opportunities as habitat degradation would continue. or sport anglers could actually forego a loss in opportunity if "weaker" Upper Watershed fish runs are protected by reducing all Green River fish harvesting. Whitewater boating opportunities could increase in late spring -- because a fish passage facility would be in place, earlier refill of the reservoir could occur allowing increased flow releases in late spring.

c. Full Development Alternative With Environmental Restoration

Under the full development alternative with environmental restoration the Upper Watershed would remain undeveloped and closed to public access within the City of Tacoma's land ownership. Recreational fishing opportunities would be improved on national forest lands above the Tacoma lands with the large increase in the number of naturally spawning adult salmon and steelhead released in the Upper Watershed. Bird and wildlife viewing opportunities would improve as a result of expected increases in the numbers of bald eagles, hawks, bear and other wildlife that would come to the river to feed on the salmon carcasses. Recreational hunting of elk would remain unchanged or could decrease slightly if mitigation features are unsuccessful.

The Lower Watershed would have an improvement in recreational fishing opportunities as habitat degradation would be reduced, if habitat restoration projects function as planned, and there could be increased angling opportunities in the Palmer/Kanaskat reach from the increased numbers of returning adult salmon and steelhead to the Upper Watershed. However, the spring refill of the full development storage volume, 32,400 ac-ft, presents uncertainty in protecting existing salmon and steelhead runs during critical life stages. If these impacts could not be avoided or minimized, the additional natural salmon and steelhead production benefits from the habitat restoration projects and flow augmentation could be reduced or lost completely. If protection of existing salmon and steelhead was successful, bird and wildlife viewing opportunities would be improved from the increased feeding opportunities for raptors and predatory mammals. Whitewater boating opportunities would decrease during late winter and early spring from the larger reservoir storage capacity in addition to the Second Supply Diversion and should increase slightly during late spring with reservoir operations mimicking natural high flow events. Casual boating opportunities would increase during the summer and fall from the increased low flow augmentation.

d. Preferred Alternative: Phased Development With Environmental Restoration

Under the phased development with environmental restoration alternative the Upper Watershed would remain undeveloped and closed to public access within the City of Tacoma's land ownership. Recreational fishing opportunities would be improved on national forest lands above the Tacoma lands with the large increase in the number of naturally spawning adult salmon and steelhead released in the Upper Watershed. Bird and wildlife viewing opportunities would improve as a result of expected increases in the numbers of bald eagles, hawks, bear and other wildlife that would come to the river to feed on the salmon carcasses. Recreational hunting of elk would remain unchanged or could decrease slightly if mitigation features are unsuccessful.

The Lower Watershed would have an improvement in recreational fishing opportunities as habitat degradation would be reduced and there could be increased angling opportunities in the Palmer/Kanaskat reach from the increased numbers of returning adult salmon and steelhead to the Upper Watershed. Unlike the full development storage volume, the spring refill of phased development storage volume, Phase I volume of 20,000 ac-ft, greatly reduces the uncertainty associated with protecting existing salmon and steelhead: if monitoring and evaluation show that spring refill of volumes beyond Phase I are detrimental, additional storage would be foregone. Bird and wildlife viewing opportunities would be improved as a result of the increased feeding opportunities for raptors and predatory mammals. In Phase I, whitewater boating opportunities would decrease slightly during late winter and early spring from the larger reservoir storage capacity and should increase during late spring with reservoir operations mimicking natural high flow events casual boating opportunities would remain unchanged. In Phase II, whitewater and casual boating opportunities would be the same as the full development alternative.

6.3 GEOLOGY

6.3.1 No Action Alternative

No construction or pool raise would occur under the no action alternative, so no impacts to soils or geologic conditions would occur around the dam or reservoir. Significant seepage along the dam face was noted during the February 1996 flood storage pool, this type of seepage is expected to continue during flood pool events. A slide area is located on the west bank of Charlie Creek. Slides have been occurring at this site for years independent of the reservoir and will probably continue in the future. A second slide occurred after initial reservoir on the east side of the North Fork Green River. Wave erosion accounts for most recent slides along the reservoir shoreline, these slides will continue to occur in the future.
Sediment transport of sand to gravel-sized materials from the upper watershed will continue to accumulate in the reservoir from disruption of the normal sediment transport regime by the dam structure and flood control operations. Floodplain and river areas below the dam will continue to see isolation of the floodplain, downcutting of the single mainstem channel, and armoring of the river bed with larger, coarser substrate materials.

6.3.2 Single Purpose Water Supply Alternative

The single purpose water supply alternative pool raise from elevation 1147 ft to 1169 ft would require reinforcement of the right abutment of the dam to 1169 ft to reduce water seepage and increase abutment stability. A test pool to elevation 1169 ft in year one of construction would be required to assess the full corrective measures necessary to decrease seepage and increase stability of the right abutment. The mitigation fish passage facility would require excavation of dam areas to the left of the existing intake tower.

The single purpose pool raise from elevation 1147 ft to 1169 ft pool raise will probably result in additional earth movement occurring around the reservoir. These movements by area include -- in the North Fork, minor raveling, bank slumping and calving of silt to boulder sized materials might occur; in Eagle Gorge, minor toe calving and slumping are anticipated; in the upper reservoir above Eagle Gorge, renewed slumping may occur along with some mass wasting of sand sediments; in Charley Creek, slip-off slides on bare slopes are expected and a major shoreline slump may occur in the initial pool raise. None of these earth movements is expected to affect project operations for water storage or providing fish passage. Much of the coarser deposited material will remain entrapped in the reservoir, above or within the turbidity pool.

Sediment transport and channel and substrate conditions in the lower river will continue to degrade because of the dam structure and flood control operations. No restoration measures to address this ecological degradation are included in this alternative.

6.3.3 Full Development Alternative With Environmental Restoration

The full development alternative with environmental restoration would require a pool raise from elevation 1147 ft to 1177 ft and would require reinforcement of the right abutment of the dam to 1177 ft to reduce water seepage and increase abutment stability . A test pool (staged, at 10 ft increments) to elevation 1177 ft in year one of construction would be required to monitor groundwater conditions and to design and construct appropriate modifications to the seepage control measures currently in place. Alternatives to decrease seepage and increase abutment stability include: 1) extension of the drainage tunnel; 2) installation of additional feeder wells; 3) horizontal and inclined drains; 4) a positive seepage cutoff wall; and 5) injection grouting. Construction of the restoration fish passage facility will require excavation in the left bank and drilling to provide access for the new 48-inch and fish bypass pipes. Portions of the left bank will require reinforcement of existing rock with bolts, steel sets, and shotcrete as well as drains, grouting and/or wells to control groundwater seepage.

The full development pool raise will result in earth movements similar to the single purpose pool raise. The areas of movement could be different, instead of being limited to reservoir areas to 1169 ft, movement could occur further upstream and at higher elevations resulting from the higher pool elevation, to 1177 ft. None of these earth movements is expected to affect project operations for water storage or providing fish passage. Much of the coarser deposited material will remain entrapped in the reservoir, above or within the turbidity pool.

The full development alternative includes a habitat restoration feature, gravel nourishment, that would annually add 3,900 cu yd (6,500 tons) of gravel in the middle Green River, RM 40-46, which will reduce the current rate of downcutting and bed armoring (700-1,000 lineal ft of mainstem channel per year). This volume of material is considered one-fifth of the estimated maximum pre-HHD bedload of 19,700 cu yd, and should not result in an elevated bed-surface elevation that could effect existing flood control measures further downstream. The sediment size distribution will be from sand to large gravel and will be trucked in from a nearby gravel pit. Angular pit run gravels input at RM 46 are expected to become rounded by abrasion within approximately 2 miles of the input site. Arkosic sandstones from the Puget Group wear quickly and would be expected to decrease in size by up to 20% between RM 46-40 (see *Appendix F, Part F1, Section 4B*). Placement would occur within the active river channel. Transport and redistribution of these unarmored gravels would occur in following fall and winter high flow events. A monitoring plan to track travel distance, redistribution and deposition of added gravels is planned to minimize the risk of downstream aggradation. Annual placement could be reduced or halted if monitoring identified problematic aggradation.

6.3.4 Preferred Alternative: Phased Development With Environmental Restoration

The phased development with environmental restoration alternative would require a phased pool raise from elevation 1147 ft to 1167 ft (Phase I), and from 1167 ft to 1177 ft (Phase II) and would require phased reinforcement of the right abutment of the dam to 1167 ft and 1177 ft to reduce water seepage and increase abutment stability. A test pool (staged at 10 ft increments) to elevation 1167 ft or 1177 ft in year one of construction would be required to monitor groundwater conditions and to design and construct appropriate modifications to the seepage control measures currently in place. Alternatives to decrease seepage and increase abutment stability are listed above in Paragraph 6.3.3. Construction of the restoration fish passage facility will require excavation in the left bank and drilling to provide access for the new bypass pipes. Portions of the left bank will require reinforcement of existing rock with bolts, steel sets, and shotcrete as well as drains, grouting and/or wells to control groundwater seepage.

The phased development pool raise will result in earth movements similar in type, size, and location to the full development purpose pool raise. The timing of movement could be different because of the phased nature of the project or could be limited to effects from the Phase I pool raise, 1167 ft. None of these earth movements is expected to affect project operations for water storage or providing fish passage. Much of the coarser deposited material will remain entrapped in the reservoir, above or within the turbidity pool.

The phased development alternative includes a habitat restoration feature, gravel nourishment, that would annually add 3,900 cu yd (6,500 tons) of gravel in the middle Green River, RM 40-46, which will reduce the current rate of downcutting and bed armoring (700-1,000 lineal ft of mainstem channel per year). Volume, sediment size, placement, and monitoring are the same as the full development alternative Annual placement could be reduced or halted if monitoring identified problematic aggradation.

6.4 AIR AND NOISE QUALITY

6.4.1 No Action Alternative

The no action alternative will not change the existing air quality, noise and lighting characteristics of the area.

6.4.2 Single Purpose Water Supply Alternative

The single purpose water supply alternative will slightly increase air pollutants, noise and light during initial construction and future maintenance activities. The Puget Sound Air Pollution Control Agency (reference Cedar River EIS) does not consider air quality impacts from construction equipment and trucks to significantly increase pollutants over the existing condition. Noise from rock blasting at Howard Hanson Dam may cause temporary discomfort to timber and watershed workers. This activity would occur during the first year of construction. Noise from dam operations and logging trucks currently is moderate, so construction should not significantly increase noise in the area. Lights will only be used if the fish passage facility is operated at night. However, there are currently lights surrounding the existing dam buildings, and the construction activities should not significantly affect the existing condition.

6.4.3 Full Development Alternative with Environmental Restoration

The full development with environmental restoration alternatives will affect air, noise, and light levels similar to the single purpose alternative with slight increases in air pollutants, noise and light during initial construction and future maintenance activities.

6.4.4 Preferred Alternative: Phased Development With Environmental Restoration

The preferred alternative will slightly increase air pollutants, noise and light during initial Phase I construction and future maintenance activities. In Phase II, the same slight increase in air pollutants, noise, and light during can be expected during construction and future maintenance.

6.5 LAND USE

6.5.1 No Action Alternative

No construction or pool raise would occur under the no action alternative, so there would be no change to lands or land use surrounding the dam and reservoir.

6.5.2 Single Purpose Water Supply Alternative

The single purpose water supply alternative would require a pool raise from 1147 to 1169 ft resulting in a change in land use around the reservoir and dam. Although these lands are within the existing flood control inundation zone they are currently owned and managed as forest lands by Tacoma Public Utilities. With the pool raise these lands would become inundated, most of the vegetation would die and these lands would then be managed as part of the summer conservation storage pool. The inundated land would provide snags for wildlife habitat, shoreline rearing habitat for juvenile salmonids and would be cleared of excess debris on an annual basis.

Terrestrial upland mitigation would result in a land use change on pasture sites from forestry to agriculture. In addition, some wildlife mitigation sites would see a change electric powerline management in ROW's to agriculture. No change in land use is expected for fish mitigation sites.

6.5.3 Full Development Alternative With Environmental Restoration

The full development with environmental restoration alternative would require a pool raise from 1147 to 1177 ft resulting in a greater land use change around the reservoir and dam than the single purpose alternative. These flooded lands would provide the same habitat functions, snags for wildlife and shoreline rearing habitat for salmonids, as under the single purpose alternative. Terrestrial upland mitigation would result in a greater land use change for pasture sites from forestry to agriculture under this alternative vs the single purpose alternative. Some fisheries restoration and mitigation sites in the Lower Watershed would require a change in land use from forestry and/or agriculture to fish and wildlife habitat. These sites are located in the historic floodplain and are virtually unmanaged.

6.5.4 Preferred Alternative: Phased Development With Environmental Restoration

The phased development with environmental restoration alternative would require a pool raise from 1147 ft to 1167 ft (Phase I) and to 1177 ft (Phase II) resulting in a lesser or equivalent land use change around the reservoir and dam compared to the full development alternative. These flooded lands would provide the same habitat functions, snags for wildlife and shoreline rearing habitat for salmonids, as under the full development alternative. Terrestrial upland mitigation would result in a lesser or equivalent land use change for pasture sites from forestry to agriculture under this alternative compared to the full development alternative. Some fisheries restoration and mitigation sites in the Lower Watershed would require a change in land use from forestry and/or agriculture to fish and wildlife habitat. These sites are located in the historic floodplain and are virtually unmanaged.

6.6 CULTURAL RESOURCES

6.6.1 No Action Alternative

a. Pre-History

Pre-historic sites are located below elevation 1147 feet. The no action alternative will not affect these sites.

b. Historical

The four historic sites were nominated for listing on the National Historic Register, but did not qualify. The no action alternative would not affect these sites nor their eligibility for listing.

6.6.2 Single Purpose Water Supply Alternative

a. Pre-History

All pre-historic sites are located below elevation 1147', and would not be affected by the pool raise.

b. Historical

Several historic sites exist above elevation 1147'. These were evaluated for potential listing on the National Register of Historic Places, but none had sufficient integrity to be eligible, due to extensive disturbance resulting from river erosion, historic period razing and demolition, recent period demolition and construction, and removal of standing structures. Thus, a pool raise would further destroy the integrity of these sites. However, no mitigation is required due to the ineligibility of these sites for historic register listing or preservation.

6.6.3 Full Development Alternative With Environmental Restoration

a. Pre-History

All pre-historic sites are located below elevation 1147 feet, and would not be affected by the pool raise.

b. Historical

Several historic sites exist above elevation 1147'.These were evaluated for potential listing on the National Register of Historic Places, but none had sufficient integrity to be eligible, due to extensive disturbance resulting from river erosion, historic period razing and demolition, recent period demolition and construction, and removal of standing structures. Thus, a pool raise would further destroy the integrity of these sites. However, no mitigation is required due to the ineligibility of these sites for historic register listing or preservation.

6.6.4 Preferred Alternative: Phased Development With Environmental Restoration

a. Pre-History

All pre-historic sites are located below elevation 1147', and would not be affected by the pool raise

b. Historical

Several historic sites exist above elevation 1147'.These were evaluated for potential listing on the National Register of Historic Places, but none had sufficient integrity to be eligible, duc to extensive disturbance resulting from river erosion, historic period razing and demolition, recent period demolition and construction, and removal of standing structures. Thus, a pool raise would further destroy the integrity of these sites. However, no mitigation is required due to the ineligibility of these sites for historic register listing or preservation.

6.7 NATIVE AMERICAN RELATIONSHIPS AND ISSUES

6.7.1 No Action Alternative

The Muckleshoot Indian Tribe (MIT) entered into an agreement with the City of Tacoma, that removes MIT's objection to Tacoma's planned withdrawal of an additional 100 cubic feet per second (cfs) of water from the lower Green River for the Pipeline 5 (Second Water Supply) project. The agreement calls for Tacoma to: 1) fund the construction and operation of a new tribal fish production facility (Fish Restoration Facility); 2) construct fish passage facilities both upstream and downstream at Tacoma's Palmer Diversion Dam; and 3) curtail the use of Tacoma's Pipeline 1 water right (First Diversion), if necessary, to meet the minimum instream flow targets, as defined in the agreement. Through mutual agreement, Tacoma and MIT have the option to consider foregoing construction of the Fish Restoration Facility; if this decision is made, MIT has the prerogative to choose between monetary compensation or the Fish Restoration Facility. The No Action alternative may adversely affect Tacoma's ability to meet the terms of this agreement, and would strain the relationship between MIT and Tacoma, as well as between MIT and the Corps of Engineers, as the Corps is an active partner in the Additional Water Supply project, and equally responsible for the success or failure of the project.

6.7.2 Single Purpose Water Supply Alternative

This alternative is solely to increase Tacoma's municipal and industrial water supply, as well as constructing fish passage facilities. This alternative would not result in improved ability to meet minimum instream flow criteria, and would not meet some tribal objectives, and would likely result in strained tribal to sponsor relationships.

6.7.3 Full Development Alternative With Environmental Restoration

The full development alternative would result in undefined impacts to fisheries, for which there is much uncertainty regarding the likely ability of proposed mitigation and restoration plans to offset the adverse effects of the project. The MIT has expressed objection to this alternative, and its implementation would strain relations between the tribe and the sponsors (including the Corps).

6.7.4 Preferred Alternative: Phased Development With Environmental Restoration

This is the alternative the tribe is expecting, though they have not formally accepted the project. In particular, the tribe has expressed its opposition to implementation of Phase II, due to the uncertainty of our ability to offset the adverse effects resulting from a pool raise to 1177', as well as (probable) reduced ability to meet minimum instream flow criteria. It is expected that implementation of the preferred alternative would be acceptable to the tribe, with the understanding that implementation of Phase II would be postponed until it could be shown that restoration and mitigation measure could offset the adverse effects

6.8 WATER RESOURCES

6.8.1 GROUNDWATER

a. No Action Alternative

There would be no change in groundwater resources around the project under the no action alternative. In the Lower Watershed, without a spring/summer water storage reservoir TPU would have to invest in alternative storage facilities. One option would include injection of diverted Green River surface water into groundwater aquifers in South King County or Pierce County.

b. Single Purpose Water Supply Alternative

Under the single purpose water supply alternative there would be a change in groundwater resources in the vicinity of the dam. The pool raise from 1147 to 1169 ft will increase groundwater recharge and would raise the groundwater table in the porous sediments of the glacial/fluvial North Fork Green River valley and could increase groundwater seepage at the dam.

c. Full Development Alternative With Environmental Restoration

Under the full development with environmental restoration alternative there would be a greater change in groundwater resources in the vicinity of the dam relative to the single purpose water supply. The pool raise from 1147 to 1177 ft will increase groundwater recharge and would raise the groundwater table in the porous sediments of the glacial/fluvial North Fork Green River valley and would increase groundwater seepage at the dam at up to 42.8 cubic feet per second. A variety of corrective measures are available to decrease seepage through the right abutment (see Paragraph 6.3 above). Additional right bank seepage corrective actions maybe necessary once the pool raise has been completed. Cost of these actions may ultimately limit the final pool raise to something less than elevation 1177 ft.

d. Preferred Alternative: Phased Development With Environmental Restoration

Under Phase I of the phased development with environmental restoration alternative there would be a smaller change in groundwater resources in the vicinity of the dam relative to the full development alternative. The pool raise from 1147 to 1167 ft will increase groundwater recharge and would raise the groundwater table in the porous sediments of the glacial/fluvial North Fork Green River valley and would increase groundwater seepage at the dam. In Phase II groundwater recharge and dam seepage would be similar to the full development alternative.

6.8.2 Surface Water

a. No Action Alternative

Upper Watershed
The no action alternative would result in no change in existing surface waters above or within the project area. Stream courses would be unaffected, no future surface water diversions are planned, nor would the existing reservoir be enlarged for additional water storage.

Lower Watershed
The no action alternative would result in little or no change in surface waters below the dam. Stream and river flows from the dam to the Middle Green River would be largely unaffected as no future surface water diversions are planned. Peak flows could continue to be intercepted, stored in the reservoir and released to allow no more than 10,000 cfs on an increasing hydrograph and a maximum of 11,000 cfs on the declining limb of the hydrograph. Stream and river flow in the Lower Green River will continue to degrade as development continues increasing the amount of impervious surfaces, reducing riparian and wetland areas with resultant changes in higher runoff and lower baseflows.

b. Single Purpose Water Supply Alternative

Unlike the full development and phased development alternatives, the impacts from storing the single purpose water supply have not been evaluated and only simple illustrations of physical changes are described here.

Upper Watershed
The single purpose water supply alternative would result in a change in the surface waters within the reservoir. The pool raise from 1147 to 1169 ft will inundate approximately 2.1 miles of stream and river habitat. Inflows to the reservoir will remain unchanged, however, water velocities will be reduced and water particle travel time (the amount of time a water particle travels from one point to another) will be greatly increased from the no action alternative. Maximum reservoir surface area will increase 311 acres from 871 acres at 1147 ft pool to 1182 acres at the 1169 ft pool. Maximum reservoir depth will increase 22 ft from 117 ft to 139 ft. Reservoir length (thalweg length or the length of the inundated Green River channel) will increase from 1.0 mile from 4.6 miles total length at 1147 ft to 5.6 miles at 1169 ft. Shoreline length will increase 3 miles from 13.1 to 16.1 miles.

Outflows from the dam would be altered under the single purpose alternative. Assuming a refill period of approximately 100 days (February 15 to May 31) and a constant refill (capture) rate (approximately 225 cfs/day) outflow volume would be reduced 113 cfs per day (from baseline condition) during the spring refill period. This capture rate would be in addition to the Second Supply Diversion Rate of 100 cfs per day. Outflow volume would be increased by 100 cfs for 113 days during the summer conservation season, June 1 to mid September.

Lower Watershed
Surface waters in the lower river would be altered under the single purpose water supply alternative. The 113 cfs reduction in flow from the dam during spring refill will reduce river height (stage), river width, river depth, flow volume, and increase water particle travel time from the dam to the mouth of the river, over 64 miles of river. The 100 cfs increase in flow from the dam during the summer will increase stage, river width, flow volume, and increase water particle travel time from the dam to the Tacoma Diversion, over 3.5 miles of river.

c. Full Development Alternative with Environmental Restoration

This alternative, along with the baseline condition and the phased development alternative were evaluated through modeling conceptual refill strategies using the 32 year historic hydrologic database (1964-1995). This alternative is considered equivalent to the full Phase II storage volume and resultant outflow releases. Figure 6-1 illustrates the change in reservoir pool elevation and total storage volume for the no action (acronym of base), full development (acronym of PH-2), and the phased development (PH-1 and PH-2) alternatives by half-month using the average pool elevation and storage volume for the 32 years of record

Upper Watershed
The full development with environmental restoration alternative would result in a larger change in the surface waters within the reservoir than the single purpose alternative. The pool raise from 1147 to 1177 ft will inundate approximately 2.9 miles of stream and river habitat. Inflows to the reservoir will remain unchanged, however, water velocities will be reduced and water particle travel time (the amount of time a water particle travels from one point to another) will be even more increased from the no action alternative. Maximum reservoir surface area will increase 383 acres from 871 acres at 1147 ft pool to 1254 acres at the 1169 ft pool. Maximum reservoir depth will increase 30 ft from 117 ft to 147 ft. Reservoir length (thalweg length or the length of the inundated river channel) will increase from 1.1 miles from 4.6 miles total length at 1147 ft to 5.7 miles at 1177 ft Shoreline length will increase 4.6 miles from 13.1 to 17.3 miles.

Because of the greatly increased storage volume, 62,400 ac-ft vs 30,400 ac-ft with no action, outflows from the dam would be altered under the full development alternative. The larger storage volume for water supply, 22,400 ac-ft, requires that refill begin earlier, February 15, and proceeds through May or June. The larger volume also provides storage capacity of an additional 9,600 ac-ft for flow augmentation in summer and fall. During spring refill minimum flows would be reduced during March and April and during flow augmentation in fall, flows would be increased from mid-September to the end of November. Median flows would be reduced from mid-February to the end of April and increased during May and September and October. Maximum flows would be reduced from February through April.

Lower Watershed
Surface waters in the Lower Watershed would be altered under the full development alternative relative to the no action and single purpose alternative. Flows in the Middle Green River parallel the changes in flow at the dam. Figure 6-2 illustrates the change in flow volume at Auburn for the no action (acronym of base), full development (acronym of PH-2), and the phased development (PH-1 and PH-2) alternatives by half-month for three hydrologic conditions – 1) minimum flows (90% exceedance); 2) median flows (50% exceedance); and 3) maximum flows (10% exceedance). The reduction in flow from the dam during spring refill will reduce river height (stage), river width, river depth, flow volume, and increase water particle travel time from the dam to the mouth of the river, over 64 miles of river. The increase in flow from the dam for flow augmentation during the late summer and early fall will increase these same metrics over the same stretch of river.

d. Preferred Alternative: Phased Development With Environmental Restoration

Upper Watershed
Phase I of the phased development with environmental restoration alternative would result in a change in the surface waters within the reservoir similar to the single purpose alternative. During Phase II of the project surface waters in the reservoir would be effected similar to the Full Development alternative. The pool raise from 1147 to 1167 ft or 1177 ft will inundate from 1.9 to 2.9 miles of stream and river habitat. Inflows to the reservoir will remain unchanged however, water velocities will be reduced and water particle travel time (the amount of time a water particle travels from one point to another) will be even more increased from the no action alternative. Table 6-2 shows the change in various reservoir measurements from no action (baseline) to the Phase I and Phase II reservoir pools.

Figure 6-1. Modeled (32-years, 1964-1995) half-month average reservoir pool elevation (top figure) and total storage volume (bottom figure) for the No Action (Base), Phase I (PH-1), and full development/Phase II (PH-2) alternatives.

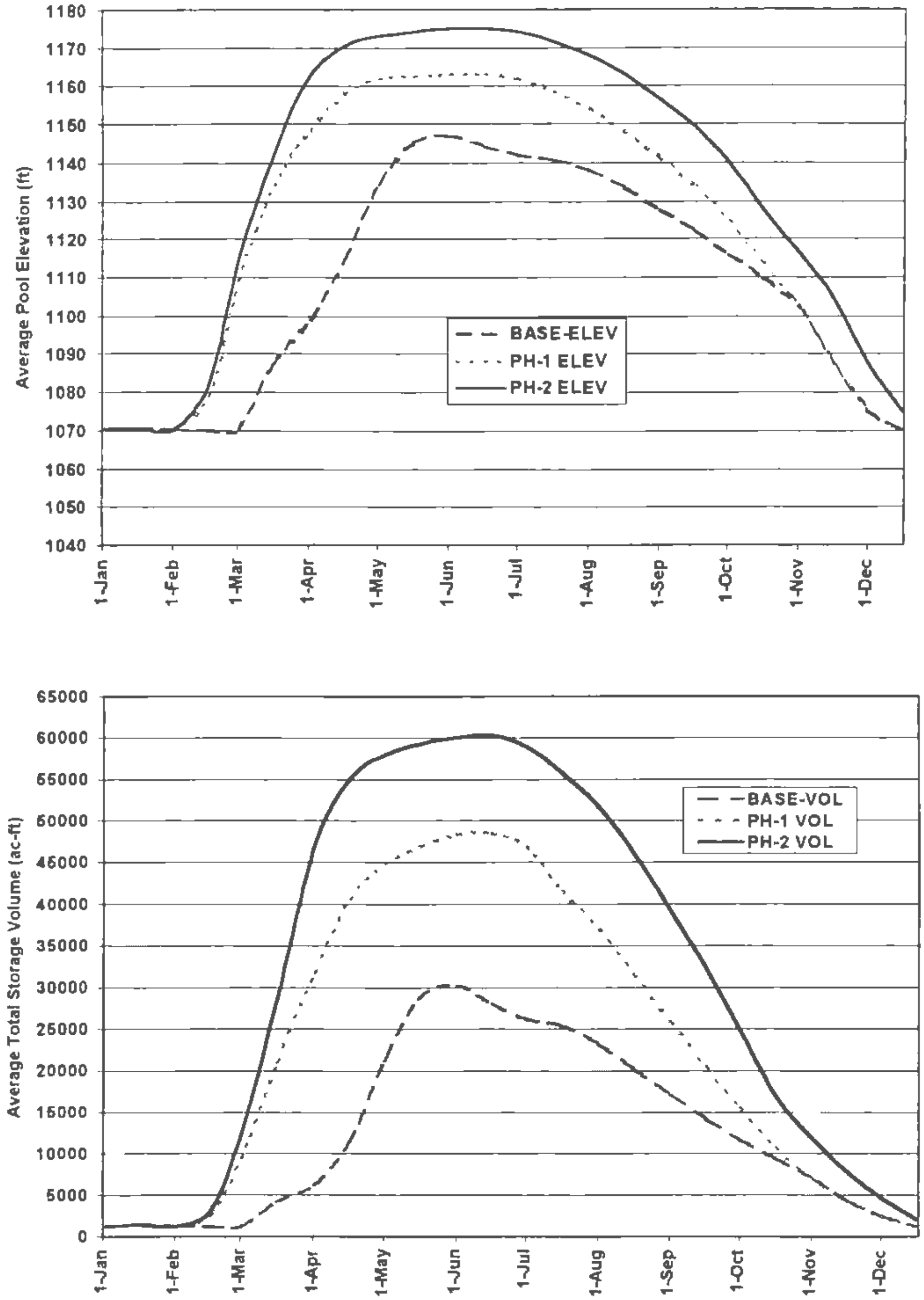
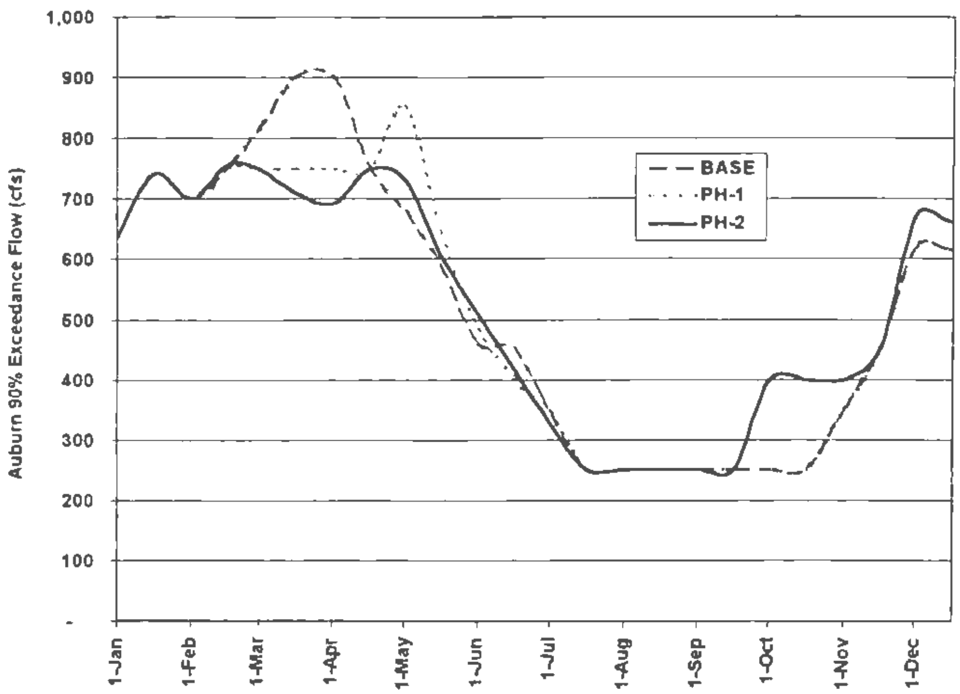


Figure 6-2 (continued on following page). Modeled (32-years, 1964-1995) half-month minimum (90% exceedance, top), median (50%, middle) and maximum (10%, bottom) flows at Auburn for the no action (Base), Phase I (PH-1), and full development/Phase II (PH-2) alternatives.



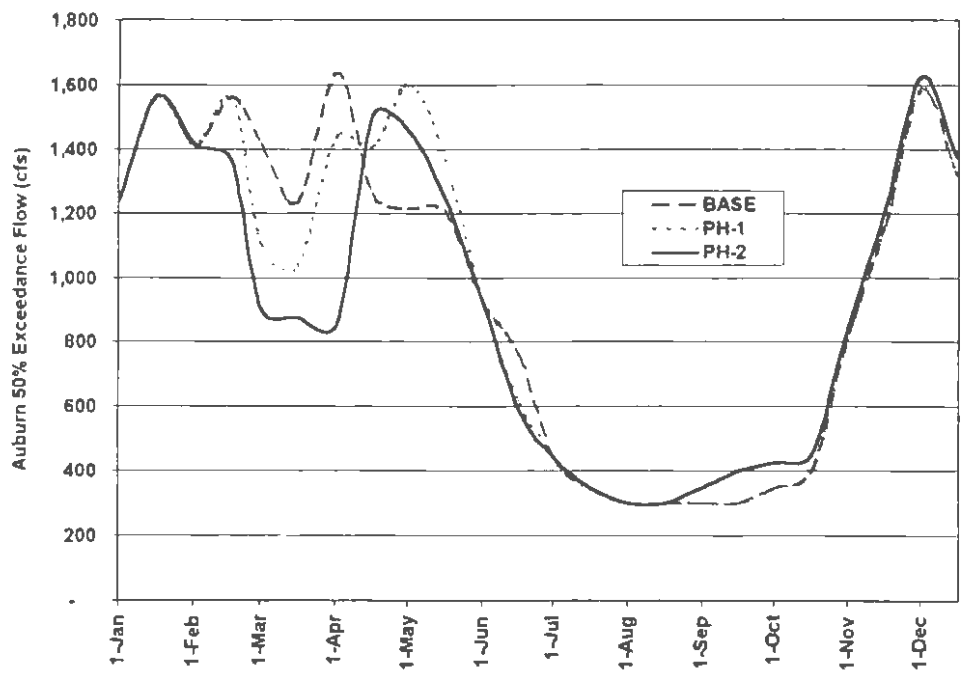


Figure 6-2 (continued from previous page). Modeled (32-years, 1964-1995) half-month minimum (90% exceedance, top), median (50%, middle) and maximum (10%, bottom) flows at Auburn for the no action (Base), Phase I (PH-1), and full development/Phase II (PH-2) alternatives.

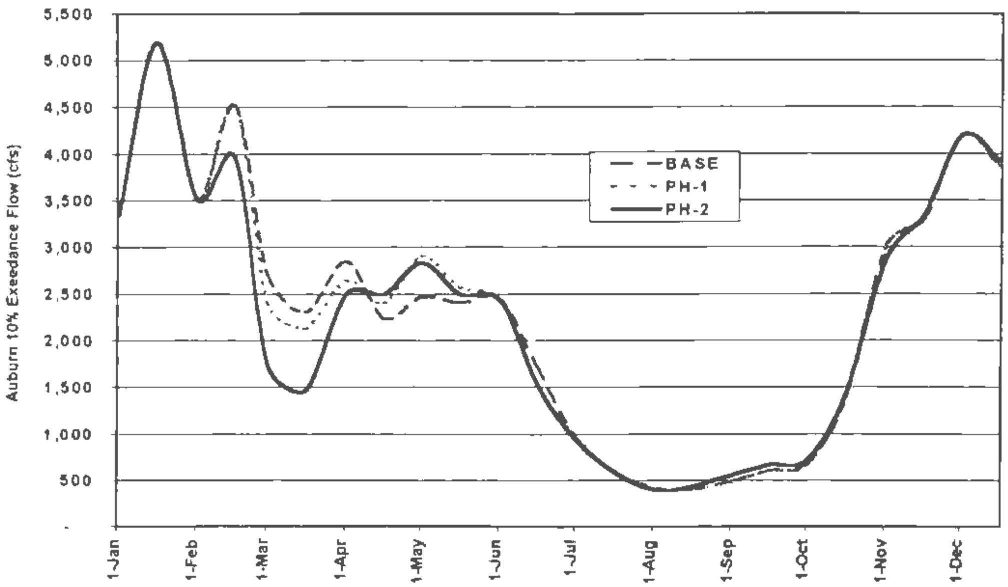


TABLE 6-2. COMPARISON OF THE CHANGE IN VARIOUS RESERVOIR VARIABLES (AT FULL POOL FOR EACH SIZE) GOING FROM THE NO ACTION (BASELINE) TO PHASED DEVELOPMENT ALTERNATIVE (PHASE I AND PHASE II). FOR EXAMPLE, MAXIMUM POOL DEPTH INCREASES FROM 1147 FT (NO ACTION) TO 1167 FT (PHASE I) A 20 FT CHANGE.

Increase in Pool Size	Baseline to Phase I	Baseline-Phase II	Phase I to Phase II
Maximum Pool Depth (ft)	20	30	10
Surface Area (acres)	263	383	120
Reservoir Length (miles)	0.7	1.0	0.3
Shoreline Perimeter (miles)	2.9	4.3	1.4
Total Volume (ac-ft)	20,000	32,000	12,000

Because of the greatly increased storage volume, 50,400 ac-ft (Phase I) or 62,400 ac-ft (Phase II) vs. 30,400 ac-ft with no action, outflows from the dam would be altered under the full development alternative. The larger storage volume for water supply, 22,400 ac-ft, requires that refill begin earlier, February 15, and proceeds through May or June. The larger volume also provides storage capacity of an additional 9,600 ac-ft for flow augmentation in summer and fall. During spring refill minimum flows would be reduced during March and April and during flow augmentation in fall, flows would be increased from mid-September to the end of November. Median flows would be reduced from mid-February to the end of April and increased during May and September and October. Maximum flows would be reduced from February through April.

Lower Watershed
Surface waters in the lower river would be altered under the phased development alternative relative to the no action alternative. Flows in the Middle Green River parallel the changes in flow at the dam. Figure 6.1 illustrates the change in flow volume at Auburn for the no action (base), full development (PH-2), and the phased development (PH-1 and PH-2) alternatives by half-month for three hydrologic conditions – 1) minimum flows (90% exceedance); 2) median flows (50% exceedance); and 3) maximum flows (10% exceedance). The reduction in flow from the dam during spring refill will reduce river height (stage), river width, river depth, flow volume, and increase water particle travel time from the dam to the mouth of the river, over 64 miles of river. The increase in flow from the dam for flow augmentation during the late summer and early fall will increase these same metrics over the same stretch of river.

6.8.3 Water Quality

a. No Action Alternative

The existing project dramatically alters water temperature in the river section immediately downstream of the dam. With the existing outflow ports, withdrawal of water occurs well below the thermocline during the temperature stratified period. The result is that early summer reservoir outflows are significantly colder than the unregulated river would be. Once the cold water below the thermocline is depleted, usually in the first half of August, the outflow temperature increases dramatically. The result is that late summer and fall outflows are significantly warmer than the unregulated river would be. Under the existing project, the downstream river often exceeds state water quality standards in the fall.

The existing project adequately meets state water quality objectives for turbidity.

b. Single Purpose Water Supply Alternative

Water temperature problems downstream of the dam that result from the existing low elevation outlets could be exacerbated with this alternative. Earlier refill of the reservoir each year, combined with greater depth and larger surface area would produce a more developed thermocline. Early summer release temperatures would be even colder than existing conditions; fall temperatures would be even warmer. The mitigation fish passage facility could provide a means to mitigate to for the outflow temperature problems. Project outflows could be blended using the warmer, near-surface fish passage outlet combined with the colder, deeper low-level outlets. However, unlike the restoration alternatives, temperature modeling was not conducted with this single purpose alternative and the modeled performance of such a blended outflow has not been evaluated.

Earlier refill of the reservoir each year would not significantly impact the project's ability to meet state water quality objectives for turbidity.

c. Full Development Alternative with Environmental Restoration

Improved water temperature in the river downstream of the dam would be a benefit of this alternative. Water temperatures problems associated with the existing project would be eliminated or significantly reduced in nearly all years. Early summer release temperatures would follow the natural river temperatures: early summer release temperatures of the existing project are much colder than natural. In the fall, blending of water from above and below the thermocline would allow the project to meet state water quality standards in most years.

Earlier refill of the reservoir each year would not negatively impact the project's ability to meet state water quality objectives for turbidity.

d. Preferred Alternative: Phased Development With Environmental Restoration

Phase I Development. This alternative would have water quality benefits similar to those of the full development alternative: improved water temperature in the river downstream of the dam. Water temperatures problems associated with the existing project would be eliminated or significantly reduced in nearly all years. Early summer release temperatures would follow the natural river temperatures: early summer release temperatures of the existing project are much colder than natural. In the fall, blending of water from above and below the thermocline would allow the project to meet state water quality standards in most years.

Earlier refill of the reservoir each year would not negatively impact the project's ability to meet state water quality objectives for turbidity.

Phase II Development. This alternative would have the water quality benefits of Phase I in addition to Low Flow Augmentation (LFA) of Phase II. LFA provides a slightly deeper, faster-moving river that would remain cooler for a further stretch downstream of the dam than under the existing project.

Earlier refill of the reservoir each year would not negatively impact the project's ability to meet state water quality objectives for turbidity.

6.8.4 Water Management

a. No Action Alternative

The management of HHD is a continually evolving process within the constraints of its authorized purposes. The role of tribal governments, state, and local agencies in the management of Green River and its resources has significantly changed. The Corps has undergone a general shift from a rigid operation procedure to a more adaptive management approach and is currently involved with other agencies in their resource management activities.

Flood control is clearly the first priority of the operation and management of HHD during the winter flood season and is largely inflexible. The flexibility in the Congressional authorization lies in the operation of HHD during refill for conservation storage. Water management is more complex after the end of the flooding season. During the spring, the project switches from its primary role (flood storage) to its secondary role (conservation storage for low flow augmentation). The formation of the annual water control plan typically begins in March, though the actual date depends on seasonal and weather factors. During the switch from flood to conservation storage, the amount of water released from HHD is reduced below the level of inflows allowing the project to refill.

Conservation storage operation involves a dynamic set of daily, weekly, and seasonal adjustments to releases, from the Project, designed to meet the variety of needs for water resources in the Lower Watershed. Discharges are adjusted to reflect changing weather and inflow conditions to assure reliability in reservoir storage and to provide instream flows to protect fisheries resources. Additional discharge adjustments may be made following community requests for specific instream flows for community activities (such as streambank clean-up programs); provide white water recreation opportunities; and to respond to emergency requests for instream flow changes (such as during search and rescue operations). These additional flow adjustments for community purposes are only made following coordination with and evaluation by the Corps and federal, state, and tribal fishery managers (HHD O&M EIS and HHD Section 1135 PMR).

The current reservoir refill and conservation management strategy was developed as a result of drought conditions in 1992 that resulted in the lowest April through June inflows into the Project since the completion of HHD. Reservoir refill begins generally in mid-April. Refill timing and release rates are based on target instream flows that are adjusted yearly in response to the existing weather conditions, snowpack, the amount of forecast precipitation and biological input from fisheries and other resource managers.

Spring refill of the existing project has two major impacts to fisheries resources. The higher pool elevation reduces the ability of juvenile salmonids reared upstream of the dam to safely exit the dam on their downstream migration to the ocean. The second impact is to Lower Watershed habitat and the survival of fish that use this habitat. Below the project, the amount of mainstem channel and connected floodplain habitats available for use by juvenile and adult fish are dependent on sustained flow releases from the dam. Spring refill can reduce flows thereby disconnecting side channel habitats and entrapping fish as well as dewatering valuable shallow water habitat along the mainstem and desiccating salmon or steelhead eggs. Besides isolation and dewatering of lower river habitat, filling of the reservoir tends to attenuate high flows that would assist in downstream migration of juvenile salmon and steelhead.

b. Single Purpose With Fish Passage For Mitigation

Spring refill of a larger pool would require either an earlier starting date, or a greater capture rate. An earlier starting date would impact Upper Watershed salmonids by reducing the migration rate through the reservoir and possibly the number of fish that survive to the dam. The mitigation fish passage facility has a limited surface flow capacity and is not expected to provide adequate attraction flows to capture the majority of fish that migrate through the reservoir. A greater capture rate would also impact downstream salmonids by further decreasing river flows during the outmigration period.

Water management associated with either earlier refill or greater capture rate would require more attention to detail than with the existing project. There would be a smaller margin for error, as the impact of not filling the pool would be directed toward water supply as well as conservation storage for fish.

c. Full Development Alternative With Environmental Restoration

The impacts to water management would be similar to those of the single purpose alternative, with the additional requirement to account for 9,600 ac-ft of Low Flow Augmentation (LFA) water. Accounting for water would require increased staffing and attention by Corps personnel as well as more coordination and communication with resource agencies to determine into which category portions of the release water belong:

Tacoma's first diversion water right, Tacoma's Second Supply water right, the original 25,000 ac-ft of conservation storage, 9600 ac-ft of LFA water in this alternative, and 5000 ac-ft of 1135 project water (existing). The priority of release would begin with assuring reliability of providing water for meeting 1) minimum year-round baseflows at Auburn (this would require new project authorization for Auburn as the new instream flow reference point; Palmer is currently authorized); 2) the first diversion water right; 3) higher baseflows during spring refill; 4) the second supply water right; and 5) higher baseflows during summer and early fall. Increased staffing would be necessary for selected periods during the spring refill period to assure targeted flow releases are met.

d. Preferred Alternative: Phased Development With Environmental Restoration

Phase I Development. The impacts to water management would be similar to those of the single development alternative. Accounting for water would require increased staffing and attention by Corps personnel as well as more coordination and communication with resource agencies to determine into which category portions of the release water belong: Tacoma's first diversion water right, Tacoma's second supply water right, the original 25,000 ac-ft of conservation storage, and 5000 ac-ft of 1135 project water (existing). The priority of release would begin with assuring reliability of providing water for meeting 1) minimum year-round baseflows at Palmer; 2) the first diversion water right; 3) higher baseflows during spring refill; and 4) the second supply water right. Increased staffing would be necessary for selected periods during the spring refill period to assure targeted flow releases are met.

Phase II Development. Impacts would be the same as for Phase I, but with additional requirement to account for 9,600 ac-ft of Low Flow Augmentation (LFA) water and possible project reauthorization of Auburn as the instream flow reference point to provide minimum year-round baseflows.

6.9 ECOSYSTEM IMPACTS

6.9.1 Terrestrial Resources

a. No Action Alternative

The no action alternative will not result in any changes to the ecosystem – sediment transport would remain disrupted with a continued decline in mainstem habitats below HHD, minimum instream flows will be limiting during drought years, and stream habitat of the Upper Watershed would remain isolated from anadromous fish.

b. Single Purpose Alternative

Impacts to terrestrial and aquatic habitat areas around the reservoir would be nearly identical to those in Phase I of the preferred alternative. Impacts to instream and floodplain habitats below the dam would be intermediate to those of Phase I and full development alternative.

c. Full Development Alternative with Environmental Restoration

Impacts would be nearly identical to those in Phase II of the preferred alternative.

d. Preferred Alternative: Phased Development With Environmental Restoration

General Vegetation

Upper Watershed
Phase I will result in a 20-foot pool raise affecting 281 acres of terrestrial habitat (including 79 acres of habitat in riparian areas). Phase II will result in an additional 10-foot pool raise inundating an additional 161 acres (including 42 acres of riparian habitat). Impacts to forests will include the following:

Loss of these habitats will adversely affect most of the species residing in them. Some species are very mobile and utilize several habitats and will suffer less impact than those species that are single habitat specific and less mobile. The habitats with the greatest loss of acreage are mature deciduous forest, mixed forest and emergent wetland. The actual loss of emergent wetland is difficult to predict. About 10 acres will be newly inundated by the Phase I pool raise, and may die as a result of the timing, depth, and duration of inundation. Yet potentially 80 additional acres (of 124 acres) below elevations 1147 feet may be drowned and eventually die. The loss of 14 acres of conifer forest, up to 90 acres of emergent wetland, 7 acres of forested wetland, and 2 acres of shrub-scrub wetlands are considered to be of concern because of their relative scarcity and difficulty to replace. Mitigation targets primarily these habitats, as well as pasture land, as 50% of the existing pasture in the project area (not including the lower quality forage found in power line rights-of-way) would be lost as a result of the pool raise.

Lower Watershed
The additional water storage project is not expected to impact any terrestrial habitat as river flows would not be above the bank or less than current low flows (i.e., no terrestrial habitat would be adversely affected).

Wetlands

Upper Watershed
Emergent wetlands will be the most affected from the proposed project. In Phase I, though only 10 acres will be inundated that are not currently inundated by normal reservoir operation, in all there are 124 acres of emergent wetland below elevation 1147 ft. Of these, 90 acres could die as a result of the greater depth and duration of water. In addition, the reservoir will begin filling about two months earlier than currently, and will be drawn down at about the same time, effectively reducing the growing season for marsh plants to only the late summer and early fall period. This reduced growing period may be inadequate for most plants to survive. In Phase II, no emergent wetlands will be inundated between elevations 1167 ft and 1177 ft, though existing wetlands will be under an additional 10 feet of water resulting in additional losses of about 21 acres. Approximately seven acres of forested wetland will be inundated in Phase I, and an additional five acres in Phase II. Scrub-shrub wetland will be the least affected, with two acres inundated in Phase I and one additional acre inundated in Phase II.

Lower Watershed
There would be no reduction in off-channel habitat area from storage of SSWR in Phase I, with construction of the side-channel restoration project at Kanaskat (see Section 4), an additional 3.4 acres of habitat would be recovered. In Phase II, existing side-channels would receive less river water during spring refill as a result of altered flows from HHD. This could affect terrestrial wildlife in the long term by dewatering of these side channel habitats. The long-term effects of such subtle changes are impossible to quantify. There could be a slight increase in total vegetated area in the floodplain because of the reduced flow volumes during spring refill.

Wildlife

Upper Watershed

Significant Species

This section addresses potential effects to those species addressed in Section 5 (Rocky Mountain elk; black-tailed deer; cougar; northern goshawk, osprey; harlequin duck; and common loon). In addition, for the purposes of mitigation, a Habitat Evaluation Procedure (HEP) analysis was performed using four target species to represent most other species that could be affected by the loss of key habitats. Those four species are Rocky Mountain elk; pileated woodpecker; red-backed vole; and wood duck.

<u>Rocky Mountain elk</u>
Elk graze on the upland grass meadows in the old McDonald field near the reservoir and the emergent wetland vegetation near the reservoir. Inundation of roughly 12 acres of grass meadows and up to 90 acres of emergent wetlands would result in loss of these forage areas. This loss represents approximately 56% of the foraging habitat for elk near the reservoir. Some forested areas where elk gain thermal protection as well as hiding

cover (particularly in those areas close to the pastures) will also be lost to inundation. Resource agencies have expressed concern that calving areas and migration corridors could be located in the inundation zone, and may be lost or impacted by the pool raise. However, no studies have been conducted to confirm the existence of these areas. An assumption was made, based on past experience that most elk calving areas are located in dense timber or brushy habitat, that there is little likelihood that such areas would be inundated by the pool raise (less than one acre of young conifer forest—the most likely calving habitat in the area—would be inundated during Phase I; and 14 acres would be inundated in Phase II). Migration corridors often follow shorelines; with a pool raise, it is assumed that the migration corridor would simply be raised with the raised shoreline. However, it has been suggested that an impassable situation could exist (steep slope, for example) at the new shoreline elevation that movements along the shoreline could be impaired. Aerial photographs and contour maps were examined, and much of the reservoir shoreline has been visited. No obvious obstacles were found, other than those that already exist at the current full reservoir elevation.

Black-tailed Deer
In contrast to elk, deer tend to be browsers instead of grazers; that is, they eat twigs and young shoots of shrubs and trees, supplementing their diet with grasses and other herbaceous plants (forbs). Elk tend to eat primarily grasses and forbs, and supplement their diet with young shoots, especially in the spring. Thus, the loss of pasture and sedge meadows will not result in the severity of impact to deer as it will to elk. The loss of forest might seem to be a severe impact to deer, except that the loss of forest, on a relative scale, is actually far less than the relative loss of pastures and sedges (56% loss of elk grazing habitat versus 15% deer browsing habitat). Thus, black-tailed deer, while suffering habitat loss, are not expected to be impacted greatly by Phase I and Phase II pool raises.

Cougar
The Washington Department of Fish and Wildlife has conducted population studies of cougar in the Green River Watershed for several years. They have found very high densities of cougar, perhaps the highest in the US The main prey of cougar in the watershed are Rocky Mountain elk. Until recently, elk have been a dependable food source; in the past two to three years, however, the number of calves in the watershed has declined each year, and the herd seems to be getting smaller. Mitigation for the project is focused on restoring the elk population, which would therefore also benefit cougar. Thus, cougar will lose some habitat, but the population is not expected to suffer significant losses. The impact to cougar in Phase II would be less than the impact of Phase I, as elk and deer are expected to be impacted less in Phase II than in Phase I.

Northern Goshawk
The pool raises will result in the loss of potentially viable future habitat for goshawks, more so in Phase I than in Phase II. Continued logging in the remainder of the watershed will only make the habitat less suitable for northern goshawk. Tacoma maintains mid- to

late-successional stands of forest near the reservoir and upper Green River. Northern goshawks may nest on Tacoma lands, though nests have not been recorded. The loss caused by the pool raises thus is significant in that these are some of the older forests remaining in the watershed. On the other hand, the area owned by Tacoma is a very small percentage of lands in the watershed, and the current area of viable northern goshawk nesting habitat is marginal at best. The pool raises would make the possibility of nesting by northern goshawks less likely.

Osprey

The pool raises will not result in the loss of nest trees for ospreys. On the contrary, since most or all of the trees in the inundation zone will not be cut prior to the pool raises, ospreys will find a wealth of dead snags close to the reservoir as potential nest sites. Combined with the restoration of the salmon runs in the upper watershed, osprey are expected to greatly benefit from both phases of the project.

Harlequin Duck

This species nests along swiftly flowing streams, under overhanging banks or in cavities among the large rocks. The enlargement of the reservoir and loss of streams will result in a loss of potential nesting habitat for harlequin ducks.

Common Loon

The pool raises will result in an enlarged reservoir, adding foraging habitat for common loons. The restoration of anadromous fish runs will increase the prey base for this species. Thus, common loons are expected to benefit as a result of project implementation.

Pileated woodpecker

Large snags suitable for pileated woodpecker nesting habitat are found in the mature mixed forest stands and forested wetland habitat. Mature conifer and deciduous forest stands do not presently contain an optimal number of large snags, but are expected to develop large snags over time. In Phase I, inundation of about 14 acres of these stands will impact pileated woodpeckers by preventing their long term future use. In Phase II this loss will be 6 acres. In both phases, however, the trees that aren't cleared from the inundation zone will die and provide forage and potentially some cavity locations for pileated woodpeckers for several years.

Red-backed vole

The red-backed vole depends on coniferous forest habitat with large diameter trees and woody debris. The existing mature forests in the project area do not presently support large amounts of woody debris and thus are not optimum red-backed vole habitat. The amount of woody debris (and corresponding habitat) is expected to increase over the 50-year analysis period. The pool raise will inundate a small amount of suitable red-backed habitat.

Wood duck
Wood ducks nest in forested wetlands, requiring large diameter snags near open water, particular canopy cover, and access to aquatic plants and floating logs. The forested wetlands currently present in the project area do not provide optimal habitat based on canopy cover and availability of snags. Nevertheless would ducks have been observed on ponds adjacent to the reservoir during the breeding season. About 7 acres of forested wetlands would be inundated during Phase II. All trees and other vegetation at the ponds would die as a result of inundation, and the ponds would no longer be viable nesting habitat.

Lower Watershed
No impacts to the above significant terrestrial wildlife species are expected in the lower watershed.

6.9.2 Aquatic Resources

The goals of the AWSP for aquatic resources are – 1) to have no net loss of lower watershed habitat while maintaining existing anadromous salmonid populations; 2) restore selected aquatic habitat limiting factors of the lower watershed; and 3) restore natural, self-sustaining runs of anadromous salmonids in the Headwaters watershed.

6.9.2.1 Aquatic Habitat

Additional changes to groundwater, surface water, and water quality characteristics are described in Paragraph 6.8.

a. No Action Alternative

Upper Watershed
The no action alternative would not result in any change in the Upper Watershed or around the project area. The current 7.7 miles of stream and riparian habitat will continue to be inundated by the dam and reservoir up to the seasonal full pool of 1147 ft elevation. Coarse sediment (gravel size and larger) transported into the reservoir by high flows will continue to accumulate and aggrade in the reservoir.

Lower Watershed
Aquatic habitat in the Lower Watershed will remain unchanged under the no action alternative. Sediment entrapment behind the dam disrupts transport downstream and will continue to result in bed armoring with a loss of spawning gravels in the Middle Green River at a rate of 700-1,000 lineal ft per year. The disruption of sediment transport is accompanied to the dampening of peak flows releases from the dam. This reduction in peak flows and sediment transport continues the process of downcutting and isolation of the mainstem river channel from the floodplain. Low flows in the Middle and Lower Green River are not improved, continued development in suburban and urbanizing upland

areas continue the decline in summer baseflows and degraded water quality. Water temperatures below HHD continue to experience unriatural fluctuations with colder temperatures (than ambient) in early summer and elevated temperatures in late summer.

b. Single Purpose Water Supply Alternative

Upper Watershed
The single purpose water supply alternative would result in a change in riparian and stream habitat around the project area. In addition to the current inundation of 7.7 miles of stream and riparian habitat, the pool raise to 1169 ft will inundate an additional 2.1 miles of riparian and stream habitat. This equates to 86.6 acres of riparian habitat and 12.7 surface acres of stream habitat. There would be no change in sediment transport.

Lower Watershed
Certain aspects of aquatic habitat in the Lower Watershed will change under the single purpose alternative. Water temperatures will be improved from HHD to the Kanaskat river reach. Habitat area and volume throughout the mainstem river will be reduced during spring refill including 1) steelhead spawning area and wetted depths; and 2) dewatering of side-channel and mainstem margin habitat: in comparison to Phase I, the single purpose alternative will result in a greater reduction in available side channel habitat, steelhead spawning and egg incubation success, and decrease the survival of juvenile salmon and steelhead migrating to ocean.. There would be a slight increase in mainstem river habitat during the summer from the Diversion Dam to HHD. There would be no change in sediment transport.

c. Full Development Alternative with Environmental Restoration

Upper Watershed
The full development with environmental restoration would include a state of the art fish passage facility which would provide the critical link in reconnecting the Upper and Lower Watersheds for use by salmon and steelhead. In addition, because of the pool raise there would be a change in riparian and stream habitat around the project area. In addition to the current inundation of 7.7 miles of stream and riparian habitat, the pool raise to 1177 ft will inundate an addition 2.9 miles of habitat. This equates to 121 acres of riparian habitat and 17.5 surface acres of stream habitat. There would be no change in sediment transport. Additional changes to reservoir metrics, groundwater, and other surface water characteristics are described in Paragraphs 6.8.1 to 6.8.3. All impacts would be fully mitigated. In addition to mitigation projects, a single habitat restoration project improving riparian and stream habitat in water courses above the new inundation pool, elevation 1177 ft to 1240 ft, would be implemented: described below in the preferred alternative.

Lower Watershed
Water temperatures will be improved a similar amount from HHD to the Kanaskat river reach. Habitat area and volume throughout the mainstem river and particularly in off-

channel areas would be reduced more during spring refill than under the single purpose alternative. Unlike the single purpose alternative, there would be an increase in mainstem river habitat during the summer and early fall throughout the entire river from low flow augmentation. Sediment transport and salmon spawning habitat would be greatly improved by addition of gravel in the Middle Green River and possibly by adaptive management to reinitiate gravel transport at HHD.

d. Preferred Alternative: Phased Development With Environmental Restoration

Fish passage, summer and fall low flows, sediment transport, and limited stream habitat improvements were identified as restoration opportunities to address aquatic limiting features in the Middle Green, Upper Green, and Headwaters sub-basin areas. Construction of HHD disconnected the Headwaters from the lower Green River basin by creating an impediment to downstream fish passage.

Upstream fish passage facilities will be constructed at the Tacoma Diversion Dam as part of an existing mitigation settlement. Downstream fish passage improvements at HHD constructed as part of the phased alternative complete the reconnection of the Upper Watershed to the Lower Watershed.

Water quantity and water quality in the lower river can limit anadromous salmonid production in most years. The storage of late winter and spring flows for flow augmentation during the summer and fall will increase available habitat for rearing and spawning and can improve water quality as well. Sediment transport of gravel sized materials was altered by the construction of HHD and operation of the project to reduce peak flows during flood season. Sediment augmentation (a.k.a. gravel nourishment) in limited areas of the lower watershed will maintain spawning habitat for salmon and steelhead. The construction of HHD resulted in the degradation of Upper Green River side-channel habitat and inundation of several miles of stream habitat above HHD. Specific habitat improvement projects can improve or restore a portion of this original dam impact.

Upper Watershed

Impacts. The phased development with environmental restoration would result in a change in riparian and stream habitat around the project area. In addition to the current inundation of 7.7 miles of stream and riparian habitat, the pool raise to 1167 ft and 1177 ft will inundate an addition 1.9 or 2.9 miles of habitat. This equates to 79 and 42 acres (121 acres total) of riparian habitat 11.5 and 5.9 (17.4 acres total) surface acres of stream habitat for Phase I and Phase II, respectively. There would be no change in sediment transport. Additional changes to reservoir metrics, groundwater, and other surface water characteristics are described in Paragraphs 6.8.1 to 6.8.3.

Restoration. Under the phased development alternative a state of the art fish passage facility will be implemented in Phase I of the project. To place the Upper Watershed in perspective, and the exceptional benefits that could result from fish passage to the basin, and thereby reconnecting the upper basin habitat to the lower basin habitat, following are some hydrologic facts – 1) the Upper Watershed of the Green River has 220 mi^2 or 45.5% of the 483 mi^2 for the entire basin; 2) there are over 23 miles of mainstem habitat and 27 tributaries (adding 83 accessible stream miles, 159 miles inaccessible); 3) virtually the entire upper Green is unconstrained by levees; 4) very few areas in the upper Green exceed 14° C, which is near the optimum range for growth of most life stages of salmon; 5) upper basin stream habitat is in generally good condition with percent pools ranging from 28-73%; 6) upper basin water quality is rated AA, or excellent, by the Washington Department of Ecology (WDOE). While the quantity of habitat may be different, the total area of the Upper Watershed is nearly equivalent to the Elwha River above the two dams considered for removal.

In addition to reconnection of Upper Watershed habitat to the Lower Watershed with the fish passage facility, a single habitat restoration project was selected. Once the fish passage facility is in place, the larger tributaries and mainstem river adjacent to the reservoir will become major spawning and rearing areas for the re-introduced salmon and steelhead. Even though the Upper Watershed is considered in good condition in comparison to the Lower Watershed, most of the area has been logged and much of the stream and riparian habitats could be improved to provide better quality habitat and assist with the restoration of the natural fish runs. To recreate forest and stream conditions that are found in more mature, undisturbed forest-lands, large structural elements (trees and boulders) will be added to streams and forest management prescriptions such as conifer planting and thinning of small even-aged trees will be implemented in stream corridors from the 1177 ft to 1240 ft elevation.

Lower Watershed

Impacts. In Phase I, habitat area and volume throughout the mainstem river will be similar in comparison to the no action alternative. In fact, timing of refill and use of higher baseflows and artificial freshets could increase connection and area of valuable side channel habitats: modeling results show a net gain of 1.0 acre of side channel habitat over the baseline conditions. There would be no change in mainstem river habitat area during summer and fall. There would be an increase in habitat between HHD and the Diversion Dam from June 1 to mid-September from release of stored M&I water from storage. In Phase II, habitat area and volume throughout the lower river would be reduced in comparison to Phase I or the no action alternative. A total of 8.4 acres of side channel habitat would be dewatered during spring refill. The mainstem width and wetted depth would be reduced during the peak steelhead spawning period. Peak flows would be reduced during the spring refill period. Baseflow targets during spring refill would be the same as Phase I.

Restoration. Under proposed operating regimes in Phase II, 9,600 ac-ft of water will be stored in late winter and spring to augment downstream releases later in the year. Augmenting flows during the summer and early fall alters the flow regime from HHD (RM 64) to the estuary (RM 7) during the period when 1) juvenile salmonids are rearing in the river; 2) steelhead eggs are incubating and fry are emerging, 3) adult chinook and coho salmon are migrating upstream; and 4) chinook salmon are spawning in the river. Flow augmentation can be used to increase summer and fall flows for meeting or exceeding -- 1) minimum flow volumes and depths for adult upstream migration; 2) increasing adult holding habitat; 3) creation of late-summer freshets to draw salmon to preferred upstream spawning areas; 4) meeting preferred fall spawning flows; and 5) potential reduction in stream temperatures that can stress or kill adults, delay spawning, and kill incubating eggs. Flow augmentation can also be used to increase summer baseflows and fall flows which will increase available rearing habitat for juvenile salmon and steelhead with potential improvements in water temperature from increased stream velocities, pool depths, and wetting of side-channel areas (cool-water refugia).

The disruption of sediment transport from the Headwaters watershed due to the interception of almost all course sediment (including gravel) by the original construction of HHD may be causing fundamental changes in the mainstem channel and associated habitats of the Upper to Lower Green River. Gravel nourishment could be used to replenish areas presently deficient of salmon and steelhead spawning-sized sediments and slow or stop the downstream extent of streambed armoring. Three levels of gravel nourishment (3900, 7800, and 11,700 yd^3) were evaluated for the placement in the Middle Green River (RM 46-40.2) under incremental analysis. The smallest amount, 3900 yd^3, was selected based on cost and flood protection impact concerns. To implement this measure, monitoring or sediment transport modeling will be required to evaluate the long-term impacts of this restoration measure. This lowest level of gravel nourishment should maintain 400,00 ft^2 of spawning habitat in the Middle Green River.

In addition to gravel nourishment, two habitat restoration projects were selected for implementation in the Lower Watershed to address original impacts of dam construction and pool inundation that impacted over 8 miles of stream and side-channel habitat. One project is a side-channel reconnection in the Upper Green River sub-basin (below HHD at Kanaskat) that will restore up to 3.2 acres of off-channel habitat. The second project is the collection, transport, and hauling of large woody debris from the reservoir to the river below Tacoma's Diversion Dam for placement. The volume, timing, and placement of large woody would be adaptively managed based on the annual accumulation of wood. The final implementation of the truck and haul and placement of the large woody debris would be dependent on developing a boater safety plan in conjunction with King County.

These projects will interact with the fish passage restoration facility and should help accelerate re-establishment of Headwaters and Upper Green River salmon and steelhead populations.

6.9.2.2 Fisheries

Impacts of the project on the various anadromous and resident species of fish in the Green can include those related to habitat features (side channels), water quantity (flow regime), water quality (primarily temperature and turbidity). Detailed technical reports for each factor are included in Appendix F and are summarized below.

The effect of the project is specific to each life history stage; but species or races of anadromous salmonids with similar life histories may have similar responses. Pacific salmon and steelhead may be considered within the context of two distinct general life history categories: species such as chum salmon which have a relatively short freshwater residence period, and those fish characterized by a relatively long freshwater residence period (e.g., coho salmon, steelhead and sea-run cutthroat trout). Another distinction occurs at the adult stage, salmon spawn from late summer through early winter (September to December) while steelhead spawn during the late winter and early spring (March 1 to end of June).

a. No Action Alternative

Upper Watershed

Sockeye Salmon. No change, sockeye salmon are not considered part of the historical anadromous fish assemblage.

Chum Salmon. No change, chum salmon are not considered part of the historical anadromous fish assemblage.

Coho Salmon. Coho salmon were part of the historical anadromous species found in the Upper Watershed. Since 1982, hatchery raised juveniles have been planted in the Upper Watershed. Under the no action alternative, and in the absence of successful downstream fish passage, juvenile fish planting would likely cease and adult coho would not be released for natural spawning.

Chinook Salmon. Chinook salmon were part of the historical anadromous species found in the Upper Watershed. Since 1982, hatchery raised juveniles have been planted in the Upper Watershed. Under the no action alternative, and in the absence of successful downstream fish passage, juvenile fish planting would likely cease and adult chinook would not be released for natural spawning.

Steelhead. Steelhead were part of the historical anadromous species found in the Upper Watershed. Since 1982, hatchery raised juveniles have been planted in the Upper Watershed and since 1992, from 20-133 adult steelhead have been released above of the dam. Under the no action alternative, and in the absence of successful downstream fish passage, juvenile fish planting would likely cease and adult steelhead would not be released for natural spawning. Unlike coho and chinook salmon, a remnant of the native genetic stock of Upper Watershed steelhead may still exist even following cessation of planting and release activities.

Sea-run Cutthroat. It is presumed that sea-run cutthroat trout were part of the historical anadromous fish species found in the Upper Watershed. It is unknown if a genetic component of the original sea-run population remains in the Upper Watershed.

Dolly Varden/Bull Trout. Bull trout are still a state candidate species for listing, though the Puget Sound population was determined by the FWS as not requiring listing under the federal Endangered Species Act (FR, June 1997). This species was included in the BA as one of special interest to agencies that work in the watershed. The BA determined that, as there are no documented records of bull trout in the watershed, the project would not affect this species.

Pacific Lamprey. No change, Pacific lamprey have not been documented as part of the historical anadromous fish assemblage in the Upper Watershed.

Resident Fish. There will be no change or reduced populations of rainbow and cutthroat trout, habitat conditions will remain as they are and an existing food source, planted juvenile salmon, will cease. Much of the Upper Watershed is closed to public access, current management for game fishing in accessible areas will remain unchanged. Brook trout (non-native char), mountain whitefish, and sculpin populations would remain unchanged.

Lower Watershed

Sockeye Salmon. A small number of sockeye salmon have been observed spawning in the Kanaskat area below the Tacoma Diversion Dam. No change in their population is expected.

Chum Salmon. Chum salmon spawn in the mainstem, side-channels and some larger tributaries in the Middle Green River. Without correction of channel degradation from downcutting and bed armoring chum spawning habitat and will most likely become reduced in the future. Loss of essential habitat could lead to reduced population status.

Coho Salmon. Coho salmon spawn and rear in the mainstem, side-channels, and tributary streams below the Tacoma Diversion Dam. Coho salmon may be affected by channel degradation just as chum, this may reduce their population status.

Chinook Salmon. Chinook salmon spawn and rear in the mainstem, some side-channels, chinook salmon populations included in the NMFS proposed listing of Puget Sound chinook salmon under the Endangered Species Act. The WDFW considered this run healthy following a stock status review in 1993: this assessment was not based on wild spawners and may have little or no relationship to the actual health of wild spawning fish in the system and to the eventual listing or non-listing of Green River chinook salmon as an endangered species. Chinook salmon may be affected by channel degradation just as chum, this may reduce their population status.

Steelhead. Steelhead spawn and rear in the mainstem, a few side-channels, and larger tributary streams below the Tacoma Diversion Dam. Steelhead may be affected by channel degradation just as chum, this may reduce their population status.

Sea-run Cutthroat. The status of sea-run cutthroat trout below Tacoma's Diversion Dam is unknown. No change is expected under the no action alternative.

Dolly Varden/Bull Trout. Char, Dolly Varden and/or bull trout, are sporadically reported in angler catches in the Lower Watershed. No currently known spawning and rearing populations occur in the Green River. No change is expected under the no action alternative.

Pacific Lamprey. Pacific lamprey spawn and rear in the mainstem, most likely in the Lower and Middle Green River. Their current population status is unknown, although Pacific lamprey populations have been declining elsewhere on the west coast. No change is expected under the no action alternative.

Resident Fish. Unlike the Upper Green River, there are over 25 species of resident (freshwater and nonandromous) fish found in the Lower Watershed. Of primary concern to the public and agencies are game species such as rainbow and cutthroat trout. There is a large, healthy population of rainbow and cutthroat trout between HHD and the Tacoma Diversion Dam. No change to resident trout or other freshwater species is expected under the no action alternative.

b. Single Purpose Alternative

Upper Watershed

Coho Salmon. Under the single purpose water supply alternative juvenile fish planting would continue and limited numbers of adult coho would be released for natural spawning in the Upper Watershed. The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 7200 smolts: the USFWS estimated the loss of smolt production by species but provided no overall estimate for adult habitat (Wunderlich and Toal 1992). Mitigation features and the enlarged reservoir surface area could off-set these losses. The fish passage facility would be a mitigation feature, equivalent to alternative 9A4, the Green Peter Gulper, described in Section 3 and the Hydraulics and Hydrology Appendix. With this facility, and the enlarged reservoir, estimated survival through the reservoir and dam would be less than 60%. Such a low survival rate will negate any possibility of self-sustaining runs and will necessitate permanent supplementation of the Upper Watershed run with hatchery fish: it is presumed a limited number of natural spawning adults would be available for release once hatchery brood stock goals were met.

Chinook Salmon. Under the single purpose water supply alternative juvenile fish planting would continue and limited numbers of adult chinook would be released for natural spawning in the Upper Watershed. The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 70,600 smolts. Mitigation features and the enlarged reservoir surface area/shoreline rearing area could off-set these losses. The fish passage facility would be a mitigation feature, equivalent to alternative 9A4, the Green Peter Dam "Gulper", described in Section 3 and the Hydraulics and Hydrology Appendix. With this facility, and the enlarged reservoir, estimated survival through the reservoir and dam would be less than 40%. Such a low survival rate will negate any possibility of self-sustaining runs and will necessitate permanent supplementation of the Upper Watershed run with hatchery fish: it is presumed a limited number of natural spawning adults would be available for release once hatchery brood stock goals were met.

Steelhead. Under the single purpose water supply alternative juvenile fish planting would continue and limited numbers of adult steelhead would be released for natural spawning in the Upper Watershed. The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 1100 smolts. Mitigation features and the enlarged reservoir surface area/shoreline rearing area could off-set these losses. The fish passage facility would be a mitigation feature, equivalent to alternative 9A4, the Green Peter Gulper, described in Section 3 and the Hydraulics and Hydrology Appendix. With this facility, and the enlarged reservoir, estimated survival through the reservoir and dam would be less than 60%. Such a low survival rate will negate any possibility of self-sustaining runs and will necessitate permanent supplementation of the Upper Watershed run with hatchery fish: it is presumed a limited number of natural spawning adults would be available for release once hatchery brood stock goals were met.

Sea-run Cutthroat. No change is expected.

Resident Fish. Under the single purpose water supply alternative the pool raise will reduce the amount of natural spawning and rearing habitat in the watershed. No estimate of the population reduction was made. Habitat mitigation features for lost salmon and steelhead habitat and the enlarged reservoir surface area/shoreline rearing area could off-set these losses. The fish passage facility provides little or no benefit to these species. In fact, the low survival for juvenile salmon and steelhead migrating through the reservoir and dam may require that trout numbers be reduced in selective areas of the river and reservoir as a mitigation feature. Monitoring and evaluation of trout populations would occur before and after inception of the project to assess the impact of these species on migratory fish. Brook trout, found in Page Mill Pond -- a reservoir tributary, would be removed as they are nonnative and a potential predator/competitor of native anadromous and nonanadromous species.

Lower Watershed

Sockeye Salmon. A small run of sockeye salmon spawns in the Kanaskat area below the Tacoma Diversion Dam. The sockeye salmon population is expected to decline under the single purpose alternative. Mitigation for this alternative would be similar to Phase II of the preferred alternative (other than low flow augmentation, which is not considered in this alternative) and could include 1) restoration of off-channel habitat to create more spawning area; 2) addition of gravel to the mainstem channel near Kanaskat; and 3) additional measures to improve instream temperatures if the fish passage facility (alternative 9A4) does not provide adequate temperature blending of surface and deep water releases.

Chum Salmon. Chum salmon spawn in the mainstem, side-channels and some larger tributaries in the Middle Green River. The chum salmon population is expected to decline more than any other species or population under the single purpose alternative: chum salmon are more dependent on higher flows in later winter and spring than any other anadromous species. Impacts to this species would require additional mitigation than that proposed for the full development or Phase II of the preferred alternative: low-flow augmentation is not available for compensation nor are habitat restoration measures available to provide habitat improvements. Mitigation for this alternative would be similar to mitigation and restoration features of Phase II of the preferred alternative (other than low flow augmentation) and could include 1) restoration of additional off-channel habitat to create more spawning area; and 2) addition of gravel to the mainstem channel in the Middle Green River.

Coho Salmon. Coho salmon spawn and rear in the mainstem, side-channels, and tributary streams below the Tacoma Diversion Dam. The coho salmon population is expected to be reduced under the single purpose alternative. Mitigation for this alternative would be similar to Phase II of the preferred alternative (other than low flow augmentation, which is not considered in this alternative) and could include 1) restoration of off-channel habitat to create more spawning area; 2) addition of gravel to the mainstem channel near Kanaskat and in the Middle Green; and 3) additional measures to improve instream temperatures if the fish passage facility (alternative 9A4) does not provide adequate temperature blending of surface and deep water releases.

Chinook Salmon. Chinook salmon spawn and rear in the mainstem, some side-channels, chinook salmon populations included in the NMFS proposed listing of Puget Sound chinook salmon under the Endangered Species Act. The chinook salmon population is expected to be reduced under the single purpose alternative. Impacts to this species would require additional mitigation than that proposed for the full development or Phase II of the preferred alternative: low-flow augmentation is not available for compensation nor are habitat restoration measures available to provide habitat improvements. Mitigation for this alternative would be similar to mitigation and restoration features of Phase II of the preferred alternative (other than low flow augmentation) and could include 1) restoration of off-channel habitat to create more spawning area; 2) addition of gravel to the mainstem channel near Kanaskat and in the Middle Green; and 3) additional measures to improve instream temperatures if the fish passage facility (alternative 9A4) does not provide adequate temperature blending of surface and deep water releases.

Steelhead. Steelhead spawn and rear in the mainstem, a few side-channels, and larger tributary streams below the Tacoma Diversion Dam. The steelhead population is expected to decline under the single purpose alternative. Impacts to this species would require additional mitigation than that proposed for the full development or Phase II of the preferred alternative: low-flow augmentation is not available for compensation nor are habitat restoration measures available to provide habitat improvements. Mitigation for this alternative would be similar to mitigation and restoration features of Phase II of the preferred alternative (other than low flow augmentation) and could include 1) restoration of off-channel habitat to create more spawning area; 2) addition of gravel to the mainstem channel near Kanaskat and in the Middle Green; and 3) additional measures to improve instream temperatures if the fish passage facility (alternative 9A4) does not provide adequate temperature blending of surface and deep water releases.

Sea-run Cutthroat. The status of sea-run cutthroat trout below Tacoma's Diversion Dam is unknown. No change is expected under the no action alternative.

Dolly Varden/Bull Trout. Char, Dolly Varden and/or bull trout, are sporadically reported in angler catches in the Lower Watershed. No currently known spawning and rearing populations occur in the Green River. No change is expected under the single purpose alternative.

Pacific Lamprey. Pacific lamprey spawn and rear in the mainstem, most likely in the Lower and Middle Green River. A reduction in population could be expected under the single purpose alternative. Mitigation requirements for Pacific lamprey have not been identified and would require additional research and evaluation.

Resident Fish. Unlike the Upper Green River, there are over 25 species of resident (freshwater and nonandromous) fish found in the Lower Watershed. Of primary concern to the public and agencies are game species such as rainbow and cutthroat trout. There is a large, healthy population of rainbow and cutthroat trout between HHD and the Tacoma Diversion Dam. A reduction in the population of resident trout is expected under the single purpose alternative.

c. Full Development Alternative with Environmental Restoration

Upper Watershed

Coho Salmon. Impacts and benefits to coho salmon are the same as Phase II of the preferred alternative.

Chinook Salmon. Chinook salmon populations are included in the NMFS proposed listing of Puget Sound chinook salmon under the Endangered Species Act. Impacts and benefits to chinook salmon are the same as Phase II of the preferred alternative.

Steelhead. Impacts and benefits to steelhead are the same as Phase II of the preferred alternative.

Sea-run Cutthroat. The status of sea-run cutthroat trout above Tacoma's Diversion Dam is unknown. No change is expected under the full development alternative.

Dolly Varden/Bull Trout. No currently known spawning and rearing populations occur in the Green River. No change is expected under the full development alternative.

Resident Fish. Impacts and benefits to resident trout and other freshwater fish are the same as Phase II of the preferred alternative.

Lower Watershed

Sockeye Salmon. A small run of sockeye salmon spawns in the Kanaskat area below the Tacoma Diversion Dam. Impacts and benefits to sockeye salmon are the same as Phase II of the preferred alternative.

Chum Salmon. Chum salmon spawn in the mainstem, side-channels and some larger tributaries in the Middle Green River. Impacts and benefits to chum salmon are the same as Phase II of the preferred alternative.

Coho Salmon. Coho salmon spawn and rear in the mainstem, side-channels, and tributary streams below the Tacoma Diversion Dam. Impacts and benefits to coho salmon are the same as Phase II of the preferred alternative.

Chinook Salmon. Chinook salmon spawn and rear in the mainstem, some side-channels, and larger tributaries from the Tacoma Diversion Dam to RM 28. Chinook salmon populations are included in the NMFS proposed listing of Puget Sound chinook salmon under the Endangered Species Act. Impacts and benefits to chinook salmon are the same as Phase II of the preferred alternative.

Steelhead. Steelhead spawn and rear in the mainstem, a few side-channels, and larger tributary streams below the Tacoma Diversion Dam. Impacts and benefits to steelhead are the same as Phase II of the preferred alternative.

Sea-run Cutthroat. The status of sea-run cutthroat trout below Tacoma's Diversion Dam is unknown. No change is expected under the full development alternative.

Dolly Varden/Bull Trout. Char, Dolly Varden and/or bull trout, are sporadically reported in angler catches in the Lower Watershed. No currently known spawning and rearing populations occur in the Green River. No change is expected under the full development alternative.

Pacific Lamprey. Pacific lamprey spawn and rear in the mainstem, most likely in the Lower and Middle Green River. No change to a slight reduction in population status is expected under the full development alternative. Mitigation requirements for Pacific lamprey have not been identified and would require additional research and evaluation.

Resident Fish. Impacts and benefits to resident trout and other freshwater fish are the same as Phase II of the preferred alternative.

d. Preferred Alternative: Phased Development With Environmental Restoration

Upper Watershed

Coho Salmon. Under the phased development with environmental restoration alternative juvenile fish planting would continue in the Upper Watershed until the escapement goal for naturally spawning adult coho salmon is reached. After the escapement goal is met, coho production in the Upper Watershed would be self-sustaining with sufficient numbers of juvenile salmon surviving passage through the dam and reservoir and returning as adults to perpetuate themselves for the life of the project.

The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 6500 smolts in Phase I and 3250 smolts in Phase II, respectively: the USFWS estimated the loss of smolt production by species but provided no overall estimate for adult habitat (Wunderlich and Toal 1992). The riparian and stream habitat inundated will be fully mitigated and these features, along with enlarged reservoir surface area could off-set these losses. Fish passage would be the restoration facility, alternative 9A8 described in Section 4, capable of passing the median daily flow for the majority of the outmigration season; mid-April through October. With this facility, and the enlarged reservoir, estimated smolt survival through the reservoir and dam should approach 90%. Such a high survival rate will enable restoration of self-sustaining runs and will eliminate the need for permanent supplementation of the Upper Watershed run with hatchery fish.

Chinook Salmon. Under the phased development with environmental restoration alternative juvenile fish planting would continue in the Upper Watershed until the escapement goal for naturally spawning adult chinook salmon is reached. After the escapement goal is met, chinook production in the Upper Watershed would be self-sustaining with sufficient numbers of juvenile salmon surviving passage through the dam and reservoir and returning as adults to perpetuate themselves for the life of the project.

The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 64,200 smolts in Phase I and 32,100 smolts in Phase II, respectively. The riparian and stream habitat inundated will be fully mitigated and these features, along with enlarged reservoir surface area could off-set these losses. Fish passage would be the restoration facility, alternative 9A8 described in Section 4, capable of passing the median daily flow for the majority of the outmigration season; mid-April through October. With this facility, and the enlarged reservoir, estimated smolt survival through the reservoir and dam should approach 65%. This survival rate is considered conservative, given that the Corps has little to no information on juvenile chinook survival through impoundments in smaller river basins. Chinook smolts may survive at a much higher rate especially given additional measures that can or will be implemented to improve smolt survival such as 1) leave of all trees along the new reservoir shoreline; 2) use of woody debris in streams above, within, and below the reservoir; 3) mimicry of natural flow fluctuations with natural or artificial freshets; and 4) selective removal of predatory fish if monitoring suggests this is necessary. The estimated survival rate could enable restoration of self-sustaining runs, but there is greater uncertainty with this species relative to coho and steelhead.

Steelhead. Under the phased development with environmental restoration alternative juvenile fish planting would continue in the Upper Watershed until the escapement goal for naturally spawning steelhead is reached. After the escapement goal is met, steelhead production in the Upper Watershed would be self-sustaining with sufficient numbers of juvenile steelhead surviving passage through the dam and reservoir and returning as adults to perpetuate themselves for the life of the project.

The pool raise will reduce the amount of natural spawning and rearing habitat in the watershed with a loss of 990 steelhead smolts in Phase I and 500 smolts in Phase II, respectively. The riparian and stream habitat inundated will be fully mitigated and these features, along with enlarged reservoir surface area could off-set these losses. Fish passage would be the restoration facility, alternative 9A8 described in Section 4, capable of passing the median daily flow for the majority of the outmigration season; mid-April through October. With this facility, and the enlarged reservoir, estimated smolt survival through the reservoir and dam should approach 90%. Such a high survival rate will enable restoration of self-sustaining runs and will eliminate the need for permanent supplementation of the Upper Watershed run with hatchery fish.

Sea-run Cutthroat. No change is expected.

Resident Fish. Under the phased development and environmental restoration alternative the pool raise will reduce the amount of natural spawning and rearing habitat in the watershed. No estimate of the population reduction is available. However, habitat restoration and mitigation features for lost salmon and steelhead habitat and the enlarged reservoir surface area/shoreline rearing area could off-set these losses. The fish passage facility provides little or no benefit to these species. In fact, if survival of chinook salmon migrating through the reservoir and dam is below levels necessary to reach escapement goals, trout numbers may be reduced in selective areas of the river and reservoir as a mitigation feature. Monitoring and evaluation of trout populations would occur before and after inception of the project to assess the impact of these species on migratory fish. Brook trout, found in Page Mill Pond – a reservoir tributary, would be removed as they are nonnative and a potential predator/competitor of native anadromous and nonanadromous species.

Lower Watershed

Sockeye Salmon. A small run of sockeye salmon spawns in the Kanaskat area below the Tacoma Diversion Dam. Under Phase I there should be an improvement in the population status of this run. Water temperatures during late summer and fall will be improved, woody debris would be added at Kanaskat, and the side channel restoration at RM 58-59 will provide a large, protected spawning and rearing area. Also, if adaptive management is successful, gravel movement out of the reservoir could be reinitiated and would provide suitable sized materials for spawning habitat in the Kanaskat reach. Under Phase II, there would be no change or possibly a slight reduction in population status due to reduction of peak flows during spring refill. Low flow augmentation during late summer and early fall could offset this impact.

Chum Salmon. Chum salmon spawn in the mainstem, side-channels and some larger tributaries in the Middle Green River. Under Phase I there should be a slight improvement in the population status of this run. Implementation of gravel nourishment in the Middle Green River should retard and replace suitable sized spawning gravels in this gravel starved reach. If adaptive management is successful, gravel movement out of the reservoir could be reinitiated and would provide suitable sized materials for spawning habitat in the Kanaskat reach: however, it is uncertain whether chum salmon spawn as far as Kanaskat. Spring refill may reduce the benefit from gravel nourishment by decreasing peak flows during the seaward migration of juvenile chum. . Under Phase II, there would be a slight reduction in the population status due to the additional storage of water and further reduction in peak flows further affecting spring migration of juvenile chinook and by dewatering of off-channel habitat. Low flow augmentation during late summer and early fall could offset this impact.

Coho Salmon. Coho salmon spawn and rear in the mainstem, side-channels, and tributary streams below the Tacoma Diversion Dam. Under Phase I there should be a neutral impact to slight improvement in the population status of this run. Water temperatures during late summer and fall will be improved, woody debris would be added at Kanaskat, and the side channel restoration at RM 58-59 will provide a large, protected spawning and rearing area. Also, if adaptive management is successful, gravel movement out of the reservoir could be reinitiated and would provide suitable sized materials for spawning habitat in the Kanaskat reach.

Implementation of gravel nourishment in the Middle Green River should retard and replace suitable sized spawning gravels in this gravel starved reach. Spring refill may reduce this benefit from decreasing peak flows during the seaward migration of juvenile coho. Under Phase II, there would be a slight reduction in the population status due to the additional storage of water and further reduction in peak flows affecting spring migration of juvenile coho and by dewatering of off-channel habitat. Low flow augmentation during summer through early fall could offset this impact.

Chinook Salmon. Chinook salmon spawn and rear in the mainstem, some side-channels and larger tributaries from the Diversion Dam to RM 28. Under Phase I there should be a neutral impact to slight improvement in the population status of this run. Water temperatures during late summer and fall will be improved, woody debris would be added at Kanaskat and the side channel restoration at RM 58-59 will provide a large, protected spawning and rearing area. Also, if adaptive management is successful, gravel movement out of the reservoir could be reinitiated and would provide suitable sized materials for spawning habitat in the Kanaskat reach.

Implementation of gravel nourishment in the Middle Green River should retard and replace suitable sized spawning gravels in this gravel starved reach providing valuable spawning habitat for this mainstem spawning stock. Spring refill may reduce this benefit from decreasing peak flows during the seaward migration of juvenile chinook. Under Phase II, there would be a slight reduction in the population status due to the additional storage of water and further reduction in peak flows affecting spring migration of juvenile chinook and by dewatering of off-channel habitat. Low flow augmentation during late summer and early fall could offset this impact.

Steelhead. Steelhead spawn and rear in the mainstem, a few side-channels, and larger tributary streams below the Tacoma Diversion Dam. Under Phase I there should be a neutral impact to slight improvement in the population status of this run. Water temperatures during late summer and fall will be improved and the side channel restoration at RM 58-59 will provide a large, protected spawning and rearing area. Also, if adaptive management is successful, gravel movement out of the reservoir could be reinitiated and would provide suitable sized materials for spawning habitat in the Kanaskat reach.

Implementation of gravel nourishment in the Middle Green River should retard and replace suitable sized spawning gravels in this gravel starved reach. Spring refill may reduce this benefit from flows during the peak spawning period of adult steelhead. Under

Phase II, there would be a slight reduction in the population status due to the additional storage of water and further reduction in peak flows during spring emigration of juvenile steelhead and by possible dewatering of steelhead redds. Low flow augmentation during late early to mid summer could offset this impact.

Sea-run Cutthroat. The status of sea-run cutthroat trout below Tacoma's Diversion Dam is unknown. No change is expected under the phased development alternative.

Dolly Varden/Bull Trout. Char, Dolly Varden and/or bull trout, are sporadically reported in angler catches in the Lower Watershed. No currently known spawning and rearing populations occur in the Green River. No change is expected under the phased development alternative.

Pacific Lamprey. Pacific lamprey spawn and rear in the mainstem, most likely in the Lower and Middle Green River. No change to a slight improvement is expected under Phase I of the preferred alternative. No change to a slight reduction in population status is expected under Phase II. Mitigation requirements for Pacific lamprey have not been identified and would require additional research and evaluation.

Resident Fish. Under Phase I, resident trout populations should have an improvement in population status for the river areas from HHD to Kanaskat due to the habitat improvements targeted for steelhead and salmon and additional prey and nutrient base provided by the returning salmon. In the Middle Green, again there should be improvement in population status. Under Phase II, no change is expected. No change to other freshwater species is expected under the phased development alternative.

6.9.2.3 Threatened and Endangered Species

a. No Action Alternative

Upper Watershed

The no action alternative will not result in any changes to the ecosystem. Threatened and endangered species would neither be adversely impacted or receive any potential benefit.

Lower Watershed

The no action alternative will not result in any changes to the ecosystem. One proposed species (chinook salmon) may continue to suffer declines as a result of the no action alternative.

b. Single Purpose Water Supply Alternative

Upper Watershed

Impacts to terrestrial and aquatic habitat areas around the reservoir would be nearly identical to those in Phase I of the preferred alternative.

Lower Watershed
Impacts to instream and floodplain habitats below the dam would be intermediate to those of Phase I and full development alternative. In comparison to Phase I, the single purpose alternative will result in a greater reduction in available side channel habitat and decrease the survival of juvenile chinook salmon migrating to ocean.

c. Full Development Alternative with Environmental Restoration

Impacts would be nearly identical to those in Phase II of the preferred alternative.

d. Preferred Alternative: Phased Development With Environmental Restoration

A biological assessment (BA) was prepared that addressed the potential effects of Phase I and II pool raises on bald eagles, gray wolves, grizzly bears, marbled murrelets, spotted owls, spotted frogs, and bull trout. The BA is included in Appendix I. The BA is being revised for future review by NMFS to address chinook salmon, a recently proposed species that occurs within the ROI. The revised BA will be included with the final Feasibility Report/EIS.

Upper Watershed

Bald Eagle
The two pool raises would result in the loss of forest habitat and potential nest sites (though there are no known nests of bald eagles in the project vicinity) as the forests mature. On the other hand, the forest in the inundation zone would not be cleared, resulting in the availability of many snags for perching. Mature forest management planned for mitigation would help to alleviate the loss of the forest habitat.

Food supply is expected to increase following implementation of the project due to the extensive mitigation for anadromous fish in the upper watershed. In particular, the trucking of up to 10,000 adult salmon and steelhead to the Upper Watershed would be a boon to bald eagles in the fall.

No other effects to bald eagles are anticipated.

Gray Wolf
Gray wolves have never been observed in the watershed. The raises in reservoir elevation are not expected to affect gray wolves.

Grizzly Bear
Grizzly bears have never been observed in the watershed. The reservoir raises are not expected to affect grizzly bears.

Marbled Murrelet

One survey of marbled murrelets in the inundation zone was conducted in 1994. Only three sites considered having trees large enough to support marbled murrelet nests are found in the inundation zone. Each of these sites is less than one acre, and one site has only one tree of suitable size. Marbled murrelets have been found to occupy sites with suitable trees of at lease 7 acres (USFS, 1996; Hamer and Nelson, 1995). No marbled murrelets were detected on the 1994 survey; in addition, numerous surveys have been conducted by timber companies, US Forest Service, Department of Natural Resources (DNR), and City of Tacoma in the Green River Watershed, and no detections of murrelets have been made. Thus, the pool raises are not likely to affect marbled murrelets.

Spotted Owl

Spotted owls require large tracts of mature and sub-mature forest for nesting. The Green River Watershed currently has few tracts suitable to support spotted owls. One owl was detected in the Charley Creek drainage in 1989 and 1990. The DNR conducted formal surveys for spotted owls between 1992 and 1994 and found no further evidence of spotted owls in the area. The inundation zone consists primarily of second growth deciduous and mixed forests. Only 14 acres of mature conifer forest would be inundated, and only 49 acres of mature forest are found in the project areas, far less than the 300 acres minimum required to support a pair of spotted owls. The biological assessment determined that spotted owls are not likely to be adversely affected by the pool raises.

Spotted Frog

An amphibian survey in the inundation zone was conducted in 1997. No evidence of spotted frogs was found, though potential habitat for this species exists in the inundation zone. The BA determined that the project is not likely to adversely affect spotted frogs.

Bull Trout

Bull trout are still a state candidate species for listing, though the Puget Sound population was determined by the US Fish and Wildlife Service as not requiring listing under the federal Endangered Species Act (FR, June 1997). This species was included in the BA as one of special interest to agencies that work in the watershed. The BA determined that, as there are no documented records of bull trout in the watershed, the project would not affect this species.

Chinook Salmon

Chinook salmon in Puget Sound have been proposed for listing as a threatened species under the Endangered Species Act (March 10, 1998). A final review and formal listing will occur within the next 12-18 months. This species was included in the BA for review by USFWS as one of special interest to agencies that work in the watershed. The BA is being revised for future review by NMFS to address chinook salmon, a recently proposed species that occurs within the ROI. The revised BA will be included with the final Feasibility Report/EIS. While chinook salmon were historically present in the Upper Watershed, NMFS final review of the status of Green River chinook will determine whether the Upper Watershed is essential or critical habitat. At this time, the Corps cannot provide a determination on project effects for Upper Watershed fish, although the Corps has a conditional letter of support from the Regional Director of NMFS (November 29, 1998).

Lower Watershed
The only terrestrial threatened or endangered species that may be affected in the lower watershed is the bald eagle. The potential impacts are dependent on the condition of anadromous fish stocks following implementation of the modified operations of Phase I and Phase II. Mitigation and restoration measures that will be undertaken (described in Appendix F1) are expected to result in no change to current anadromous fish populations in the river. As a result, bald eagles are not expected to be affected in the lower watershed by implementation of either Phase I or Phase II. (See biological assessment, Appendix I, for more details.)

Chinook Salmon
Chinook salmon in Puget Sound have been proposed for listing as a threatened species under the Endangered Species Act (March 10, 1998). A final review and formal listing will occur within the next 12-18 months. This species was included in the BA for review by USFWS as one of special interest to agencies that work in the watershed. The BA is being revised for future review by NMFS to address chinook salmon, a recently proposed species that occurs within the ROI. The revised BA will be included with the final Feasibility Report/EIS.

Chinook salmon are still present in the Lower Watershed; a stock status review by the WDFW in 1993 considered this one of only two healthy populations of chinook salmon in Puget Sound (SASSI 1993). NMFS has yet to provide final determination on the status and recovery needs for Lower Watershed chinook salmon. At this time, the Corps cannot provide a determination on project effects for Lower Watershed fish, although the Corps has had intense coordination with NMFS staff and received a conditional letter of support from the Regional Director of NMFS (November 29, 1998).

6.10 MITIGATION

6.10.1 Terrestrial Resources

a. No Action Alternative

Upper Watershed
No mitigation is required for the no action alternative.

Lower Watershed
No mitigation is required for the no action alternative.

b. Single Purpose Water Supply Alternative

Upper Watershed
Mitigation for this alternative would be quite similar to that described for Phase I of the preferred alternative (see Paragraph 6.10.4). However, the impacts of this alternative would be slightly greater than those in Phase I of the preferred alternative, so that the mitigation effort would be necessarily greater for this alternative than in Phase I of the preferred alternative.

Lower Watershed
No mitigation would be required for terrestrial resources.

c. Full Development Alternative with Environmental Restoration

Upper Watershed
Full development would have the same impacts as if Phase II of the preferred alternative was implemented. Thus, mitigation would be the same as for Phase II of the preferred alternative, except that it would be implemented immediately instead of in phases.

Lower Watershed
No mitigation would be required for terrestrial resources.

d. Preferred Alternative: Phased Development With Environmental Restoration

Upper Watershed
Mitigation will be accomplished as each project phase is implemented. Mitigation plans are similar for Phase I and Phase II; mitigation measures will simply be added to or placed in different locations for Phase II. The following description is a summary that applies to both phases.

Mitigation for terrestrial resources will be aimed toward particular wildlife species, including multiple-habitat users such as elk, black-tailed deer, and black bear; emergent wetland users such as green-winged teal, mallard, common loon, and red-legged frog; and forested wetland users such as wood duck, hooded merganser, and mink. Of these, elk are the most publicly visible and economically important species, and receive the most attention in the proposed mitigation plan. The mitigation plan is detailed in Appendix F2 and summarized in Section 4 of the DFR. An interagency team of biologists elected to focus mitigation efforts on elk, which is a multiple-habitat user. Elk in the project area use primarily grasslands and mature conifer forest, with lesser use of emergent and forested wetlands, and mixed forests. Thus, mitigation for elk includes creation of several managed pastures, and management of nearly mature forest stands to meet targeted stand conditions for snags, down woody debris, and stand density, to more quickly achieve ecological conditions that are representative of mature forests. Pasture sites were selected in habitats that are currently of low quality or of little value to target species in the project area. These sites include power line rights-of-way, which are regularly cleared of trees and tall shrubs; and young deciduous and coniferous forests.

Management of forests to accelerate the succession toward mature forest characteristics will benefit species that adapted to life in mature conifer forests, including red-backed voles, Hutton's vireos, and accipitrine hawks, including the uncommon northern goshawk, which has been observed three times since 1995 in the project area.

Wetlands will be replaced through planting of sedges in all available low-gradient areas of the reservoir. Columbia sedge (*Carex aperta*) was selected as the primary species as it is the only aquatic plant native to the Northwest US that can tolerate inundation to great depths and duration during the growing season. Tests conducted in Oregon found that this species can tolerate inundation of up to 60 feet in depth for about 6 weeks. However, the plants were not healthy and did not grow; it is hoped that planting to a depth of slightly more than 30 feet these sedges would grow and sustain themselves over time. Columbia sedge would be planted in the zone approximately 10-30 feet in elevation below the projected high pool in each phase. At higher elevations, other species would be planted that can tolerate up to 10 feet of inundation. Inflated sedge (*Carex vesicaria*) and Kellogg sedge (*Carex lenticularis*) will be planted in this upper zone. In Phase II, the 10-foot pool raise, would kill the sedges planted in the upper ten feet during Phase I; so Columbia sedge would be planted in that zone to replace those sedges; then, those other species would be replanted in the upper 10 feet of the Phase II pool.

About 10 acres of forested wetland will be inundated. Mitigation for these types of wetlands is much more difficult due to the complex hydrology and physical and biological structure of forested wetlands. Three sites have been identified as suitable areas to construct subimpoundments. The subimpoundments would be placed on streams or at the base of hillside seeps, such that permanent water would be assured behind the subimpoundments. Aquatic plants, as well as hydrophytic shrubs and trees would be planted to provide food and structure. Full mitigation will not be achieved until the trees have attained similar size and density to those currently present.

Assessment of the level of mitigation required to compensate for the inundated habitats was accomplished through the use of habitat evaluation procedures (HEP). The HEP analysis is summarized in Appendix F2. To simplify analysis, four target species were used to represent the range of species found in the principal habitats being replaced (pastures, mature forest, emergent wetland, and forested wetland). The four indicator species are elk (pastures, mature forest, and emergent wetland); pileated woodpecker (mature forest and forested wetland); red-backed vole (mature forest); and wood duck (forested wetland). These species were selected on the basis of their life requisites and are felt to encompass the majority of habitat features required by all species found in their respective habitats. The analysis enabled decision-makers to determine the number of acres of each habitat type that was needed for full compensation of losses.

Lower Watershed
No mitigation for terrestrial resources is currently planned.

6.10.2 Aquatic Resources

a. No Action Alternative

Upper Watershed
No mitigation for aquatic resources impacted by the original dam construction and operation is currently planned. Tacoma Public Utilities has a an existing mitigation Agreement (Paragraph 1.6.3) for pipeline #5 and the original barrier dam, which includes a fish restoration hatchery, a fish ladder, and a truck and haul program for releasing adult salmon and steelhead into the Upper Watershed. These features would be implemented but they could require a change in emphasis given the lack of adequate downstream fish passage at HHD.

Through the Green-Duwamish Basin Ecosystem Restoration Study, the Corps and King County are studying the feasibility of projects to ameliorate selected aquatic limiting factors in areas below HHD, however, they will not be addressing fish passage at HHD nor additional storage for low flow augmentation.

Lower Watershed
No mitigation for aquatic resources impacted by the original dam construction and operation is currently planned. Under the Green-Duwamish Basin Ecosystem Restoration Study, projects are being studied that could ameliorate selected aquatic limiting factors in areas below HHD, however, this study will not be addressing fish passage at the Tacoma Diversion Dam and HHD nor will it look at additional storage for low flow augmentation.

b. Single Purpose Alternative

Upper Watershed
Mitigation projects for inundated stream and riparian habitat under this alternative would be quite similar to that described for the preferred alternative (see Paragraph 6.10.4). However, the impacts of this alternative would be intermediate to those of Phase I and Phase II of the preferred alternative, so that the mitigation effort would be necessarily greater for this alternative than in Phase I of the preferred alternative.

Mitigation for fish passage would be distinct from the preferred alternative. A smaller, less costly facility would be built under the single purpose water supply alternative. The facility would consist of modifications to the existing intake tower to add a surface level outlet, similar to the Green Peter "gulper", as mitigation for the increased depth of the reservoir. This facility could pass a maximum of 550 cfs, equivalent to the minimum flows during the spring outmigration season of April through June. Since the majority of water would continue to be passed through the low-level outlets the fish collection efficiency of this facility would be low and the survival rate of juveniles migrating passing through the facility is estimated to reflect this, being between 35-60%. This fish passage survival rate is too low to support self-sustaining runs of salmon or steelhead and permanent supplementation of all fish runs with hatchery fish would be required to maintain some level of production: the source of these hatchery fish would either come from the planned fish restoration facility or from existing state or tribal facilities in the Lower Watershed.

Lower Watershed
Mitigation projects for this alternative would be quite similar to that described for Phase II of the preferred alternative (see Paragraph 6.10.4); although low flow augmentation is not an available mitigation choice. However, the impact effect of this alternative would be intermediate to those of Phase I and Phase II of the preferred alternative, so that the mitigation effort would be necessarily less for this alternative than in Phase II of the preferred alternative.

c. Full Development Alternative with Environmental Restoration

Upper Watershed
Full development would have the same impacts on riparian and tributary habitat inundation as if Phase II of the preferred alternative were implemented. Thus, mitigation would be the same as for both phases of the preferred alternative, except that it would be implemented immediately instead of phased.

The magnitude of impact on downstream fish passage from full development would be the same as the preferred alternative, the pool depth and reservoir size would be similar, but the actual effect of the full development may be greater than Phase II of the preferred alternative. Unlike the phased alternative, immediate full development of the additional storage project provides no period of adaptive management with the opportunity to learn (monitor and evaluate) what effects storing additional water has on fish migration and habitat use. Nor does it provide time to implement different operational strategies to avoid or minimize negative effects. Ultimately, this lack of understanding and inability to adapt through progressive stages of additional storage could result in additional fish passage mitigation being required.

Lower Watershed
The magnitude of impact to downstream fish populations and habitats from full development would be the same as if Phase II of the preferred alternative were implemented, the additional storage volume is the same, but the actual effect of the full development may be greater than Phase II of the preferred alternative. Unlike the phased alternative, immediate full development of the additional storage project provides no period of adaptive management with the opportunity to learn (monitor and evaluate) what effects storing additional water has on fish migration and habitat use. Nor does it provide time to implement different operational strategies to avoid or minimize negative effects.

Ultimately, this lack of understanding and inability to adapt through progressive stages of additional storage could result in additional mitigation being required for unavoidable impacts to Lower Watershed resources.

d. Preferred Alternative: Phased Development With Environmental Restoration

Upper Watershed

Mitigation will be accomplished as each project phase is implemented. Mitigation plans are similar for Phase I and Phase II; mitigation measures will simply be added to or placed in different locations for Phase II. Mitigation projects are evaluated by impact and watershed area – 1) fish passage facility, including facility and predator monitoring and evaluation ; 2) flow management; 3) tributary and riparian habitat inundation in the Upper Watershed; 4) side-channel disconnection and steelhead spawning habitat dewatering in the Lower Watershed; and 5) instream survival of migrating juvenile and adult fish. Mitigation and restoration projects developed were either ecosystem function or process driven. The following description is a summary that applies to both phases.

Fish Passage Facility. The fish passage facility is considered a restoration and mitigation feature of the project. To address the original impact of creating a downstream fish passage barrier, building the dam and the spring filling of the conservation pool, building the facility to the height of the existing storage pool (1035 ft to 1147 ft) is considered an ecosystem restoration project. The additional pool height under Phase I (1147 ft to 1167 ft) is considered mitigation attributed to the storage of water for M&I purposes and the additional pool height in Phase II (1167 ft to 1177 ft) is considered mitigation for M&I water and for storage of low flow augmentation water. To assure maximum fish passage efficiency, the fish passage facility will be operated up to 24 hours per day and 7 days per week during selected periods of the refill season. Operation and maintenance of the facility for the first 15 years is considered part of the ecosystem restoration component of the project and is cost-shared between the Corps and the sponsor, after 15 years O&M is considered a requirement of the local sponsor: cost allocation is discussed in the *Economics Appendix*.

The final design for the fish passage facility has been altered to provide the maximum flow capacity through the intake of the facility -- the facility was increased in size from a flow capacity of 400-550 cfs to the current capacity of 400-1250 cfs (to 1600 cfs under certain conditions). The new screened outflow volume represents up to a 300% increase in total flow volume. The Fish Passage Technical Committee recommended the maximum expansion of the facility in consideration of the uncertainty of juvenile fish survival during migration through the enlarged reservoir. Operation and design features of the facility are discussed in Section 4.

Monitoring and Evaluation: Fish Passage Facility and Predators. For steelhead, coho and chinook salmon, up to15 years of outmigrant monitoring is planned under the ecosystem restoration project; after year 15 any monitoring is considered a mitigation requirement.

A sampling station, hydroacoustic monitoring equipment, and a PIT-tag release and evaluation program are major features of the ecosystem monitoring. These monitoring tools are considered integral to the adaptive management plan and are necessary to evaluate the operation of the fish passage facility and reservoir operations (flow management) in relation to the Phase I project objective of maximizing the survival of juvenile fish migrating through the reservoir and dam. The monitoring and evaluation program are discussed in more detail in Section 10 of Appendix F1.

In addition to the monitoring tools listed above, five years of coded-wire-tagging (CWT) of up to 500,000 chinook salmon fry reared in the Fish Restoration Facility and planted in the Upper Watershed will be covered under the restoration monitoring program. Evaluation of the adult returns of the CWT juveniles would be considered the responsibility of the WDFW and/or the Muckleshoot Indian Tribe.

Beginning in 1999, before project construction, two years of monitoring of resident trout and/or avian predator abundance in the reservoir will be conducted. This is a preventative measure to insure successful outmigration of chinook juveniles (the smallest migratory fish). Members of an interagency team of biologists were concerned about the possible increase in predation that may occur at migratory transition points such as the confluence of the tributaries with the reservoir and at the fish passage facility. Monitoring of predators would continue in Phase I and II and would be evaluated in relation to the larger juvenile outmigration study using PIT-tags, hydroacoustics and other sampling methods. If there is an increase in overall predator abundance in response to juvenile migratory presence, a selective predator removal program could be initiated. Such a program would be developed by the appropriate state, federal or tribal fish and wildlife managers and would require coordination with the City of Tacoma. The pre-construction predator monitoring plan will be developed during winter of 1998.

Flow Adjustments and Reservoir Operations. To minimize impacts to fish migrating through the reservoir and to avoid and minimize impacts to downstream fish and habitat a series of flow adjustments were developed and will be applied to operation of the additional storage project. Flow adjustments (refill guidelines and flow targets) were developed to meet project objectives for protecting instream resources, meeting existing conservation storage requirements, and providing reliability for storing additional water for M&I and low flow augmentation. The primary flow adjustments considered during the spring refill period (February 15-June 30) include 1) a maximum refill rate; 2) a minimum baseflow (usually greater than DOE requirements); 3) a river stage decline from May 1 to June 30 to protect steelhead eggs and fry; 4) maintaining natural freshets or creating artificial freshets to speed juvenile migrants downstream; and 5) mimicking the natural temperature regime of the river with blended outflow releases (surface with low-level release). To assure guidelines and targets are met with a high degree of reliability reservoir operations and flow releases will be managed for selected periods up to 24 hours per day and 7 days per week during spring refill through early summer when steelhead egg incubation occurs. Each flow adjustment is described in more detail in Paragraph 4.7.2. The refill targets are shown in more detail in Paragraph 4.2.7.

Habitat Mitigation Measures. Mitigation for stream and riparian habitat inundated by the pool raise was not aimed towards a single species but will target opportunities to improve riparian and aquatic habitat to assist in the project goal of restoring native, anadromous fish to the Upper Watershed, principally steelhead, coho and chinook salmon. An interagency team of biologists elected to focus aquatic habitat and mitigation efforts on these species. The mitigation plan is detailed in Appendix F1. All of these species were historically found in the project area, main channel and most tributaries, and would be expected to return given adequate upstream and downstream fish passage.

Assessment of the level of mitigation required to compensate for the inundated habitats was accomplished through 1) the use of a simple areal measurement of total stream and riparian habitat inundated by the pool raise; and 2) a modified habitat evaluation procedure (HEP). The areal estimate of habitat impacted is discussed in Section 3A of Appendix F1. The modified HEP procedure is discussed in Section 8 of Appendix F1. To simplify analysis, target species were not used, only an areal and quality measurement of habitat was estimated.

Lower Watershed

Flow Adjustments and Reservoir Operations. To minimize impacts to fish migrating through the reservoir and to avoid and minimize impacts to downstream fish and habitat a series of flow adjustments were developed and will be applied to operation of the additional storage project. Flow adjustments (refill guidelines and flow targets) were developed to meet project objectives for protecting instream resources, meeting existing conservation storage requirements, and providing reliability for storing additional water for M&I and low flow augmentation. The primary flow adjustments considered during the spring refill period (February 15-June 30) include 1) a maximum refill rate; 2) a minimum baseflow (usually greater than DOE requirements); 3) a river stage decline from May 1 to June 30 to protect steelhead eggs and fry; 4) maintaining natural freshets or creating artificial freshets to speed juvenile migrants downstream; and 5) mimicking the natural temperature regime of the river with blended outflow releases (surface with low-level release). To assure guidelines and targets are met with a high degree of reliability reservoir operations and flow releases will be managed for selected periods up to 24 hours per day and 7 days per week during spring refill through early summer when steelhead egg incubation occurs. Each flow adjustment is described in more detail in Paragraph 4.7.2. The refill targets are shown in more detail in Paragraph 4.2.7.

Habitat Mitigation Measures. Mitigation for side-channel habitat dewatered by the storage of additional water was not aimed towards a single species but was targeted to improve the connection and quality of off-channel habitats necessary to maintain and improve the health of native, anadromous fish runs in the Lower Watershed, including steelhead, and all four salmon species. The mitigation plan is detailed in Appendix F1. All of these species were historically found in the Lower Watershed, main channel and off-channel areas, and would be expected to remain or return given adequate protection and passage into these habitats.

Mitigation for steelhead spawning habitat and incubating eggs dewatered by the storage of additional water was aimed to protect the existing level of natural production in the Lower Watershed. Biologists for the WDFW elected to focus mitigation efforts on this objective. The mitigation plan is detailed in Appendix F1. Steelhead are currently found throughout the Lower Watershed, main channel and off-channel areas, and would be expected to remain at current production levels given adequate protection.

Assessment of the level of mitigation required to compensate for the dewatered habitats was accomplished through 1) use of an areal estimate of side channel and steelhead spawning habitat dewatered, using the 32-year historic flow database with flow adjustments listed above; and 2) a modified habitat evaluation procedure (HEP). The areal estimate of side-channel habitat impacted is discussed in Section 7 of Appendix F1. The areal estimate of steelhead habitat impacted is discussed in Section 6 of Appendix F1. The modified HEP procedure is discussed in Section 8 of Appendix F1. To simplify analysis, target species were not used, only an areal and quality measurement of habitat was estimated.

6.11 CUMULATIVE IMPACTS

Cumulative impacts to the Green River basin include the beginnings of agricultural practices in the lower Green River valley floodplains in the late 1800s and early 1900s; followed by continuing population pressures and construction of a greater density of transportation corridors; construction of levees in the lower Green River valley; the construction of Howard Hanson Dam in 1963, which led to greater flood protection in the lower Green River valley, and the subsequent economic growth in the valley, where industry and retail businesses have replaced agricultural practices; and the initial loss of habitat due to filling of the reservoir behind Howard Hanson Dam; in the upper watershed, intensive timber harvesting has removed most stands of mature forest; a land exchange in the upper watershed between Plum Creek Timber Company and the US Forest Service could result in more intensive removal of late successional forest, and the construction of new logging roads. These land use changes not only result in the direct loss of habitats, but also affect water quality in streams by increasing runoff and erosion and removing streamside riparian cover; the Second Water Supply Project (Pipeline 5) will be constructed within the next five years, resulting in minor impacts on habitat loss and fragmentation—local communities who have signed an agreement with the City of Tacoma to share in the Pipeline 5 water will have assurances of additional water supply, though probably not in drought periods under the no action alternative.

6.11.1 No Action Alternative

The no action alternative will not change any of the cumulative impacts that have already occurred, but it would not provide increased ability to provide minimum instream flows for salmon, or additional municipal and industrial water (M&I) supply for the City of Tacoma and south King County communities during low water periods. No restoration to watershed habitats would be provided in the no action alternative.

6.11.2 Single Purpose Water Supply Alternative

This alternative would result in additional river basin habitat losses near the reservoir as a result of a 22-foot pool raise. In addition, the additional storage volume would reduce mainstem and off-channel habitat area and availability in the Lower Watershed. Mitigation would be implemented to offset the losses and to provide minimum downstream fish passage, but there would be no restoration measures. Self-sustaining fish runs would not be restored to the Upper Watershed but hatchery runs could be achievable if allowed under future fish management laws. M&I water supply would be provided to the City of Tacoma and others, but there would be no additional provision for maintaining minimum instream flows for salmon, thus contributing to further cumulative impacts. Additional development of housing and businesses, particularly in the middle reach of the Green River, may be a secondary effect with the promise of future water supply, thus potentially resulting in further loss and fragmentation of habitat.

6.11.3 Full Development Alternative with Environmental Restoration

Maximum habitat loss in the vicinity of reservoir and from dewatering Lower Watershed aquatic habitats would result with the pool raise and additional storage volume under this alternative. However, mitigation would be implemented to offset the losses, as would ecosystem restoration measures, such that cumulative effects would be somewhat less with this alternative than with the single purpose water supply alternative. The likelihood of attaining self-sustaining runs of salmon and steelhead in the Upper Watershed is greater than the single purpose alternative but less likely than Phase I of the preferred alternative, in particular it is presumed that chinook salmon would require permanent supplementation to maintain their population. City of Tacoma and other communities would receive the maximum M&I water supply benefit with this alternative, likely resulting in economic growth and development throughout the service area of Tacoma's Second Water Supply Right project, likely resulting in habitat loss and fragmentation.

6.11.4 Preferred Alternative: Phased Development with Environmental Restoration

Phase I of the preferred alternative would result in the least amount of habitat loss of the three "build" alternatives, and thus results in the least amount of cumulative impact. Mitigation plans for fish and wildlife would be implemented to offset these losses, as would an ecosystem restoration plan. Phase I provides the maximum ecosystem restoration benefits for habitat improvement and the greatest likelihood of restoring self-sustaining salmon and steelhead runs in the Upper Watershed. The larger reservoir and new dam outlet works improves the ability to meet higher baseflows and provide more natural high flow releases in spring than under the no action alternative. The Phase I M&I water supply is somewhat less than that provided in the Single Purpose Water Supply Alternative, but still provides a reliable regional supply source for 40 years. Assurance of future water supply should spur additional economic growth in local communities, resulting in habitat loss and fragmentation.

Phase II of the preferred alternative would be implemented only after intensive monitoring and evaluation of Phase I water storage effects and restoration and mitigation success, such that assurances could be provided that Phase II would not inalterably result in permanent loss of habitats and fish and wildlife populations. Implementation of Phase II would result in further assurances of future water supply and could spur further economic growth.

6.12 UNAVOIDABLE ADVERSE IMPACTS

6.12.1 No Action Alternative

The no action alternative will impact the ability of TPU to meet its mitigation requirements for pipeline #5, in particular the ability to restore anadromous salmon and steelhead to the Upper Watershed, because of the continued lack of adequate fish passage facilities at HHD. If Puget Sound chinook salmon are listed as a threatened species, the overall recovery of the Green River population will not be achievable if the Upper Watershed is considered essential and/or critical fish habitat necessary for the recovery and sustainability of this species. This alternative would also result in a loss of faith from the local sponsor, resource agencies and tribes who have made commitments to construction of a fish passage facility at Howard Hanson Dam, and a fish hatchery in the basin, as well as expectations of improved confidence in meeting minimum flow criteria. No other unavoidable adverse impacts are expected as a result of the no action alternative.

6.12.2 Single Purpose Alternative

The single purpose alternative would result in the inundation of approximately 281 acres of terrestrial habitats (including 86.6 acres of riparian habitat) and about 2.1 miles of mainstem river and tributary stream habitats (12.7 surface acres). If Puget Sound chinook salmon are listed as a threatened species, the recovery of the overall Green River population will not be achievable if the Upper Watershed is considered essential and/or critical fish habitat necessary for the recovery and sustainability of this species. The mitigation fish passage facility is considered inadequate to meet an objective of self-sustaining runs and would necessitate long-term hatchery supplementation to maintain production of chinook salmon in the Upper Watershed.

6.12.3 Full Development Alternative With Environmental Restoration

This alternative would result in the inundation of approximately 442 acres of terrestrial habitats (including 121 acres of riparian habitat), as well as 17.4 acres of tributary stream habitats. If Puget Sound chinook salmon are listed as a threatened species, the recovery of the overall Green River population will not be achievable if the Upper Watershed is considered essential and/or critical fish habitat necessary for the recovery and sustainability of this species. The mitigation fish passage facility is considered inadequate to meet an objective of self-sustaining runs and would necessitate long-term hatchery supplementation to maintain production of chinook salmon in the Upper Watershed.

6.12.4 Preferred Alternative: Phased Development with Environmental Restoration

Phase I would inundate approximately 281 acres of terrestrial habitats (including 79 acres of riparian) and 11.5 acres of tributary stream habitats. Phase II would inundate 161 acres of terrestrial habitats (including 42 acres of riparian) and about 5.9 acres of tributary stream habitats. Unavoidable impacts will be mitigated. Downstream impacts to fish and aquatic habitat will be avoided or minimized through an adaptive management process of monitoring and evaluating flow release impacts on habitats and fish survival with resultant agency coordination and possible changes in reservoir operations. Effects that could not be avoided through this process will be mitigated, or will be rectified through modification of ecosystem restoration projects.

6.13 IRREVERSIBLE IRRETRIEVABLE CHANGES

6.13.1 No Action Alternative

The no action alternative will have no irretrievable commitment of resources. However, minimum instream flows during drought years will continue to be inadequate for anadromous fish, municipal and industrial water supplies in the Tacoma and south King County service areas may be critical in the near future, and the Upper Watershed will remain disconnected from the Lower Watershed and unable to support self-sustaining runs of anadromous fish.

6.13.2 Single Purpose Alternative

Construction and maintenance of this alternative will require additional uses of non-renewable energy sources, such as gasoline/diesel to fuel the heavy equipment and trucks. Following construction, the new administration and maintenance buildings and the fish passage facility will become permanent features of the project

6.13.3 Full Development Alternative With Environmental Restoration

Construction and maintenance of this alternative will require additional uses of non-renewable energy sources, such as gasoline/diesel to fuel the heavy equipment and trucks. Following construction, the new administration and maintenance buildings and the fish passage facility will become permanent features of the project.

6.13.4 Preferred Alternative: Phased Development With Environmental Restoration

Construction and maintenance of this alternative will require additional uses of non-renewable energy sources, such as gasoline/diesel to fuel the heavy equipment and trucks. Following construction, the new administration and maintenance buildings and the fish passage facility will become permanent features of the project.

SECTION 7. CONCLUSIONS

There is a need and opportunity to modify the existing Howard Hanson Dam Project to provide a source of M&I water supply storage needed in the region and an opportunity to provide restoration of important environmental resources particularly the anadromous fishery resource. The regional need for the water supply has been established, and the water supply portion of the proposed project is dependent on construction of a new pipeline (Pipeline No. 5) by Tacoma Public Utilities to transport stored water to the regional customers. Tacoma Public Utilities was granted a permit under Section 404 of the Clean Water Act to construct pipeline 5, and the construction is scheduled to be completed before year 2003. The goal to satisfy water supply needs in the 50-year project life is nearly achievable under Phase I and can be achieved under Phase II. The storage of an additional 22,400 ac-ft of water for M&I water, as proposed in the ultimate development, will provide a stable, cost-effective water supply for Tacoma and vicinity well into the next century.

Restoration of fish passage through the Howard Hanson Dam Project is the keystone of the ecosystem restoration purposes considered in this feasibility study. At a cost of over $34 million, the fish passage feature represents a major investment with an equally significant benefit to the anadromous fishery resources in the basin. The study schedule and cost was increased in 1992 by $ 2.5 million and an additional 3 years to collect additional information necessary to formulate and design the fish mitigation and restoration features, primarily the fish passage feature. A fish passage technical committee, comprised of five experts in fish passage design and operation, was utilized in a modified Delphi Process to review, modify and refine the proposed fish passage features.

Finally, the combined water supply and restoration project proposed was subjected to an agency resolution process involving Washington State Departments of Ecology, Fish and Wildlife, US Fish and Wildlife Service, the Muckleshoot Indian Tribe, the City of Tacoma and the Corps of Engineers. The outcome of these efforts is the phased adaptive management plan presented herein as the recommended plan, which provides early outputs of water supply and restoration benefits with an opportunity to review and adjust the project as experience is gained.

The pool raise, and the consequent longer period that the existing vegetation will be inundated, will result in the loss of grasses, shrubs, trees, and other species that are unable to survive the increased inundation. The habitat restoration measures proposed are expected to increase the habitat diversity and structure.

The storage of an additional 9,600 ac-ft of water for low flow augmentation, proposed in Phase II, would be of significant benefit to the anadromous fish and resident fish population in the Green River watershed, even though some fish species or life stages could be adversely impacted by the reduced flows during the refill period of the reservoir.

The combination of water supply and restoration is an excellent use of the existing Howard Hanson Dam Project, and Tacoma Public Utilities intends to act as local sponsor. The adaptive management approach to the project will provide an opportunity to optimize the benefits and minimize the impacts of the project as the Corps learns more through operation of the project.

SECTION 8. RECOMMENDATIONS

I have given careful consideration to all significant aspects of this study in the overall public interest, including engineering and economic feasibility, as well as social and environmental effects. The recommended plan described in this report provides the optimum solution for increasing summer conservation storage at Howard A. Hanson Dam on the Green River, Washington.

I recommend that the existing Howard A. Hanson Dam Project be modified for the purpose of water supply and environmental restoration. This modification has significant value to the Puget Sound region. The fully-funded cost estimate for all modifications is estimated at $77.8 million. The cost of the modifications will be repaid according to the allocations to water supply and restoration.

I recommend that the existing Howard A. Hanson Dam Project authorized by the River and Harbor Act of 17 May 1950 be modified to include the following:

1. New intake tower with new fish collection and transport facility including: a wet-well, a floating fish collector, a fish lock, a discharge conduit, a fish transport pipeline and monitoring equipment.
2. Mitigation features including management of riparian forests, planting of water-tolerant vegetation and maintenance of instream habitat in Phase I and Phase II.
3. Ecosystem restoration features other than fish passage including gravel nourishment, a side channel reconnection project, and river and stream habitat improvements.
4. Right abutment drainage remediation.
5. New access bridge and access road.
6. New buildings, or additions to existing buildings, including: an administration, a maintenance and a generator building.
7. Change reservoir operation (Phase I) to store 20,000 ac-ft of M&I water to elevation 1,167 feet in the spring for release in the summer and fall.
8. Change reservoir operation (Phase II) to store an additional 12,000 ac-ft of water, 2,400 ac-ft for M&I water supply and 9,600 ac-ft of water for LFA, to elevation 1,177 feet in the spring for release in the summer and fall.

These recommendations reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of national Civil Works Construction programs nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and/or implementation of funding.

James M. Rigsby date
Colonel
Commanding

SECTION 9. PERTINENT DATA

Reservoir Data

Water surface measured at	Mile 64.5	220 square miles	USGS streamgage
Turbidity pool	1070 feet	1,200 ac-ft (inactive)	
Conservation Storage	1141 feet	25,400 ac-ft	
Section 1135 storage	1147 feet	30,400 ac-ft	adds 5,000 ac-ft
Phase I Full Pool	1167 feet	50,400 ac-ft	adds 20,000 ac-ft
Water Supply Pool	1169 feet	52,800 ac-ft	adds 22,400 ac-ft
2nd highest flood pool	1176 feet	Dec. 1975, used to scope max. summer pool	
Phase II Full Pool	1177 feet	62,400 ac-ft	adds 12,000 ac-ft
Highest pool of record	1182 feet	10 Feb. 1996, helps verify maximum pool	
Flood Control Storage	1206 feet	106,00 ac-ft	max. pool for exist. Dam

Data for Dam

Streamflows measured at	Mile 63.8	221 square miles	USGS streamgage
Crest Elevation	1228 feet	completed in 1962	
Required Outflow	223 cfs	110 cfs instream flow + 113 cfs diversion	
Outlet Works			
Type	Intake tower with gated tunnel		
Tunnel size	19 feet diameter		900 feet in length
Intake elevation	1035 feet		too low for fish passage
2 radial gates	10 feet wide by 12 feet high		too large for fine control
Low Flow			
Type	Tunnel with vertical intake tower		
Intake and diameter	1070 feet	48-inch diameter	includes a tight bend
Discharge capacity	500 cfs	at maximum pool elevation	

Data for Diversion

Tacoma Diversion Dam	Mile 61.	17 ft high by 152 ft long
1st Water Supply Diversion	113 cfs	Existing Tacoma Diversion
2nd Water Supply Diversion	100 cfs	To be constructed

Data for Instream Flows

at Palmer

Streamflows measured at	Mile 60.3	231 square miles	USGS streamgage

at Auburn

Streamflows measured at	Mile 32.	399 square miles	USGS streamgage

Instream Flows for the Green River Below Hanson Dam

	Federal	Washington State Instream Protection by Department of Ecology		Agreement between Muckleshoot & Tacoma	Proposed Flow Conditions For Auburn From Adaptive Management Flow Modeling[D/]		
Month & Day	Minimum Outflow at Hanson	Normal & *Critical* Flows at Palmer	Instream Flow at Auburn	Instream Flow at Palmer[E/]	For Weather that is Wet	For Weather that is Average	For Weather that is Dry
Jan. 1	113[A/]	300	650	300	n.a.[F/]	n.a.	n.a.
Jan. 15	113	300	650	300	n.a.	n.a.	n.a.
Feb. 1	113	300	650	300	900	900	900
Feb. 15	113	300	650	300	900	900	900
Mar. 1	113	300	650	300	900[G/]	750[H/]	575[I/]
Mar. 15	113	300	650	300	900	750	575
Mar. 31	113	300	650	300	900	750	575
Apr. 1	223[B/]	300	650	300	2500[J/]	2500[J/]	1250[J/]
Apr. 2	223	300	650	300	900	750	575
Apr. 14	223	300	650	300	900	750	575
Apr. 15	223	300	650	300	2500[J/]	2500[J/]	1250[J/]
Apr. 16	223	300	650	300	900	750	575
Apr. 30	223	300	650	300	900	750	575
May 1	223	300	650	300	2500[J/]	2500[J/]	1250[J/]
May 2	223	300	650	300	892	744	570
May 14	223	300	650	300	793[C/]	675[C/]	506[C/]
May 15	223	300	650	300	2500[J/]	2500[J/]	1250[J/]
May 16	223	300	650	300	777	664	495
June 1	223	300	650	300	646[C/]	572[C/]	410[C/]
June 15	223	300/*210*[C/]	650	300	531[C/]	492[C/]	335[C/]
July 1	223	300/*150*[C/]	550[C/]	300	400[C/]	400[C/]	250[C/]
July 14	223	158[C/]/*/150*	313[C/]	300	350	300	250
July 15	223	150[C/]	300[C/]	200	350	300	250
Aug. 1	223	150	300	200	350	300	250
Aug. 15	223	150	300	200	350	300	250
Aug. 31	223	150	300	200	350	300	250
Sept. 1	223	150	300	200	700	700	700
Sept. 2	223	150	300	200	350	300	250
Sept. 15	223	150	300	200	350	300	250
Sept. 16	223	152[C/]/*/150*	300	300	400[K/]	300	250
Sept. 30	223	187[C/]/*/150*	300	300	400	300	250
Oct. 1	223	190[C/]/*/150*	300	300	450[L/]	400[M/]	350[N/]
Oct. 15	223	240[C/]/*/150*	350[C/]	300	450	400	350
Oct. 31	223	296[C/]/*/187*[C/]	536[C/]	300	450	400	350
Nov. 1	223	300[C/]/*/190*[C/]	550[C/]	300	400[O/]	300[O/]	250[O/]
Nov. 15	223	300/*240*[C/]	550	300	400	300	250
Dec. 1	223	300[C/]	650[C/]	300	400	300	250
Dec. 5	223	300	650	300	400	300	250
Dec. 31	113	300	650	300	400	300	250

A/ 113 cfs or inflow, whichever is least

B/ 110 cfs is added to 113 cfs to provide 110 cfs instream flow below Tacoma's diversion site during storage operations (refill and drawdown) at Howard Hanson Dam reservoir .

Critical Year (italicized) flow values are reduced from Normal at the discretion of the director, see Chapter 173-509 of the Washington Administrative Code for the Green-Duwamish River Basin Instream Resources Program.

C/ Use a uniform daily change from the previous period value and date to the current period value and date.

D/ Includes conditions from the Muckleshoot & Tacoma Agreement and raises instream flows during the spring runoff that is coincident with the reservoir refill period.

E/ In addition to Palmer, there are some instream flows at Auburn for some specific dates and conditions. Between 15 July and 15 September;
the instream flow is 400 cfs for operation of the 2nd water supply diversion,
the instream flow is 250 cfs for operation of the 5,000 ac-ft of storage,
the instream flow is 225 cfs for operation of the 1st water supply diversion.

F/ n.a. means not applicable during periods without active storage.

G/ Stampede Pass snow water equivalent is examined on 1 March,
if it is greater than 50 inches, condition is set as wet.

H/ Stampede Pass snow water equivalent is examined on 1 March,
if it is less than 50 inches, but greater than 24 inches, condition is set as average.

I/ Stampede Pass snow water equivalent is examined on 1 March,
if it is less than 24 inches, condition is set as dry.

J/ Freshets have a duration of 38 hours. Whenever storage for freshets is below 65% full, the scheduled freshet is skipped. The last freshet of 700 cfs on 1 September is met in all years for all conditions.

K/ If the storage on 15 September is greater than 15,740 ac-ft, then reset the condition to wet (400 cfs), otherwise make no change until the end of the month.

L/ If the storage on 30 September is greater than 12,920 ac-ft, then set the fall condition to wet (450 cfs).

M/ If the storage on 30 September is greater than 8,261 ac-ft, then set the fall condition to average (400 cfs).

N/ If the storage on 30 September is less than 8,261 ac-ft, then set the fall condition to dry (350 cfs).

O/ Resume the late fall augmentation at the level set in mid September until the storage is empty or until the rains return and reservoir water is spilled to provide the needed flood control storage.

The reference for the Adaptive Management flow modeling flows is, *Howard Hanson Dam Additional Water Storage Project: Modeling Results for Baseline, Phase I, and Phase II Reservoir Operations Final report prepared by CH2M Hill dated March 4, 1997.*

GREEN RIVER HYDROLOGICAL CONDITIONS BASED ON SEASON-SPECIFIC CRITERIA DURING THE PERIOD 1964-1995 USED IN MODELING IMPACTS OF THE PREFERRED ALTERNATIVE (SOURCE: CH2MHILL 1997).

	Seasonal Flow Condition Set on			
Year	**1-Mar**	**1-Jul**	**15-Sep**	**30-Sep**
1964	Average	Average	Wet	Wet
1965	Average	Average	Average	Average
1966	Average	Average	Average	Average
1967	Average	Average	Average	Average
1968	Dry	Average	Wet	Wet
1969	Wet	Average	Wet	Wet
1970	Average	Average	Average	Average
1971	Average	Average	Wet	Wet
1972	Wet	Average	Wet	Wet
1973	Dry	Dry	Average	Average
1974	Wet	Average	Wet	Average
1975	Wet	Average	Wet	Wet
1976	Average	Average	Wet	Wet
1977	Dry	Average	Wet	Wet
1978	Average	Dry	Average	Average
1979	Average	Dry	Average	Average
1980	Average	Average	Wet	Wet
1981	Dry	Average	Wet	Wet
1982	Average	Average	Wet	Wet
1983	Average	Average	Wet	Wet
1984	Average	Average	Wet	Wet
1985	Average	Average	Average	Average
1986	Dry	Average	Average	Average
1987	Average	Dry	Average	Average
1988	Average	Average	Average	Average
1989	Average	Average	Dry	Dry
1990	Wet	Average	Wet	Average
1991	Dry	Average	Average	Average
1992	Dry	Dry	Average	Average
1993	Average	Average	Wet	Average
1994	Average	Dry	Average	Average
1995	Average	Dry	Average	Average

PHASE I HYDROLOGIC AND RESERVOIR CONDITIONS FOR MEETING STORAGE AND RELEASE TARGETS FOR 1) FRESHETS; 2) SECOND SUPPLY STORAGE (DIVERSION DAM); 3) EXISTING FLOW AUGMENTATION STORAGE (FISH DAM 1);MARCH, APRIL, MAY, AND JUNE FILL LIMITS; AND 4) SECTION 1135 DROUGHT YEAR STORAGE. NOTE, MODELING WAS CONDUCTED PRIOR TO NEGOTIATIONS THAT RESULTED IN INITIATION OF YEARLY STORAGE OF SECTION 1135 WATER IN PHASE I AND DOES NOT REFLECT NOVEMBER 1997 REMODELED RESULTS OF STORAGE REPRIORITIZATION WITH BASEFLOWS HAVING HIGHER PRIORITY THAN M&I STORAGE.

Year	Number of Spring Freshets	Diversion Dam Full 1-Jul	Fish Flow Levels Met	Condition Set 1-Mar	Condition Set 1-May	Volume in Diversion Dam 30-Jun	Volume in Fish Dam 1 30-Jun	Volume in Fish Dam 2 30-Jun
1964	2	Yes	Yes	Average	Average	20,000	24,200	0
1965	2	Yes	Yes	Average	Average	20,000	24,200	0
1966	2	Yes	Yes	Average	Average	20,000	24,200	0
1967	2	Yes	Yes	Average	Average	20,000	24,200	0
1968	1	Yes	Yes	Dry	Average	20,000	24,200	0
1969	2	Yes	Yes	Wet	Average	20,000	24,200	0
1970	2	Yes	Yes	Average	Average	20,000	24,200	0
1971	2	Yes	Yes	Average	Average	20,000	24,200	0
1972	2	Yes	Yes	Wet	Average	20,000	24,200	0
1973	1	Yes	Yes	Dry	Average	20,000	24,200	0
1974	2	Yes	Yes	Wet	Average	20,000	24,200	0
1975	2	Yes	Yes	Wet	Average	20,000	24,200	0
1976	2	Yes	Yes	Average	Average	20,000	24,200	0
1977	1	Yes	Yes	Dry	Dry	20,000	26,700	2,500
1978	1	Yes	Yes	Average	Dry	20,000	26,700	2,493
1979	2	Yes	No-6/10	Average	Average	20,000	23,746	0
1980	1	Yes	Yes	Average	Average	20,000	24,200	0
1981	1	Yes	Yes	Dry	Dry	20,000	26,700	2,500
1982	2	Yes	Yes	Average	Average	20,000	24,200	0
1983	2	Yes	No-6/1	Average	Average	20,000	24,200	0
1984	2	Yes	Yes	Average	Average	20,000	24,200	0
1985	2	Yes	Yes	Average	Average	20,000	24,200	0
1986	1	Yes	Yes	Dry	Average	20,000	24,200	0
1987	2	Yes	No-6/20	Average	Dry	20,000	26,700	0
1988	2	Yes	Yes	Average	Average	22,810	24,200	0
1989	2	Yes	Yes	Average	Dry	20,000	26,700	1,947
1990	2	Yes	Yes	Wet	Average	21,620	24,200	0
1991	1	Yes	Yes	Dry	Average	20,000	24,200	0
1992	1	No	No-6/1	Dry	Dry	13,083	26,186	0
1993	2	Yes	Yes	Average	Average	23,600	24,200	0
1994	1	Yes	No-5/25	Average	Average	20,000	24,200	0
1995	2	No	No-6/1	Average	Average	18,838	24,091	0
Avg.	1.69	Yes-30; No-2	Yes-26; No-6			19,998	24,635	295

SEASONAL PHASE II HYDROLOGIC AND RESERVOIR CONDITIONS AND YEARLY ABILITY FOR MEETING STORAGE AND RELEASE TARGETS FOR 1) FRESHETS; 2) SECOND SUPPLY STORAGE (DIVERSION DAM); 3) SPRING REFILL BASELINE FLOWS (FISH FLOW LEVELS); AND 4) AWSP FLOW AUGMENTATION STORAGE FOR EARLY AND LATE SUMMER (FISH DAM 2, INCLUDES SECTION 1135 5,000 AC-FT).

Year	Number of Spring Freshets	Diversion Dam Full 15-Apr	Fish Flow Levels Met	Condition Set 1-Mar	Condition Set 1-Jul	Volume in Diversion Dam 30-Jun	Volume in Fish Dam 2 30-Jun	Condition Set 15-Sep	Volume in Fish Dam 2 15-Sep	Condition Set 30-Sep	Volume in Fish Dam 2 30-Sep
1964	4	Yes	Yes	Average	Average	22,400	14,600	Wet	12,981	Wet	10,633
1965	3	No	Yes	Average	Average	22,400	14,584	-	12,668	Average	10,633
1966	3	Yes	Yes	Average	Average	22,400	14,600	-	12,981	Average	10,633
1967	1	No	Yes	Average	Average	22,400	14,582	-	11,977	Average	10,489
1968	3	Yes	Yes	Dry	Average	22,400	14,600	Wet	12,981	Wet	10,633
1969	3	Yes	Yes	Wet	Average	22,400	14,600	Wet	12,882	Wet	10,633
1970	3	Yes	Yes	Average	Average	22,400	14,555	-	11,205	Average	10,633
1971	3	Yes	Yes	Average	Average	22,400	14,600	Wet	12,981	Wet	10,633
1972	4	Yes	Yes	Wet	Average	22,400	14,600	Wet	12,981	Wet	10,633
1973	0	No	Yes	Dry	Dry	12,712	5,638	-	5,010	Average	5,319
1974	4	Yes	Yes	Wet	Average	22,400	14,600	Wet	12,931	Average	10,633
1975	1	No	Yes	Wet	Average	22,400	14,600	Wet	12,981	Wet	10,534
1976	3	Yes	Yes	Average	Average	22,400	14,600	Wet	12,981	Wet	10,534
1977	2	Yes	Yes	Dry	Average	22,400	14,600	Wet	12,947	Wet	10,633
1978	0	No	Yes	Average	Dry	16,787	10,638	-	10,481	Average	8,133
1979	4	Yes	Yes	Average	Dry	22,400	12,375	-	10,481	Average	8,127
1980	4	Yes	Yes	Average	Average	22,400	14,422	Wet	12,981	Wet	10,633
1981	1	No	Yes	Dry	Average	22,400	14,600	Wet	12,897	Wet	10,633
1982	3	No	Yes	Average	Average	22,400	14,600	Wet	12,981	Wet	10,633
1983	4	Yes	Yes	Average	Average	22,400	14,162	Wet	12,981	Wet	10,633
1984	4	Yes	Yes	Average	Average	22,400	14,600	Wet	12,981	Wet	10,534
1985	3	Yes	Yes	Average	Average	22,400	14,600	-	11,032	Average	10,633
1986	4	Yes	Yes	Dry	Average	22,400	14,600	-	12,416	Average	10,633
1987	4	Yes	No-10/26	Average	Dry	22,400	12,132	-	8,987	Average	8,034
1988	4	Yes	Yes	Average	Average	22,400	14,541	-	12,981	Average	10,633
1989	4	Yes	No-10/16	Average	Average	22,400	14,047	-	7,198	Dry	4,736
1990	4	Yes	Yes	Wet	Average	22,400	14,600	Wet	12,964	Average	10,549
1991	3	Yes	No-10/30	Dry	Average	22,400	14,600	-	12,751	Average	10,483
1992	0	No	Yes	Dry	Dry	10,574	2,353	-	1,103	Average	6,885
1993	4	Yes	Yes	Average	Average	22,400	14,600	Wet	12,882	Average	10,340
1994	4	Yes	Yes	Average	Dry	22,400	12,113	-	10,042	Average	8,133
1995	2	No	Yes	Average	Dry	22,400	11,262	-	8,622	Average	8,034
Avg.	2.91	Yes-23 No-9	Yes-29 No-3			21,552	13,440		11,477		9,707

PHASE I ALTERNATIVE REFILL STRATEGY AND INITIAL REFILL PRIORITIES

Tacoma Public Utilities, the Corps of Engineers, R2 Resource Consultants and CH2M Hill modeled and conceptualized the following Phase I refill strategy, using the historic database (1964-1995). This model run was completed to verify that Tacoma's SSWR refill reliability assumed for the with-project condition (95%) could be achieved given a series of resource protection objectives.

On October 17 and 24, 1997, following discussion with MIT, WDFW, USFWS, NMFS, Corps and TPU staff CH2M Hill conducted additional model runs including: 1) reordering the listed priorities putting baseflow protection above SSWR storage ; 2) dropped freshets; and 3) incorporated a constant capture rate. The reordering of priorities places a higher level of protection on baseflows and should increase baseflow reliability (a critical resource protection objective) with the reordering of baseflows; dropping freshets maintains the SSWR refill at 95% reliability. The reordering with baseflow as a higher priority will be retained as long as the SSWR storage reliability is guaranteed. The constant capture model was provided to evaluate the March 1997 refill strategy against WDFW/MIT requests for a constant capture strategy. The constant capture model did not maintain baseflows throughout the refill period.

October 17, 1997 Model Phase I Refill Strategy:

1. The priorities for use of water that flows into Howard Hanson Reservoir are as follows:
    - Pipeline 1 water right (First Supply Water Right) of 72 mgd (111 cfs) from natural Green River flows
    - 110 cfs base flow at Palmer
    - Existing storage following the 98% rule curve
    - Palmer and Auburn instream flows as approved in the Agreement
    - Baseflow requirement of 900 cfs from 15 February to 28 February, and from 1 March to 1 May flows of 900 cfs, 750 cfs, and 575 cfs for a wet, average, and dry spring, respectively, and 900 cfs to 400 cfs ramp from 1 May to 1 July
    - SSWR of 65 mgd (100 cfs); this water is stored behind the dam from 15 February to 30 June
    - Section 1135 and Dampen Dam storage requirements following refill level and rate limitations.

2. The start of refill is 15 February. Under Phase I modeling, prior to 1 March, a maximum of 3000 ac-ft is stored for SSWR. The maximum volume available in February is 5,000 ac-ft and must be verified by the Corps: new model runs could incorporate both fish and SSWR storage in February.
3. The maximum refill rates for the SSWR and Section 1135 and Dampen Dam are: 1)

from 15 February to 28 February: 100 cfs or 200 ac-ft/day (SSWR); 2) 1 March to 30 March: 400 cfs or 800 ac-ft/day; 3) 1 April to 30 April: 300 cfs or 600 ac-ft/day; and 4) from 1 May to 30 June: 200 cfs or 400 ac-ft/day.

SECTION 10. DFR/EIS PREPARERS

Name	Affiliation	Responsibility	Expertise
David Rice	Corps	Cultural Resources	Archaeologist
Ken Brunner	Corps	Wildlife	Wildlife Biologist
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Cyrus M. McNeely	Corps	Impact Analysis	Biologist
Kris Loll	Corps	Project Manager	Planner
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Paul Hickey	TPU	Fisheries	Fish Biologist
John Kimer	TPU	Water Supply	Water Department Manager

Beak = Beak Consultants Incorporated
Corps = Corps of Engineers, Seattle District
CH2M Hill = CH2M Hill Incorporated
DEA = David Evans and Associates, Incorporated
R2 = R2 Resource Consultants
TPU = Tacoma Public Utilities, Water Department

SECTION 11. GLOSSARY OF ACRONYMS

ac-ft	acre-feet
AWS	Additional Water Supply
BA	Biological Assessment
cfs	cubic feet per second
DEIS	Draft Environmental Impact Statement
DFR	Draft Feasibility Report
DO	dissolved oxygen
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FDWR	First Diversion Water Right
FEIS	Final Environmental Impact Statement
HHD	Howard Hanson Dam
LFA	Low Flow Augmentation
mgd	million gallons per day
MIT	Muckleshoot Indian Tribe
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NTU	Nephelometric Turbidity Units
O&M	Operations and Maintenance
PMF	probably maximum flood
PMP	probable maximum precipitation
RM	river mile
ROD	Record of Decision
ROI	Region of Impact
SHPO	[Washington] State Historic Preservation Office
SSWR	Second Supply Water Right
USACE	US Army Corps of Engineers; the Corps
USFS	United States Forest Service
USFWS	Unites States Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology

SECTION 12. DEFINITIONS

acre-foot (feet)	volume of water that will cover an acre to the depth of one foot
anadromous	Fishes with a life cycle where breeding occurs in a fresh water system (usually a stream or river), rearing in freshwater ranges from hours to years. After initial growth, individuals under a physiological change that allows their survival in salt water, then move to salt water, returning to freshwater to spawn after maturity. In the context of this document "anadromous species" generally refers to salmon and steelhead.
andesite	gray, fine-grained volcanic rock, mainly feldspar and plagioclase
augmentation	In the context of this document, "augmentation" refers to the process where water from the reservoir is added to natural inflows to increase instream flows below HHD.
authorized use	the Congressional authorized purposes of HHD as established by law
breccias	rocks composed of sharp, angled fragments cemented in a fine matrix.
colluvium	deposits of loose debris that accumulated at the base of a steep slope.
conservation pool	The quantity of water reserved behind HHD during the spring and summer months that allows for the augmentation of natural instream flows (synonymous with reservoir).
conservation season	the annual period of refilling of the reservoir for summer conservation uses
crib wall	a wall made of logs stacked one log above a lower log
dewatering	Lowering instream flows to the point where gravel that was formally inundated is exposed. In the context of this document "dewatering" refers to the removal of surface water from redds after spawning, but before the emergence of fry, generally resulting in the death of the maturing eggs.
diversion dam	A low structure constructed in impound water and redirecting the impounded waters for another use typically industrial, irrigation, or municipal water supply. In the context of this document the "diversion dam" or simply "diversion" refers to the structure built by the city of Tacoma in 1912 at RM 61 to reroute Green River water for municipal use. Construction of this structure blocked the upstream migration of fish.
Downramping	The term applied to the reduction of outflow from a water control structure such as a dam. In the context of this document "downramping" refers to the practice of gradually reducing outflows from the project to lower instream flows below HHD or to impound water behind the dam during the spring refill of the conservation pool.

drawdown	Lowering the water in a reservoir. In the context of this document "drawdown" generally refers to the annual reduction of water impounded behind HHD as the project changes from conservation storage to flood storage operation during the fall.
edgewaters	Areas of slack or reduced current occurring along the banks of a stream or river. In the context of this document "edgewater" refers to pools formed typically from rocks, logs, or other streambank obstructions along gravel bars. Edgewaters are generally small and shallow and are not separated from the main flow of the river.
felsite	a fine grained igneous rock, mainly feldspar and quartz
first order stream	a small stream without tributaries
fish stocks	term used to distinguish different populations of fish of the same species
fish strains	term to distinguish fish of the same species with differing genetic characteristics
flushing flow	the idea of flushing flows or mimicking natural "flood pulses" in regulated rivers with a programmed release of a predetermined discharge for a given period is used to maintain desired steam habitat conditions and to provide transport for migrating fish.
flood pulse	term (also known as "flushing flow") applied o mimicking a natural rise in river flows through a controlled, predictable increase in outflow. The "flood pulse" advantage means increased fish yield for multiple species with this rise in outflow.
freshet	A sudden increase of instream flows in a stream or river resulting from heavy rain or a thaw. In the context of this document "freshet" refers to additional short term releases from HHD intended to imitate conditions in unabated river systems resulting from late season precipitation.
fluvial	pertaining to a river
glaciolacustrine	associated with a lake formed by melt water from a glacier
flood hydrograph	A mathematical graph showing the relationship between rainfall discharge and temporal duration.
lacustrine	In the context of this document "lacustrine" is a wetland system created by and associated with a lake.
lagomorphs	any order of gnawing mammals including rabbits and hares
live storage	volume of water stored behind the dam held for later release
Lower Watershed	Green and Duwamish Rivers below HHD, not including tributary streams outside of influence of the Green River mainstream or side channels. In the context of this document "Lower Watershed" is the mainstream of the Green River and the directly influenced areas below HHD at RM64.5.

oligotrophic	a lake, pond, etc., poor in plant nutrient minerals and organisms, and rich in oxygen at all depths.
inflow	a term given to describe the quantity of water being added to a reservoir system. In the context of this document "inflow" refers to the quantity of water provided to the project by the tributaries in the Upper Watershed.
outflow	opposite of inflow, a term given to describe the quantity of water being released from the reservoir.
passerines	perching birds
pervious	surfaces through which fluids are able to enter and pass
pool level	The elevation of water at a given time impounded by a dam or other structure, expressed as the elevation of the surface of the water in feet above mean sea level.
piezometer	instrument for measuring pressure
project	HHD and Reservoir
project area	Upper and Lower Green River Watersheds within the direct influence of HHD
pyroclastic	formed from rock fragments as a result of volcanic eruption
raptors	birds with talons, including hawks and eagles
refill	The process of filling the reservoir behind HHD in the spring, after the danger of flooding, to prepare for low flow augmentation.
refill reliability	Timing of the refill and downramping at a rate to insure filling a conservation pool (reservoir) to a predetermined full pool elevation to provide sufficient water for low flow augmentation throughout the dry season.
region	Upper Watershed, Lower Watershed, and surrounding Green River Valley including Auburn, Kent, Tukwila, Seattle, And unincorporated King County.
reservoir	Water stored behind the dam for future use. In the context of this document "reservoir" refers to the artificial pool or lake created by water impounded by HHD. Synonymous with conservation pool.
redds	In-gravel spawning beds of various fishes (usually salmonids) formed typically by the female of the species prior to and during mating through the action of agitating stream bed gravel with the tail. Females deposit eggs in the newly cleared gravel where they are fertilized by the male and then typically covered with a shallow layer of gravel. The fertilized eggs develop in the redds until the fry emerge. In the context of this document "redds" generally refer to the location of developing salmon or steelhead eggs.

river mile	distance in miles along the stream center line as measured from its mouth or confluence in an upstream direction
second order stream	a stream below the confluence of two first order streams
storage dam	A dam constructed for the purpose of impounding water for later use. In the context of this document "storage dam" refers to HHD, that was constructed, in part, to impound spring runoff and reserve this water as augmentation of flows in the season, as well as store flood waters to prevent downstream floods.
spillway	Channel for an overflow of water from the reservoir. In the context of this document "spillway" refers to the large concrete structure located along the right embankment of HHD (looking upstream) constructed to allow extremely high flood flows to be released so that the dam is not breached. Flood storage pool levels at HHD have never been so high that use of the spillway was necessary.
turbidity	A quantifiable measure of the ability of particulate matter suspended in a water column to scatter particles of light. The suspended particles often give the water the appearance of being cloudy or muddy. Waters that appear muddy are often describe as having a high level turbidity or being turbid.
Upper Watershed	Areas upstream of HHD (RM 64.5) within the Green River Drainage Basin including the reservoir and areas regulated by the city of Tacoma directly influenced by HHD.
watershed	The areal extent of a drainage basin including all lands that contribute surface water flow or runoff into a body of surface water such as a river, lake, stream or reservoir.