CHAPTER 5.
BASIN-SPECIFIC CHARACTERISTICS, STRATEGIES AND ACTION PLAN

This chapter provides a basin by basin description of the flood conditions along each of the major rivers in King County and proposes both county wide and basin specific actions to reduce or eliminate many of the risk associated with these hazardous conditions. Together, these proposed actions comprise King County's 10-Year flood hazard management Action Plan. Elements of the Action Plan are presented throughout this chapter The Action Plan is presented in its entirety in Appendix F. Each of the basin-specific actions is also included in Appendix G. Appendix G summarizes the known flood hazard management risk areas and flood protection facility maintenance needs in King County, and includes list of projects for which assessment and feasibility has yet to be completed. The total flood hazard management need identified in Appendix G estimated to be between $179 million and $335 million.

Chapter 5 chapter begins with a section on proposed countywide projects and programs, followed by sections describing each of the major rivers and tributaries in King County. The river-specific sections include the following:

- **Background—**Each river-specific section begins with an overview of the river system, followed by discussions of system geology, geomorphology, hydrology and hydraulics. The ecological context of the river is also discussed, with an emphasis on salmonid use. This background information is important for understanding the characteristics of each basin that must be considered when making flood hazard management decisions.
- **Flood and Flood Hazard Management Information—**Following the presentation of background information, each river-specific section presents flooding and flood hazard management information for that basin, including an overview of King County flood protection facilities, major flooding and flood damage history, and key accomplishments since the *1993 King County Flood Hazard Reduction Plan* was adopted.
- **Flood Hazard Management Corridor Information—**Each river-specific section then moves into a discussion of that basin's flood hazard management corridor which is the area most directly affected by flooding and by flood hazard management actions. The data used to assess the flood hazard management corridor generally included mapped floodplains, floodways and channel migration hazard areas, or other relevant studies where such maps were not available. Flood hazard management corridor information also included areas of deep fast flow, potential levee failure areas, steep slopes adjacent to river channels and riparian buffers. Appendix C and G (described above) provide additional flood risk assessment information.
- **Objectives and Strategies—**Each river-specific section describes overarching flood risk reduction objectives and strategies. These objectives and strategies focus on reducing flood risk described in policy G-2 of this Plan. The objectives and strategies sections describe the dominant risks in each basin and the approach used to address these risk.
- **Action Plan—** Each basin-specific section concludes with a summary table of proposed actions. These actions include a combination of hazard mapping, feasibility analyses and on-the-ground projects. Proposed actions to address flood risk reduction needs for each basin are presented in an basin-specific action plan table that is split into two groups. The first group of proposed actions include work that can be accomplished with available or "status quo" funding. The second or "enhanced funding" set of actions, describes work which would only be initiated within the ten-year timeframe of the Plan if additional funding were available.

Categorization of proposed actions as "status quo" or "enhanced funding" is intended to provide a general sense of what can be accomplished at two Plan implementation funding levels:

- The actions under the "status quo funding" subheading will be pursued between 2007 and 2016 using current River and Floodplain Management Program revenues, including grant funding at a level typically leveraged by the program.
- The actions under the "enhanced funding" subheading address other high priority needs that will be pursued either in later years or, if flood hazard management funding is sufficiently increased, during the ten-year life of this Plan. Chapter 7 provides additional funding information, including alternatives that would support the implementation of the actions on the "enhanced funding" list.

The Action Plan tables include basin-wide actions such as flood hazard or channel migration mapping, which support recommendations described elsewhere in this Plan. The tables indicate the recommendations that these actions are associated with, using reference codes such as "IMP-1", which represents the first recommendation related to Plan implementation. For all other proposed actions, project summary sheets are provided as described below.

- **Project Summaries—**For each site-specific project outlined within the 10-Year Action Plan, such as levee improvements or concentrated areas of home buyouts, a project summary is included to provide a better understanding of the flood or erosion conditions of concern and the action or actions proposed to address them. The project summaries are planning level documents; the nature and cost of the proposed actions are likely to change as the flood conditions are analyzed in greater detail and as alternatives to the proposed actions are developed and considered.

Implementation of some actions may change as alternative analyses are performed for each project, or as field conditions change. In addition, it may be appropriate to implement some projects in phases over a long period, with early completion of phases that promise the greatest benefits, or for which opportunities might be lost without prompt implementation. Participation of affected parties and partners will have a significant effect on project implementation timelines.

Some proposed actions involve property acquisition—either stand-alone buyouts of homes in areas at risk from flooding, or acquisitions associated with future flood protection facility retrofit projects. Some of the acquisitions are identified by FEMA as repetitive loss properties. King County will work with interested property owners to acquire at-risk homes at fair market value. All proposed acquisitions will include early and ongoing coordination with the affected property owners.

5.1 COUNTYWIDE PROJECTS AND PROGRAMS

A number of countywide programs and projects will be implemented across all basins. These include programs such as flood preparedness, emergency response, flood protection facility maintenance and countywide opportunity funds for emergency repair of flood protection facilities. Together, these countywide projects and programs, and the basin-specific projects and programs described at the end of subsequent sections in this chapter, make up King County's Flood Hazard Management Action Plan. The entire Action Plan is compiled and reprinted in Appendix F.

Table 5-1 lists proposed countywide programs. These generally focus on the collection, use and dissemination of information on an annual or nearly annual basis, but also include routine maintenance of flood protection facilities and public outreach programs. While most of countywide programs are proposed to be covered under status quo funding, proposals for enhanced funding for flood protection facility maintenance and public outreach have been included. Cost estimates provided are for implementation of these programs over the ten-year timeframe of the Plan.

TABLE 5-1.
PROPOSED COUNTYWIDE PROGRAMS AND COSTS (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Flood Preparedness, Warning and Emergency Response	Provide regional flood preparedness, warning and flood emergency response services. Supports recommendations PREP-1 through 5; WARN-1 through 4; RESP-1 and 2.	$3,900,000
Flood Protection Facility Inventory and Assessment	Develop and implement a flood protection facility inventory database and a routine program of inspection, condition assessment, and monitoring for all flood protection facilities and appurtenances, including levees, revetments, raised banks, pump stations, stormwater discharge structures, cross-culverts and closure structures. Supports recommendations INFRA-2 through 4.	$750,000
Flood Protection Facility Maintenance	Carry out annual routine maintenance, including flood protection facility mowing, noxious weed control, installation and repair of access controls, and minor repair and maintenance of flood protection facilities and related properties and appurtenances. Supports recommendation INFRA-1.	$1,450,000
Sediment Management Program	Establish a sediment management program that includes expanded channel monitoring, establishment of thresholds to trigger actions, and analysis of sediment management action alternatives. Supports recommendations SED-1 and SED-2.	$500,000
Floodplain Information and Permit Review Technical Support	Provide technical support to King County's Department of Development and Environmental Services for floodplain permits and inquiries, floodplain mapping, elevation certificates, and Critical Areas Ordinance updates. Supports recommendations MAP-2, COR-1, REG-1 to 3, TECH-3,-4, ERA-3	$400,000
Salmon Habitat Recovery Technical Support	Provide floodplain management technical support to Snohomish, Cedar, Green and White River watershed coordination and salmon habitat recovery activities. Supports recommendation TECH-6.	$1,000,000

TABLE 5-1 (CONTINUED).
PROPOSED COUNTYWIDE PROGRAMS AND COSTS (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding (continued)		
Technical Support to Other Agencies	Provide floodplain management technical support to all King County departments proposing activities or projects that affect floodplain functions. Supports recommendations TECH-3 through 5.	$250,000
Public Outreach	Carry out public outreach on floodplain management programs and projects, and respond to inquiries and complaints from citizen and other public and private agencies. Supports recommendations TECH-3, ERA-2 through 4, PREP-1 through 5.	$500,000
Grant Applications	Maximize federal, state and local funding opportunities through grant application submittals in support of completing capital improvement projects, technical studies and other flood hazard management activities. Supports recommendations ERA-4, INFRA-6 and MAP-5.	$100,000
Community Rating System Certification	Provide supporting documentation, technical support and staff training required to maintain favorable status in the FEMA's Community Rating System. This work supplements work, carried out in the Department of Natural Resources and Parks and compliment-related work carried out by the Department of Development and Environmental Services. Supports recommendation IMP-3.	$500,000
River and Floodplain Unit Administration	Provide for program administration, staff supervision and training, Flood Hazard Management Plan updates, Comprehensive Plan Consistency, and the River and Floodplain Management Unit Annual Report. Supports recommendations IMP-3 through 9.	$4,685,000
	Total Status Quo Funding	**$14,035,000**
Enhanced Funding		
Flood Protection Facility Maintenance Enhancements	Meet routine maintenance needs associated with the implementation of an enhanced flood hazards management program, and carry out routine maintenance on underserved flood protection facilities Supports recommendation INFRA-2.	$3,550,000
Public Outreach Enhancements	Meet additional public outreach needs associated with an expanded program, including increased interaction with incorporated cities and preparation of an annual report. Supports recommendations TECH-3, ERA-2 through 4, PREP-1 through 5.	$1,000,000
	Total Enhanced Funding	**$4,550,000**
	Total Countywide Programs	**$18,585,000**

Table 5-2 lists proposed countywide projects, which are one-time or infrequently repeated actions, such as completing flood or channel migration studies; these consist of both status quo and enhanced funding projects. Cost estimates for these projects, which are proposed for completion within the ten-year time frame of the Plan, are one-time expenses.

TABLE 5-2.
PROPOSED COUNTYWIDE PROJECTS AND COSTS (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Flood Hazard Corridor Mapping	Update flood hazard management corridor maps with flood hazard, land use and evaluate the feasibility of assessing the cumulative effects of flood risk reduction projects. Integrate flood hazard and ecological data in a readily accessible information management system. Supports recommendations COR-1, 4 and 5.	$50,000
Countywide Risk Assessment	Carry out flood damage risk assessments to evaluate the potential consequences of flood protection facility failure along major river systems. Risk assessments will focus on areas of potential levee failure and known repetitive loss areas. Supports recommendation COR-2.	$500,000
Flood Protection Facility Revegetation	Implement flood protection facility revegetation projects to promote the growth of native vegetation to decrease long-term maintenance needs and enhance fish and wildlife habitat. Funding adequate to support one or two small projects per year. Supports recommendations INFRA-1 and 2.	$250,000
Flood Emergency Response Reserve	Provide funding to repair flood protection facilities damaged by floods. To the maximum extent possible, funds would be used to match state and federal emergency and disaster mitigation funds. Supports recommendations RESP-1 and 2.	$1,800,000
Adaptive Management Analyses and Implementation	Monitor projects using performance measures and adaptive management to track the effectiveness of completed projects and inform the design and implementation of future projects. Supports recommendation IMP-8.	$100,000
	Total Status Quo Funding	**$2,700,000**
Enhanced Funding		
Flood Protection Facility Revegetation	Implement enhanced flood protection facility revegetation projects to promote the growth of native vegetation, decrease long-term maintenance needs, and enhance fish and wildlife habitat. Enhanced funding would allow completion of an additional one or two projects per year. Supports recommendations INFRA-1.	$250,000
Large Woody Debris and Landslide Hazard Assessment and Management Alternatives Analyses	Complete an assessment of flood hazards associated with increasing accumulations of large woody debris in river channels and the potential impacts future landslides may have on flooding and erosion. Develop alternative analysis and protocols for the management of flood hazards related to these natural river and floodplain elements. Supports recommendations WD-1 through 3 and LS-4.	$200,000

TABLE 5-2 (CONTINUED).
PROPOSED COUNTYWIDE PROJECTS AND COSTS (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Enhanced Funding (continued)		
Small Stream and Marine Shoreline Area Flood Studies	Complete flood studies and flood boundary delineations to update the corresponding FEMA Flood Insurance Studies and Flood Insurance Rate Maps for small streams and marine shoreline areas in unincorporated King County. Supports recommendations MAP-2, MAP-5 and MAP-7.	$1,125,000
Sediment Management Reserve Fund	Provide funding to implement one or more gravel removal projects based on sediment management program monitoring findings. Supports recommendation SED-2.	$1,000,000
Flood Emergency Response Reserve Enhancement	Increase rate of accrual and total amount of funds available to repair flood protection facilities damaged by floods. To the maximum extent possible, funds would be used to match state and federal emergency and disaster mitigation funds. Supports recommendations RESP-1 and 2.	$700,000
Flood Mitigation Opportunity Fund	Identify and provide funding for home elevations and floodplain property acquisitions recommended through the analyses of repetitive loss areas, basin-specific alternative analyses, and countywide risk assessment. Supports recommendation ERA-1.	$20,000,000
	Total Enhanced Funding	**$23,275,000**
	Total Countywide Projects	**$25,975,000**

5.2 SOUTH FORK SKYKOMISH RIVER

5.2.1 Overview

The South Fork Skykomish River is formed at the confluence of the Tye and Foss Rivers about 13 river miles upstream of the King and Snohomish county line. The South Fork Skykomish runs through the incorporated Town of Skykomish, which is located between the major tributaries of the Beckler and Miller Rivers. The headwaters of the South Fork Skykomish and its tributaries are high in the Cascades and include the west side of Stevens Pass. The South Fork Skykomish flows into Snohomish County near Baring; it combines downstream with the North Fork Skykomish to form the mainstem Skykomish River. The Skykomish feeds the Snohomish River, which empties into Puget Sound at Port Gardner in Everett. Map 5-1 shows major features in this basin. An electronic version of this map can found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf//5-1.pdf

In general, the South Fork Skykomish is a relatively unpolluted and free-flowing river, of which the State of Washington has designated large portions as "scenic." The portion of the South Fork Skykomish and its tributaries within King County are generally of steep gradient, with numerous rocky cascades of white water. The flow regime, including flood peaks, on the South Fork Skykomish is unregulated, as there are no significant dams in the watershed. The flood hazard management corridor includes the mainstem South Fork Skykomish and valley bottom, plus the lower parts of the Miller, Beckler, Foss and Tye Rivers.

5.2.2 Geology and Geomorphology

The South Fork Skykomish drains steep and rugged mountains composed of tertiary and cretaceous bedrock. In this mountainous setting, bedrock is exposed or underlies shallow soils along most of the hillslopes of the basin; bedrock is also exposed along some of the valley wall bounding the floodplain and river. The remaining valley wall that the river could encounter is composed of sediments deposited by continental glaciation or by landslides. Through most of the flood hazard management corridor, the river flows in a meandering and single thread channel across a floodplain of young alluvium.

The channel is relatively steep and confined compared to that of other large King County rivers, particularly from the confluence with the Foss River to the Town of Skykomish. There is also about a mile of river from the Town of Skykomish to the Miller River along which the floodplain is narrow and confined by bedrock. Otherwise, the channel gradient decreases and the floodplain widens going downstream to the county line.

The steep and narrow South Fork Skykomish valley generates deep, fast-moving flood flows capable of severe bank erosion, as evidenced by erosion during the November 1990 flood that claimed several riverfront homes (King County 1993b). A preliminary review of historical channel locations indicates that there are some localized areas where the river channel has moved around markedly, but that other stretches of the South Fork Skykomish have exhibited little change in location over the period recorded on historical maps and aerial photos.

5.2.3 Hydrology and Hydraulics

There are no significant dams or reservoirs on the South Fork Skykomish or its tributaries. With its steep upper basin slopes in high elevation terrain forming the entire watershed, significant runoff can be delivered directly to the flood hazard management corridor along the South Fork Skykomish. Precipitation at these high elevations can generate flooding from rain-on-snow events.

There is currently no functioning U.S. Geological Survey river gage along the South Fork Skykomish in King County or the Town of Skykomish, although the U.S. Geological Survey has had several river gages in the King County portion of the Skykomish River basin in the past. A gage on the South Fork Skykomish near Index (USGS #12133000) recorded data from 1897 to 1982. The flow frequencies listed for the South Fork Skykomish near Index in Table 5-3 are based on this period of record. The closest available flow measurements are taken downstream in Snohomish County at the Skykomish River near Gold Bar gage (USGS #12134500).

Although a U.S. Geological Survey gage on the mainstem of the Skykomish River exists (USGS #12134500), the flows in Table 5-3 reflect the flow estimates derived from a hydrologic study of the Skykomish and Snoqualmie Rivers.

TABLE 5-3.
SOUTH FORK SKYKOMISH RIVER FLOWS

Recurrence Interval (years)	Discharge (cubic feet per second)	
	South Fork Skykomish near Index[a]	Skykomish River at Gold Bar[b]
10	44,300	75,300
50	65,200	106,100
100	74,700	119,300
500	98,500	149,900

a. FEMA 2005.
b. Flow estimates based on hydrologic analysis for the Lower Snoqualmie and Skykomish River Revised Flood Insurance Study (Draft, 2005).

See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

5.2.4 Ecological Context

The South Fork Skykomish drainage is in good ecological condition relative to other King County drainages. The vast majority of the area is managed for natural resources or is relatively unmanaged as wilderness and is mostly in federal ownership. The dominant federal agency is the U.S. Forest Service, which manages most of the drainage for wilderness and natural resource values, primarily timber, fish and wildlife, water quantity and quality, and recreation.

There are potential impacts from forestry-related uses throughout this drainage basin, generally upstream of the flood hazard management corridor, which can have effects on downstream flooding and channel conditions. These impacts include altered watershed hydrology, increased erosion and sediment caused by timber removal and forest roads, and reduced levels of large woody debris. These changes contribute to a reduction in instream habitat. Many forestry-related impacts are legacies of historical timber harvesting using harvest and forest road building rates and practices that are not used anymore. Thus the future prognosis is good for protecting and restoring natural hydrology, sediment and large woody debris functions on timber lands, although this may take decades in degraded areas such as along the Beckler River.

Residential development is absent from the vast majority of the drainage. Such development is concentrated in a few locations along the mainstem of the South Fork Skykomish near the Town of Skykomish, the unincorporated community of Baring, and along the lowermost reaches of a few of its larger tributaries, mainly the Miller, Tye and Foss Rivers. Residential development in these areas, while rural in nature, often encroaches on river banks and floodplains. In many places river-side development has reduced the quantity and quality of riparian forests and resulted in bank hardening. These impacts, in turn, alter natural rates of erosion, channel migration and large woody debris recruitment.

The South Fork Skykomish valley is also an east-west transportation corridor for BNSF Railway and State Highway 2 over Stevens Pass. A small network of minor residential roads exists along the valley floor. These features often run along, near or over the river, lower portions of its tributaries and associated floodplains and historical channel migration areas. Where these developments co-exist with stream channels, the stream banks are often stabilized, limiting natural rates of erosion, channel migration and large woody debris recruitment.

5.2.5 Salmonid Use

The South Fork Skykomish was historically used only by resident non-migratory fishes, due to impassable falls in Snohomish County at approximately River Mile 1.9. Since the Washington Department of Fish and Wildlife began its trap-and-haul program in 1958, local populations of Chinook and coho salmon and summer run steelhead and bull trout have been established. The coho, steelhead and bull trout populations were considered to be "healthy" in a review by Haring (2002). The *Salmon and Steelhead Stream Inventory* (SASSI 1992) estimated that about 15 percent of the Chinook salmon and ten percent of the bull trout adults that spawn in the Snohomish River occur in the South Fork Skykomish above the falls.

The Snohomish River Basin Salmonid Recovery Technical Committee (SRBSRTC 2004) assigned the following ratings in the South Fork Skykomish basin:

- The South Fork Skykomish above Sunset Falls was rated "degraded" for shoreline condition and connectivity and "moderately degraded" for water quality and condition of wetlands, for shoreline vegetation, for large woody debris levels, and for barriers, because of culverts blocking access.
- Of the major tributaries, the Beckler River and its tributary, the Rapid River, showed the greatest cause for concern, being rated as "degraded" for sediment and riparian vegetation and large woody debris.
- The other major tributaries—the Miller, Foss and Tye Rivers—were in better shape, being "intact" for most parameters for which data existed. These tributaries' worst ratings were "moderately degraded," for water quality on the Tye River, sediment on the Miller River, and riparian and large woody debris conditions on the Foss River.

5.2.6 King County Flood Protection Facilities, Major Flooding, Flood Damage

The primary King County flood protection facilities along the South Fork Skykomish line most of the left river bank and several hundred feet of the right bank through the Town of Skykomish. These flood protection facilities are training levees and revetments that hold the channel in place and resist bank erosion, but are not containment levees designed to prevent overbank flooding.

The largest flood on record on the Skykomish River in Gold Bar occurred in November 1990, when flows reached 102,000 cubic feet per second. This flood inundated the Town of Skykomish along the South

Fork Skykomish River. Other recent large floods on the Skykomish at Gold Bar occurred in December 1995, at 79,600 cubic feet per second, and November 1986, at 76,500 cubic feet per second.

Most of the levees and revetments on the South Fork Skykomish River and its tributaries were damaged in the November 1990 flood. Most were rebuilt with traditional rock riprap installations, but suffered similar damage from floods during the winter of 1995-96.

In the Town of Skykomish, the South Fork Skykomish River has heavily eroded its left bank many times in the past century. Virtually the entire left bank through the town was damaged in the November 1990 flood and rebuilt thereafter. Similar damage was experienced through much of the same area in the November 1995 and February 1996 floods.

Homes and other structures at many locations along the river have suffered damage from deep and fast moving water. One home in the Timber Lane Village subdivision upstream of the Town of Skykomish was undermined and destroyed by river bank erosion in the November 1990 flood. Several homes in the Town of Skykomish have been struck by flood-borne debris moving at high speed.

In the 1995 flood, an unusually large log jam formed on the Tye River. The jam filled the width of the river channel for a length of roughly 800 feet and to a depth of more than 10 feet. The jam was found to be structurally stable, such that it did not pose a dam-break threat to downstream properties. Although the jam is thought to increase backwater and avulsion hazards to two nearby homes, the cost of jam removal would exceed the value of those homes. The jam remains intact.

5.2.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

FEMA published flood insurance maps for most of the flood hazard management corridor in this basin in 1998. Channel migration hazard mapping studies are in progress. The following projects were built to resist ongoing damage to county roads:

- The Miller River crossing of the Old Cascade Highway has experienced chronic flood damage. The highway has one major bridge over the Miller River channel, as well as one small bridge and one large culvert where overbank channels cross the highway west of the river channel. In the 1970s, a discontinuous system of earthen levees was built along the left bank of the Miller River channel to direct flow toward the primary bridge, limiting flows toward the small bridge and culvert. These levees were damaged in the November 1990 flood and subsequently rebuilt. The same levees were damaged more severely in 1995 and 1996, when an upstream avulsion changed the river's angle of attack on the levee system and on nearby unprotected banks. In order to reduce the risk of an avulsion toward the culvert, the discontinuous earthen levees were rebuilt and then supplemented with a log crib along the river bank between the discontinuous levee segments. An erosion resistant spillway section was also installed in the Old Cascade Highway. Although subsequent floods have frequently overtopped the highway, forcing temporary closure, the highway has not had repetitive structural damage as it had in earlier years.
- In Baring, erosion along the right bank of the South Fork Skykomish reached the shoulder of NE 196th Street in November 2000. An emergency revetment was built of large rock to support the failing road. The revetment has a very steep slope and does not have a deep rock toe, so it may suffer damage when it is tested by high flow.
- In the Town of Skykomish, erosion damage to the left bank flood protection facility in front of the Sky River Inn, between 4th and 5th Streets, was repaired using large rock, native vegetation, large woody debris, and one large rock deflector. Erosion damage to other parts

of the this facility were not repaired because existing flood protection easements were judged insufficient, and several property owners decided not to extend sufficient easement rights to allow the needed repairs.

5.2.8 Flood Hazard Management Corridor Data

Hazard mapping in this basin includes detailed flood studies and Flood Insurance Rate Maps along the South Fork Skykomish River. The existing maps do not account for hazards along several major tributaries to the South Fork Skykomish River. These include Index Creek, Money Creek, and Anthracite Creek, each of which has caused flood damage to homes and infrastructure. These creek systems represent the most significant flood mapping needs in this basin. Channel migration hazard studies have begun in this basin but have not yet produced any predictive channel migration hazard zone mapping. Flood hazard corridor maps for the South Fork Skykomish River in King County included a riparian buffer based on the King County Critical Areas Ordinance aquatic-area buffer.

5.2.9 Flood Hazard Management Corridor Conditions

Despite the presence of revetments and some training levees, the residential developments along the river banks and floodplains are subject to significant flood risk. Flooding in this steep and narrow valley means deep, fast-moving water with a significant debris load. Land uses near the river channels are subject to erosion, inundation, and debris impact, each of which can be life-threatening.

5.2.10 Flood Hazard Management Objectives and Strategies

In the South Fork Skykomish River basin in King County, flood risks as outlined in Policy G-2 include risks to public safety, primarily in residential areas and on roads; risks to public infrastructure, primarily the Old Cascade Highway; and risks to private structures, again, mostly in residential areas.

The current flood hazard reduction objectives for the South Fork Skykomish River basin in King County include the reduction of flood hazard associated with the inundation of homes, protection of the Old Cascade Highway, and minimization of the impacts of flood risk reduction projects on endangered or threatened species. Each of these objectives is described below, along with the associated strategies and projects that will be used to meet these objectives.

1. The overarching objective for the South Fork Skykomish River is to reduce risk to public safety posed by flooding and erosion in residential areas. Throughout the basin, the greatest flood risks involve individual homes that are subject to deep and fast flood conditions, impact damage from flood-borne debris, and undermining by river bank erosion. Some of these flood-prone homes have had repetitive flood loss claims to the National Flood Insurance Program, while others are exposed to less frequent flood conditions that can cause very sudden loss. Because of the nature of these flood-related risks, the primary strategy for the basin is the purchase and removal of homes that are at risk from serious flooding and erosion hazards.

2. A second major objective involves preserving safe access to homes and businesses along the river. However, this Plan assumes that state and federal agencies will continue to protect the Stevens Pass Highway (State Route 2) from flood damage. Similarly, this Plan assumes that private parties will continue to maintain their existing private roads and driveways. This Plan does recommend a project to help protect the Old Cascade Highway which is at risk from flood damage.

3. The third primary objective is to carefully minimize the creation of new risks to public safety as this basin responds to development pressure. Completion of ongoing efforts to identify and map areas of channel migration hazard will help meet this objective.

4. Finally, ensuring that flood hazard management actions do not adversely affect, and where possible, support, salmon habitat restoration efforts is an essential part of the flood hazard management program. The emphasis of the Plan on non-structural solutions, or, in the case of the project designed to reduce flood damages to the Old Cascade Highway, a solution that will result in the addition of a substantial amount of large woody debris, strongly support this objective.

5.2.11 Proposed Actions

Table 5-4 summarizes the start list of proposed flood hazard management actions for the Skykomish River in King County. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-4. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-4.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE SOUTH FORK SKYKOMISH RIVER IN KING COUNTY (2007-2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Miller River Road Protection	Enhance constructed log jam to reduce erosion risks to the Old Cascade Highway.	$96,000
Timber Lane Village Home Buyouts (Erosion)	Purchase homes and property in this residential neighborhood, which is subject to extreme erosion.	$3,367,000
South Fork Skykomish River Channel Migration Zone	South Fork Skykomish River Channel Migration Zone Study and Mapping. Supports recommendation CMZ-1.	$30,000
	Total Status Quo Funding	**$3,493,000**

TABLE 5-4. (CONTINUED)
PROPOSED ACTIONS AND COST ESTIMATES FOR THE SOUTH FORK SKYKOMISH RIVER IN KING COUNTY (2007-2016)

Proposed Action	Description	Estimated 10-Year Cost
Enhanced Funding		
South Fork Skykomish River Early Action Residential Flood Hazard Mitigation.	Purchase or otherwise mitigate flood risks to repetitive loss properties. Supports recommendations ERA-1 and ERA-4.	$1,059,000
Miller River Home Buyout	Purchase residential compound threatened by flooding and erosion.	$683,000
Town of Skykomish Home Buyouts	Purchase homes and property in this residential neighborhood, which is subject to flood-borne debris.	$1,952,000
Timber Lane Village Home Buyouts (Flooding)	Purchase homes and property in this residential neighborhood, which is subject to extreme flooding.	$800,000
	Total Enhanced Funding	**$4,494,000**
	Total South Fork Skykomish River	**$7,987,000**

Miller River Road Protection

Location Information

Water Resource Inventory Area 07-1329, Miller River
River Mile 0.2 to 0.3, Left Bank
Council District 3
Jurisdiction: Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$96,000

Problem Statement

The Old Cascade Highway crosses the Miller River near its confluence with the South Fork of the Skykomish River. The left bank (west) road approach is at relatively low elevation across the Miller River's broad alluvial fan. The highway has been severely damaged in past floods. Structural improvements have strengthened the road, but it remains at risk to channel migration on the fan. From a flood risk reduction standpoint, the ideal solution would be to relocate the Old Cascade Highway to a more stable location away from the alluvial fan. However, this does not appear to be feasible in the near term.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure primarily the Old Cascade Highway.

Proposed Project or Action

Supplement and extend the log crib that helps to direct flow toward the Miller River bridge.

Project Benefits

Protection of public safety and of transportation corridor.

Coordination

Coordination with the King County Department of Transportation will be needed.

Other Information or Needs

This project is in the First Priority Restoration Area designated in the *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan.

Project Area Map

A map of the project area may be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Miller1.pdf

Timber Lane Village Home Buyouts (Erosion & Flooding)

Location Information

Water Resource Inventory Area 07-0012, South Fork Skykomish River
River Mile 18.3 – 18.4 and 18.6 – 19, Left Bank
Council District 3
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$3,367,000 for high erosion risk area, $800,000 for flood-prone area.

Problem Statement

Deep, fast flood water surrounds and inundates several homes in this residential area. Some are also subject to significant erosion hazard; one home was lost to erosion during the November 1990 flood. Rapid channel change is an unusually high risk along this left bank subdivision. This flood hazard involves significant risk to public safety. Two of the homes in question have been identified by FEMA as repetitive loss properties.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

Acquire properties and remove homes and other structures from these flood hazard areas.

Project Benefits

Protection of public safety.

Coordination

Coordination with current property owners will be needed.

Other Information or Needs

This project is in the First Priority Restoration Area designated in the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan.

Project Area Map

A map of the flood-prone area project site may be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Timber1.pdf

A map of the erosion-prone area project site may be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Timber2.pdf

Miller River Home Buyout

Location Information

Water Resource Inventory Area 07-1329, Miller River
River Mile 0.00 – 0.07, Left Bank.
Council District 3
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$683,000

Problem Statement

The Old Cascade Highway crosses the Miller River near its confluence with the South Fork Skykomish River. The left bank (west) road approach is at relatively low elevation across the Miller River's broad alluvial fan. Flood flows across this road threaten homes downstream of the Miller River Road.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

Acquire property and remove housing and other structures from the flood hazard area.

Project Benefits

Protection of public safety.

Coordination

Coordination with current property owners will be needed.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Miller2.pdf

Town of Skykomish Home Buyouts

Location Information

Water Resource Inventory Area 07-0012, South Fork Skykomish River
River Mile 15.95 – 16.00 and 16.2 – 16.5, Left Bank
Council District 3
Jurisdiction: Town of Skykomish
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,952,000

Problem Statement

Deep, fast flood water carries an extensive debris load that has caused sudden damage by striking residential structures. This flood hazard involves significant risk to public safety for the residents in this area.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if homes are struck by flood-borne debris;
- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

Acquire properties and remove homes and other structures from the flood hazard area.

Project Benefits

Protection of public safety.

Coordination

Coordination with current property owners will be needed.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Skykomish.pdf

5.3 UPPER SNOQUALMIE RIVER

5.3.1 Overview

The upper Snoqualmie River basin includes the entire watershed above Snoqualmie Falls, with a drainage area of 367 square miles, or about half of the entire Snoqualmie basin. The three forks of the Snoqualmie River are the North Fork, the Middle Fork and the South Fork. Each has its beginnings in the high peaks of the Cascades and follows steep watercourses through the mountains to the confluence of the three forks near the foot of Mount Si. The South Fork of the Snoqualmie flows through the City of North Bend. The three forks combine to form the mainstem Snoqualmie River, which flows through the City of Snoqualmie and over Snoqualmie Falls. See Map 5-2 for the major features of the upper Snoqualmie River. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-2.pdf

Land use in North Bend and Snoqualmie is primarily residential and commercial. The upper basin outside the two cities is within unincorporated King County, with land use that includes rural residential and forestry. The upper reaches of the three forks are almost entirely owned by the U.S. Forest Service.

Flows along the forks are unregulated, with no major reservoirs in the system. Several hydroelectric facilities divert flows, including a dam operated by Puget Sound Energy immediately above Snoqualmie Falls. All of the hydroelectric facilities in this sub-basin lack sufficient storage volumes to control downstream flooding.

The upper Snoqualmie River flood hazard management corridor includes the mainstem Snoqualmie and the channels of the three forks to the upstream end of the mapped flood hazard areas. It includes the channel migration hazard areas plus a riparian buffer through that same length. The downstream boundary of the upper Snoqualmie basin is the 270-foot Snoqualmie Falls, which is a natural impediment to anadromous fish passage from the lower Snoqualmie basin.

5.3.2 Geology and Geomorphology

The steep boulder- and bedrock-dominated slopes and channels of the upper watershed transition to hillslopes and valley walls of glacial sediments in the three-forks confluence area. The continental glaciation that shaped much of Puget Sound Lowland also affected the upper Snoqualmie basin.

The three forks of the Snoqualmie River emerge from the mountains and deposit their coarse sediment load on a broad, gently sloping valley floor (Booth et al. 1991). Along most of their course, the three forks flow primarily through unconsolidated alluvial deposits of gravel, sand, and silt that have been laid down and reworked by the rivers. In places, the rivers abut older geologic materials at the edge of the valley floor, including glacial deposits and the bedrock escarpment of Mount Si. Valley walls consisting of glacial and non-glacial sediments and older bedrock units are less erodible than alluvium and limit the lateral migration of the three forks and the mainstem Snoqualmie River (Perkins 1996).

Each of the three forks of the Snoqualmie within the flood hazard management corridor is in a post-glacial valley that has incised into glacial sediments deposited in continental glaciations. Downstream of Snoqualmie Falls, the lower Snoqualmie basin is an example of a basin sculpted as a glacial trough. The area along the mainstem from the confluence of the three forks to Snoqualmie Falls is in an area of transition where the influence from one land-forming process gives way to the next. The entire three-forks area of the Snoqualmie is a rapidly migrating river system (Perkins 1996), whether it is in an incised post-glacial valley of one of the Snoqualmie forks or the transitional area of the mainstem river to Snoqualmie Falls.

5.3.3 Hydrology and Hydraulics

Like the South Fork of the Skykomish River, there are no significant dams on the upper Snoqualmie River to regulated flood flows. All three forks of the Snoqualmie River are relatively steep and confined through most of their course upstream of the confluence area. The combination of no flood control impoundments and steep, confined upstream channels that open to lower gradient floodplains make for areas of widespread flood risk from inundation and channel migration during winter throughout the three forks area. Rain-on-snow events can have a significant effect in this unregulated system with headwaters in the high elevations of the Cascades.

King County flood response efforts do not key to any one river gage, but instead collectively consider flows as the sum of the three forks. The Snoqualmie River near Snoqualmie gage (USGS #12144500) is located at the base of Snoqualmie Falls. U.S. Geological Survey gages are located on the Middle, North and South Forks of the Snoqualmie River. Table 5-5 summarizes flow data from these gages.

TABLE 5-5.
UPPER SNOQUALMIE RIVER FLOWS

Recurrence Interval (years)	Discharge (cubic feet per second)			
	Snoqualmie River near Snoqualmie[a]	Middle Fork Snoqualmie[b]	North Fork Snoqualmie[b]	South Fork Snoqualmie[b]
10	51,700	28,000	18,600	9,000
50	71,100	38,300	24,600	13,000
100	79,100	43,800	27,200	15,000
500	95,200	55,800	32,800	19,200

a. Flow estimates based on hydrologic analysis for the Lower Snoqualmie and Skykomish River Revised Flood Insurance Study (Draft, 2005).
b. FEMA 2005.

See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

5.3.4 Ecological Context

All three forks of the Snoqualmie drain a combination of wilderness in their uppermost reaches and public and private timberlands, much of which has been extensively logged. Once the forks leave the timberlands, development has encroached on the river and much of the length of the once-dynamic channels is now heavily armored and locked in place. Natural river processes are more evident in the three forks areas; however, even in this largely undeveloped area, several flood protection facilities influence channel migration patterns.

Riparian conditions vary greatly above Snoqualmie Falls. Headwater riparian areas are densely vegetated mostly with conifers. On the valley floor, riparian vegetation becomes dominated by deciduous trees, and a range of rural to urban development has encroached on the river channels, often in old swales once occupied by one of the forks or the mainstem river. At the larger scale, most of the upper watershed is in the Forest Production District, as designated by the King County Comprehensive Plan, and is maintained as forest, in the form of wilderness or for long-term forestry uses.

5.3.5 Salmonid Use

Salmonid use above Snoqualmie Falls is limited to cutthroat and rainbow trout, mountain whitefish and non-native brook trout (Berge and Mavros 2001). Although appropriate habitat is present and there are anecdotal reports of bull trout, a concerted survey effort to detect them following American Fisheries Society protocols in 2000 did not find any bull trout.

5.3.6 King County Flood Protection Facilities, Major Flooding, Flood Damage

Flood protection facilities in this area maintained by King County include a system of continuous levees along the South Fork Snoqualmie River through North Bend and many discontinuous levees and revetments along the other two forks and the mainstem Snoqualmie River. With the exception of the lower mile and a half of the South Fork Snoqualmie River, most outside river bends are armored. The original construction methods and materials used during the construction of most of the flood protection facilities are largely unknown. It appears from historical aerial photos and file materials that both continuous levees along the South Fork Snoqualmie River were either constructed or significantly improved in the mid-1960s.

The highest flows recorded at the Snoqualmie River near Snoqualmie gage were 78,800 cubic feet per second in November 1990, 61,000 cubic feet per second in November 1959, and 58,100 cubic feet per second in November 1986. Recent high flows at the same gage include 44,000 cubic feet per second in November 1989, 34,200 cubic feet per second in February 1995 and 51,700 cubic feet per second in February 1996.

Floods in 1995 and 1996 caused damage to King County levees and revetments in this area. Most of this damage was subsequently repaired, as described in the next subsection.

5.3.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

A major excavation project was completed in 2004 to relieve flooding in the City of Snoqualmie, which has been the source of more flood insurance claims than any other city in Washington State. The Snoqualmie Flood Reduction Project, or Snoqualmie 205, was a U.S. Army Corps of Engineers project under section 205 Small Flood Control Project authority that was jointly sponsored by the City of Snoqualmie and King County. By widening 800 feet of the river channel to roughly match the upstream and downstream width, the project will reduce flood depths in the heart of old Snoqualmie. Damage is projected to be cut by more than 50 percent, saving an average of $800,000 per year.

The Meadowbrook Bank Stabilization project was completed in 2000 to resist erosion damage to several homes and to a public park in the City of Snoqualmie. This project used untreated wooden pilings to anchor a series of engineered log jams at the toe of an eroding bank. In this way, the project strengthened 1,170 feet of eroding bank without using rock riprap or causing short-term turbidity, which is typical of bank stabilization projects.

Eight smaller projects were completed to repair damage to levees and revetments after the November 1995 and February 1996 floods. These projects had a combined length of 2,040 feet of river bank. Of that total, 1,400 feet of bank repairs were along the South Fork Snoqualmie levee system through the City of North Bend.

Ten homes have been purchased and removed from areas subject to deep and fast floodwater. The largest single concentration of these homes has been in the Williams Addition neighborhood, just west of Snoqualmie. An additional 66 homes have been elevated to resist flood damage. This includes 57 homes for which the City of Snoqualmie secured federal and state funding for the elevation work.

A Flood Insurance Study and Flood Insurance Rate Maps published by FEMA in 2005 identified and mapped flood inundation areas along all three of the Snoqualmie River forks and in the North Bend area where the forks interact. A channel migration zone study and map were completed in 1996 and adopted by public rule by the King County Department of Development and Environmental Services in 1999.

The U.S. Army Corps of Engineers has completed a reconnaissance of levee improvement concepts that were suggested jointly by the City of North Bend and King County. That study identified U.S. Army Corps of Engineers requirements for levee improvement projects that are cost-prohibitive in this situation. Although the U.S. Army Corps of Engineers has terminated its study of levee improvement concepts, it did offer other project concepts, which could involve raising individual structures above flood levels and removing individual structures from dangerous locations.

5.3.8 Flood Hazard Management Corridor Data

Hazard mapping in this basin includes detailed flood studies and Flood Insurance Rate Maps along the mainstem Snoqualmie and each of its three forks. The existing maps do not reflect the locally reduced flood elevations that are the result of the channel widening project done in 2004. Further, the existing maps did not incorporate specific flood studies for several major creeks in this area. These include Kimball, Coal, Gardiner, Ribary and Clough Creeks. The lack of floodplain mapping along these creek systems, and the area affected by the channel widening project on the mainstem Snoqualmie, represent the most significant flood mapping needs in this basin. Channel migration hazard mapping is complete for this basin, covering the mainstem Snoqualmie River from Snoqualmie Falls upstream and along the lower 2 to 3 miles of each of the three forks. Flood hazard corridor maps for the upper Snoqualmie River basin included a riparian buffer based on the King County Critical Areas Ordinance aquatic-area buffer.

5.3.9 Flood Hazard Management Corridor Conditions

The containment levee system along the South Fork Snoqualmie River through the North Bend area is the most significant flood control feature in the upper Snoqualmie basin. The levees are not certified as reliable 100-year flood protection, and they do not meet standards for certification. Deficiencies include a lack of sufficient containment capacity, problems with structural stability, and problems with erosion resistance. Therefore, the Flood Insurance Rate Maps identify extensive 100-year flood hazard areas behind the levees. Much of the property in these hazard areas has been developed in a relatively dense pattern of homes and businesses. These developed properties are at risk.

Another significant levee system exists along the left bank of the Middle Fork Snoqualmie River in the North Bend area. However, this is not a containment levee system. The Middle Fork levees are discontinuous and adjoin only a fraction of the river's length. Floodwaters can flow over the unleveed river banks between the levees. Moreover, in an extreme event, the levees themselves can be overtopped. Therefore, the Flood Insurance Rate Maps identify extensive flood hazard areas behind the levees. Further, the channel migration hazard maps identify extensive erosion hazards along a series of channel features that fall toward the northwest, from the Middle Fork toward the South Fork. Much of the property in these hazard areas has been developed and is at risk.

The North Fork levees are discontinuous and adjoin only a fraction of the river's length. Floodwaters can flow over the unleveed river banks between the levees. Moreover, in an extreme event, the levees themselves can be overtopped. Both the Flood Insurance Rate Maps and the channel migration hazard

maps identify extensive hazards along the North Fork. Much of the property in these hazard areas has been developed and is at risk.

Despite the recently completed channel excavations in the Snoqualmie area, the City of Snoqualmie and the surrounding area continue to be subject to significant flood risk. The excavation project has reduced the depth that any given flood will reach, thereby reducing the frequency and severity of flood damage, but the floodplain still contains hundreds of homes and businesses that are at risk.

5.3.10 Flood Hazard Management Objectives and Strategies

In the Upper Snoqualmie River basin, flood risks as outlined in Policy G-2 include risks to public safety from deep fast flows; risks to public infrastructure including drainage systems, streets and buildings; potential impacts on the regional economy if the City of Snoqualmie or the City of North Bend are severely flooded; risks to private structures, both residential and commercial; and the potential for all of these risks to worsen suddenly in the event of a levee failure.

Flood hazard management objectives for the upper Snoqualmie River basin are focused on reducing flood risks in and around the Cities of North Bend and Snoqualmie. Objective and strategies for reducing flood risks in these areas described below.

1. Minimize flood impacts on the North Bend area. The containment levees along the South Fork Snoqualmie River provide significant but incomplete protection to much of the North Bend community. Failure of these levees could lead to extensive, catastrophic flood damages. In addition, channel constrictions on the Middle Fork Snoqualmie River, created by the alignment of two levee segments, further increase flood risks in this area. The strategy that will be used to achieve this objective includes implementing both structural elements intended to help contain flood flows in the South and Middle Forks of the Snoqualmie River, and non structural projects intended to reduce or eliminate risks to the most flood prone properties. These project will result in the strengthening of the levee system on the South Fork Snoqualmie River, improvements in the conveyance of flood flows in the Middle Fork Snoqualmie River; and removal or elevation of individual flood prone structure.

2. Protection of properties both within and around the City of Snoqualmie. While the recent completion of the Snoqualmie 205 project will substantially reduce the severity and frequency of flood hazards in around the City of Snoqualmie, this area will continue to be subjected to flood hazards. Both home elevations and acquisition of flood prone properties will be used to further reduce property losses and public exposure to flood hazards. The countywide flood mitigation opportunity fund described in Table 5-2 will provide potential funding for these elevation and buyout projects.

5.3.11 Proposed Actions

Table 5-6 summarizes the start list of proposed flood hazard management actions for the upper Snoqualmie River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-6. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using

2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-6.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE UPPER SNOQUALMIE RIVER (2007-2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
South Fork Levee System Improvements	Initiate rehabilitation of the levee system on the South Fork Snoqualmie River.	$5,039,000
North Bend Area Residential Flood Mitigation	Reduce flood risks to homes in the North Bend area. Initially focus on five unmitigated repetitive loss properties and surrounding areas.	$4,827,000
	Total Status Quo Funding	**$9,866,000**
Enhanced Funding		
Middle Fork Levee System Capacity Improvements	Reduce flood risks associated with constrictions caused by segments of the incomplete levee system on the Middle Fork Snoqualmie River.	$2,831,000
	Total Enhanced Funding	**$2,831,000**
	Total Upper Snoqualmie River	**$12,697,000**

South Fork Levee System Improvements

Location Information

Water Resource Inventory Area 07-0467, South Fork Snoqualmie River
River Mile 2 to 7, Both Banks
Council District 3
Jurisdictions: City of North Bend, Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$5,039,000

Problem Statement

Extensive geotechnical deficiencies have been observed on the existing levee system along both banks of the South Fork Snoqualmie River through North Bend and the surrounding unincorporated areas. These problems can compromise the flood protection benefits of the levee system.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levees fail, resulting in sudden deep fast flows in areas of roads, businesses and residences;
- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure including roads, drainage systems, public facilities and flood protection facilities;
- Impacts on the regional economy resulting from severe damages to the City of North Bend;
- Damage to private structures.

Proposed Project or Action

Rebuild and strengthen selected portions of the existing levee system in an approach that maintains current preferential protection of the more heavily developed parts of the City of North Bend.

Project Benefits

Improve performance of levee system, reducing levee failure related risks to neighboring areas.

Coordination

Coordination with property owners and the City of North Bend will be needed.

Other Information or Needs

This project is in the Headwaters Restoration Above Falls and Dam area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource

Inventory Area 7. The proposed action is counter to the general direction of that plan, which would generally eliminate hardened banks. However, the salmon habitat recovery plan puts a relatively low priority on restoration above Snoqualmie Falls. Therefore, action to preserve the existing hardened structures along these river banks would not interfere with high-priority salmon conservation work.

At King County's request, the U.S. Army Corps of Engineers has considered use of its Section 205 Small Flood Control Project authority to resolve the structural deficiencies in this levee system. The U.S. Army Corps of Engineers found that its project requirements would force removal and replacement of the entire levee system. U.S. Army Corps of Engineers staff has suggested that the local governments might achieve more cost-effective levee improvements by working only on selected portions of the levee system. This approach would preclude participation by the U.S. Army Corps of Engineers.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/SF.pdf

North Bend Area Residential Flood Mitigation

Location Information

Water Resource Inventory Area 07-0219, Middle Fork Snoqualmie River
River Mile 0.5 – 3.5, Both Banks
Water Resource Inventory Area 07-0467, South Fork Snoqualmie River
River Mile 0.5 – 4.8, both banks
Council District 3
Jurisdictions: City of North Bend, Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,827,000

Problem Statement

Although a system of levees generally protects most homes in the North Bend area from damage during minor floods, the capacity of the levee system is limited. Flows in excess of roughly 20-year magnitude will overtop portions of the levee system and cause damage to neighboring properties. Hazards are associated with both the Middle Fork Snoqualmie River and the South Fork Snoqualmie River, as well as several smaller tributary streams.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levees overtop or fail, resulting in sudden deep fast flows in areas of roads, businesses and residences;
- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure including roads, drainage systems, public facilities and flood protection facilities;
- Impacts on the regional economy resulting from severe damages to the City of North Bend;
- Damage to private structures.

Proposed Project or Action

Relocate or elevate individual structures to eliminate the associated risk of flood damage.

Project Benefits

Protect safety for those who would occupy these otherwise at-risk structures. Reduce frequency and severity of damage to structure and contents. Reduce water quality problems associated with such damage.

Coordination

The U.S. Army Corps of Engineers has suggested that its Section 205 Small Flood Control Project authority could provide significant federal funding for this project. The City of North Bend has further suggested that it would partner with King County to fulfill the local sponsorship requirements for U.S. Army Corps of Engineers project participation. Coordination with property owners and the City of North Bend and the United State Army Corps of Engineers will be needed to complete this project.

Other Information or Needs

This project is in the Headwaters Restoration Above Falls and Dam area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The proposed action is consistent with that plan.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/NB.pdf

Middle Fork Levee System Capacity Improvements

Location Information

Water Resource Inventory Area 07-0219, Middle Fork Snoqualmie River
River Mile 1.4 to 2.0, Left Bank
Council District 3
Jurisdiction: Unincorporated King County
Private and Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$2,831,000

Problem Statement

The existing levees along the Middle Fork Snoqualmie River are relatively short and separate segments of a continuous levee system that was proposed but never completed. The containment capacity of this incomplete levee system is therefore limited to that of the natural banks between the levee segments. However, the levees were placed such that they sharply narrow the flow path along the river channel. These constrictions may limit the containment capacity of the overall system.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if channel cannot contain flood flows, resulting in potentially deep fast flows moving though the northeastern part of the City of North Bend and parts of unincorporated King County;
- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure including roads, drainage systems and public facilities;
- Impacts on the regional economy resulting from severe damages to the City of North Bend;
- Damage to private structures.

Proposed Project or Action

Shorten or realign the downstream ends of the existing levee segments to improve the flow capacity along the river channel.

Project Benefits

Reduce frequency and severity of flows leaving the Middle Fork Snoqualmie River channel and damaging homes and businesses.

Coordination

Coordination with property owners and the City of North Bend will be needed.

Other Information or Needs

This project is in the Headwaters Restoration Above Falls and Dam area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The proposed action is consistent with that plan.

Hydraulic models were developed for this area in 1994 as part of a Flood Insurance Study. Those models should be used to evaluate the hydraulic design issues and optimize the configuration of these levee segments.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/MF.pdf

5.4 LOWER SNOQUALMIE RIVER

5.4.1 Overview

The lower Snoqualmie River basin begins at Snoqualmie Falls and generally drains north toward Snohomish County. At the base of Snoqualmie Falls, the river is relatively steep, but it soon loses most of its elevation; the lower reaches of the Snoqualmie River are relatively flat. The river meanders in wide loops through a largely agricultural valley floodplain, passing through the unincorporated community of Fall City and the Cities of Carnation and Duvall. Aside from these three residential and commercial centers, most of the lower Snoqualmie valley bottom supports agricultural and recreational land uses.

Several tributaries join the Snoqualmie River in its lower reaches: the Tolt and Raging Rivers, and Tokul, Patterson, Griffin, Harris, Tuck and Cherry Creeks. Most of these tributaries have relatively steep gradients and high-velocity flood flows until they meet the flat valley floor of the Snoqualmie River. The largest tributary, the Tolt River, is partially regulated by the City of Seattle through its operation of a water supply dam on the South Fork Tolt River.

Like the South Fork Skykomish River, the Snoqualmie River feeds the Snohomish River, which empties into Puget Sound at Port Gardner in Everett. Anadromous fish use the entire length of the Snoqualmie River below Snoqualmie Falls, as well as many of the river's tributaries.

The lower Snoqualmie River flood hazard management corridor runs from the King and Snohomish county line to Snoqualmie Falls and includes the river channel, mapped flood hazard areas and a riparian buffer. See Map 5-3 for the major features of the lower Snoqualmie River. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-3.pdf

5.4.2 Geology and Geomorphology

The river's vertical drop of 270 feet over tertiary bedrock at Snoqualmie Falls divides the profile of the overall mainstem and also divides the upper and lower Snoqualmie River. The lower Snoqualmie River is unique among Puget Sound rivers in that the majority of its hydraulic head is lost at a single point, Snoqualmie Falls, resulting in very low average channel gradient of about 0.05 percent for most of the lower 40 miles of river. After a short distance of bedrock downstream of Snoqualmie Falls, there is a transition to alluvial channel and floodplain that persists through the remainder of the lower Snoqualmie. Proceeding downstream past Fall City, the river enters a broad valley with a wide floodplain that encompasses much of the valley floor. The river shows a meandering channel pattern incised into silts and fine sand deposits for much of its length (Booth et al. 1991).

Bed load sediment from the upper basin is naturally trapped above Snoqualmie Falls, so the lower river's coarse sediment supply must come from its banks and steep tributaries, such as the Tolt and Raging Rivers and Tokul Creek, which can deliver gravel and cobble across the valley floor to the river. Even then, most of this coarse sediment stays within the tributary deltas because of the Snoqualmie River's low sediment transport capacity. With its very low channel gradient, a gravel and cobble channel substrate persists for only a few miles downstream of the Tolt and Raging Rivers and Tokul Creek. For most of its length, the mainstem Snoqualmie River channel is a sand- and silt-bedded meandering river.

The lower Snoqualmie valley was covered by continental glaciation that affected much of Puget Sound Lowland. The lower Snoqualmie River, from Snoqualmie Falls to the Skykomish River, exemplifies the pattern of river valleys created by sub-glacial runoff in a glacial trough. The meandering lower Snoqualmie River has river banks and a distinct meander belt that are several feet higher than the

surrounding floodplain, which result from river sediments that have been deposited adjacent to the channel within the broad and low-gradient valley (Collins et al. 2003). With riverbanks at a higher elevation than much of the valley floor, even relatively small overbank flows can result in flooding from valley wall to valley wall. The valley walls are composed of glacial and non-glacial sediments, with local areas affected by relatively large landslides.

The mainstem Snoqualmie flows in a sinuous and meandering single thread channel pattern, with many oxbow ponds and wetlands. However, with the exception of a few areas, there has been very little change in the river position or oxbows in the 130 years since the earliest mapping. The river appears to migrate slowly and to avulse infrequently, by which process the oxbows are created (Collins and Sheikh 2002; Collins et al. 2003). Consequently, lateral channel migration presents a lower level of flood hazard along much of the lower Snoqualmie River than on some rapidly migrating King County rivers, such as the Tolt. And while the sinuous meanders set the stage for meander cutoffs, these avulsions are infrequent. In all, the relatively common overbank inundation appears to be a more prominent flood hazard than channel migration along the lower Snoqualmie River.

5.4.3 Hydrology and Hydraulics

With headwaters and much of the eastern basin highlands in the Cascades and a drainage area of about 600 square miles at Carnation, the Snoqualmie basin typically responds to winter rains with flood levels that rise and fall slowly and steadily. With such high elevations and unregulated drainages, rain-on-snow events can be significant. None of the dams and modifications in the basin significantly alters the flood flows that these mountain conditions produce on the lower mainstem Snoqualmie River.

The low-gradient channel of the lower Snoqualmie meets the relatively steeper and faster-responding Skykomish River in Snohomish County, which can result in Skykomish River backwater influencing the lower Snoqualmie as far upstream as Duvall.

Table 5-7 summarizes flow frequencies for the lower Snoqualmie River at Carnation.

TABLE 5-7. LOWER SNOQUALMIE RIVER FLOWS

	Discharge[a] (cubic feet per second)	
Recurrence Interval (years)	Snoqualmie River at Carnation	Snoqualmie River at Duvall
10	58,200	53,400
50	82,400	75,800
100	91,800	84,600
500	113,300	99,700

a. Flow estimates based on hydrologic analysis for the Lower Snoqualmie and Skykomish River Revised Flood Insurance Study (Draft, 2005).

The period of record of gage data used to derive values in this table may differ from the period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

5.4.4 Ecological Context

The lower Snoqualmie River has a broad valley floor, generally one mile wide, but sometimes as much as two miles wide. The valley floor contains numerous old and large oxbow ponds, side channels and shallow swales marking where the river once flowed. In order of their geomorphic and ecological influence on the lower Snoqualmie, major tributaries include the Tolt River, Tokul Creek, Raging River, and Cherry, Patterson, Griffin, Harris and Ames Creeks (Martin et al. 2004). Other notable named tributaries include Tuck, Adair, Ames and Weiss Creeks. With few exceptions, these tributaries meander along the valley floor for a significant distance before emptying into the mainstem river. Most provide good to excellent salmon habitat, but upstream of the valley floor several of these streams are too steep to support salmonids other than cutthroat trout.

Collins and Sheikh (2002) described historical habitat conditions along the Snoqualmie, where wetlands were abundant, hardwoods made up a relatively large proportion of riparian forest cover, and some very large conifers, such as cedars and spruces, were also present in riparian areas. It appears that the Snoqualmie may have had lower levels of large woody debris than most other large Puget Sound rivers. Current habitat conditions were characterized by Solomon and Boles (2002), who found that 8.5 of 32 river miles surveyed exhibited "good" habitat conditions for all habitat features, while the remaining 23.5 miles of river had one or more habitat problems, such as extensive bank hardening and erosion, cattle access points, few or no side channels and back channels, channel modifications, sparse or mostly nonnative vegetation, and limited or no large woody debris. Peak summer temperatures were higher than desired for juvenile rearing and adult holding, which is the period prior to spawning. There were an average of two large pools per mile, or approximately 70 over a 35-mile reach, many of which were very long and relatively deep.

The Snohomish River Basin Salmonid Recovery Technical Committee (SRBSRTC 2004) assessed stream habitat conditions and watershed processes, such as hydrologic, riparian and sediment, as related to recovery and maintenance of salmonids and their habitats. They split the lower Snoqualmie into four sub-basins: the mouth, extending upstream to approximately Duvall; mid, from approximately Duvall to the Tolt River; upper, from the Tolt River to Raging River; and Coal Creek Lower, from Raging River to Snoqualmie Falls. The committee assigned the following ratings for these sub-basins:

- For all but the Coal Creek Lower sub-basin, a rating of "degraded" was given for instream artificial barriers to habitats, water quality, wetlands and riparian zone, shoreline vegetation and large woody debris, and shoreline condition and floodplain connectivity. The Coal Creek Lower sub-basin differed from this only with respect to artificial barriers, which were rated as a data gap.
- Hydrology was rated as "intact" for all four sub-basins.
- Sediment in the mid and upper sub-basins was rated as "moderately degraded" but noted as a "data gap" for the mouth and Coal Creek Lower.
- At the watershed scale, the committee rated the mouth and middle sub-basin as "intact" for hydrologic processes, whereas the upper sub-basin was rated as "moderately degraded" and the Coal Creek Lower sub-basin was rated "degraded."
- For riparian processes, the mouth, middle and upper sub-basin were rated as "degraded" whereas the Coal Creek Lower sub-basin was rated as "moderately degraded."
- The committee rated overall watershed processes as "moderately degraded", meaning one or two of the key processes were "degraded" or "moderately degraded."

The committee did not rate the mainstem Snoqualmie River for sediment processes because of concern that the model used was not appropriate for Puget Sound lowland sub-basins.

5.4.5 Salmonid Use

The lower Snoqualmie River is used by federal Endangered Species Act-listed Chinook salmon and bull trout as well as chum, pink, coho and sockeye salmon, rainbow trout, including winter steelhead, cutthroat trout and mountain whitefish (Williams et al. 1975; Haring 2002; Johnson et al. 2003; Lucchetti 2005). The Snohomish River Basin Salmonid Recovery Technical Committee made the following assessments of current relative use for Chinook salmon, bull trout and coho salmon:

- For Chinook salmon, all sub-basins but the Coal Creek Lower sub-basin were in the highest tier of use, meaning that they contained at least 12 percent of the total spawning escapement for the Snohomish River basin (Water Resource Inventory Area 7).
- For bull trout, the primary value was for foraging, with no spawning or early rearing value.
- For coho salmon, rated the mouth as "high," the upper sub-basin as "moderate" and the middle and Coal Creek Lower sub-basins as "known," meaning that the degree of use is uncertain and more data are needed to make a strong statement.

Based on geology and consistent patterns of relatively high year-to-year spawning density, Martin et al. (2004) concluded that the Tolt and Raging delta reaches are likely Chinook salmon "core areas" that extended into the spawning areas of the respective tributary rivers.

5.4.6 King County Flood Protection Facilities, Major Flooding, Flood Damage

There is no single system or set of continuous flood protection facilities along the lower Snoqualmie basin. However, there are many discontinuous revetments and training levees, which are located at most of the outside river bends from near Tokul Creek at River Mile 39.5 all the way downstream to the King and Snohomish county line at River Mile 6. Many of these flood protection facilities probably originated as privately constructed bank protection along farm properties many decades ago. In addition, the two flood control bonds of the 1960s funded construction or significant improvement for several relatively long levees. The Carnation Farms Upper Levee at Chinook Bend, north of Carnation, is an example of a flood protection facility funded through these bonds. Most of the lower Snoqualmie flood protection facilities were not intended to provide significant containment of flood flows. None of the lower Snoqualmie River flood protection facilities satisfy federal certification criteria to be mapped as reliable 100-year flood protection.

Recent large floods at the Carnation gage include November 1990, which had a discharge of 65,200 cubic feet per second and flood elevation of 60.70 feet. The November 1995 flood discharged 61,200 cubic feet per second, at 60.30 feet elevation. The February 1996 flood discharged 61,600 cubic feet per second, at 60.34 feet elevation. All three events produced widespread flooding.

Two people were killed by flooding in the lower Snoqualmie River basin in the 1990s. Both failed in attempts to drive across the mile-wide valley bottom on flooded roadways. The November 1990 flood killed hundreds of dairy cows and other livestock in the lower Snoqualmie basin. Subsequent floods have not had similar animal mortality, in part because the dairy industry no longer dominates valley land use.

Homes and other structures throughout the lower Snoqualmie basin are subject to flood damage. For the most part, these structures were developed for agricultural use and have been placed on the highest

portions of large floodplain parcels. Nonetheless, deep and fast flows are a hazard throughout the lower Snoqualmie River floodplain.

Flood protection facilities in the basin have sustained damage in several recent floods. The McElhoe/Pearson levee was breached in the flood of November 1995. Repairs were partially completed before the flood of February 1996, and the repaired levee was credited with limiting flood depths in the Garden Tracts neighborhood north of Carnation. Additional structural repairs were completed in 1998.

With a wide floodplain and a large percentage of the river flow during floods taking an overbank route rather than remaining in the channel, flood damage can occur around constrictions, where flow energies become concentrated. This hazard is not limited to major constrictions such as elevated roadways, but also applies to small-scale constrictions such as foundation walls around homes and other structures.

5.4.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

Nine homes have been elevated to resist flood damage. Of these nine homes, three were funded through grants administered by the River and Floodplain Management Program and six were funded with no-interest loans administered by King County Housing Repair Program. As part of the Snoqualmie 205 conveyance improvement project completed in 2005 near the town of Snoqualmie, King County has entered contracts to cost-share elevation of twelve more structures in the lower Snoqualmie floodplain, including seven houses, three barns, an office, and a shop.

A nearly completed FEMA flood insurance study for the entire lower Snoqualmie River and the lower Skykomish River will be used to update the existing out-of-date flood maps. A study is in progress to assess gravel accumulation and the potential effectiveness of gravel removal as a flood hazard management measure for selected areas of the Snoqualmie River and tributaries.

5.4.8 Flood Hazard Management Corridor Data

Hazard mapping in this basin includes detailed flood studies and Flood Insurance Rate Maps along the mainstem Snoqualmie. The existing maps are out of date and do not accurately represent current-day flood hazards. Map revisions are being prepared to federal guidelines and specifications. Preliminary flood insurance rate maps are expected to be available in the fall of 2006. Draft flood boundary work maps were completed in December 2005 and are available to the public. Channel migration hazard mapping has not been done on the lower Snoqualmie and is not a priority because of the very limited degree to which channel migration occurs on this part of the river. Flood hazard corridor maps for the mainstem Snoqualmie River in King County included a riparian buffer based on the King County Critical Areas Ordinance aquatic-area buffer.

5.4.9 Flood Hazard Management Corridor Conditions

None of the levees in the lower Snoqualmie River basin are certified as reliable 100-year flood protection, nor do they meet standards for certification. Deficiencies include a lack of sufficient containment capacity, problems with structural stability, and problems with erosion resistance. Therefore, the Flood Insurance Rate Maps identify extensive flood hazard areas behind the levees, as well as the revetments. Much of the property in these hazard areas has been developed for agricultural use, with both homes and businesses scattered throughout the hazard area. These developed properties are at risk.

The lower Snoqualmie River floodplain also includes significant public infrastructure that is at risk of flood damage. State Highways 202 and 203 and other roads that cross the river are subject to closure when they are inundated with floodwaters. Some portions of these roads have been damaged by

floodwaters. For instance, the Carnation Farms Road has had significant scour damage when floodwaters have overtopped the elevated road grade and cascaded down its downstream shoulder. Between Fall City and Carnation, riverfront portions of both the Neal Road and SE 19th Way have developed sinkhole problems.

Perhaps the most significant threat of flood damage to public infrastructure in this basin involves the Snoqualmie River floodplain crossing of the City of Seattle's Tolt River water supply pipeline. This pipeline supplies potable water for much of Seattle and the surrounding communities. Portions of the pipeline infrastructure have been buried deep beneath the floodplain and the river channel, where they should be safe from flood damage. However, portions of the pipeline are above grade across the floodplain and, according to a consultant study done for the City of Seattle, advancing erosion of a right bank Snoqualmie River bend at River Mile 13.5 could undermine the pipeline within the next 20 years.

5.4.10 Flood Hazard Management Objectives and Strategies

In the lower Snoqualmie River basin, flood risks as outlined in Policy G-2 include risks to public safety associated with widespread flooding; risks to public infrastructure, including the Tolt River water supply pipeline; and risks to private structures, primarily homes and agricultural buildings.

The current flood hazard reduction objectives for the lower Snoqualmie River valley include the reduction of flood hazards associated with the inundation of homes and farms, reduction in the risks to public infrastructure, minimizing the impacts of flooding on agriculture and, to the maximum extent practicable, ensuring that flood hazard management strategies are consistent with salmon habitat restoration efforts. Each of these objectives is described below, along with the associated strategies and projects that will be used to meet these objectives.

1. Reduce both the public safety and property damages associated with the widespread flooding that can occur in this area. While residents of the Snoqualmie valley tend to be well aware of flood hazards, and the need to take appropriate safety precautions, the presence of floodwaters does pose a threat to those living, working and traveling in the lower Snoqualmie valley. Throughout the basin, individual homes, barns, and other structures are subject to deep and fast flood conditions, impact damage from flood-borne debris, and undermining by river bank erosion. Several structures in the lower Snoqualmie valley have been the subject of repetitive flood loss claims to the National Flood Insurance Program. In order to meet this public safety and property protection objective, this Plan proposes to elevate, and in some cases remove, the homes and structures that are at greatest risk from flooding and erosion. The Plan includes both targeted acquisition projects and a countywide acquisition opportunity fund to help meet this object.

2. Preserving safe access to homes and businesses along the river. However, this Plan assumes that state and federal agencies will continue to protect state highways (SR 202 and 203) from flood damage. Similarly, this Plan assumes that private parties will continue to maintain their private roads and driveways. This Plan does, however, recommend two projects intended to reduce or eliminate erosion-related risk associated with county roads.

3. The most significant risk to public infrastructure in the lower Snoqualmie Basin involves the City of Seattle's Tolt River water supply pipeline. While this pipeline does not directly benefit properties in this basin, it does provide an essential regional benefit. Protecting this pipeline from erosion is a relatively high priority flood risk reduction objective. This Plan recommends construction of an engineered log jam to help protect this pipeline from future damage resulting from river bank erosion

4. Protecting prime agricultural soils is an important flood hazard management objective in King County and to the maximum extent possible, coordinate with the King County Agriculture Program to ensure that proposed flood risk reduction projects located in an Agricultural Production District, or near properties enrolled in the Farmland Preservation Program, do not negatively impact productive agricultural soils.

5. Finally, ensuring that flood hazard management actions do not adversely affect, and where possible, support salmon habitat restoration efforts. The emphasis of the Plan on non-structural solutions or, in the case of the Tolt Pipeline, a solution that will result in the addition of a substantial amount of large woody debris, strongly supports this objective.

5.4.11 Proposed Actions

Table 5-8 summarizes the start list of proposed flood hazard management actions for the lower Snoqualmie River in King County. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-8. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-8.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE LOWER SNOQUALMIE RIVER (2007-2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Aldair Buyout	Purchase homes and property at risk from failure of the Aldair levee.	$2,299,000
Lower Snoqualmie River Early Action Residential Flood Hazard Mitigation	Elevate structures or otherwise mitigate flood risks to ten repetitive loss properties. Supports recommendations ERA-1 through 4.	$660,000
	Total Status Quo Funding	**$2,959,000**
Enhanced Funding		
Tolt Pipeline Protection	Construct wood piling and log revetment to halt erosion that threatens the Tolt water supply pipeline.	$2,367,000
SE 19th Way Buyout	Purchase farm which is at risk of being isolated by bank erosion.	$1,772,000
Neal Road Relocation	Realign road currently closed due to bank failure.	$1,450,000
	Total Enhanced Funding	**$5,589,000**
	Total Lower Snoqualmie River	**$8,548,000**

Aldair Buyout

Location Information

Water Resource Inventory Area 07-0219, Snoqualmie River
River Mile 33.5 – 34.3, Left Bank
Council District 3
Jurisdiction: Unincorporated King County
Public and Private lands
In Agricultural Production District, may affect Farmland Preservation Program lands

Estimated Cost

$2,299,000

Problem Statement

During recent flood events, the Aldair levee has had recent problems with extensive and increasing seepage. Ponds behind the levee have shown an unusual silty coloration when these seepage problems have been observed. This suggests possible piping (underground erosion) of fine material from the levee and the underlying banks. Piping can lead to sudden, catastrophic levee breach.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee fails, resulting in potentially deep fast flows moving through this rural area;
- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, primarily public roads;
- Damage to private structures.

Proposed Project or Action

Remove existing homes from low-lying ground immediately behind the Aldair levee.

Project Benefits

Greatly reduce the public safety risk associated with potential levee failure.

Coordination

Coordination with current property owners and the King County Agriculture Program.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is consistent with that plan.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Aldair.pdf

Tolt Pipeline Protection

Location Information

Water Resource Inventory Area 07-0219, Snoqualmie River
River Mile 13.50 – 13.65, Right Bank
Council District 3
Jurisdiction: Unincorporated King County
Private lands
In Agricultural Production District, may affect Farmland Preservation Program lands

Estimated Cost

$2,367,000

Problem Statement

Erosion along the right bank of the Snoqualmie River channel threatens to undermine the Tolt River water supply pipeline at this location south of Duvall. A rock revetment was installed in response to this problem in the 1960s, but little sign of that revetment remains. The bank erosion process in this area involves slumping of discrete failure blocks that can extend horizontally more than 50 feet from the top of bank. Replacement of the thin rock riprap revetment would do little to inhibit future bank failures of this type.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Impact on regional economy if the Tolt Pipeline, a primary source of potable water to the City of Seattle and surrounding communities is interrupted;
- Damage to public infrastructure if the Tolt Pipeline is undermined.

Proposed Project or Action

Install one or more engineered log jams to roughen the river channel near the toe of the eroding bank, thereby helping to reduce local water velocities and the resulting toe erosion process.

Project Benefits

Protect the water supply pipeline, which carries potable water to the City of Seattle's distribution system, serving as roughly 30% of the system supply. In addition, provide significant fish habitat benefits.

Coordination

Seattle Public Utilities has indicated a willingness to partner on this project. Coordination with Seattle Public Utilities and the underlying property owner will be needed.

Other Information or Needs

This project is in the First Priority Restoration Area designated in the salmon habitat recovery plan for Water Resource Inventory Area 7. Placement of engineered log jam structures is consistent with that plan. Seattle Public Utilities has indicated a desire to partner in this effort.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Pipeline.pdf

SE 19th Way Buyout

Location Information

Water Resource Inventory Area 07-0219, Snoqualmie River
River Mile 30.5 to 32.8, Right Bank
Council District 3
Jurisdiction: Unincorporated King County
Public and Private lands
In Agricultural Production District, may affect Farmland Preservation Program lands

Estimated Cost

$1,772,000

Problem Statement

Erosion along the left bank of the Snoqualmie River channel threatens to undermine the road bed of SE 19th Way, which serves one farm. A rock revetment was installed in response to this problem in the 1960s, but the problems involve deep failure surfaces that have not been stabilized by the rock riprap.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if county road fails unexpectedly and motorists drive into river;
- Risk to public safety if residents of the farm served by the road at risk need emergency assistance and cannot be reached due to road failure;
- Damage to public infrastructure: county road.

Proposed Project or Action

Purchase the farm served by this road. Then abandon the road and allow natural river processes to occur.

Project Benefits

Eliminate public safety risk associated with potential road failure. Minimize disturbance of river channel environment, as well as need for future inspection, maintenance and repair.

Coordination

This project would need to be coordinated with the current property owner, the King County Department of Transportation, and the King County Agriculture Program.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/19th-Way.pdf

Neal Road Relocation

Location Information

Water Resource Inventory Area 07-0219, Snoqualmie River
River Mile 32.5 to 33.5, Right Bank
Council District 3
Unincorporated King County
Private Lands
In Agricultural Production District, may affect Farmland Preservation Program lands

Estimated Cost

$1,450,000

Problem Statement

Erosion along the right bank of the Snoqualmie River channel has undermined a portion of the Neal Road, which runs parallel to the Fall City-Carnation Road (State Route 203) and serves several farms and a public boat ramp. A rock revetment was installed in response to this problem in the 1960s, but the problems involve deep failure surfaces that have not been stabilized by the rock riprap. The north end of the Neal Road has been closed since it was undermined in 2003.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if fire and rescue personnel are unable to reach those in need due to closure of Neal Road;
- Damage to public infrastructure, including Neal Road.

Proposed Project or Action

Relocate the north end of the Neal Road to outside the erosion risk area. Abandon the north end of the road (from the existing State Route 203 intersection to the public boat ramp) and allow natural river processes to occur.

Project Benefits

Eliminate the risk to public safety associated with potential road failure. Improve emergency access to flood-prone farms. Minimize disturbance of river channel environment, as well as need for future inspection, maintenance and repair.

Coordination

This project would need to be coordinated current property owners, the King County Department of Transportation and the King County Agriculture Program.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Neal.pdf

5.5 TOLT RIVER

5.5.1 Overview

The Tolt River is a major tributary that enters the Snoqualmie River from the east, near the City of Carnation. The Tolt River headwaters are at the crest of the Cascades, with an elevation change of over 4,000 feet from crest to mouth, and the river drains a total area of about 100 square miles. Land use in the Tolt River valley bottom is primarily residential development that ranges from low density in the upstream valley to higher density near the downstream end. The upper reaches of the Tolt River basin are mostly within the Forest Production District, as designated by the King County Comprehensive Plan, where timber harvesting has occurred on an ongoing basis since the early 1900s. The North and South Fork Tolt Rivers meet near Tolt River Mile 9. The City of Seattle operates a water supply and hydroelectric power dam on the South Fork Tolt River, which was completed in 1963.

Most of the Tolt River basin is in unincorporated King County. The City of Carnation is located along the north bank of the river between River Mile 1.8 and State Route 203. Flood and erosion hazards affect unincorporated areas and incorporated areas. Levees line both banks from about River Mile 2 to the mouth. The State Route 203 Bridge crosses the Tolt River at River Mile 0.55 and the Snoqualmie Valley Trail Bridge, formerly a railroad bridge, crosses the Tolt River at River Mile 1.1. The Tolt River flood hazard management corridor includes the mainstem Tolt channel, the mapped flood hazard areas, including channel migration zones from River Mile 0 to River Mile 4.9, and a riparian buffer from River Mile 0 to River Mile 6. Major features of the Tolt River basin are shown in Map 5-4. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-4.pdf

5.5.2 Geology and Geomorphology

The upper reaches of the Tolt River drain steep forested slopes, where the predominant geology is volcanic and intrusive bedrock. Surface geology in the upper and middle basin is mostly glacial deposits left by continental glaciations. The Tolt River emerges from its steeper and confined reaches at about Tolt River Mile 6 to flow through a relatively narrow valley floor of alluvium that widens downstream to the confluence with the Snoqualmie River. Along this section, the steep valley walls consist mostly of glacial and non-glacial sedimentary deposits, with some large landslide deposits along the south valley wall. The lower mainstem Tolt River valley floor opens to the broader Snoqualmie valley floor near Tolt River Mile 2. The City of Carnation rests upon a depositional fan built by the Tolt River across the Snoqualmie River floodplain.

The Tolt River has cut its valley into the surrounding glacial and non-glacial materials since the last glaciation. The mainstem Tolt River exhibits some of the highest lateral migration rates and significant channel shifts by avulsion of all King County rivers. From about River Mile 2 to River Mile 6, the Tolt River has a meandering channel pattern with occasional locations of multiple channels. Historical photos and maps indicate that the mainstem Tolt River was a more sinuous, multiple-threaded channel during the last 100 years, prior to levee construction.

5.5.3 Hydrology and Hydraulics

With its steep upper basin, the Tolt basin has a relatively fast runoff response. The high elevations of the basin can produce rain-on-snow events, which can increase downstream flood magnitude and extent. A typical Tolt River flood reaches its maximum peak 10 to 12 hours before the larger Snoqualmie River.

Although the South Fork Tolt River dam is not intended for flood control purposes, dam operations are such that peak flows on the mainstem Tolt have been diminished by about 30 percent relative to pre-dam flows (Parametrix 2001).

The primary gage referenced for Tolt River floods is the Tolt River near Carnation gage (USGS #12148500), which is located on the Tolt River mainstem at River Mile 8.7, with an 82-square-mile drainage area. Flow magnitudes and recurrence intervals are calculated by a standard flood frequency analysis based on flows measured at the USGS #12128500 gage throughout the period of record, which is 1928 to 1931 and 1937 to the present. There is no gage at the Tolt River mouth at River Mile 0.0; flow magnitudes there are calculated based on the relation between the drainage areas at the mouth and at the USGS #12148500 gage. Table 5-9 summarizes flow data for the Tolt River.

TABLE 5-9.
TOLT RIVER FLOWS

Recurrence Interval (years)	Discharge (cubic feet per second)[a]	
	Tolt River at Carnation	Tolt River at Mouth
10	11,900	13,900
50	16,700	19,500
100	18,800	22,000
500	23,800	27,800

a. FEMA 2005.

See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

5.5.4 Ecological Context

The Tolt River is the largest tributary to the lower Snoqualmie River, and is by far the greatest source of coarse sediment, including salmonid spawning gravel, for the lower Snoqualmie. This sediment forms a delta reach that is among the most heavily used reaches for salmonid spawning in the Snohomish basin. Geomorphically, the Tolt River delta exerts a great influence on the larger Snoqualmie River channel, constricting and steepening it enough to create a diversity of habitats, including large pools and gravel-bedded spawning riffles that differ greatly from the majority of the Snoqualmie River's low gradient, sand- and silt-bedded, meandering channel.

Upstream of the delta, the Tolt River valley can be viewed as two distinct reaches: a reach of mostly steep, boulder- and bedrock-dominated channels, often deep in canyons, extending from the river's headwaters down to about River Mile 6, below which the river leaves a bedrock canyon and travels through a narrow valley before depositing sediments onto the Snoqualmie valley floor and creating the aforementioned delta. The lower six miles of the Tolt River are the most productive for salmon. Historically this reach exhibited considerable channel migration, due to deposition of sediments upstream of the main delta. The process of sediment deposition and subsequent channel migration resulted in a myriad of complex mainstem and floodplain side-channel habitats. In many places, the historical side channels still exist, but revetments and levees prevent the river from periodically flushing out or reoccupying these side channels or migrating to create new ones. The net effect is a decline in habitat

diversity and productivity as the long-term value of existing habitats is reduced due to sedimentation and encroachment by vegetation, and the absence of creation of new side channels.

Riparian areas affect adjacent aquatic areas and are productive habitats in their own right. The lower Tolt River riparian areas have been extensively modified, first by logging and more recently by moderate to low density residential development. Much of the riparian vegetation is dominated by hardwoods, such as black cottonwood and big leaf maple, with occasional but significant occurrences of conifers, either as patches or as occasional trees. While all native trees have value, a preponderance of hardwoods suggests a deviation from the predevelopment, conifer-dominant, natural condition. Conifer trees grow much larger, live much longer and, when they die and fall, last much longer before they decay than hardwoods. Thus a shift in dominance from conifer to hardwoods can create a much different river and riparian system than what was historically present.

5.5.5 Salmonid Use

The Tolt River is used by all the same salmonids that use the lower Snoqualmie River. It also is highly valuable as wildlife habitat, in large part due to the extensive forest with little or no development-related impacts. Despite existing development in its lower reaches, overall the Tolt River rated "high" in a countywide rating of catchments, indicating high value for protecting and restoring fish and wildlife habitat and as a long-term refuge for many fish and wildlife species.

The Snohomish River Basin Salmonid Recovery Technical Committee (SRBSRTC 2004) assessed current relative use for Chinook salmon, bull trout and coho salmon, and assigned the following ratings:

- For bull trout, the primary value of the Tolt River was foraging by sub-adults and adults, with no spawning or early rearing value.
- For coho salmon, the Tolt River was rated as having high use.
- The Tolt River is in the highest tier of use for Chinook salmon, meaning that it contains at least 12 percent of the total spawning escapement for the Snohomish River basin.

5.5.6 King County Flood Protection Facilities, Major Flooding, Flood Damage

The main King County flood protection facility on the Tolt River is the set of continuous levees and revetments along both sides of about the lower two miles of river. Built in about 1940, these levees keep the river in place while providing a varying level of flood containment through the leveed reach. The greatest level of flood containment is provided along both banks upstream of the Trail Bridge; there is moderate to low flood containment from the Trail Bridge to State Route 203. Downstream of the State Route 203 Bridge, where Snoqualmie River backwater and overbank flow can have as much of an effect on flooding as the Tolt River itself, there is negligible flood containment and widespread flooding even during smaller events. Overall, the Tolt River levees do not provide protection to the 100-year event and are not federally certified.

At River Mile 3, there are two continuous King County-maintained revetments that protect the Tolt River Road and a few residential properties. These revetments are subject to bank erosion and channel migration.

Recent major floods on the Tolt River occurred in November 1990, November 1995, and February 1996, all of which had peak magnitudes that are smaller than the current-day 10-year flood. The three largest Tolt floods on record occurred in the 1950s, before dam operation began, and all three were close to the current-day 20-year flood.

The Tolt River levees were damaged at three locations in the winter of 1995-96 and subsequently repaired. The 1990 flood caused extensive damage to the north bank levee downstream of State Route 203, primarily along the top of the levee. At that time, King County decided to abandon the levee and no longer maintain it as a flood protection facility.

5.5.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

Pursuant to the *1993 King County Flood Hazard Reduction Plan* Policy FP-8, the Tolt and other completed channel migration hazard maps have been used to regulate land use since adoption of a King County channel migration public rule in 1999, and more recently through the King County Critical Areas Ordinance of 2004. As recommended by the *1993 King County Flood Hazard Reduction Plan*, a Flood Insurance Study and flood maps that delineate the regulatory 100-year floodplain and floodway were completed by King County in the late 1990s and published by FEMA in 2001 and 2002.

Other accomplishments since 1993 include repair of King County flood protection facilities, including Holberg in the early 1990s; repairs at four spots within the leveed segment in 1996-97; the Frew side channel project in 1997; and the Tolt River Road in 1997. Both King County and the City of Seattle have also acquired lands along the Tolt River for purposes of preserving channel and floodplain areas to achieve multiple benefits, including flood flow conveyance.

In the mid-1990s the *Tolt Watershed Analysis* (Weyerhaeuser Co. 1993) was completed, which resulted in prescriptions for timber harvest practices in the forested upper basin. The Lower Tolt River Floodplain reconnection project, a levee setback project, is in the design process. Finally, the lower Tolt River is a study reach in the Snoqualmie gravel study that is now in progress and is a part of the River and Floodplain Management Program's ongoing channel monitoring effort.

5.5.8 Flood Hazard Management Corridor Data

The Tolt River flood hazard management corridor begins at the confluence of the Tolt River and the Snoqualmie River at Tolt River Mile 0.0 and extends upstream to approximately River Mile 6. Base data sets for this 6-mile flood hazard management corridor are largely complete. Both the floodplain and the floodway have been mapped for the entire length of the corridor. Channel migration hazard areas have been mapped from River Mile 1.7 to River Mile 6. Channel migration hazards were not mapped along the lower 1.7 miles of the river, based on the assumption that existing levees on both sides of the river will be maintained and will prevent any channel migration. A riparian buffer, based on the King County Critical Areas Ordinance aquatic-areas buffer, was included for the entire Tolt River flood hazard management corridor.

5.5.9 Flood Hazard Management Corridor Conditions

Following is a summary of conditions relevant to the identification of flooding and erosion risks in the Tolt River flood hazard management corridor. The summary begins at the confluence of the Tolt and Snoqualmie Rivers and continues upstream to Tolt River Mile 6.0.

The left bank levee downstream of the State Route 203 bridge to the Tolt River mouth is believed to exacerbate mainstem Snoqualmie River flooding upstream of the confluence of the two rivers. The right bank levee in this reach contributes to this flood hazard and also isolates high habitat value remnant channels and relatively healthy riparian forest from the active channel.

Farther upstream, the left bank neighborhood served by NE 32nd Street between State Route 203 and the Snoqualmie River Trail bridge is only marginally protected from flooding and erosion by a levee of

questionable integrity, which is overtopped even during moderate flood events. This overtopping often inundates NE 32nd street, impacting access to the Remlinger Farm, a restaurant and retail facility, and a scout camp served by this dead end road. Both the farm and scout camp are also in the 100-year floodplain.

The Snoqualmie Trail bridge, which crosses the Tolt River at River Mile 1.1, frequently collects large woody debris during floods, causing depths to increase upstream of the bridge. This brings added flood risk over the right bank levee into the City of Carnation, so it represents an ongoing need for emergency debris removal. The possibility of channel blockage at the bridge increases the threat of overbank flow in that area. While a secondary berm constructed approximately 300 feet north of the right bank levee would provide some protection, the potential for flooding through parts of the City of Carnation persists.

The right bank levee, which is also used as a formal public trail between State Route 203 and River Mile 1.6, largely separates the mainstem channel from potentially valuable fish and wildlife habitat. A fish passage and side channel enhancement project along the right bank near River Mile 0.6 was completed in 1998 and, although quite successful, it is only a partial and temporary solution to this problem.

The right bank levee system continues upstream from the end of the public trail along private property from about River Mile 1.5 to River Mile 1.7. The most critical segment of this levee segment, called the Holberg levee, was reconstructed in 1995, greatly reducing the flood risk to the City of Carnation from this location. Between 15 and 20acres of the City of Carnation is within flood hazard areas associated with the Tolt River.

There is ongoing sedimentation within the full length of the lower Tolt levee system due to its location in a natural depositional area. A past flood control response was to remove gravel from the leveed reach, especially by dredging the Tolt River delta at the Snoqualmie River, but that has been discontinued since the 1960s. Ongoing sedimentation is reducing the flood containment capacity of the levees.

The levee ends at River Mile 1.7, but bank protection continues upstream along a side channel known as the North Channel to River Mile 2.1. This revetted segment of the North Channel is not considered a barrier to channel migration and is the sole protection for ten homes built within the mapped channel migration zone. Currently the North Channel receives relatively little flow, but the potential exists for a greater percentage of the river to occupy this channel, which would increase the likelihood of erosion of this revetment. Traditional access to this revetment was lost when these homes were constructed in the late 1990s.

Moving upstream of the continuous system of levees and revetments, the primary existing and potential flood risks are related to inundation and erosion of the Tolt River Road and the rural residential communities dependent upon this 2.7-mile dead-end road. Approximately 1.7 miles of the Tolt River Road, two King County flood protection facilities, and several additional homes are in or adjacent to the channel migration zone in this area. Flood risks in this reach include frequent flooding of the Tolt River Road in two locations and a developing erosion threat in one other location. Flooding and erosion at these locations can cut off access to as many as 80 homes.

The San Souci neighborhood of seven homes is currently afforded some protection by a private levee constructed in the early 1990s, but is still at risk from flooding, erosion and channel migration. This neighborhood is frequently isolated not only by flooding on the Tolt River Road, but by high velocity flows crossing the privately owned NE 69th Street. There is the very real threat of avulsion, in which the Tolt River would shift location and flow across NE 69th Street.

5.5.10 Flood Hazard Management Objectives and Strategies

In the Tolt River basin, flood risks as outlined in Policy G-2 include risks to public safety from deep fast flows; risks to public infrastructure including drainage systems, streets and buildings; potential impacts on the regional economy if the City of Carnation is severely flooded; risks to private structures, both residential and commercial; and the potential for all of these risks to worsen suddenly in the event of a levee failure.

The current flood hazard reduction objectives for the Tolt River valley include the reduction of flood hazards associated with the inundation of homes and farms, reduction in the risks to public infrastructure, minimizing the impacts of flooding and flood hazard reduction on agriculture and, to the maximum extent practicable, ensuring that flood hazard management strategies are consistent with salmon habitat restoration efforts. Each of these objectives is described below, along with the associated strategies and projects that will be used to meet these objectives.

1. The containment levees along the Tolt River provide significant but incomplete protection to much of the City of Carnation. Failure of these levees could lead to extensive, catastrophic flood damage. Therefore, these levees represent a very high priority for King County action. Maintenance and flood damage repairs should continue as a priority along this levee system. Levee setback projects that can increase the capacity for flood water and sediment deposition within the levee system should be pursued as funding opportunities allow.

2. Purchase and removal of homes at the greatest risk to deep and fast flood conditions, impact damage from flood-borne debris, and undermining by river bank erosion. Some of these homes at risk have had repetitive flood loss claims to the National Flood Insurance Program, but some of these risks involve infrequent flood conditions that can cause very sudden loss. This Plan proposes the purchase and removal of homes at greatest risk.

3. Preserve safe access to homes and businesses along the river. However, this Plan assumes that private parties will continue to maintain their existing private roads and driveways. This Plan recommends project action to help protect existing county roads at risk of flood damage.

4. To the maximum extent possible, coordinate with the King County Agriculture Program to ensure that proposed flood risk reduction projects located in an Agricultural Production District or near properties enrolled in the Farmland Preservation Program do not negatively impact productive agricultural soils.

5. Ensure actions do not have an adverse impact on threatened or endangered species or other fish and wildlife. To the extent possible, flood and erosion risk reduction actions proposed for the Tolt River should be developed and designed in a manner that does not degrade, but rather improves, habitat conditions in this highly valued watershed.

5.5.11 Proposed Actions

Table 5-10 summarizes the start list of proposed flood hazard management actions for the Tolt River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-10. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-10.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE TOLT RIVER (2007– 2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Tolt River Mouth to State Route 203 Floodplain Reconnection Technical Support	Continue providing technical support for flood and channel dynamics aspects of the Tolt River Levee Setback project.	$105,000
Tolt River Road Shoulder Protection	Protect road from channel migration.	$385,000
San Souci Neighborhood Buyout	Purchase homes in high flood and erosion hazard area.	$2,003,000
	Total Status Quo Funding	**$2,493,000**
Enhanced Funding		
Tolt River Flood Early Action Residential Flood Hazard Mitigation	Elevate structures on two repetitive loss properties. Supports recommendations ERA-1 through 4.	$132,000
Tolt River State Route 203 to Trail Bridge Floodplain Reconnection	Setback levee to improve conveyance and allow habitat enhancement.	$4,585,000
Tolt River Mile 1.1 Levee Setback	Setback levee to improve conveyance and allow habitat enhancement. Include purchase and removal of homes.	$5,677,000
	Total Enhanced Funding	**$10,394,000**
	Total Tolt River	**$12,887,000**

Tolt River Mouth to State Route 203 Floodplain Reconnection Technical Support

Location Information

Water Resource Inventory Area 07-0291, Tolt River
River Mile 0.0 to 0.5, Right Bank
Council District: 3
Jurisdiction: Unincorporated King County
Public lands (entirely within Tolt-MacDonald Park)
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$105,000

Problem Statement

The primary goal of this project is to restore fish and wildlife habitat function by setting back an existing levee that now isolates a 35-acre wetland/channel complex from the Tolt River channel. Because the existing levee also restricts the river's transport of both water and sediment, the setback project can also help to address related flood risks.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that participation in this project is intended to reduce or eliminate include:

- Risk to public safety if floodplain reconnection project is not designed and constructed in a manner that maintains current level of flood protection for those living and working in the vicinity of the project;
- Damage to public infrastructure, including roads and Tolt McDonald Park, if floodplain reconnection project is not designed and constructed in a manner that maintains current level of flood protection;
- Damage to private structures if floodplain reconnection project is not designed and constructed in a manner that maintains current level of flood protection.

Proposed Project or Action

Setback existing levee.

Project Benefits

The primary flood benefit of this project is that it will allow sediment deposition to occur throughout the reconnected floodplain. This will generally reduce the vertical rate of aggradation in the lower Tolt River channel, thereby helping to preserve the effectiveness of the existing levee system.

Coordination

Ongoing coordination with the Cities of Seattle and Carnation and the King County Parks and Recreation Division will be essential to the completion of this project.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan. Grant funding for design has been provided by the Salmon Recovery Funding Board. King County and the City of Seattle have each provided additional funding for design. Design will be roughly 70 percent complete in the summer of 2006.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Mouth.pdf

Tolt River Road Shoulder Protection

Location Information

Water Resource Inventory Area 07-0291, Tolt River
River Mile 2.8 to 2.9, Right Bank
Council District: 3
Jurisdiction: Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$385,000

Problem Statement

Erosion along the right bank of the Tolt River channel threatens to undermine the Tolt River Road at this location, roughly 1.5 miles east of State Route 203. A rock revetment was installed as an emergency response to this problem during the 1990 flood and is still working to stabilize a portion of the road. However, the road is not defended against recent erosion upstream of that rock revetment.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure: Tolt River Road, which serves as sole access to approximately 80 homes.

Proposed Project or Action

Install a 200-foot windrow of buried rock riprap along the shoulder of the Tolt River Road to protect it from erosion upstream of the existing revetment.

Project Benefits

Protect the public road, which serves as sole access approximately 80 homes. Minimize disturbance of river and hindrance of process and function.

Coordination

This project will need to be coordinated with the King County Department of Transpiration.

Other Information or Needs

This project is in the First Priority Restoration Area designated in the *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The proposed rock riprap protection is counter to the general direction of that plan, which would generally eliminate hardened banks, but this proposal represents a minimally intrusive means to protect the Tolt River Road.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Road.pdf

San Souci Neighborhood Buyout

Location Information

Water Resource Inventory Area 07-0291, Tolt River
River Mile 4.2 to 4.9, Right Bank
Council District: 3
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$2,003,000

Problem Statement

Deep, fast flood waters surround several residences in the San Souci area during flood events. These can isolate the neighborhood, preventing travel in or out, during relatively minor flood events. Many residents elect to stay in these homes, which are higher than moderate flood levels. However, all of the homes are at risk during extreme flood events. By the time the hazard becomes convincingly visible, high water will prevent evacuation. Therefore, the situation is a life safety poses a public safety risk.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures from both flooding and erosion.

Proposed Project or Action

Remove all homes from this hazardous area followed by removal of an existing, privately-assembled rubble levee at upstream end of community access road.

Project Benefits

Protect public safety. Restore process to floodplain.

Coordination

Coordination with current property owners and the City of Seattle will be needed to complete this project.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7, and is fully consistent with that plan. Seattle City Light and King County have purchased property in this vicinity. The City of Seattle has been interested in these parcels as well.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/SS.pdf

Tolt River State Route 203 to Trail Bridge Floodplain Reconnection

Location Information

Water Resource Inventory Area 07-0291, Tolt River
River Mile 0.5 to 1.0, Right Bank
Council District 3
Jurisdiction: City of Carnation
Private and Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,585,000

Problem Statement

The existing Tolt River levee system has a limited capacity for conveyance of flood water. In addition, the levees limit the area available for the accumulation of sediment that is dropped in this depositional area. Because the area for sediment accumulation is restricted, its vertical rate of change is increased. In this way, the levee system contributes to its own decreasing effectiveness over time. The levees also impact fish and wildlife habitat because the levees separate a pond and side channel complex from the Tolt River channel.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that participation in this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, including roads, drainage systems, and flood protection facilities;
- Damage to private structures, primarily from shallow flooding.

Proposed Project or Action

Setback existing levee.

Project Benefits

The primary flood benefit of this project is that it will allow sediment deposition to occur throughout the reconnected floodplain. This will generally reduce the vertical rate of aggradation in the lower Tolt River channel, thereby helping to preserve the effectiveness of the existing levee system.

Coordination

This project would need to be coordinated with current property owners, the City of Carnation and King County Parks and Recreation Division.

Other Information or Needs

This project is in the First Priority Restoration Area designated in *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7. The project is responsive to, and fully consistent with, that plan. This would be a second phase of cooperative floodplain restoration work that is being jointly funded by the Salmon Recovery Funding Board, the City of Seattle, and King County.

Feasibility analyses were completed in 2003.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/203.pdf

Tolt River Mile 1.1 Levee Setback

Location Information

Water Resource Inventory Area 7, Tolt River
River Mile 0.8 to 1.2, Left Bank
Council District 3
King County, Carnation
Public and Private Land
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$5,677,000

Problem Statement

Channel confinement by the right and left bank levee, and frequent accumulation of large woody debris on the Snoqualmie Trail Bridge, currently creates a risk of serious flooding through the City of Carnation via overtopping of the right bank levee and a secondary containment berm. In addition, several homes and as-yet-undeveloped parcels along NE 32nd Street on the left bank are subject to frequent flooding.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, primarily a county road;
- Damage to private structures.

Proposed Project or Action

The existing left bank levee was constructed well riverward of the southernmost abutment of the Snoqualmie Trial Bridge, unnecessarily confining the channel beneath this span. The proposed project would increase conveyance beneath the Trail Bridge by removing 2,000 feet of the existing levee and reconstructing a new levee adjacent to the southern bridge abutment. This construction would require the acquisition of 16 flood-prone parcels on the left bank as well as approximately 1.5 acres of Remlinger Farm. The new levee would be constructed at a more stable slope than the existing flood protection facility and would include the installation of large woody debris and establishment of native vegetation in the project area.

Project Benefits

The probability and severity of flooding through the City of Carnation will be reduced by increasing the channel conveyance under the bridge. In addition, homes acquired on the left bank will be removed, eliminating all associated risks and any future flood insurance claims. Reconstructing the levee in a more stable configuration should reduce, and may eliminate, future post-flood maintenance needs. Widening the channel in this location, and adding large woody debris and native vegetation, will supplement salmon habitat improvement efforts on the Tolt River.

Coordination

Coordination with current property owners and the King County Agriculture Program will be needed.

Other Information or Needs

This project will be coordinated with the Snohomish Basin Salmon Recovery Forum and Committee. The part of Remlinger Farm that would be affected by this project is not in agricultural production and is outside the Agricultural Production District.

Information needs will require the following:

- Determine the degree of flood risk reduction that would be provided by the project.
- Understand and quantify the history of flood insurance claims in benefit areas.
- Research the history of King County levee construction and maintenance downstream of the Trail Bridge.
- Determine whether agricultural lands will be affected (positively or negatively).

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/t1-1.pdf

5.6 RAGING RIVER

5.6.1 Overview

The Raging River flows into the Snoqualmie River from the southwest at unincorporated Fall City, downstream of Snoqualmie Falls. The Raging River basin drains about 33 square miles. There is an overall elevation change of about 3,500 feet from the mouth to the headwaters southeast of Tiger Mountain, with a mainstem channel length of about 15 miles. There are no major dams in this basin.

The entire basin is located in unincorporated King County; the communities of Preston, near River Mile 5 at Interstate 90, and Fall City, at the mouth, are centers of residential and commercial land use. Timber harvesting has been the main land use in the upper two-thirds of the Raging River basin since the early 1900s. Residential development exists throughout the Raging River valley bottom. The 328th Way SE Bridge crosses the Raging River at River Mile 1.45, and the lowermost Preston-Fall City Road Bridge crosses at River Mile 0.50. Levees line both banks from River Mile 1.5 to the mouth. The flood hazard management corridor for the Raging River includes the river channel, mapped flood hazard areas, including channel migration zones, and a riparian buffer from the mouth to about River Mile 8. Major features of the Raging River basin are shown in Map 5-5. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/T5-5.pdf

5.6.2 Geology and Geomorphology

The Raging River basin is underlain by bedrock of marine sandstones and siltstones as well as a mixture of sedimentary and volcanic rocks. The entire basin was covered in continental glaciation, so bedrock units are overlain by glacial sediments ranging from lake deposits and outwash to till throughout the basin, except in higher elevations and within the lower Raging River inner gorge. At about River Mile 8, the Raging River emerges from the steep and narrow upper valley to flow across a still relatively narrow alluvial floodplain.

From about River Mile 8 to the mouth, the Raging River can be broken into three segments: a segment of moderate gradient between River Mile 8 and River Mile 5; a steep boulder-dominated segment extending from Interstate 90 downstream to Fall City (River Mile 5 to River Mile 1.5); and the alluvial fan (River Mile 1.5 to River Mile 0). From River Mile 8 to River Mile 5 at Interstate 90 and Preston, the mainstem channel flows generally northwest and becomes increasingly wide, less confined, more sinuous and more depositional. This upper segment exhibits the highest degree of lateral migration, although it is still restricted by bank armoring, and a few locations of side channel habitat.

At Preston, the river turns abruptly to the northeast and flows through a confined inner gorge toward the Snoqualmie River at Fall City. This middle segment exhibits a limited lateral extent of channel migration and interaction with its floodplain due to narrow confinement. However, the river still undermines and erodes the glacial outwash and tills within the confines of this gorge. In both the upper and middle segments, the active floodplain is generally only a few hundred feet wide and lies between higher terraces.

The Raging River exits the inner gorge near River Mile 1.5, where it opens to the broader Snoqualmie valley and flows across its alluvial fan to the confluence with the Snoqualmie River. Much of Fall City is located on the alluvial fan built by the Raging River. This lower segment is confined by levees along both banks, effectively eliminating channel migration and any potential for the channel to move across the alluvial fan or interact with its floodplain to create and maintain side channels or other floodplain habitats.

The Raging River exhibits a channel pattern of small-amplitude meanders flowing in a single thread channel through most of its unleveed length, whether within the tightly confined gorge or within the relatively narrow floodplain upstream of Interstate 90. Though relatively small, steep, and confined, the Raging River is a rapidly migrating channel (Shannon and Wilson 1991), with some of the highest lateral channel migration rates of all King County rivers.

5.6.3 Hydrology and Hydraulics

Most Raging River floods occur from during the rainy season in November through February. Raging River flows are unregulated, as there are no major dams in the basin. This relatively steep and short river basin produces floods that are quick to rise to a peak, have high velocity and erosive flows along the steep channel and confined floodplain, and are quick to subside. The upper basin receives some snowfall, so rain-on-snow events can affect flood flows.

The gage used by King County and other agencies for flood monitoring on the Raging River is USGS gage #12145500 near Fall City, which records runoff from approximately 93 percent of the watershed. Flow magnitudes and recurrence intervals were calculated for the FEMA Flood Insurance Study based on flows measured at this gage for the period of record from 1946 to 1992. There is no gage at the Raging River mouth at River Mile 0.0; flow magnitudes there are calculated based on the relationship between the drainage areas at the mouth and USGS gage #12145500. Table 5-11 summarizes flow data for the Raging River.

TABLE 5-11.
RAGING RIVER FLOWS

Recurrence Interval (years)	Discharge (cubic feet per second)[a]	
	Raging River near Fall City	Raging River at Mouth
10	3,790	4,031
50	5,910	6,286
100	6,970	7,413
500	9,840	10,465

a. FEMA 2005

See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

5.6.4 Ecological Context

The Raging River is a relatively short, steep, dynamic river. After the Tolt River, the Raging River is the second largest and second most ecologically influential tributary to the lower Snoqualmie (Martin et al. 2004). Like the Tolt River, it is a major contributor of gravel to the lower Snoqualmie, and its delta locally constricts and steepens the lower Snoqualmie River channel. This constriction creates a river reach much different from the majority of the lower Snoqualmie River and results in high quality spawning and rearing conditions for salmonids in the mainstem lower Snoqualmie. Its proximity to the upper extent of anadromous fish use at Snoqualmie Falls, located about 4 miles upstream, and its distance from the Tolt River, about 11 miles downstream, provides spatial separation of salmonid spawning habitats that may be helpful in maintaining geographic distribution and genetic diversity, two factors that are important in maintaining viable salmon populations (McElhany et al. 2000).

A striking aspect of the Raging River is its lack of large woody debris and large, deep complex pools. The "plane bed" morphology exhibited by the Raging River (Bethel 2004; Montgomery and Buffington 1997) tends to form large pools when there is large enough woody debris in the channel; without such material, plane bed stream channels become dominated by riffles. The small amount of large woody debris in the Raging River is presumably due to a combination of historical logging and development in riparian areas, which has left few large trees along the banks; bank hardening, which has reduced the ability of trees to be undermined and fall into the river; and large woody debris removal for commercial harvest and flood control. It has been reported (unidentified personal communication to Gino Lucchetti, 1990) that as much as 2 million board-feet of wood contained in a single log jam was removed several decades ago at what is now the upstream end of the Alpine Manor Mobile Home court. More recently, a log jam in 1990 contributed to the destruction of a private bridge in this location that served as sole access to several homes.

Another factor that may have contributed to the Raging River's altered channel conditions is timber harvesting in the upper basin, where forestry is the major land use. Potential forestry-related impacts include altered watershed hydrology, increased erosion and sediment caused by timber removal and forest roads, reduced levels of instream large woody debris and associated reductions in instream habitat. Such impacts are likely associated with historical logging before recent environmental restrictions on logging were in place. To the extent that impacts from excessive rates of headwater logging have been felt, they are likely to diminish over the next 25 or more years as headwater forests mature and large woody debris is captured by stream channels.

5.6.5 Salmonid Use

The Snohomish River Basin Salmonid Recovery Technical Committee (SRBSRTC 2004) assessed stream habitat conditions and watershed processes as related to recovery and maintenance of salmonids and their habitats. The committee assigned the following ratings:

- Stream habitat was rated as "degraded," for artificial barriers, wetland and riparian zone, shoreline vegetation and large woody debris, and shoreline condition and floodplain connectivity.
- Substrate sediment was rated as "moderately degraded."
- Hydrology and water quality were noted as "data gaps," meaning more data were needed to make a strong statement about the condition of these parameters.
- At the watershed scale, the committee rated the Raging River as "degraded" for hydrologic processes, such as increases in peak flow, "moderately degraded" for riparian processes and "intact" for sediment processes.
- The committee rated overall watershed processes as "moderately degraded," meaning one or two of the key processes were "degraded" or "moderately degraded."

Solomon and Boles (2004) reconnaissance-level surveys in 2001 and 2002 found habitat with more dense native vegetation and more large woody debris in areas with little or no bank hardening and residential development.

The lower Raging River is used by federal Endangered Species Act-listed Chinook salmon and bull trout, chum and coho salmon, rainbow trout, including winter steelhead, cutthroat trout and mountain whitefish. Historically, pink salmon were abundant, but since the 1950s they have mostly disappeared, except for a small population that still exists in the mainstem up to River Mile 4.45 (Haring 2002). It is also possible

that a riverine form of sockeye salmon spawn in the lowermost reaches of the river, as they have been found elsewhere in the Snoqualmie River (Lucchetti 2005).

The Snohomish River Basin Salmonid Recovery Technical Committee assessed current relative use for Chinook salmon, bull trout and coho salmon, and assigned the following ratings:

- For bull trout, the primary value of the Raging River was foraging by sub-adults and adults, with no spawning or early rearing value.
- For coho salmon, the Raging River was rated as having moderate use.
- The Raging River is in the highest tier of Chinook salmon use, meaning that it contains at least 12 percent of the total spawning escapement for the Snohomish River basin.

Johnson et al. (2003) note that high density "cluster spawning" for Chinook salmon occurs in the lower Raging River delta segment. Based on geology and consistent patterns of relatively high year-to-year spawning density, Martin et al. (2004) concluded that the Raging River delta is likely part of a larger Chinook salmon "core area" that extended into the spawning areas of the Snoqualmie River immediately downstream of the Raging River. Kraemer (WDFW biologist, personal communication) has observed that Chinook salmon use of the Raging River delta is variable from year to year with higher numbers returning during wet falls. Presumably, Chinook salmon in the Raging River will use the nearby Snoqualmie River to spawn during low flow years, reinforcing the notion that the Raging River delta and Snoqualmie act as a single "core area" for Chinook salmon.

5.6.6 King County Facilities, Major Flooding, Flood Damage

The main King County flood protection facility on the Raging River is a set of continuous levees, constructed in the late 1930s, that run along both sides of the river from the 328th Way SE Bridge (River Mile 1.5) to the mouth. These levees keep the river from migrating across its alluvial fan and provide variable levels of flood containment. Although the existing levees are taller than the 100-year base flood elevation in some areas, they do not have sufficient freeboard to be federally certified.

Upstream of the Fall City levee system, there are about fifteen additional County-maintained flood protection facilities, most of which are revetments. These flood protection facilities protect roads and residences up to about River Mile 8 but are subject to damage from bank erosion and channel migration.

The November 1990 flow of 6,220 cubic feet per second was very close to a 100-year event and is the flood of record on the Raging River. The next highest recorded events were a 50-year event in November 1986 and a 25-year event in January 1990. The 1995 and 1996 floods were between 2-year and 10-year events. A large flood on the Raging River in 1932 preceded the gage record.

The November 1990 flood overtopped the right bank along Preston-Fall City Road, upstream of the levees at River Mile 1.8. Emergency placement of fill and riprap contained flood flows at that site. The same 1990 flood would probably have overtopped the left bank at River Mile 0.30 if emergency sandbagging had not taken place. This flood also nearly filled the entire opening under the Preston-Fall City Bridge in Fall City. This bridge has since been replaced and now has a greater capacity for flood flow, as the new bridge is both higher and wider than the old structure.

5.6.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

A Flood Insurance Study and flood maps that delineate the regulatory 100-year floodplain and floodway were completed by King County in 1993 and published by FEMA in 1996. With the enactment of a King

County channel migration public rule in 1999, and more recently, the King County Critical Areas Ordinance which became effective in 2005, land use in channel migration hazard areas has been regulated to reduce flood risks.

In 1997, King County raised the left bank levee top elevation so that it would contain the 100-year flood along most of the distance from the mouth to about River Mile 1.4. The right bank levee top elevation was also increased from River Mile 0.3 to about River Mile 1. Although the project raised these levees above the 100-year flood elevation, it did not provide the freeboard to meet federal certification standards.

Other accomplishments since 1993 include:

- Seven King County flood protection facilities have been repaired, including: Bridge to Mouth right, Bridge to Mouth left, Above 328th Bridge, Bryce, Hursh, Waring and Arruda.
- One home was purchased and removed from high flood and erosion hazard area, and one parcel needed for future protection of the Preston-Fall City Road was purchased in 1998. An additional home and parcel were purchased in 1998. This acquisition will allow a levee removal and floodplain restoration project to be carried out in this location. This project is scheduled for completion in 2006.
- The lower Raging River is a study reach in the Snoqualmie gravel study that is in progress and is part of the River and Floodplain Management Program's ongoing channel monitoring effort.

5.6.8 Flood Hazard Management Corridor Data

The Raging River flood hazard management corridor begins at the confluence of the Raging River and the Snoqualmie River at River Mile 0.0 and extends upstream to River Mile 8.3. Base data sets for this 8.3-mile river segment and corridor are largely complete. Both the floodplain and the floodway have been mapped for the entire length of the corridor, and channel migration hazard areas have been mapped from River Mile 1.5 to River Mile 8.3. Along the lower 1.5 miles of the river, channel migration hazards were not mapped, based on the assumption that existing levees on both side of the river will be maintained and will prevent channel migration. The King County Critical Areas Ordinance aquatic-areas buffer was included on the Raging River flood hazard management corridor maps. Other data, such as areas of deep fast flow beyond those delineated in the updated FEMA mapping, are not available for the Raging River.

5.6.10 Flood Hazard Management Objectives and Strategies

Flood risks in the Raging, as outlined in Policy G-2 include risks to public safety from deep fast flows; risks to public infrastructure, including drainage systems, streets and buildings; potential impacts on the regional economy if the Fall City community is severely flooded; risks to private structures, both residential and commercial; and the potential for all of these risks to worsen suddenly in the event of a levee failure.

The current flood hazard reduction objectives for the Raging River valley include the reduction of flood hazard associated with the inundation of homes, reduction in the risks to public infrastructure and, to the maximum extent practicable, ensuring that flood hazard management strategies are consistent with salmon habitat restoration efforts. Each of these objectives is described below, along with the associated strategies and projects that will be used to meet these objectives.

1. Fall City is at risk of flooding both from levee overtopping and levee breaching. This unincorporated community is the most densely populated area in the Raging River flood hazard management corridor. By design, the left bank levees that protect most of Fall City are slightly

higher than those on the right bank, allowing extreme high flood flows to overtop the right bank. Further, continued gravel accumulation in this reach will likely reduce the current level of protection on both banks in the future. The previous flood protection approaches must be revised to reduce flood risks on both sides of the river in a manner that is compatible with salmon habitat recovery efforts in this important salmon stream.

2. Prevent functional impacts on key transportation routes that serve Fall City and the surrounding area. These include the Redmond-Fall City Road and Preston-Fall City Road. Given the steep slopes in most of the locations of concern on the Preston-Fall City Road, monitoring and on-site repair of existing protection is probably the most cost-effective strategy. Protection of the Redmond-Fall City Road, which is threatened more by flooding than by undercutting, should be achieved through the same initiatives used to reduce flood risk in Fall City.

3. The safety of those living in small communities upstream of Fall City, including Preston and areas upstream along the Upper Preston Road. Monitoring and, if necessary, protection of the Upper Preston Road in the vicinity of River Mile 5.5, and selective buyout and removal of high-risk development upstream of Interstate 90 is the preferred strategy for this area.

4. Finally, ensure no adverse impact on threatened or endangered species or other fish and wildlife. To the extent possible, flood and erosion risk reduction actions proposed for the Raging River should be developed and designed in a manner that does not degrade, but rather improves habitat conditions in this highly valued watershed.

5.6.11 Proposed Actions

Table 5-12 summarizes the start list of proposed flood hazard management actions for the Raging River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-12. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-12.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE RAGING RIVER (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Fall City Levee Setback Feasibility Study	Determine best alternative for homes in areas subject to flood hazards areas.	$50,000
	Total Status Quo Funding	**$50,000**
Enhanced Funding		
Alpine Manor Mobile Home Park Neighborhood Buyout	Purchase and remove homes from high flood and erosion hazard area and allow habitat enhancement.	$5,596,000
	Total Enhanced Funding	**$5,596,000**
	Total Raging River	**$5,646,000**

Fall City Levee Setback Feasibility Study

Location Information

Water Resource Inventory Area 07, Raging River
River Mile 0.0 to 1.5, Left and Right Banks
Council District 3
Jurisdiction: King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$50,000

Problem Statement

Although the Fall City levees were raised in 1997, channel aggradation continues in a manner that is expected to diminish flood containment capacity, particularly downstream of the Preston-Fall City Road Bridge at River Mile 0.5. Channel aggradation upstream of the Preston-Fall City Road bridge is not as severe as in the downstream reach, but continued aggradation, combined with the already constrained channel and the angle at which the river passes under the bridge, will create an increasing risk of flooding through Fall City.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Impact to regional economy if businesses are damaged;
- Damage to public infrastructure, primarily roads, but could include schools, and emergency and public works services;
- Damage to private structures.

Proposed Project or Action

The proposed project would involve setting back portions of the existing levee system on both the right and left banks to increase channel capacity and optimize the angle at which the Raging River passes under the Preston-Fall City Road Bridge. The project would require acquisition of, or additional easement rights across, up to seven privately held parcels on the left bank of the river and up to 31 parcels on the right bank of the river. Because of the large number of property owners and stakeholders that would be involved in project, and the potential for alternative solutions, work on this project is currently proposed to be limited to the completion of a feasibility study.

Project Benefits

As currently conceived the proposed project would increase the channel flow capacity and improve the conveyance of flood flows through the 1.5-mile-long leveed reach of the Raging River. These

conveyance improvements will reduce flooding risk for dozens of homes and the central business district in Fall City, and will increase the possibility of implementing a low-impact gravel removal program, which will likely be needed to offset ongoing sedimentation and channel aggradation. The project will also result in the removal of up to five homes from the floodplain. Finally, the project will facilitate salmon habitat recovery efforts in the Raging River in a manner consistent with *Snohomish River Basin Salmon Conservation Plan*, which is the salmon habitat recovery plan for Water Resource Inventory Area 7.

Coordination

The primary partner in this project will be the Snohomish Basin Salmon Recovery Forum and Committee. Other key stakeholders include Fall City residents, the Snoqualmie Tribe, and the King County Department of Transportation and the Washington State Department of Transportation. The proposed project should also be evaluated for consistency with the Fall City Sub-area Plan.

Project Area Map

A map of the potential project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/fall-city.pdf

Alpine Manor Mobile Home Park Neighborhood Buyout

Location Information

Water Resource Inventory Area 07, Raging River
River Mile 5.1 to 5.4, Left Bank
Council District 9
Jurisdiction: King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$5,596,000

Problem Statement

Flow between or through the cabled-log Jelstrup revetment and the Hess rock revetment could result in a channel avulsion though the Alpine Mobile Home Park. Nine of the approximately 35 homes in the mobile home park are in the severe or moderate channel migration zone. Five homes in the neighborhood are also within the channel migration zone. While none of these homes are within the regulatory floodplain; this neighborhood is in the area mapped as being subject to shallow flooding. Such flooding was observed throughout this neighborhood during the November 1990 flood, which reached a peak of 6,220 cubic feet per second at the USGS gage, somewhat lower than the calculated 100-year flood peak of 6,970 cubic feet per second for the Raging River.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

The proposed project would include the acquisition and removal of most, if not all, of the homes in the neighborhood, and restoration of this riparian area in a manner that supports salmon habitat recovery needs. The project could be phased though a long-term acquisition and restoration strategy.

Project Benefits

The project will permanently remove the risk to residents and private property in this location and allow restoration of this site in a manner consistent with the salmon habitat recovery plan for Water Resource Inventory Area 7, *Snohomish River Basin Salmon Conservation Plan*.

Coordination

Coordination with the Snoqualmie River Coordination Team will be needed to leverage funds for the project and to ensure that site restoration plans are fully consistent with salmon habitat recovery efforts. Property owner cooperation and willingness to sell will also be essential.

Other Information or Needs

Depending on the outcome of the risk assessment, alternatives that include only partial removal of the mobile home park should be considered.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/AlpineMobile.pdf

5.7 SAMMAMISH RIVER

5.7.1 Overview

The Sammamish River flows 14 miles from the weir at the outlet of Lake Sammamish to its mouth in Lake Washington and is the lowest portion of the Sammamish basin, draining 240 square miles. Major tributaries to the river include Bear, Little Bear, North and Swamp Creeks. Tributaries contributing to the watershed through Lake Sammamish include Issaquah, Tibbetts and Laughing Jacobs Creeks. Map 5-6 shows the major features of the Sammamish basin. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-6.pdf

The Sammamish is a low-gradient river, dropping only 14 feet in elevation over its 14-mile length, approximately 0.02 percent. The floodplain is generally a half-mile wide, covering much of the valley floor through the upper and middle portions of the river, but it narrows to near the bank-full width for most of the lower half of its length. The entire river is part of a flood control project completed by the U.S. Army Corps of Engineers in 1966 that channelized, dredged and straightened the previously meandering channel network. King County was a partner and accepted full responsibility for long-term maintenance of the project. The Sammamish River flood hazard management corridor includes the mainstem channel, mapped flood hazard areas and a riparian buffer along the entire 14-mile length of the Sammamish River.

The majority of the Sammamish River basin lies within incorporated areas. Starting at the mouth and moving upstream, the river and its associated flood hazard areas pass through the Cities of Kenmore, Bothell, Woodinville, and Redmond. A wide variety of land uses can be found along the river, which was once used almost exclusively for agriculture. Agriculture remains a significant use today, with much of the wide floodplain area in the middle and upper portions of the river protected for farming uses in perpetuity by the Farmland Preservation Program. In and around the city cores, land uses include moderate-density residential, business districts, and some light industrial uses.

Possibly the most significant riparian land use is recreation. The paved, well-maintained Sammamish River Trail lines the entire length of the river. The Sammamish River Trail is a major connection between a number of other trail and park systems, including the Burke Gilman Trail to the City of Seattle, Sixty Acres soccer fields, the Sammamish Regional Park and Willowmoor Golf Course. The trail ends in the City of Redmond at Marymoor Park.

The most significant changes to the river's character in the past decade have occurred near the city hubs. Residential development has been mostly in the form of moderate- to high-density housing units such as apartments and condos. The City of Redmond has constructed numerous large-scale restoration projects to improve the ecological and aesthetic conditions in the river, and Bothell and Woodinville have completed several smaller restorations. Many of the city parks along the river in the Cities of Bothell, Woodinville and Redmond have been improved, including revegetation of the river banks. Several older bridges have been replaced and others have been newly constructed in recent years; each has been designed to provide a sufficiently wide span to accommodate trail passage and flood conveyance. Environmental mitigation for these projects has typically included bank revegetation with native plants and other habitat enhancements.

5.7.2 Geology and Geomorphology

With its course between Lake Sammamish and Lake Washington, the Sammamish River basin does not drain high elevation, bedrock-dominated headwaters as do other major King County rivers. There are no bedrock exposures in the Sammamish basin of any consequence with regard to flooding characteristics. The entire Sammamish River flood hazard management corridor lies within a landscape shaped primarily by continental glaciation and subsequently by fluvial erosion and deposition. The valley walls along the Sammamish River are composed mostly of glacial and inter-glacial sediments. The present-day river is a single thread channel with a mildly meandering constructed channel pattern. Landward of the armored riverbanks is a floodplain of young alluvium and older terraces.

Lake Sammamish and the Sammamish River valley are an example of a glacial trough, probably carved by sub-glacial meltwater during continental glaciation (Booth 1994). The historically sinuous channel meandering through a wide, low-gradient valley bottom with sand and silt channel substrate is consistent with the glacial trough features seen in the lower Snoqualmie River (Collins et al. 2003). As such, naturally slow rates of lateral channel migration could be expected even before the massive alterations that have revised the Sammamish River channel and floodplain. With the entire river now channelized and locked in place by bank armoring, there is little likelihood of channel movement.

5.7.3 Hydrology and Hydraulics

Water from the Lake Sammamish basin originally flowed into Lake Washington through the old Sammamish Slough, a widely meandering, low-gradient river bordered by extensive wetlands and floodplains. When Lake Washington was lowered by 9 feet after construction of the Lake Washington Ship Canal in 1912, property owners along the slough formed a drainage district to straighten and deepen the channel in order to reclaim the adjacent lands for agriculture. Lands along the renamed Sammamish River were converted into agricultural use, but from the beginning they were subjected to almost annual flooding from spring runoff.

Flood control studies for the Sammamish River were initiated by Congress in 1944, and a project designed to reduce flooding on agricultural lands was selected and built in the early 1960s. The U.S. Army Corps of Engineers completed river channelization in 1966. Nearly 14 miles of the river, from Lake Sammamish to its outflow at Kenmore, was dredged, deepening the channel approximately 5 feet and increasing the channel width from approximately 15 feet to 32 to 50 feet. A low weir at the outlet of Lake Sammamish marks the upper boundary of the river. The weir outlet slows release from Lake Sammamish during low-flow periods. During high flows, the weir is completely submerged by the river, acting as an uncontrolled spillway. The project was designed to pass approximately a 40-year springtime flood, equivalent to a 10-year winter storm, over the weir without the water surface elevation in Lake Sammamish exceeding 29.0 feet. The result of the project has been significantly reduced the frequency and severity of flooding risks around the lake and adjacent to the river. When flooding does occur, it predominantly affects the agricultural and recreational lands that occupy the wide central floodplain.

Largely as a result of the flood control project, flooding is generally less damaging along the Sammamish River than on the other major rivers in King County. Not only are the characteristics of the flooding different, but so is its timing. While the other major rivers have their headwaters in the Cascade Range, the Sammamish flows between two lowland lakes. The high flows associated with rain-on-snow events at higher elevations are not observed in this basin. Instead, the Sammamish River is responsive to the timing and distribution of precipitation in the watershed.

Flows in the river are recorded at the USGS gage #12125200, currently operated by King County, located at NE 116th Street in Redmond. Lake Sammamish surface water levels are also recorded near Vasa Park at USGS gage #12122000.

Table 5-13 summarizes flow data used for current floodplain mapping. These flows are considerably out of date. The hydraulic model and topographic maps used to establish flows and create the maps were developed in 1966, based on conditions at the time. Recent hydrologic studies have updated some of the flow estimates, and the hydraulic model has been updated for a limited selection of parameters and locations along the river. However, floodplain maps for the basin have never been updated to reflect changes in topography and hydrology over the last 40 years.

TABLE 5-13.
LAKE SAMMAMISH LEVELS AND SAMMAMISH RIVER FLOWS

Recurrence Interval (years)	Surface Elevation (NGVD 1929)[a]	Discharge (cubic feet per second)[a]	
	Lake Sammamish	Redmond downstream of Bear Creek	Sammamish River at Mouth
10	29.0	1,740	2,300
50	31.3	2,480	3,300
100	32.5	2,830	4,300
500	34.0	3,820	5,600

a. FEMA 2005.

The period of record of USGS gage data used to derive values in table may differ from the period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

The FEMA Flood Insurance Study for the Sammamish River indicates that Lake Washington is regulated to between 13.2 and 15.0 feet NGVD 1929 (FEMA, 2005).

5.7.4 Ecological Context

The Sammamish River is a small, low-gradient, mostly silt- and sand-bedded river linking Lake Sammamish, Washington's sixth largest lake, to the northern end of Lake Washington, the state's second largest lake. It can generally be divided into two sections based on topography. The upstream section, running from the outlet at Lake Sammamish to River Mile 4.5, runs through a broad valley that is more than a mile wide in places; this area contains the mouths of Bear and Little Bear Creeks. The lower section of the river, from River Mile 4.5 to the confluence with Lake Washington, has a narrower valley that includes the mouths of Swamp and North Creeks. The Sammamish River is used mainly as a migratory corridor for salmon, with some rearing, by the City of Issaquah and North Lake Washington populations.

The Sammamish River has undergone dramatic alterations. When Lake Washington's level was lowered by nine feet as a result of construction of the Lake Washington Ship Canal, floodplain farming became possible on a large scale as much of the wetland area was drained. Subsequently, much of the river was straightened, and projects to reduce flooding through dredging and bank armoring further eliminated connections between the river and its floodplain. Dredging and channel straightening have shortened the river to only about half its historical length, and wetland areas were reduced from approximately 3,000 acres to 150 acres (King County 2002b). These actions have altered sediment transport and reduced aquatic habitat quantity and quality. Adjacent land uses and bank armoring have degraded riparian conditions, leaving a riparian area largely devoid of mature trees, and affecting sediment and

large woody debris contributions from riparian areas. The channel and instream habitat have been highly simplified, with less than 1 percent pool habitat (R2 Resource Consultants 1999). The river also exhibits extremely high temperatures during summer and early fall. To some extent, the Sammamish River would naturally be warm since it drains the surface waters of a large lake. However, loss of channel diversity and riparian vegetation has resulted in water temperatures higher than historical levels.

5.7.5 Salmonid Use

The Sammamish River is used by federal Endangered Species Act-listed Chinook salmon as well as coho and sockeye salmon, including kokanee salmon, and rainbow and cutthroat trout (Kerwin 2001). There are historical accounts of salmonid spawning in the Sammamish River prior to its modifications (Mattila, personal communication), but today there is little or no spawning. Thus the river serves as a migration and rearing corridor for salmon spawning streams such as Bear, Issaquah, Little Bear, North and Swamp Creeks and a myriad of smaller streams that still retain some salmon use, mostly for coho salmon and cutthroat trout. No bull trout have been observed in the Sammamish River, although on one occasion a pair of char, or possibly bull trout, was observed in Carey Creek (R. Fuerstenberg, personal communication), which is a headwater tributary to Issaquah Creek, suggesting that bull trout may migrate through the river.

To assist in North Lake Washington salmon recovery, the salmon habitat recovery plan for Water Resource Inventory Area 8, *Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan* (Water Resource Inventory Area 8 Forum and Steering Committee 2005) recommends restoring floodplain connectivity and channel meander as well as riparian forest and large woody debris to the Sammamish River channel. The plan also recommends enhancements at the mouths of tributaries to create cool refuge pools. These actions would help support survival and productivity of salmon spawned in upstream areas by reducing temperature problems and increasing habitat complexity, such as pools and hiding cover, along their migratory pathway.

5.7.6 King County Facilities, Major Flooding, Flood Damage

The entire river is considered a flood protection facility that was constructed by the U.S. Army Corps of Engineers through straightening and dredging in the mid-1960s. Easements extending approximately 22 feet from the top-of-bank line both sides of the river's 14-mile length. During the 1970s, public ownership was acquired for a trail system along much of the river's length. This easement extends landward 50 to 100 feet from the top of the riverbank. Most of the flood protection facility consists of rock-lined banks that are flush with the adjacent grade at the top. A low weir is installed at the uppermost end of the river. The weir functions to retain water in the lake at a higher level during the summer, when it is used heavily for recreational activities. Water that leaves the outlet of Lake Sammamish flows across the weir, transitioning over a 1,400-foot-long transition section into the trapezoidal river channel.

The flood control project was designed to reduce the frequency and severity of spring flooding, which, prior to channelization, often destroyed newly seeded row crops. The design flood carries 1,200 cubic feet per second of flow, estimated to have a springtime recurrence interval of 40 years. The project is designed to pass this flow without causing Lake Sammamish to rise above 29.0 feet mean sea level or NGVD 1929. The maximum recorded lake level of 33.44 feet, recorded in 1951, has not been matched since the construction of this project. The maintenance practices set forth in the original project agreement were intended to drain water through the channel as expeditiously as possible. These practices typically included mowing the banks of all vegetation and keeping the channel clear of any material other than the riprap that lines the banks.

While major river flooding has become an infrequent occurrence since the river was deepened and straightened, ongoing development continues, potentially reducing flood storage areas throughout the watershed, and increasing runoff volumes and peak flows. Many land uses in the Sammamish River floodplain, such as recreation and agriculture, are largely compatible with infrequent, short-term, and low-velocity flooding.

The largest flood event for the present-day channel occurred on January 3, 1997. Other significant flood events occurred in March 1972, January 1986, February 1996 and December 2005/January 2006. Flooding during these events consisted primarily of overbank inundation with minimal velocities and depths covering portions of the agriculturally dominated central valley. During the most severe events, the Sammamish River Trail is overtopped near NE 124th Street. These high flow events in the river are commonly accompanied by high water in Lake Sammamish. Typically, private docks and lawns for waterfront properties along Lake Sammamish, upstream from the river, experience overtopping or damage. Flooding in the lowest floor level of a condominium near the lake was reported during the 2005/2006 high water. There are no known threats to public safety that are likely to result from Sammamish River flooding.

5.7.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

The channelization project completed by the U.S. Army Corps of Engineers in 1966 significantly reduced the frequency and severity of flooding in the Sammamish River valley. However, while construction and maintenance of a flood control channel increases the usability of the valley for farming and recreation, it diminishes the potential for other beneficial uses, such as habitat for fish and wildlife.

In 1994, King County partnered with the U.S. Army Corps of Engineers under a new federal authority to promote enhancement of the natural resource functions of the constructed channel. The Mammoth Sammamish Project improved habitat conditions at three locations along the river. Work involved replacing invasive vegetation with native plant species, installing instream wood and rock to diversify the channel and flow pattern, and creating a reconnection between the river and one of its unnamed tributary streams. The project made use of extensive community involvement for a volunteer planting event. In one day, over 1,200 volunteers showed up to plant over 6,000 native trees and shrubs, initiating the restoration of over one half-mile of river. This event accelerated public education and involvement in river restoration throughout King County.

Since the completion of the 1994 project, the Cities of Redmond, Woodinville and Bothell, which line the river, have joined with King County in what has become a nearly annual event to replace invasive plants with native species along the river's banks. This effort, known as Sammamish Re-Leaf, continues to foster involvement of the local communities. The project has been valuable in restoring the river and in broadening citizen awareness and stewardship opportunities for protecting the river and its natural resources.

1998 saw another partnership with the U.S. Army Corps of Engineers. The deteriorating weir structure was redesigned and rebuilt in concert with fish passage improvements and extensive bank stabilization and revegetation. The project covered several thousand feet of bank within Marymoor Park, one of the most heavily used recreational sites in the region. Partners and stakeholders included park users and clubs.

5.7.8 Flood Hazard Management Corridor Data

Data available for the Sammamish River includes the floodplain and floodway boundaries mapped and published in the Flood Insurance Rate Maps and a buffer based on the King County Critical Areas Ordinance aquatic-areas buffer. The Flood Insurance Rate Maps reflect floodplain and floodway delineations defined by hydraulic modeling using topographic and hydrologic data collected in the 1960s. As a result of changes in land use patterns in the Sammamish watershed and advances in hydrologic modeling techniques, current floodplain and floodway delineations are considered out-of-date. No channel migration zone maps have been prepared for the Sammamish River, and no steep slopes abut the river or its floodway.

5.7.9 Flood Hazard Management Corridor Conditions

Flooding in the Sammamish River basin poses almost no risk to public safety and poses relatively low risk to existing public and private development within the flood hazard management corridor. Flooding, when it occurs, is generally limited to agricultural and recreational fields and is usually neither fast nor deep. This is a result of the extensive flood control works that deepened and straightened the entire length of the river some 40 years ago. However, these efforts require ongoing maintenance to ensure that the necessary conveyance of the channel is not compromised by natural or human-induced changes in the river environment.

Maintenance practices most often consist of thinning or managing bank vegetation in a manner that will allow thorough inspection of the flood protection facility and will ensure sufficient conveyance of flood flows. Less frequently, these practices entail dredging within the channel or delta where deposition has impaired conveyance. The dredging and wholesale clearing of vegetation growing on the rock-lined banks, typical of historical maintenance practices, has led to a riparian buffer dominated by relatively low growing, non-native vegetation, a lack of instream diversity, and degraded water quality. Such practices are not consistent with many newer regulations, programs, and regional needs, including the recovery of Endangered Species Act-listed native salmonid species. More contemporary maintenance practices address flood protection needs while remaining consistent with salmon habitat recovery plans. These practices can include hand-cutting of vegetation within select areas, mowing stands of invasive vegetation on the banks or along flood protection facility access areas, benching back the banks to provide a greater channel cross-sectional area, replacing stands of invasive plants with native vegetation, and occasionally sediment removal.

On the Sammamish River, project proposals and ongoing maintenance will need to consider impacts and benefits on the regional trail that runs along much of the Sammamish River. The high visibility of most of the river from Marymoor Park to Kenmore has facilitated public involvement in restoration work in the park and along the trail. Future efforts should encourage ongoing hands-on public participation in the enhancement of this river corridor.

5.7.10 Flood Hazard Management Objectives and Strategies

In the Sammamish River basin, flood risks, as outlined in Policy G-2, are minimal, largely because of the nature and intensity of past flood risk reduction efforts. The Sammamish River is unique among King County's rivers in that the entire river is considered a flood protection facility. As such, the majority of flood risk reduction work in this basin revolves around maintenance of that facility. Under a maintenance agreement developed 40 years ago, management objectives and even specific practices are dictated. Any modification, natural or constructed, to the river or its banks must therefore be consistent with the flood control objective for the design flood. Specifically, the channel and its banks are expected to be kept sufficiently free from obstructions that could impede the conveyance of flood flows. Potential

obstructions include both riparian vegetation and instream elements such as sediment accumulation, or in rare instances, wood or other debris.

Flood hazard management objectives for the Sammamish basin include ensuring that flood risk both along the river and around Lake Sammamish are kept to a minimum, reduction or elimination of flood risks to repetitive loss properties on Issaquah Creek, and minimizing the impact of past and current flood hazard management actions on salmonids. Each of these objectives are described below, along with the associated strategies and projects that will be used to meet these objectives.

1. Ensure that those living working and the basin continue to enjoy a relatively low level of flood risk. This will be achieved through a combination of routine maintenance of the river channel, reconfiguration or the transition area between Lake Sammamish and the Sammamish River, and flood hazard mapping that can be used to inform the review of future development proposals. The plan includes a countywide enhanced maintenance line item that would allow improved maintenance on this largely under-maintained river channel, a proposal to reconfigure the channel leading out of Lake Sammamish, and an a new flood study that would be used to update information on flood hazards in the basin.

2. Reduce property losses on Issaquah Creek. Two homes along this major tributary to lake Sammamish have been subject to repeated damages as indicated by records of flood insurance claims through the National Flood Insurance Program. Other properties on this, and perhaps other major tributaries in this system, may also have had repeated flood damages, but not documented through the National Flood Insurance Program. The plan includes a proposal to mitigate known repetitive loss properties on Issaquah Creek; other frequently damaged homes in the basin may be eligible for assistance through the countywide residential flood hazard mitigation project described in Table 5-2.

3. Minimizing the impact of flood risk reduction actions on fish and wildlife habitat is essential to the continued operation of the continued maintenance and operation of the Sammamish river a flood protection facility. While the channelization of Sammamish River has greatly reduced flood risks in the Sammamish River and around lake Sammamish, ecological considerations were not taken into account in development of the flood control project or its maintenance practices. Greater parity is needed between the competing demands. A significant challenge in this river basin will be to continue to meet the ongoing flood protection objectives and maintenance obligations while accommodating and supporting Chinook salmon habitat recovery and reducing the impact of past flood control practices.

   As a first step, agreement will be necessary between the U.S. Army Corps of Engineers and King County on the approach and assumptions that should be used to develop an updated hydraulic model of the river. This model can be used for updating flood hazard mapping and as a tool for the design, construction and long-term maintenance of future projects in the basin. Projects will focus on increasing self-maintaining native riparian vegetation on the banks and overhanging the channel, increasing channel complexity, and creating cool water refuge areas. Efforts to date have targeted places where tributaries or other unique features interact with the river. Building upon nodes of cool tributary and ground waters and diverse instream conditions, the projects have expanded upon these existing habitat values.

   As mentioned under objective number one above, this Plan includes a proposal to reconfigure the transition zone between Lake Sammamish and the Sammamish River. While this project may improve conveyance of flood flows from the lake, the primary outcome, will be to allow the preservation of the existing level of flood risk reduction on the lake. Recent maintenance of the

transition zone was permitted on the condition that an alternative to routine removal of vegetation in this critical part of the channel be developed. In response to this permit requirement, the Willowmoor Floodplain Restoration project as been initiated, but is still in the early phases of design. When completed, this project will create a largely self-sustaining flood protection facility that accommodates the needs of various fish and wildlife species, including those migrating upstream across the weir and into Lake Sammamish and its upper drainages, such as Issaquah Creek.

5.7.11 Proposed Actions

Table 5-14 summarizes the start list of proposed flood hazard management actions for the Sammamish River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-14. The river miles used in the project summaries to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-14.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE SAMMAMISH RIVER (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Willowmoor Floodplain Restoration	Reconfigure outflow from Lake Sammamish to maintain or reduced current level of flood risk along the lake in a manner that reduces impacts on fish and wildlife in the transition zone between the lake and the Sammamish River. Project is required mitigation for current maintenance practices required by the U.S. Army Corps of Engineers.	$2,944,000
	Total Status Quo Funding	**$2,944,000**
Enhanced Funding		
Sammamish River (Issaquah Creek) Early Residential Flood Hazard Mitigation	Mitigate two repetitive loss properties on Issaquah Creek. Investigate other potential at-risk homes in repetitive loss areas. Supports recommendations ERA-1 through 4.	$132,000
Sammamish River Flood Study	Prepare flood study and corresponding FEMA Flood Insurance Studies and Flood Insurance Rate Maps for the Sammamish River. Supports recommendation MAP-1.	$225,000
	Total Enhanced Funding	**$357,000**
	Total Sammamish Basin	**$3,301,000**

Willowmoor Floodplain Restoration

Location Information

Water Resource Inventory Area 8, Sammamish River
River Mile 13.0 to 13.5, Left and Right Banks
Council District 3
Jurisdiction: Redmond
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$2,944,000

Problem Statement

The headwaters of the Sammamish River are in Marymoor Park, where the river is formed by the outflow from Lake Sammamish. This headwater area contains a number of sizable wetlands that hint at the rich wetland complex that once covered much of this landscape and provided natural flood storage and release. The engineered flood control functions of this river system are initiated within its first 1,400 feet, in an area called the transition zone. At the start of this reach, lake outflows spill over a low weir into a wide river cross-section. This area encompasses the steepest gradient portion of the entire river. At the downstream end of the transition zone, the river tapers to the standard cross-section that defines the remaining 13.5 miles of the river. The configuration of this transition zone is considered central in establishing the flood conveyance capability for this river system. Maintenance of the flood protection mechanism of this transition zone, as currently constructed, requires regular removal of the vegetative buffer, which is not only adversely affects water quality and habitat, but is at odds with federal, state, and local imperatives to protect these ecological elements and recover Endangered Species Act-listed species. This poses a serious challenge, and even a potential obstacle, for the long-term maintenance of the flood protection facility.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to private structures caused by increased water surface elevation of lake Sammamish.

Proposed Project or Action

Reconfigure the transition zone in order to increase channel complexity, establish a native plant community and riparian buffer, and maintain adequate flow conveyance to meet flood control obligations in a sustainable manner. This will involve widening the total cross-sectional area available for flood flows so that plants can be allowed to grow within the banks and not be an obstruction to that flow. Instream complexity will be improved by both structural changes that are engineered in the design, as well as natural geomorphic changes that occur over time in response to the structural modifications.

Project Benefits

The project will eliminate the need to cut native vegetation on the riverbanks and within the channel below the ordinary high water mark, which has become more difficult to do because of permit requirements associated with such work in and around the habitat of Endangered Species Act-listed

species. It will also provide an increased degree of certainty surrounding the conveyance, which presently can vary depending on the timing of the maintenance cycle. Equally significant will be the habitat improvements that result from the creation of the new channel alignment, instream features, and establishment of streamside vegetation, all of which will work together to provide food, shade, pools, cover, and increased channel mobility and diversity for fish and wildlife. This will help reverse any environmental impact that resulted from construction of the original flood control project.

Coordination

This complex project will involve many clients and stakeholders. Any modification to the 1960s-constructed Sammamish River channel will need to be coordinated with and approved by the U.S. Army Corps of Engineers. In addition, the project is located in a major County park, and all design and construction plans will need to be coordinated with the King County Parks and Recreation Division and park users. The underlying lands are in the vicinity of known areas of archaeological significance. Any work in this area will need to be coordinated with local tribes and cultural resource offices.

Other Information or Needs

Several detailed engineering studies have been completed for this project. Development of conceptual design plans is underway. A website

(http://www.kingcounty.gov/environment/waterandland/flooding/willowmoor.aspx)

has been created to share project information as it develops and to solicit public input.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/willowmoor.pdf

5.8 CEDAR RIVER

5.8.1 Overview

The Cedar River drains 188 square miles and flows 45 miles from its headwaters in the Cascade Range to the mouth at Lake Washington, ultimately draining to Puget Sound. The Cedar River basin lies in the southern Puget Sound lowlands between the Green River watershed to the south and the Snohomish River watershed to the north. The river is largely a single thread channel fed by snowmelt from the combined Cedar and Rex Rivers in its upper reaches, and fed by numerous small tributary streams in its middle and lower reaches.

The watershed is divided by several dams built during the last century. The upper river, above the dams, is distinctly different in character and management from the lower river. The entire upper watershed, which covers about two-thirds of the overall basin, is preserved in forest and is managed by the City of Seattle for the primary purpose of municipal water supply and secondary purpose of hydroelectric power generation. The lower part of the watershed, downstream of Landsburg, is typified by residential, commercial and industrial uses. The flood hazard management corridor for the Cedar River includes the river channel, mapped flood hazard areas, areas of deep fast flow, and a riparian buffer, running about 22 river miles downstream from Landsburg to the mouth of the river. Map 5-7 shows the major features of the Cedar River basin. An electronic version of this map can be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-7.pdf

The lowest 5 miles of the river and its floodplain are almost entirely within the City of Renton and its urban growth boundary. This area contains parks, single- and multi-family residential development, commercial development, and portions of the downtown business core. Key features in the lower Cedar River valley include the City of Renton's Maplewood Golf Course, a Boeing Company plant, Renton Municipal Airport, the Renton Public Library, which is built on top of a platform spanning the river, several major subdivisions, and two recently active landslides that abut the river channel. Sediment carried from upstream is deposited in the lower-most portion of the river due to the low channel gradient. The City of Renton, with assistance from King County and the U.S. Army Corps of Engineers, has repeatedly dredged the deposits from this lowest portion of the river.

Upstream from Renton's city limits, the flood hazard management corridor lies primarily in unincorporated King County, but it includes areas within the urban growth boundaries of Cities of Renton and Maple valley. Eastward from the Renton urban area, commercial and industrial uses drop off and residential uses decrease in density, becoming dominated by rural and medium-density residential development near the upstream City of Maple valley around River Mile 15. Between Maple Valley and the Landsburg Diversion, residential development tapers further. Training levees (levees that help direct, but do not contain flood flow) and revetments line the riverbanks along many of the meander bends along the lower and middle portions of the river. Most of these were built in the 1960s and 70s to prevent lateral migration of the river that might cause flood or erosion damage to developed properties and the infrastructure that supports them. Hundreds of acres of open space lands along the Cedar River between the City of Renton and Landsburg are owned by King County.

During the winter flood season, areas of low-lying floodplain, channel banks, and active gravel bars can be inundated, eroded, or shifted by floodwaters. At approximately a 5-year event, significant overbank flooding and inundation of structures starts to occur. Between a 10-year and 20-year event, homes, businesses, and infrastructure begin to experience areas of deep, fast flows and damage. Higher flows typically lead to widespread flooding, major safety concerns, evacuations, road closures, and substantial flood damage to structures and property. The Cedar River also is flanked by numerous steep landslide-prone hillsides. A landslide from an immediately adjacent hillside can deposit enough material in the river to block all or a portion of the mainstem channel and backing the river up or rerouting its course, as was the case in February 2001 as a result of the Nisqually Earthquake.

5.8.2 Geology and Geomorphology

The Cedar River basin is underlain by Tertiary volcanic and sedimentary bedrock, which is exposed along the valley walls near the City of Renton and downstream of Cedar Grove, where the valley narrows considerably from River Mile 9 to 10 (King County 1993a). Most of the Cedar River basin from River Mile 22 at Landsburg to the mouth has valley walls composed of glacial and non-glacial sediments and a valley bottom composed of young alluvium.

The Cedar River basin is a post-glacial valley that incised through glacial and non-glacial deposits after continental glacial retreat. This incision and downcutting process left behind high and steep valley walls that exhibit severe landslides and erosion along both sides of the river. Consequently, many of the lower slopes of the valley walls are mantled with landslide deposits (Booth 1995). Episodically, landslides deposit large volumes of sediment directly into the mainstem Cedar River, such as near River Mile 4 across from the Maplewood Subdivision in 1987, and near River Mile 5 across from Ron Regis Park in 2001. Overall, landslides and cliff retreat contribute over 90 percent of the gravel-size substrate in the Cedar River below the upstream dams, and the majority of that originates in the first 6 miles of river below Landsburg. Tributaries do not contribute significant volumes of gravel to the Cedar (Perkins et al. 2002).

The Cedar is a migrating river, typical of a post-glacial valley. Unconstrained, the river will migrate laterally through its alluvial floodplain and older flood terrace deposits until it encounters the valley wall, where it maintains steep sideslopes by eroding and redistributing landslide deposits (Booth 1995). Historical maps and aerial photos show a Cedar River with a greater channel width and more of its length in a braided channel pattern than today (Perkins 1994), suggesting active channel migration. Today, almost all river bends downstream of Landsburg are lined by bank armor or abut erosion-resistant geology, generally constraining channel migration relative to historical conditions. Most, but not all, of the present Cedar River runs in a single-thread meandering channel pattern. Still, channel migration continues to pose a significant risk along the Cedar River where residential development occurs near the present or historical river channels.

5.8.3 Hydrology and Hydraulics

Flooding on the Cedar River typically occurs from November through the winter months. The most severe floods have historically developed when a warm front brings highly saturated air off the Pacific Ocean and deposits heavy rainfall on top of the pre-existing snow pack common to the higher elevations of the upper watershed. The combination of precipitation and snowmelt produces a larger volume of water than can be contained behind the dams in the upper watershed, and which can quickly fill the river beyond capacity.

The hydrology and hydraulics of the Cedar River basin have been substantially altered from the natural conditions. The lowest mile of the river was rerouted by the U.S. Army Corps of Engineers in 1914. The

mouth of the Cedar River, which previously drained to the Black River and subsequently the Green River and into Puget Sound, was diverted into Lake Washington through a straightened, dredged channel with rock-stabilized banks. This lowest part of the existing Cedar River passes through what is now the industrial, commercial and residential center of Renton. This section of the river has been regularly dredged, and recently the levees were raised and, flood walls constructed between Logan Avenue and Lake Washington in order to provide containment for the 100-year flood. In the upper Cedar River watershed, the City of Seattle operates three dams designed for municipal water supply and hydropower purposes.

Major tributaries include Madsen Creek at River Mile 4.8; Taylor Creek at River Mile 13.4; Peterson Creek at River Mile 14.5; Rock Creek at River Mile 18.5; and Walsh Lake Division at River Mile 20.4. These tributaries account for the majority of local inflows to the river in the flood hazard management corridor. The contributions to flood flows vary among the tributaries, depending mostly on sub-basin soils and the presence of lakes and wetlands. However, the influence of all tributaries on Cedar River flood flows is relatively modest, providing about 18 percent of the flow for a 10-year event and only 14 percent of the flow in a 100-year event. By far the greatest impact on flood flows comes from the hydrologic inputs and management of the dams in the upper watershed. Dam operations and Cedar River instream flow requirements were established under the salmon habitat recovery plan for the City of Seattle, which must be considered when developing any flood hazard mitigation measures.

The three dams currently operated on the Cedar River by the City of Seattle are the Masonry Dam, the reconstructed Crib Dam or Overflow Dike, and the Landsburg Diversion. The first dam on the Cedar River was the rock-fill, timber-structured Crib Dam, constructed in 1903 and rebuilt as the Overflow Dike in 1987, at the outlet of what is now Chester Morse Lake. In 1914, the Masonry Dam was constructed three miles downstream from the Crib Dam. Valve-operated openings in the Overflow Dike are used to manage the level of Masonry Pool, which abuts a highly permeable moraine between the the Overflow Dike and the Masonry Dam. Built 44 feet higher than the Overflow Dike, the Masonry Dam is the primary reservoir containment structure. As such, the Masonry Dam controls storage capacity in Chester Morse Lake and the outflows used to produce hydroelectric power. At the Masonry Dam, water is diverted through an intake to power generators three miles downstream at Cedar Falls before returning to the river. Eleven miles farther downstream is the Landsburg Diversion constructed in 1899, which diverts municipal and industrial water supply for the City of Seattle. Landsburg is the lowest dam on the river.

In June 2002, the Landsburg Diversion was made fish passable for the first time since its construction. However, due to water quality concerns, the number of fish allowed to pass is limited to a preset number of Chinook salmon, coho salmon and steelhead. This limit is intended to ensure that the presence of fish in the watershed pose little or no risk to water quality. Sockeye will not be passed above the diversion because they have the potential to spawn in very high numbers and could pose unacceptable risks to water quality.

The Masonry Dam was not designed or built to serve as a flood control dam; however, in addition to its hydropower generation and water supply functions, it has the capacity to store up to 15,000 acre-feet of flood water. During the flood season, operation of the dam is managed to maintain a buffer or “flood pocket” in the reservoir whenever possible, so that high flow events can be partially captured behind the dam and released gradually. The effect of this management practice has been a reduction in peak flood magnitude and the frequency and severity of flooding downstream of the dam. However, the dam is neither intended for, nor capable of, holding back high-volume or long-duration flood events, so existing flood-prone areas downstream remain vulnerable to severe flood risks.

The two primary gages used for monitoring flood flows along the Cedar River flood hazard management corridor are the Cedar River at Renton (USGS #12119000) and the Cedar River at Landsburg (USGS #12117500). Table 5-15 summarizes flow data.

TABLE 5-15.
CEDAR RIVER FLOWS

Recurrence Interval (years)	Discharge (cubic feet per second)[a]	
	Cedar River at Renton	Cedar River at Landsburg
10	5,940	4,880
50	9,860	8,340
100	12,000	10,300
500	18,400	16,100

a. Final Flood Frequency Analysis Curve for Year 2000 Floodplain Mapping on the Lower Cedar River, March 2000; included with King County's submittal to FEMA for a revised Flood Insurance Study for the Cedar River.

Water supply management by the City of Seattle in its upstream dams has altered seasonal flow regimes and reduced flood peaks since the early 1900s. By 1936, the average mainstem channel width was reduced by approximately 30 percent, from the 1865 average of 259 feet to 170 feet. Since there was relatively little bank armoring at the time, the primary cause for this change is believed to be reduction in peak flows due to water supply management, which reduced periodic flood scour of banks and river bars, allowing river vegetation to encroach on and shrink the channel (Perkins 1994). The extensive network of levees and revetments that was constructed in the mid-1900s is believed to have caused an additional 35-percent reduction in active channel width by 1989 (Ibid.). The net result is that today, the surface area of the Cedar River channel has been reduced by about 56 percent compared to the 1865 survey (Ibid.).

5.8.4 Ecological Context

The Cedar River is a small, moderate-gradient, gravel-bedded river for most of the distance from Landsburg to its mouth in Lake Washington. The physical structure and ecological processes of the mainstem Cedar River have been altered considerably from pre-development conditions as a result of water supply operations, land development and channel modifications (King County 1993a).

Changes to the river were initiated by logging, agriculture, coal mining, light rural development and railroad construction in the late 1880s. By 1887, land clearing associated with early agriculture and residential floodplain development was extensive enough to be considered a main contributor to that year's major flood (Paul 1937).

As described earlier, the lower Cedar River was rerouted and channelized in about 1914, when the outlet of Lake Washington was switched to the present location of the Lake Washington Ship Canal. As a result of these activities, the elevation of Lake Washington dropped about nine feet and a large delta wetland at the mouth of the Cedar River, presumably with complex channels and diverse habitat structure, was lost (Chryzastowski 1983).

A consequence of the river's extensive bank armoring has been a decrease of local inputs of gravel and large woody debris from bank erosion, which otherwise would improve salmonid habitat. The primary

source of gravel-size substrate to the lower Cedar continues to be landslides and cliff retreat in the six miles downstream of Landsburg, which is an area largely unaffected by bank armor down to about River Mile 18. Downstream of about River Mile 18, the presence of bank armor steadily increases, while at the same time there are fewer eroding cliffs. Where eroding cliffs do occur, their sediment has a much smaller fraction of gravel than the upstream eroding cliffs (Perkins et al. 2002). Even with lesser fractions of gravel contributed by landslides in the lower river reaches, these landslide areas benefit habitat in the lower Cedar River by contributing coarse sands, and as a result of the physical bulk of some landslide deposits, cause hydraulic diversity.

There are several obvious bluffs along the Cedar River that historically have slumped and dumped large amounts of sand and gravel into the river, often becoming places that salmon congregate to spawn. Known slump areas are located in the following neighborhoods: Maplewood at River Mile 4.0; Elliott Park at River Mile 5.0; Lion's Club at River Mile 11.9; Royal Arch at River Mile 14.2; and Arcadia at River Mile 19.3. The landslide resulting from the Nisqually earthquake in 2001 provided the additional benefit of creating side channel and off channel fish habitat in an area now considered a reference reach for salmon habitat recovery efforts in the Cedar River.

Riparian conditions in the lower Cedar are also much altered from pre-development conditions. King County (1993a) estimated that the presence of riparian forest varied from zero percent in the channelized Renton Reach (River Mile 0.0 to 1.6) to 40 to 60 percent in the lower mainstem (River Mile 1.6 to 14.8) to 60 to 80 percent in the reaches approaching Landsburg (River Mile 14.8 to 21.6). Where riparian forests exist, they are often dominated by immature or deciduous trees. Ecological conditions improve closer to Landsburg.

Managing for retention of naturally occurring large woody debris in the Cedar River and elsewhere in King County has only occurred since the *1993 King County Flood Hazard Reduction Plan* was adopted. Prior to then, there was an extended history of actively removing large woody debris which, when combined with immature or absent riparian forests, have contributed to relatively low current levels of large woody debris. Although more large woody debris is clearly evident in the river channel than in the early 1990s, it remains low relative to rivers in unmanaged areas.

The effects of the these changes and channel alterations can include reduction in the number and size of pools. In the early 1990s, King County (1993a) estimated the number of "large" pools—pools that are at least one channel width in length—and found that the frequency ranged from zero in the Renton reach to 2.6 to 3.9 per mile in upper reaches. This is approximately 70 percent fewer large pools than would be expected to occur in unmanaged systems (Sedell and Everest 1991).

In addition to its mainstem channel, the Cedar River contains an array of aquatic habitats outside the mainstem channel but within the river's floodplain. King County (1993a) identified 68 aquatic habitat features on the valley floor, including tributary streams, wall-base tributaries, side channels, and riparian wetlands. Some of these features, such as wall-base tributaries, are often the most productive salmonid habitats of river systems in the Pacific Northwest (Peterson and Reid 1984). Typically they are formed in swales or channels left behind by past river channel migrations. Many are small, highly complex habitats that are currently out of the direct influence of mainstem flood flows; others are important for routing floodwaters across the valley floor. Such habitats are typically subject to some instability due to flooding. Many have been damaged or lost to changes in land use practices on the floodplain, and new habitats are rarely created because revetments or levees prevent river channel migration in most places (King County 1993a).

In summary, Cedar River management prior to the 1990s largely occurred without preservation or restoration of ecological process as a goal. As a result, the Cedar River exhibits a much-reduced range of

ecological processes—such as flooding, channel migration, sediment and large woody debris recruitment, transport and storage—and is much less physically complex than in predevelopment conditions. Despite this, areas such as the Belmondo Reach, from about River Mile 9 to River Mile 10.6, indicate that much complexity could be regained if limitations to channel migration are removed or set back and mature native riparian forests are reestablished. This reach is characterized by relatively little armoring, a relatively high quality riparian forest, accumulations of large woody debris, and active channel migration back and forth across its floodplain.

5.8.5 Salmonid Use

The lower Cedar River is used by federal Endangered Species Act-listed Chinook salmon as well as coho and sockeye salmon, rainbow and cutthroat trout and mountain whitefish (King County 1993a; Kerwin 2001). On rare occasions, bull trout have been observed in the lower river. They are believed to be either migrants from the upper Cedar River watershed, where there is a self-sustaining population centered in Chester Morse Lake, or individuals wandering from other systems, as there is no habitat in the lower Cedar River sufficiently cold to allow bull trout to spawn and sustain a population.

The salmon habitat recovery plan for Water Resource Inventory Area 8, *Lake Washington/ Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan* (Water Resource Inventory Area 8 Forum and Steering Committee 2005), rates both Cedar River and North Lake Washington Chinook salmon populations as being "in crisis with an extreme risk of extinction." The salmon habitat recovery plan identifies the Cedar River above Renton and up to Landsburg as a core area for Chinook salmon. Martin et al. (2004) hypothesized that since the lower Cedar River has no large tributaries, specific Chinook salmon core areas would form around landslides and canyon mouths, locations where gravel and upwelling water are likely to occur. Based on several years of Chinook salmon spawner surveys, Berge (personal communication) has indicated that Chinook salmon spawning does intensify in the vicinity and downstream of recent and old landslide areas, suggesting the importance of landslide activity for salmonid use on the lower Cedar. As part of an overall strategy to reduce extinction risk and promote recovery of Chinook salmon along the lower Cedar River, the salmon habitat recovery plan recommends restoration of floodplain connectivity, such as by removing or setting back flood protection facilities, and channel structural complexity, such as allowing for long-term recruitment, transport and accumulation of large woody debris (Water Resource Inventory Area 8 Forum and Steering Committee 2005).

Because Lake Washington Chinook and coho salmon and steelhead management has been heavily influenced by hatcheries, there has been considerable recent discussion as to whether the Lake Washington populations are genetically native, mixed with, or supplanted by hatchery-origin fish. Recent genetic work (Bettles 2005) indicates that while it appears that hatchery introgression has occurred in the Cedar River Chinook salmon population, the population is distinct and native gene pools appear to be present, suggesting that straying of adult hatchery Chinook salmon into the Cedar River has not resulted in complete loss of locally adapted Chinook salmon. The National Oceanographic and Atmospheric Administration has determined that Cedar River Chinook salmon are an independent population. Phelps (1994 as cited in Kerwin 2001) found that there was limited hatchery introgression into Cedar River steelhead despite many years of stocking non-native hatchery fish prior to the early 1990s. Cedar River coho are called a mixed wild/hatchery stock (WDFW and WWTIT 1994 in Kerwin 2001), although no definitive genetic analysis has been done.

5.8.6 King County Facilities, Major Flooding, Flood Damage

Flooding in residential areas poses the greatest risk to public safety in the lower and middle Cedar River basins. Even moderate floods can cause high velocity flows in and around homes and over sole access

roadways. Seventeen homes have already been identified by FEMA as "repetitive losses" based on flood insurance claims, and many other homes that lack flood insurance are known to have experienced repeated flood damage. Risks to those living, working, and traveling through these flood-prone areas include damage to the structural integrity of homes, health hazards from contamination of water supplies or damaged septic systems, inundation of living spaces, and the dangers associated with attempts to walk or drive on flooded or damaged roads.

Since the 1960s, King County has constructed 65 flood protection facilities for flood and erosion control in the lower Cedar valley. Most were built to protect individual homes, neighborhoods, or County roads, particularly those located along the outside of a meander bend. The majority of these facilities on the river are revetments or training levees designed to prevent bank erosion or lateral migration of the channel. Many of these revetments also function as partial containment levees, which reduce overbank flooding to varying degrees along their length. Typically, these facilities were constructed by simply blanketing the bank with angular rock, starting in the river channel at the toe of the slope, and extending to the top of bank. King County and the City of Renton also historically performed routine dredging and removal of gravel and fallen trees in order to maintain the river channel solely for the purpose of uninterrupted conveyance of flood flows.

Historical construction and maintenance techniques have not adequately reduced flood risk or other adverse impacts. Despite decades of attention to these flood protection facilities and channel maintenance practices, flooding and flood damage continue to occur throughout the basin. This is the result of inconsistencies in coverage, design and construction standards, deterioration of the existing facilities, and an increase in the number of structures located in flood hazard areas. Lack of a stable embedded toe and instream elements such as large woody debris and gravel bars, which would slow localized velocities near the bank, has subjected these facilities to deterioration from scour, undercutting, and erosion and led to the need for repeated repairs. Over time, King County's flood protection facilities and the homes and lands they protect, will increasingly become more vulnerable to damage. Further, such structures may make salmon habitat recovery efforts difficult, especially with regard to habitat needs.

Naturally occurring landslides are common to this basin. The potential for nearly instantaneous deposition of large volumes directly into the river channel poses a flood risk that cannot be entirely eliminate by constructed flood protection facilities.

The record flood on the present-day Cedar River occurred in November 1990, when the river reach a peak flow of 10,800 cubic feet per second as measured at the Landsburg gage. Due to a successful flood warning and emergency response program, there were no casualties, but damage to public and private property was extensive. Damage to levees and revetments was estimated at that time to be $1.2 million, and an unknown amount of damage was sustained by other public infrastructure, such as roads, bridges, and utilities, as well as private property. Many homes were surrounded by deep and fast flows, numerous roads became impassable, and residents engaged in flood fighting activities to protect their property. Homes and furnishings were destroyed, wells were contaminated, and some residents were forced to access their homes by rowboat. Parts of the City of Renton, including the Renton Municipal Airport and industrial properties were also flooded. Major floods also occurred in 1975, 1995 and 1996, resulting in similar public and private damage and losses.

5.8.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

King County has completed 23 major flood hazard management projects on the Cedar River since adoption of the *1993 King County Flood Hazard Reduction Plan*. Projects have included capital projects,

involving retrofits and repairs to flood protection facilities, setbacks, and home buyouts, as well as programmatic actions involving detailed studies and mapping of flood hazards.

Flood protection facility repairs have used biotechnical bank stabilization techniques to retrofit and repair 4,585 feet of river bank. These projects have integrated native vegetation into the fabric of the structure in a way that strengthens the flood protection facility and improves habitat value in its vicinity. The branching vegetation slows localized velocities, reducing erosion, while the root system binds the soil increasingly over time. Overhanging vegetation and in-water structures provide food, cover and refuge for fish and wildlife.

In many neighborhoods along the Cedar River, the flood risk to residents cannot be eliminated through the construction of flood protection facilities, and buyout and relocation of homes may provide the permanent solution. King County has acquired 18 flood-prone homes in the Cedar River basin through an ongoing voluntary home buyout effort. Demolition of all structures on the property and stabilization of disturbed areas using native vegetation completes the projects; and all lands are maintained as open space in perpetuity. In the future, some of these lands may be restored to improve fish and wildlife habitat, consistent with the deed restrictions prohibiting further development that is adversely affected by flooding. Additional floodplain restoration has already been completed or is underway on five of the flood buyout properties and is under consideration for eight others. Such coordination of mutually beneficial project goals in partnerships with the Water Resource Inventory Area 8 Forum and Steering Committee, King County's Parks and Recreation and Department of Transportation, or cities, further increases the benefit of these flood hazard management projects.

One of the major programmatic accomplishments in the Cedar River basin was the completion of updated flood hazard boundary work maps, which were produced for the portion of the Cedar River in unincorporated King County. These maps represent the best available information for delineation of flood hazard areas, and King County uses them for regulatory purposes. These maps were submitted to FEMA for adoption as an update to the Flood Insurance Rate Maps promulgated by the National Flood Insurance Program.

Channel migration hazard area maps for the Cedar River are currently being prepared. Interim products to date include a collection of historical aerial photographs and maps in a coordinated geographic information system database that were used to document historical channel alignments. Interim products and analyses now underway have been used to inform the update of this Plan. Once completed, the channel migration hazard maps will be used by King County to regulate development in channel migration hazard areas.

Public and agency coordination and outreach activities conducted annually have helped local communities prepare for flood season. Each fall the region's first-responders meet to review operations, communications, and weather predictions, as well as any special conditions to watch. Following a catastrophic landslide in 2001, when a section of the river was completely blocked by slide material, King County worked with the property owners and emergency response personnel from the City of Renton, dam operators for the City of Seattle and the U.S. Army Corps of Engineers to prepare a site-specific plan for notification and flood fighting until a new river channel downstream could be fully established. Similarly, close coordination with the City of Seattle has resulted in considerable and ongoing success in reducing flood magnitude, frequency and severity by careful monitoring and modification of operations at the Masonry Dam.

5.8.8 Flood Hazard Management Corridor Data

Flood data for the Cedar River is relatively current and comprehensive for the entire flood hazard management corridor for the Cedar River from the mouth of the river to Landsburg at River Mile 22. Flood hazard boundary work maps from Landsburg down to River Mile 5.3 were updated in 2001 and are currently underway to the mouth using new topographic maps and hydrologic and hydraulic studies and models. Data and preliminary findings from development of the channel migration hazard area maps were used for the entire corridor area. A riparian buffer based on the King County Critical Areas Ordinance aquatic-areas buffer was also included. Where steep slopes immediately abut the channel, the areas of potential landslides were also included. Observations of flood conditions during major floods provided significant anecdotal and localized information not readily captured by the other mapping tools.

5.8.9 Flood Hazard Management Corridor Conditions

Flood-prone areas of the Cedar River are dominated by residential uses. Many homes, and even entire neighborhoods, are located in the FEMA floodway, a likely severe channel migration hazard area, or both. Historical protection methods have focused on armoring the bank to limit channel migration and erosion. This work has stabilized the bank in many locations, supporting the retention of buildings in the floodplain, but has done little to prevent the damage and risks associated with ongoing and sometimes severe overbank flooding. Additionally, the river abuts the steep valley wall in many locations, posing major landslide hazards to nearby homes from debris movement or flood backwater.

The condition of the flood protection facilities is also a concern. The older levees and revetments which line the Cedar River are frequently less robust than flood protection facilities built using more current standards and biotechnical bank stabilization techniques. Many of these facilities are also a subject of concern with respect to the recovery of Endangered Species Act-listed species native to the Cedar River. The simple blankets of rock used to armor most of the Cedar River flood protection facilities do not foster development of a healthy riparian buffer or interaction between the river and its floodplain.

5.8.10 Flood Hazard Management Objectives and Strategies

In the Cedar River basin, flood risks as outlined in Policy G-2 include risks to public safety associated with localized flooding; risks to public infrastructure, including drainage systems, transportation routes, a municipal airport and a variety of other public service facilities; and impacts on the regional economy related to flooding; and risks to private structures, including homes, businesses and industrial properties in the City of Renton.

Flood hazard management objectives for the Cedar River include reducing risks to safety and property , protecting roads and other public infrastructure, and minimizing the impacts of flood risk reduction projects on endangered or threatened species. Each of these objectives is described below, along with the associated strategies and actions that will be used to meet the objectives.

1. Minimize the risks to the safety of residents living along the river. The safety of residents depends on reducing their direct exposure to flood hazards at home, along transportation routes and in commercial areas in the City of Renton. In many cases, it is not feasible to build new flood protection facilities or expand or improve existing facilities to the extent that would be needed to provide a reasonable margin of safety. One of the most successful strategies for eliminating risks in these situations is providing property owners with the opportunity to participate in a voluntary flood buyout project, in which King County purchases flood-prone homes from willing sellers at fair market value. A second key public safety and property damage mitigation measure is maintenance of the conveyance capacity through the lower two miles of the Cedar River, which will be accomplished by carefully monitoring sediment accumulation and

performing selective removal. The Plan includes proposals for the acquisition of a number specific flood prone homes, as well as an alternatives analysis to determine the best risk reduction option for many other homes also believed to be at risk of severe flooding.

2. Protect public infrastructure is another high priority need in the Cedar River basin. Within the City of Renton, this objective will be met largely through the sediment management program. Along the majority of the river an emphasis will be placed on providing ongoing maintenance and repair for the many existing flood protection facilities that protect public infrastructure such as major roadways, bridges, and regional trails. These facilities will be monitored during and after floods for signs of damage. Ongoing repair and maintenance will be carried out in a way that does not prevent potential retrofit, set back, or whole or partial removal of the facilities in the future. This plan includes several project proposals for the Cedar River that will open up greater access to the floodplain for conveyance to reduce the impact of flood flows on roads, the Cedar River Trail, and the levees and revetments themselves.

3. Minimize threats to the regional economy, the residential, commercial and industrial areas in the City of Renton, and the major transportation corridors, will largely be accomplished through the actions taken to meet public safety and infrastructure protection, which are described above.

4. Manage flood hazards in a way that does not adversely affect, and preferably improves fish and wildlife habitat is an over-arching objective for all King Count rivers. In the Cedar River, this objective will be met by selectively setting back flood protection facilities to reconnect the river with its floodplain and allow habitat restoration work to take place. Potential impacts to fish, related to the proposed sediment management program in the City of Renton, will be addressed through the permitting process for the work, as an approved mitigation plan.

5.8.11 Proposed Actions

Table 5-16 summarizes the start list of proposed flood hazard management actions for the Cedar River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-16. The river miles used in the project summaries to identify approximate project locations are based on 1999 and 2000 topographic maps created for King County by David Smith and Associates, Inc for use in developing FEMA flood insurance rate maps; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-16.
PROPOSED ACTIONS AND COST ESTIMATES FOR THE CEDAR RIVER (2007 – 2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Cedar River Channel Migration Zone Study and Mapping.	Prepare channel migration zone study and maps for the Cedar River. Supports recommendation CMZ-1.	$30,000
Cedar Rapids Levee Setback	Setback levee to improve flood conveyance and restore habitat. Complete project design, permits, and construction. Funding will cover project management and non reimbursable grant expenses associated with this grant funded project. Total project cost is estimated at $1,500,000.	$137,000
Jan Road-Rutledge Johnson Levee Setbacks	Remove portions of both levees that protect only open space. Segments of existing levees constrict conveyance and direct erosive flood flows into the Cedar River Trail and State Route 169.	$955,000
Cedar River Residential Flood Hazard Mitigation Analysis	Determine best alternative(s) for reducing risks to homes in areas subject to flood hazards including both repetitive loss and proposed project areas. Emphasis will be on residential neighborhoods with extensive flood hazard areas. Supports recommendations ERA-1 through 4.	$175,000
	Total Status Quo Funding	**$1,297,000**
Enhanced Funding		
Cedar River Early Action Residential Flood Hazard Mitigation	Purchase or otherwise mitigate flood risks to nine repetitive loss properties not addressed by other projects in this basin. Supports recommendations ERA-1 and 4.	$2,811,000
Cedar River Gravel Removal Project	Support periodic gravel removal from the lower Cedar River to maintain 100-year flood protection.	$4,827,000
Lower Jones Road Setback Project	Purchase the homes and property, and set back road and associated revetment.	$4,408,000
Herzman Levee Setback & Floodplain Reconnection	Setback levee to reduce erosive forces on the Cedar River Trail and State Route 169.	$1,023,000
Cedar Grove Mobile Home Park Acquisition Project	Purchase mobile home park and provide relocation assistance to the residents in this area of major flood hazards.	$4,349,000
Rainbow Bend Levee Setback and Floodplain Reconnection	Setback or remove levee to improve flood conveyance and storage through this reach and to restore floodplain functions.	$1,733,000
Getchman Levee Setback and Floodplain Reconnection	Setback the levee to improve river's flood conveyance, flood storage, and its interaction with lower Taylor Creek, while maintaining protection for Maxwell Road. Most of the acquisitions for this project are already completed or are underway.	$2,670,000
Rhode Levee Setback and Home Buyouts	Purchase homes along path of fastest, deepest flood flow, and set back the levee to lower localized velocities and depths.	$3,518,000
	Total Enhanced Funding	**$25,339,000**
	Total Cedar River	**$26,636,000**

Cedar Rapids Levee Setback

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 7.3 to 7.75, Both Banks
Council District 9
Jurisdiction: Unincorporated King County
Public or Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,500,000 total. River and Floodplain Management Program share: $137,000

Problem Statement

Levees on both banks in this area constrict the floodway, increasing velocities and flood depths within the channel, resulting in a higher risk of scour and erosion to flood protection facilities within and downstream from the site, including the flood protection facilities at Ricardi, Riverbend and Brassfield-Maxwell, as well as Jones Road. In the early 1990s, two severely flood-prone homes on the right bank were purchased, the structures were removed, and the lands were designated as permanent open space. The Ricardi Levee that formerly protected the homes, however, was left in place and remains an impediment to flood conveyance and floodplain processes. Similarly, on the left bank, the Riverbend Levee cuts off conveyance through about 5 acres of undeveloped floodplain land along the upstream portion of a 100-unit mobile home park. The position of these levees, right at the edge of the low flow channel, unnecessarily isolates the river from its adjacent floodplain, increasing the risk of flood damage to these and neighboring flood protection facilities and limiting natural habitat-forming processes.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that participation in this project is intended to reduce or eliminate include:

- Risk to public safety if setbacks are not designed and constructed in a manner that maintains or exceeds the current level of protection afforded to downstream residential areas on both the left and right bank of the river;
- Damage to public infrastructure, including Jones Road, if levee setback on right bank is not designed and constructed in a manner that maintains or exceeds the current level of protection from erosion hazards;
- Damage to privately owned structures if setback levees are not designed and constructed in a manner that maintains or exceeds the current level of protection afforded to downstream residential areas on both the left and right bank of the river.

Proposed Project or Action

Additional acquisitions of adjacent and contiguous lands on both the left bank and the right bank would create an opportunity to set back the existing levees and restore beneficial floodplain functions and processes. The project will involve removing or setting back approximately 800 linear feet of fill and riprap making up the right bank levee and setting back a similar length of levee on the left bank, in order to open up the floodplain to more frequent overbank flows while continuing to maintain existing levels of flood protection to Jones Road and downstream properties, including the mobile home park. The long-

range plans for this area could include acquisition of additional properties remaining at risk from flood hazards and set back of greater length or extent.

Project Benefits

The project will provide both flood reduction benefits and habitat enhancement. Setting back the levee will allow high flows to spread across the floodplain, thereby reducing flood elevations and erosive velocities through this reach. Additionally, it will reconnect the river with its floodplain and allow natural floodplain processes, such as channel migration or side-channel formation, to occur. It is anticipated that off-channel habitat will form and be available for rearing, and instream habitat will be improved for spawning by salmonids.

Coordination

The project will be managed and constructed by the River and Floodplain Management Program consistent with the 1997 Cedar River Basin Plan. It will also be coordinated with the King County Department of Transportation, which manages some of the lands, and the Salmon Recovery Funding Board for funding of some of the work. This project is also a recommendation in the salmon habitat recovery plan for Water Resource Inventory Area 8, and will be conducted in coordination with the efforts associated with that plan.

Other Information or Needs

Negotiations are currently underway to acquire the properties needed to accommodate the levee setback. Coordination with current and future land mangers will also be needed.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Rapids.pdf

Jan Road – Rutledge Johnson Levee Setbacks

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 13.15 to 13.45, Both Banks
Council District 9
Jurisdiction: Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$955,000

Problem Statement

The Jan Road levee, on the right bank of the Cedar River, and the Rutledge-Johnson levee, on the left bank of the river, constrict flood flows and increase flow velocities through this reach. This constriction directs the full force of the river downstream, across the channel and into the Cedar River Trail Levee. The integrity of the trail levee is essential to flood protection for this regionally significant trail system and the adjacent Maple Valley Highway (State Route 169). A major bank failure at the Cedar River Trail Levee was repaired following the floods of 1995 and 1996; however, this over-steepened levee could not be reconstructed to a more stable slope angle due to its proximity to State Route 169. The repaired flood protection facility, therefore, remains over-steepened and vulnerable to future damage.

Neither the Jan Road Levee nor the Rutledge-Johnson Levee was designed to provide 100-year flood containment protection, nor are they tied off to high ground at either their upstream or downstream ends. As a result, the properties behind them are subject to flooding from water coming over the top of the levees as well as around the upstream and downstream ends. The upstream sections of both the Jan Road and Rutledge-Johnson levees do serve important flood protection functions: they reduce the frequency and severity of overtopping and prevent migration of the river channel. However, while the levees contain small floods, overtopping and flooding can occur during larger events, affecting several homes in the immediate vicinity.

In addition, Taylor Creek, which enters the river at the upstream end of the Jan Road levee, can exacerbate flooding behind the Jan Road levee. Floodwaters from this location can flow across Jan Road and through the neighborhood before re-entering the river further downstream. Toward the downstream ends of both the Rutledge-Johnson and Jan Road Levees, the areas immediately landward of the levee are undeveloped floodplain. At these locations, the two flood protection facilities unnecessarily direct the flow into the Cedar River Trail Levee, and separate the river from its floodplain. In addition, the levees were not designed or constructed to current standards and their rip-rap slopes sit at a relatively steep angle at the river's edge, resulting in a poorly vegetated riparian zone that is vulnerable to erosion and scour.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public infrastructure: erosion of the Cedar River Trail and State Route 169;
- Impact on regional economy if State Route 169 were extensively damaged.

Proposed Project or Action

Initial project actions will involve design of a flood protection facility retrofit for both the Jan Road and Rutledge-Johnson Levees to reduce the channel constrictions and associated high velocities. The initial design phase for the project will evaluate various alternatives that may include removal or setback of levee segments at the downstream end of each flood protection facility. The principle objective will be to allow higher flows, and the associated erosive energy, to be spread out and dissipated over a larger area of the floodplain, thereby reducing flood damage to the levees themselves and the Cedar River Trail levee. Engineering analyses will be used to determine the dimensions and alignment of the removal or setback alternatives in order to achieve the desired flood conveyance improvements without creating any undesirable flood impacts on neighboring homes and properties. Communication with local residents will take place both formally and informally during the project's design development and implementation phases to provide an opportunity for them to be involved and informed. Results of the design development phase of the project may indicate that additional property easements or ownership are needed to fully achieve the proposed conveyance and floodplain reconnection improvements as recommended. King County will work cooperatively with adjacent property owners to acquire conservation easements or other property interests, or to modify designs, as needed.

Project Benefits

Removal or set back of the downstream end of these levees will reduce the risk of damage to three important flood protection facilities, and will also provide habitat enhancement benefits. By reducing channel confinement, high flows can spread out and be safely conveyed across the floodplain, ultimately lowering flood elevations and velocities. This will reduce the risk of levee failure or damage to the regional trail, the Maple Valley Highway and the levee themselves. Routine and preventive maintenance costs will also be reduced over the long term. The modified levees will continue to provide the targeted flood benefits they currently provide in the form of reduced frequency of overtopping and reduced risk of channel migration in the vicinity of local residences.

While existing flood risks to neighboring homes will be lowered, they will not be eliminated. The floodplain extends almost to the valley wall through this reach, and the majority of homes in the neighborhood immediately downstream from this project are located in the floodway. Aerial photos taken during past flood events show many of these downstream homes to be surrounded by floodwaters, and channel migration studies show a history of multiple flow locations in this reach. The proposed project is therefore only a part of a comprehensive solution, but would not preclude future efforts to minimize bank erosion along King County-maintained flood protection facilities, reduce vulnerability of the major arterial roadway, and reduce the frequency and severity of overbank flooding across Jan Road and throughout the neighborhood.

Other benefits of the proposed project include increased channel complexity and improved habitat conditions that result from giving the river greater freedom to interact with its floodplain. Setting back the existing levees will also create opportunities for future habitat restoration projects in the reconnected riparian corridor.

Coordination

The project will be managed and constructed by the River and Floodplain Management Program, in coordination with the Water Resource Inventory Area 8 salmon habitat recovery efforts. Elements that will directly affect individual properties will be coordinated with the property owners. Design and construction of specific instream or off-channel habitat improvements may accompany or follow the flood protection facility modifications.

Other Information or Needs

The levee has been maintained under the U.S. Army Corps of Engineers Rehabilitation and Inspection Program, and modifications may require additional coordination or authorization.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Jan.pdf

Cedar River Residential Flood Hazard Mitigation Analysis

Location Information

Water Resource Inventory Area 8, Cedar River
Multiple Locations
Council District 9
Jurisdiction: Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$175,000

Problem Statement

Many of the flood hazard areas of the Cedar River encompass large tracts or even entire neighborhoods. Two prime examples of known high hazard areas are the Dorre Don and Byers Road neighborhoods. Of the many homes located in the Dorre Don neighborhood, almost all are located within the mapped floodplain, floodway or what appears to be the severe channel migration hazard area (based on preliminary findings of channel migration zone mapping in progress). Many of these homes are built right along the river's edge. Much of the bank is lined by public and private flood protection facilities, limiting channel conveyance and mobility and encroaching into the stream buffer. The river commonly overtops the banks during flood events, and sometimes also transports and deposits substantial amounts of large woody debris. Several of the flood-prone homes have been elevated, reducing the risk of damage from inundation, but not the risks from debris build-up against the structures or from access cut-off due to fast and deep flows through the neighborhood.

Similarly, homes in the Byers Road neighborhood are threatened by overbank flooding. An additional risk in this neighborhood is the tendency for flows from the river to leave the main channel and cut across the neighborhood, cutting off emergency access to and from homes. A flood protection facility at the upstream end reduces the frequency of overbank flows, but does not provide flood containment for even moderate flood events.

These widespread flood risks have not been substantially reduce, as evidenced by the fact that despite a substantial investment in the construction and maintenance of both public and private flood protection facilities, the flooding and associated losses continue. Encroachment on the river corridor by homes and levees has diminished the available conveyance capacity of the river, while at the same time flows have increased basin-wide. The river lacks sufficient conveyance capacity to accommodate the flooding. Further compounding the flood risk, the proximity of the homes to the river precludes many structural solutions, such as raising or setting back levees. In addition, regulations restrict construction efforts to those that do not increase flooding elsewhere.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, primarily roads and drainage systems;
- Damage to privately owned structures.

Proposed Project or Action

Home buyouts appear to be one of the most feasible and effective solution in many of these high hazard areas, but the magnitude of impact of such a solution on both the community and existing flood hazard management resources is significant. Therefore, recommendations for these areas warrant further consideration. A range of flood hazard management alternatives for this area should be developed and evaluated to determine the most prudent course of action. The analyses should consider the flood risk, especially for residential developments; the level of protection provided by existing flood protection facilities; options for flood protection facility modifications or retrofits; and the impact of those facilities on flooding and habitat use in the vicinity.

Project Benefits

Project benefits will need to be identified and considered as part of the alternatives analysis.

Coordination

It will be important to coordinate with both internal and external customers. Likely partners include the homeowners, the Water Resource Inventory Area 8 Forum and Steering Committee, and the King County Department of Transportation.

Project Area Map

A map of the Byers Bend neighborhood may be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Byers.pdf

A map of the Dorre Don neighborhood may be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Dorre.pdf

Cedar River Gravel Removal Project

Location Information

Water Resource Inventory Area 8, Cedar River
River Miles 0 to 1.25, 3.5 and 21
Council District 5
Jurisdiction: Renton
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,827,000

Problem Statement

On average, 10,000 to 12,000 cubic yards of gravel passes as bedload through the lower mainstem Cedar River each year. Of that, about half is deposited in the lowest 1.25 miles of the river at an average annual rate of gravel accumulation of about 6,000 cubic yards per year, while the balance comes to rest on the delta in Lake Washington. Rates of bedload yield from the basin and subsequent deposition in the lower Cedar River can fluctuate greatly in any given year from these annual average values. This ongoing deposition occurs in a segment of the Cedar River that lies adjacent to Renton Municipal Airport, Boeing property, areas of downtown Renton, and other public and private properties. Periodic dredging of gravel and sediment has been employed to maintain flow conveyance through this reach in order to avert flood damages to the regionally significant economic investments clustered in the vicinity. Gravel and sediment removal was last performed in 1998, and simultaneously, improvements were made to the levees and floodwalls along both right and left banks of the river to provide 100-year flood protection to the area.

The 1998 gravel and sediment removal and structural improvement project, entitled the Lower Cedar River Section 205 Flood Hazard Reduction Project (known as the Lower Cedar 205 Project), was constructed through a partnership among the City of Renton, the U.S. Army Corps of Engineers, and King County. The City of Renton, as the local project sponsor, signed a formal agreement committing to ongoing maintenance of the bed elevation of the channel to ensure long-term benefits of the project. Each year, a detailed sediment study of the lower Cedar River is conducted to ensure that the allowable bed elevation is not reached, and hydraulic modeling is performed to predict sediment capacity associated with gravel removal maintenance intervals.

In addition to the maintenance responsibilities, project permits required extensive mitigation for the initial construction impacts and impacts associated with the anticipated future maintenance dredging. Mitigation features for the Lower Cedar 205 Project included creation and enhancement of off-channel habitat and gravel supplementation in upstream river reaches. Gravel supplementation involves depositing gravel, suitably sized for spawning, into the upstream reaches of the river below the dams (which prevent the natural recruitment of gravel). Off-channel habitat was expanded by excavation of a groundwater-fed spawning channel to provide sockeye spawning habitat as well as rearing and refuge habitat for coho and Chinook salmon. The 2001 Nisqually Earthquake, however, caused a landslide that blocked the main channel of the Cedar River, resulting in the occupation of the groundwater spawning channel by the river, and ultimately the loss of the spawning channel habitat as a mitigation site. Replacement mitigation is needed to meet the permit requirements.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if homes, businesses and industrial areas in downtown Renton are inundated due to reduced channel capacity;
- Risk to the local economy if homes, businesses and industrial areas in downtown Renton are inundated due to reduced channel capacity;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes and businesses;
- Damage to public infrastructure, including drainage systems, roads and public facilities;
- Damage to privately owned structures.

Proposed Project or Action

The proposed action includes three elements: periodic gravel removal, spawning channel replacement and upper watershed gravel supplementation.

The periodic gravel removal maintenance will be performed to maintain the project flood protection benefits as required in the Project Cooperation Agreement between the City of Renton and the U.S. Army Corps of Engineers. The threshold for periodic gravel removal maintenance is based on ensuring flood protection against the 100-year recurrence interval event with at least 90 percent reliability. During gravel removal maintenance actions, the Cedar River channel within the project area will be excavated to a depth of 4 feet below the 1995 bed profile. The average annual maintenance dredging as estimated by the U.S. Army Corp of Engineers is expected to be $2.4 million every three years.

To replace the lost ground water spawning channel, the spawning channel replacement project is proposed at River Mile 3.5. The spawning channel replacement is targeted for construction in 2006 or 2007. It will consist of constructing a 950-foot long by 10-foot wide channel that contains large woody debris, native plants and spawning gravel and is connected to the Cedar River with an inlet structure.

The gravel supplementation, which is also carried out for mitigation purposes, is performed annually prior to August 15. The gravel supplementation is placed during the summer low-flow period in a berm in the Landsburg reach at River Mile 21.0. As of August 2005, a total of 4,000 cubic yards of gravel has been placed at the Landsburg Gravel Supplementation site and it is anticipated that at a minimum an additional six years of gravel supplementation will be necessary to place the required 10,000 cubic yards of spawning gravel. The cost for the gravel supplementation is between $25,000 and $35,000 annually.

Extensive spawning surveys, fry out-migration surveys, vegetation monitoring and maintenance, and other monitoring will be performed as required for the gravel removal project and associated mitigation projects.

Project Benefits

The existing channel bed will be maintained at a level that will ensure that 100-year flood protection is provided through the project area to minimize future damage to Renton Municipal Airport, Boeing property, areas of downtown Renton, and other public and private properties in the project area. The U.S. Army Corp of Engineers has determined that the flood protection benefits provided by the construction of the Lower Cedar River Section 205 Flood Hazard Reduction Project and the associated periodic maintenance dredging provides an average annual benefit of $7,797,000.

Coordination

This project will require, at a minimum, coordination among Boeing operations personnel, FEMA, the Washington Departments of Fish and Wildlife and Ecology, the Muckleshoot Indian Tribe, the City of Renton, the National Oceanographic and Atmospheric Administration–Fisheries, the U.S. Army Corps of Engineers–Seattle District and other public agencies and private property owners adjacent to the project area. The proposed spawning channel replacement project will require easements from Seattle Public Utilities and Shadow Hawk, and temporary construction easements will need to be obtained from private property owners.

Other Information or Needs

This project contains habitat enhancement requirements from the Washington Department of Fish and Wildlife, National Oceanic and Atmospheric Administration–Fisheries, and the Muckleshoot Indian Tribe. These requirements include gravel replacement at Landsburg and annual operation and monitoring reports.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/gravel.pdf

Lower Jones Road Setback Project

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 5.5 to 6.2, Right Bank
Council District 9
Jurisdiction: Unincorporated King County
Public or Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,408,000

Problem Statement

The entire length of Jones Road follows the Cedar River, much of which lies within the river's floodplain and areas of historical channel migration. At Buck's Curve, where the river immediately abuts the road shoulder, King County maintains a flood protection facility to protect the road. This flood protection facility is prone to scour and erosion and is vulnerable to significant structural damage during high flows. In addition, the confinement perpetuated by the armored right bank deflects flood flows directly toward the Cedar River Trail Revetment that protects not only the regional trail, but also the Maple Valley Highway (State Route 169) on the opposite bank. The revetment protecting the road regularly experiences flood damage and requires costly maintenance, but has no room within the existing right-of-way to be set back or retrofitted to a more stable slope.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if right bank residents are caught unaware of flood conditions or attempt to enter or re-enter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, including Jones Road, the Cedar River Trail and State Route 169;
- Impact on regional economy if State Route 169 is severely damaged;
- Damage to private structures.

Proposed Project or Action

The riverbanks should be set back along this entire length of river to provide more room for flood conveyance and to reduce the risks of ongoing flood damage. At its upstream end, the flood protection facility and about a 1,500-foot section of Jones Road will need to be relocated landward to accommodate a stable slope angle on the banks, improved conveyance in the channel, and a buffer separating the river and the road. This will require purchase of an easement through several contiguous properties on the landward side of the road, and may require some additional property easements or acquisitions. As part of a longer term solution, the remaining high risk flood-prone homes downstream should be acquired; banks should be set back; and the riparian buffer should be restored with native vegetation. Elements of this project have already been initiated. In recent years, King County has purchased numerous homes

along this reach for both flood hazard management and road construction purposes, reducing the number of vulnerable structures.

Project Benefits

The set back or removal of the armored banks would tend to lower flood elevations and velocities through the reach, reducing future flood damage and the subsequent need for repair to the road and flood protection facilities on both banks. This will also protect the usability of Jones Road, which is an important transportation corridor for residents throughout the adjacent valley. Removal of the flood-prone homes from the river's edge, implemented over the long term, will completely eliminate the flood risk for those residents. It would also allow for restoration of the riparian buffer and creation of projects to enhance habitat conditions in the area.

Coordination

This project will be coordinated with King County Department of Transportation for planning, design, and construction of modifications to the road. It would also be coordinated with the 1997 Cedar River Basin Plan implementation efforts, the salmon habitat recovery plan for Water Resource Inventory Area 8, and other regional resource management and permit agencies as appropriate. Elements that will directly affect individual properties will be coordinated with the property owners. Homeowner interest in buyout participation has not yet been assessed for this area.

Other Information or Needs

This project could be done in several phases; the road set back and home buyouts are not interdependent in most locations.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Jones.pdf

Herzman Levee Setback and Floodplain Reconnection

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 6.5 to 6.7, Right Bank
Council District 9
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,023,000

Problem Statement

The Herzman Levee extends 17 to 18 feet high in an over-steepened configuration lining 840 feet of river bank. While the levee reduces the risk of channel migration, it is not continuous with high ground and does not provide flood containment. Seepage is common behind the levee in an area of low undeveloped floodplain formerly occupied by the river. Several residential properties, as well as a section of Jones Road, are located further behind the levee. These structures are set back several hundred feet from the river on a section of high ground above the flood elevation, and they do not experience flooding as a result of the seepage, overtopping or backwater behind the levee. The flood protection facility, therefore, unnecessarily constricts flows within the channel, forcing the full momentum of the river directly into Cedar River Trail levee on the immediate opposite bank. This significantly increases the risk of flood damage to that levee, which protects both the trail and the Maple Valley Highway (State Route 169). In addition, the Herzman levee prevents the river's ability to occupy the undeveloped land immediately behind the levee, and in doing so obstructs the natural floodplain processes, reducing the quality and quantity of riparian habitat, and preventing development of a healthy vegetative buffer in an area of high fish use.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure, including the Cedar River Trail and State Route 169;
- Impact on regional economy if State Route 169 is severely damaged.

Proposed Project or Action

Remove approximately 350 linear feet of the levee and set back another 190 linear feet in a manner that will reconnect the river with its floodplain without increasing flood risks to the existing homes or Jones Road.

Project Benefits

Partial removal and set back of this flood protection facility will reduce channel confinement to allow overbank flows to spread across the right bank floodplains. The improved conveyance and floodplain function will reduce the erosive force of flood flows against the trail and road protection on the opposite bank, lower flood elevations, reduce velocities, and reduce vulnerability to flood damage for the flood protection facility itself. It will also improve instream habitat and provide for refuge during high flows

for juvenile fish. Additional habitat enhancements such as planting native vegetation or creation of pools, side-channels or backwater areas, may be proposed in concert with, or subsequent to, this flood protection facility setback project.

Coordination

The project will be managed and constructed by the River and Floodplain Management Program in coordination in the Water Resource Inventory Area 8 Forum and Steering Committee. Construction of specific instream or off-channel habitat improvements may accompany or follow the removal of the flood protection facility. Elements that will directly affect individual properties will be coordinated with the property owners.

Other Information or Needs

There may be a need to acquire an additional easement along the undeveloped portion of the properties located behind the levee.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Herzman.pdf

Cedar Grove Mobile Home Park Acquisition Project

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 10.75 to 11.10, Right Bank
Council District 9
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,349,000

Problem Statement

The Cedar Grove Mobile Home Park is located entirely within the floodplain and a high hazard overbank flood path of the Cedar River. Repeated flooding and damage of property and basic services have made this perennially one of the highest flood risk areas in the basin. In 1990, flows overtopped the levee upstream, inundating the entire area, which caused the septic system to fail, contaminated the drinking water supply, cut off the sole access in and out of the area, and damaged residents' homes.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to privately owned structures.

Proposed Project or Action

Acquire the entire flood-prone property (at fair market value); assist in relocating park residents; remove the homes and all associated structures; and decommission and remove supporting infrastructure, such as the road, utilities, septic systems, and water supply wells.

Project Benefits

This project will eliminate all future flood damage and safety risks for these residents. There is also a considerable efficiency in administering the project across the entire neighborhood: public infrastructure that supports residential use in this area will no longer need to be maintained; the construction costs for removal of the structures will be minimized because properties are contiguous; and it will make a complete project for this area. It will build on similar projects in the reach immediately upstream, and will expand on the benefits associated with allowing for natural floodplain processes. It will also pave the way for a future restoration project extending along three quarters of a mile of the Cedar River from the Cedar Grove Road Bridge downstream through the Cedar Grove Mobile Home Park.

Coordination

This project is also a recommendation in the Cedar River Basin Plan (King County 1997) and the salmon habitat recovery plan for Water Resource Inventory Area 8. Some time has passed since the owner of the mobile home park expressed interest in selling to King County, and his current level of interest is not known. Coordination with current property owners will be needed.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Rainbow1.pdf

Rainbow Bend Levee Setback and Floodplain Reconnection

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 11.3 to 11.5, Right Bank
Council District 9
Jurisdiction: Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,733,000

Problem Statement

The Rainbow Bend Levee on the right bank shunts deep, fast flood flows directly into the Cedar River Trail Revetment on the left bank. Together, these two flood protection facilities on opposite sides of the river severely constrict flows, particularly at flood stage, through this reach. This type of channel confinement tends to increase localized scour velocities and flood elevations, increasing the frequency of overtopping and exacerbating flood damage and risks to the flood protection facilities themselves as well as to neighboring residential and recreational uses. One of the greatest risks is erosion and scour along the levee protecting the regionally significant Cedar River Trail and the Maple Valley Highway (State Route 169). Further, the levee, which was not built to provide 100-year flood protection and provides neither sufficient freeboard nor ties into high ground at its downstream end, is subject to frequent overtopping, backwater flooding, and damage, leaving the properties it is intended to protect at risk for personal losses or property damages.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if sudden failure of the levee results in deep fast flows in the area behind the levee;
- Risk to public infrastructure: erosion of the Cedar River Trail and eventually State Route 169;
- Impact on regional economy if State Route 169 were extensively damaged;
- Damage to privately owned structures.

Proposed Project or Action

Once acquisition of the flood-prone properties immediately behind the levee is complete, the levee can be set back or removed to provide greater accommodation of flood conveyance and natural riverine processes within the extensive floodplain currently cut off from the river. The project will extend along three quarters of a mile of the mainstem Cedar River, starting at Cedar Grove Road Bridge and proceeding downstream.

Project Benefits

Removal or set back of the levee would lower flood elevations and velocities through the reach, thereby reducing or even eliminating future maintenance costs. It would also take the pressure off the opposite bank, reducing erosion and scour along the flood protection facility protecting the trail and State Route

169. The removal of bank armor and widening of the floodplain would allow for a dynamic interaction between the river and its floodplain and establishment of a fully functional riparian buffer, which would provide natural flood attenuation and would also support habitat restoration efforts within this reach. This reconnected floodplain area will expand upon the high quality corridor conditions in the Belmondo reach downstream and the restored Cedar Grove Road reach upstream.

Coordination

This project will need to be coordinated with land mangers responsible for the properties previously purchased to allow completion of this project.

Other Information or Needs

This project is also a recommendation in the Cedar River Basin Plan (King County 1997) and the salmon habitat recovery plan for Water Resource Inventory Area 8.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Rainbow3.pdf

Getchman Levee Setback and Floodplain Reconnection

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 13.75 to 14.05, Right Bank
Council District 9
Jurisdiction: Unincorporated King County
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$2,670,000

Problem Statement

The Getchman Levee was built to prevent bank erosion and channel migration toward several homes and a section of Maxwell Road. The two most severely flood-prone homes located behind the Getchman Levee have been acquired and removed. The levee, in combination with the Rhode Levee on the opposite bank (see Rhode Levee Setback and Home Buyouts), severely constricts flood conveyance through this reach. This type of channel confinement tends to increase localized scour velocities and flood elevations, increasing the frequency of overtopping and exacerbating flood damage and risks to both the flood protection facilities and the surrounding residential properties. Both levees overtop at moderate flows, surrounding a number of the homes on the opposite bank with deep and fast flows. In addition to these flood impacts, the Getchman Levee disconnects the river from its floodplain, an historical oxbow channel, and the lower end of Taylor Creek, diminishing the ability of the river and its buffer to provide valuable habitat.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, including local county roads and flood protection facilities;
- Damage to privately owned structures.

Proposed Project or Action

The Getchman Levee should be set back to reconnect the river with its floodplain in order to establish a greater area for flood conveyance and natural floodplain processes. The setback should be designed to maintain protection for Maxwell Road while opening up access for flow in the floodplain where homes have been removed or are sufficiently set back from the riverbank. A hydraulic model should be updated to reflect the new topographic conditions, and the results evaluated to determine the impact on flood hazards and future projects in the vicinity, such as along the Rhode Levee on the opposite bank. The one remaining home located behind the levee may still be at risk from flooding, and should be considered for acquisition as part of a long-term flood hazard management strategy.

Project Benefits

Setting back this flood protection facility will provide substantial flood and habitat benefits. By reducing the channel confinement, high flows will be able to spread out over the right bank to reduce flood elevations and velocities through this section of river. This will reduce the extent of future repairs to King County-maintained flood protection facilities on both the right and left banks. It will also lower flood risks to the remaining homes and properties, especially the highly flood-prone homes across the river. Additionally, a setback will allow the river to reoccupy the remnant oxbow and to interact with lower Taylor Creek, creating a more complex channel network.

Coordination

This project will need to be coordinated with any modification to the Rhode Levee and with agencies implementing the salmon habitat recovery plan for Water Resource Inventory Area 8 and the Cedar River Basin Plan. Design of this project should be coordinated with other resource management entities to build upon the substantial habitat improvements already underway for the lower reach of Taylor Creek that runs through the Cedar River floodplain in this reach. Elements of project design that address the need to protect Maxwell Road will need to be coordinated with the King County Department of Transportation.

Other Information or Needs

An evaluation of flood risks should be made in conjunction with design of this project to determine the need for acquiring the last remaining home behind the levee. The homeowner has expressed a willingness to discuss this option with King County. Any actual acquisition will depend upon securing funding and reaching agreement with the property owner on purchase of the property.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Getchman.pdf

Rhode Levee Setback and Home Buyouts

Location Information

Water Resource Inventory Area 8, Cedar River
River Mile 13.75 to 14.05, Left Bank
Council District 9
Jurisdiction: Unincorporated King County
Public or Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$3,518,000

Problem Statement

Erosion, scour, and lack of containment along the Rhode Levee allows fast and deep flows to overtop the banks and flow through the adjacent residential neighborhood and across SE 203rd Street. The flood protection facility, the homes and the roadway have all required regular repair and maintenance due to flood damages. With levees flanking both banks for approximately 1,600 linear feet, the river is severely constricted through this reach. This confinement leads to an increase in localized scour velocities and flood elevations, exacerbating flood damage and risks to the flood protection facilities as well as the surrounding residential properties. The Rhode Levee also separates the river from its floodplain and disrupts the natural floodplain processes and interactions.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if right bank residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, primarily flood protection facilities;
- Damage to privately owned structures.

Proposed Project or Action

Project designs for reducing flood damage and loss behind the Rhode Levee will need to give consideration to projects planned for the Getchman Levee on the opposite bank. The hydraulic model may need to be updated to reflect the new topographic conditions, and the results evaluated to determine the impact on flood hazards and future projects in the vicinity. Homes in the highest hazard areas should be acquired and the structures removed from the floodplain. Following acquisition of these flood-prone homes, and as part of a long-term flood hazard management strategy, channel conveyance should be expanded to safely accommodate flood flows while protecting SE 203rd Street and the remaining homes from any increased flood risk. This may be accomplished by setting back the levee or by constructing a conveyance channel through the floodplain.

Project Benefits

Acquiring and removing the flood-prone homes will eliminate both the flood risk for homeowners and the need to repair damage. Subsequent conveyance improvements will reduce localized flood elevations and velocities, which will reduce flood damage and the need for future repairs on both the right and left bank flood protection facilities. Construction of a levee setback would provide additional habitat benefits by allowing natural floodplain processes and interaction with the river. The project will complement work on the opposite bank to reconnect the floodplain and to improve lower Taylor Creek, creating a wide floodplain area within which the river has room to flood, to move and to create more complex channel and riparian habitat.

Coordination

This project will need to be coordinated with any modification of the Getchman Levee as well as with agencies implementing the salmon habitat recovery plan for Water Resource Inventory Area 8 and the Cedar River Basin Plan. Elements of project design that address the need to protect SE 203rd Street will need to be coordinated with the King County Department of Transportation. Elements that will directly affect individual properties will be coordinated with the property owners.

Other Information or Needs

The level of homeowner interest in participating in a voluntary buyout program has not yet been assessed.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Rhode.pdf

5.9 GREEN RIVER

5.9.1 Overview

The Green River flows northwest about 93 miles from its headwaters in the Cascades, at an approximate elevation of 4,500 feet, to its outlet in Elliott Bay via the Duwamish River. The Green River basin drains 483 square miles and is bounded on the north by the Cedar Sammamish watershed and on the south by the White Puyallup watershed. Major tributaries to the Green River include Soos, Newaukum and Mill Creeks, and the Black River. Map 5-8 shows the Green River and its major features. An electronic version of this map can be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-8.pdf

The Green River basin is located entirely within King County. The river flows through several cities, primarily in its lower reaches, including Auburn, Kent, Renton, Tukwila and Seattle. The basin typically is divided into four sub-watersheds. This Plan focuses on the lower three: the middle Green River, which runs from the outlet of the Green River Gorge at about River Mile 45 near Flaming Geyser down to Auburn at about River Mile 31; the lower Green River, which runs from Auburn down to the Duwamish River at River Mile 11; and the Duwamish River, which runs from River Mile 11 to the mouth in Elliot Bay. The Green River flood hazard management corridor includes the river channel and the mapped flood hazards, areas of potential levee failure and areas of deep fast flow not otherwise mapped as hazard areas, landslide hazard areas, and a riparian buffer in these lower three sub-watersheds.

The Duwamish River is the tidal-influenced portion of the Green River, below River Mile 11. Historically, the Duwamish River consisted of three major tributaries: the Green, White, and Black Rivers. In the early 1900s, the White River was diverted south into the Stuck River, which joins the Puyallup River. The Cedar River was diverted from the Black River, a tributary to the Duwamish River, to Lake Washington. These changes reduced the flow out of the Duwamish River by two-thirds of its historical discharge (Fuerstenberg et al. 1999), permanently affecting flood characteristics in the lower Green and Duwamish Rivers.

Major flood control features along the Green River include Howard Hanson Dam, which is in the upper Green River sub-watershed, and the levee system that lines almost all riverbanks of the lower Green and Duwamish Rivers. Howard Hanson Dam and the levee system combine to reduce flooding in the lower river to a fraction of its historical magnitudes. In addition, the Green River Flood Control Zone District (District) is a special purpose district through which King County and the Cities of Auburn, Kent, Renton and Tukwila have coordinated floodplain management efforts on the lower Green and Duwamish Rivers. The District was created in 1960, but was not given revenue-generating authority at that time. In 1978, the participating jurisdictions signed an interlocal agreement to provide funding for District activities. The interlocal agreement was renewed in 1992 and again in 2002. In addition, the District's authority to raise revenue through a levy of its own was activated in 1990.

With major historical flooding largely controlled by a dam and levees, commercial and industrial land use in the largely flat and generally accessible lower Green and Duwamish River valleys has proliferated in what were formerly less populated rural and agricultural communities. Agriculture persists in some parts of the lower Green River around the Cities of Auburn and Kent, and agriculture and rural residential development are the primary land uses in the middle Green River.

5.9.2 Geology and Geomorphology

The entire Green River flood hazard management corridor is within the area affected by the continental glacial advances that have shaped much of the topography of the Puget Sound Lowland. Upstream of the

Green River flood hazard management corridor, the river has cut a steep, narrow canyon through Tertiary bedrock to form the Green River Gorge. The middle Green River and the lower Green and Duwamish Rivers exemplify two vastly different landscapes formed by and in response to continental glaciation. The middle Green River basin is a moderate-gradient, post-glacial valley incised by the river into glacial and non-glacial sediments after glacial retreat. The broad and flat lower Green River and Duwamish River basins are a glacial trough, eroded by subglacial meltwater and scour of the glacier itself. The two different landscapes will have bearing on flood hazards in each area.

Since glacial retreat, the middle Green River has meandered across its valley, depositing and reworking alluvial sediment on its floodplain. Movement of the river back and forth episodically undercuts steep valley walls, causing landslides that line the valley walls in many places (Perkins 1993). The middle Green River now flows through an alluvial floodplain with valley walls composed mostly of glacial and non-glacial sediments and landslides, with some bedrock exposures near Flaming Geyser. In this post-glacial valley, the flood hazards from inundation and channel migration pose a threat to much of the valley bottom of the middle Green River. The middle Green River is a migrating river, in some places exhibiting very rapid rates of lateral channel migration and avulsion. Downstream of State Highway 18 near Auburn Narrows at River Mile 33, an avulsion occurred in 1995 as a meander cut-off chute incised a new path through the neck of a wooded meander bend, abandoning over a half mile of the previous channel. This feature continued to change in 1996 and during subsequent floods, and it remains highly dynamic. By contrast, there are also portions of the channel through the middle Green that have shown little movement historically or currently.

At the City of Auburn, the Green River opens to the much wider and flatter lower Green River and Duwamish River valleys. Following glacial retreat, the glacial trough that formed the present lower Green and Duwamish valley was a shallow embayment of the Puget Sound. Some 5,700 years ago, the Osceola Mudflow, a lahar originating on the slopes of Mount Rainier, made major changes to the White River drainage and deposited sediments in the lower Green as far as Auburn. Erosion and deposition of sediments from the Osceola and subsequent lahars eventually filled the previously marine lower Green and Duwamish River valley to form the broad low-gradient alluvial valley of today (Dragovich et al. 1994). More recent deposition of alluvial sediments formed the White River alluvial fan, a fan-shaped depositional feature composed of coarser sediments emanating from the White River basin north into the lower Green River basin near Auburn.

With the very low channel gradient and down-valley gradient along the lower Green and Duwamish Rivers, sediments in overbank flooding are deposited close to the channel, resulting in higher elevations at the top of bank next to the channel and lower elevations on the floodplain farther from the channel. During even relatively common flood events prior to dam and levee construction, the entire valley bottom, from valley wall to valley wall, was likely to be inundated.

The plan view of the lower Green and Duwamish Rivers shows a single-thread, sinuous, meandering channel pattern. Although the channel is sinuous, there is little evidence of channel movement since the late 1800s (Collins and Sheikh draft 2003), so there appears to be a low hazard from lateral channel migration along the lower Green and Duwamish Rivers. In a natural, unleveed condition, characteristics of typical glacial trough basins would apply to the lower Green and Duwamish Rivers; meander cutoffs would be the main form of change in channel location, but they would occur infrequently. However, the existing continuous levee system, if maintained intact, would effectively preclude the likelihood of cutoff or avulsion from about River Mile 25 to the mouth of the Duwamish River.

5.9.3 Hydrology and Hydraulics

The main period of runoff and major flood events on the Green River is from November through February. The primary control on flooding characteristics is Howard Hanson Dam, at approximately River Mile 64. Howard Hanson Dam was completed in 1962 and is operated by the U.S. Army Corps of Engineers, with a primary purpose of flood control and secondary purpose of water conservation and municipal water supply. During the summer, low flows are augmented through release of waters stored in a conservation pool in the reservoir behind Howard Hanson Dam. Additional flows are stored and released to supply summer withdrawal needs at the Tacoma Public Utilities water supply diversion structure downstream.

The target flood control parameter for Howard Hanson Dam is a Congressionally authorized flow of 12,000 cubic feet per second at the Green River near Auburn gage (USGS #12113000), at about River Mile 31 in Auburn. Operations at Howard Hanson Dam that target flows at Auburn must also consider the magnitude and timing of local inflows from tributaries such as Soos and Newaukum Creeks.

Placing a cap of 12,000 cubic feet per second on Green River flood flows at Auburn has reduced all larger flood events to what would be the pre-dam equivalent of a 2-year event at Auburn. Howard Hanson Dam is capable of storing floods up to and including a 500-year reservoir inflow event and converting them to a discharge at Auburn of the historical 2-year flood, with such flows extending over a much longer duration than they would under natural conditions. Dam operations in combination with the lower Green levees contain most flood events from Auburn downstream to the mouth. Table 5-17 summarizes flow data.

TABLE 5-17.
GREEN RIVER FLOWS

Recurrence Interval (years)	Discharge at Auburn Gage[a, b] (cubic feet per second)
10	12,000
50	12,000
100	12,000
500	12,000

a. FEMA 2005
b. Affected by regulation at Howard Hanson Dam.

Major historical floods on the mainstem Green River produced flows at Auburn of 24,000 cubic feet per second in 1933, which had a pre-dam recurrence interval of 19 years; 18,400 cubic feet per second in 1951, a 7-year pre-dam recurrence interval; and 28,100 cubic feet per second in 1959, a 39-year pre-dam recurrence interval.

While dam operations and levees contain floods on the mainstem Green River, free-flowing tributaries may still back up under elevated river conditions during 12,000 cubic feet per second flows, inundating lands along the valley floor even during controlled releases from Howard Hanson Dam. To address this backwater flooding condition, pump stations have been constructed over the years on various tributaries. The Black River Pump Station, also known as the P-1 Pump Station, was built in 1972 by the Natural Resources Conservation Service, formerly the Soil Conservation Service, just upstream from the confluence of the Black and Duwamish Rivers. Similar pump systems have been installed at other

locations along the lower Green River, such as the P-17 Pump Station at the easterly terminus of Minkler Street in Tukwila, which serves the Southcenter area near River Mile 13.91, and other pumps near River Mile 23.99 and River Mile 26.02 in Kent. Smaller local pump systems continue to be built, such as a recently constructed system serving Strander Boulevard near River Mile 13.19 in Tukwila.

As recently as the 1990s, several studies were completed to investigate the feasibility of constructing another major pump station to serve Mullen Slough and Mill Creek, which flow into the Green River at River Mile 21.58 and 23.84, respectively. These tributaries share a large agricultural floodplain with the Green River. Although this pump station proposal was a key element in the 1970s-era Natural Resource Conservation Service flood control plan for the Green River valley, more contemporary studies indicate that any economic benefits that might result from construction of another large pump station at this location would be far exceeded by the project costs. Therefore, the shared floodplain of these tributaries near their confluence with the Green River remains designated as part of the Green River's FEMA-mapped floodway.

In addition to pumped tributary outlets to the river, many other drainage systems are connected to the river by passive "flap gate" style flood closure devices. Examples of these structures are at the Gilliam Creek outfall near River Mile 12.61 in Tukwila, at the mouth of Johnson Creek near River Mile 17.34 near Tukwila, at the confluence of the Northeast Auburn Tributary near River Mile 25.44, and at the Cooter Pond tributary outfall near River Mile 27.35. Such systems are difficult to inspect and service when inundated during floods. As a result, they may fail to control backwater flooding from the mainstem when, for example, debris lodges inside and prevents full closure of the flap. Section III.C.(2) of the September 9, 1986 Green River Pump Operations Procedures Plan requires newly installed flap gates to have accessible backup closure systems, and the salmon habitat recovery plan for Water Resource Inventory Area 9 proposes initiatives to retrofit older flap gates in its Policies FP-1 and FP-2, Conservation Hypothesis All-3, and Projects LG-11, LG-16 and DUW-8. Even if the flap gates are properly closed, tributary runoff ponding behind the closed outlet can still inundate large areas, as is presently the case in the Johnson Creek floodplain.

5.9.4 Ecological Context

The middle Green, lower Green and Duwamish Rivers cover a wide array of river and estuarine conditions, ranging from a moderate-gradient, gravel-bedded channel, especially good for salmon spawning, in the middle Green below the gorge, to low-gradient, silt- and sand-bedded channels in the lower river and estuary areas as the river approaches and empties into Puget Sound at Elliot Bay. Multiple transformations of historical river flow paths, such as diversion of the White River into the Stuck and Puyallup River system and loss of the Black River as a result of Lake Washington Ship Canal construction, have reduced the contributing drainage area to the river below about River Mile 31, at the historical location of the White River mouth, to only about a third of its original size. The river's riparian areas and surrounding floodplains have also been heavily developed for industrial, commercial, agriculture, and residential purposes from the estuary to the upstream end of the City of Auburn at about River Mile 32, a short distance downstream of the mouth of Soos Creek.

Howard Hansen Dam exerts a strong influence on downstream conditions by stopping passage of sediment and large woody debris, altering seasonal temperature and flood flow regimes, and preventing fish passage into the upper watershed (Kerwin and Nelson 2000). The dam traps coarse sediment and large woody debris from upstream sources, both major building blocks for downstream habitat, preventing their transport and deposition to reaches below the dam and contributing to loss and simplification of mainstem and side-channel habitat in the middle and lower Green and Duwamish Rivers.

Along most of the lower Green and Duwamish Rivers, the river channel is highly constrained by levees and revetments, often creating sinuous, hydraulically simplified, flume-like conditions typified by extensive hardened banks, very little large woody debris and little recruitment potential for such. There is little or no connection between the river's floodplain and associated habitats in this reach. In addition, recent habitat surveys between River Mile 5.7 and River Mile 32.1 found (Anchor Environmental, LTD 2004):

- In-river habitat is dominated by a single habitat type, and there has been extensive reduction and isolation of off-channel habitats, such as side channels, oxbows, and tributaries.
- Pools were largely formed by bridges and bank armoring, as opposed to large woody debris.
- To the extent it exists, spawning gravel is limited mostly to upstream of River Mile 26.6, with some evident down to River Mile 19.1.
- Below River Mile 19.1, the river is almost entirely sand- and silt-bedded.
- Levees and revetments severely limit the connectivity, amount and diversity of riparian vegetation along the river and its adjacent floodplain.
- The existing riparian vegetation is dominated by invasive species.
- Numerous outfalls and water withdrawal pipes are present throughout.

Similar or more altered conditions are found in the lower Duwamish River (TerraLogic and Landau 2004).

The middle Green River basin includes the Green River's best salmon habitat and is where the majority of its salmon spawn. This portion of the watershed also contains Soos and Newaukum Creeks, the two largest and most geomorphically influential tributaries (Martin et al. 2004). Development is far less intense, and riparian and floodplain areas are much less constrained by development in the middle Green River valley than in the lower Green River. The middle Green River valley has a variety of habitat conditions, ranging from reaches heavily confined by artificial constraints such as levees to unconfined channels with little or no bank armoring, active channel migration or well-connected side channels, such as the Metzler-O'Grady Reach from River Mile 38 to River Mile 40.

5.9.5 Salmonid Use

Federal Endangered Species Act-listed Puget Sound Chinook, coho and chum salmon, rainbow trout, including winter steelhead, cutthroat trout and mountain whitefish use the Green and Duwamish Rivers for spawning, rearing and migration (Williams et al. 1975; Kerwin and Nelson 2000). Pink salmon were historically very abundant but have been infrequent users of the system over the past several decades; however, in 2005, there was a significant run of over a million pink salmon in the Green River. On occasion, bull trout and sockeye salmon have also been observed in the river (Williams et al. 1975; King County 2005).

Between 1997 and 2002, while about 80 percent of Chinook salmon redds in the Green River occurred in the middle Green River, approximately 60 percent of the fish were from either the Soos Creek Hatchery or Icy Creek Ponds (King County 2005). Martin et al. (2004) concluded that core areas for Chinook salmon would orient around large, geomorphically influential tributaries, major landslides, and canyon mouths. To reach this conclusion, they collected information on Chinook salmon redd densities and physical characteristics of Chinook salmon rivers and found densities were highest:

- Near the mouths of Soos and Newaukum Creeks.
- On the historical White River alluvial fan.

- At two landslides at approximately River Mile 42.6 and approximately River Mile 49.
- At the mouth of the Green River gorge near Flaming Geyser State Park.

There was also high density of redds directly downstream of Howard Hanson Dam, consistent with evidence that Chinook salmon will migrate up to an upstream blockage and then drop back to spawn in the first suitable spot.

The salmon habitat recovery plan for Water Resource Inventory Area 9, *Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan: Making Our Watershed Fit for a King* (Water Resource Inventory Area 9 Forum and Steering Committee 2005) identified the following goals:

- Increasing the productivity (growth rate) of the population;
- Improving the diversity in terms of genetic makeup and behavioral traits;
- Improving the spatial structure of the population to better distribute fish to take advantage of good habitat and to lower risk from catastrophic events.

5.9.6 King County Facilities, Major Flooding, Flood Damage

The lower Green and Duwamish River levees and revetments form a nearly continuous bank protection and flood containment system from the City of Auburn to the mouth of the Duwamish River. By restraining floodwaters from the commercial and industrial areas of Southcenter in the City of Tukwila and other nearby areas, these flood protection facilities collectively protect what may be the highest land and improvement values in any floodplain area in King County. Therefore these flood protection facilities probably have the highest consequence and risk associated with any potential failure.

Many levees and revetments along the lower Green and Duwamish Rivers were originally constructed by farmers as protection to the formerly agricultural lands of the area. So while there is a continuous levee and revetment system from the City of Auburn to the mouth, uncertain origins and construction methods and materials are associated with most of the Green River flood protection facilities, such that much of the continuous Green River levee system may not meet current construction standards for new flood protection facilities.

In particular, lower Green River flood protection facilities typically have oversteepened banks, areas with inadequate rock buttressing at the toe, and a lack of habitat-enhancing features such as overhanging vegetation or large woody debris. Although Howard Hanson Dam operations significantly reduce flood peaks, they can result in longer durations of lower flows with rapid rates of change in water levels. Such operations can stress the levee and revetment system along the lower Green River, with potential to increase the occurrence of slump failures. As a result, these flood protection facilities require frequent maintenance.

Because of these design and construction shortcomings, the Green River levee system has not always performed as intended to confine flooding within the mainstem channel. Most notably, a portion of the right bank levee failed near River Mile 22.0 during a flood in 1965. Although river flow levels during this event were not unusual, the floodwaters resulting from the levee failure covered nearly the entire eastern portion of the lower Green River valley to a depth of 3 to 4 feet in lower-lying areas near the present-day location of State Route 167 in the City of Renton.

Subsequent floods in 1983, 1986, 1990, 1991, 1995 and 1996 also resulted in significant flood-related damage to levees throughout the Green River levee system. In particular, floodplain excavation in 1973 along landward portions of the Segale Levee near River Mile 15.4 in Tukwila led to extensive piping,

subgrade liquefaction, levee seepage, and sloughing in 1983, 1991, 1995 and 1996. In spite of significant concerns regarding the potential for failure of the Segale Levee during these flood events, levee failure was averted by emergency response by King County and the U.S. Army Corps of Engineers and with repairs partially funded by FEMA. The overall cost to address levee stability concerns at this location has exceeded $2.8 million to date.

In the middle Green River, there are discontinuous bank protection revetments and training levees along several river bends. They are not intended to contain flood flows or prevent inundation, but rather to inhibit bank erosion and channel migration. These flood protection facilities have had varying levels of success in constraining channel migration.

Recent large floods on the Green River occurred in November 1990, November 1995, and February 1996. Typical flood damage included undermining by scour along the toe of levees and revetments in the lower Green River and erosion of flood protection facilities or avulsion around them in the middle Green River. Repairs and modifications made to Green River flood protection facilities since 1993 are described below.

5.9.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

Major Projects

Since the completion of the *1993 King County Flood Hazard Reduction Plan* was completed, the Green River Flood Control Zone District has carried out an annual program that includes maintenance, repair and reconstruction of revetments and levees, as listed in Table 5-18. Several of these projects constitute different segments of the same major levee and, taken together, represent major projects. Significant among these are improvements of flood-damaged containment levee segments that were oversteepened and structurally unstable, which required relocation landward of their original 1960s-era easement locations and reconstruction at stable angles of slope repose. Additional easement widths were obtained in order to complete these repairs at the Desimone Levee in the City of Tukwila and the Boeing, Pipeline and Narita Levees in the City of Kent.

TABLE 5-18.
GREEN RIVER FLOOD CONTROL ZONE DISTRICT PROJECTS SINCE 1993

Project Name	Facility Type	Year	Bank	River Mile	GRFCZD[a] Cost	Federal, State and Other Cost Share	Total Cost
Brannon	Levee	1993	L	30.3	$5,894	—	$5,894
Okimoto	Levee	1993	R	23.3	—	$136,145	$136,145
Dykstra/Lone's		1994	L	30.7	$32,510	$97,529	$130,039
Hamakami	Levee	1994	R	36.1	—	$153,000	$153,000
Plemmons U/S	Levee	1994	L	25.4	$20,627	$61,880	$82,507
Segale Riverward	Levee	1995	L	15.5	$185,409	$556,226	$741,635
42nd Avenue South	Revetment	1996	R	7.6	$129,478	$336,523	$466,001
Boeing	Levee	1996	R	17.8	$14,484	$101,388	$115,872
Home Depot	Levee	1996	L	14.42	$27,435	$215,000	$242,435
McCoy Breda	Levee	1996	R	24.7	$80,000	$293,820	$373,820
Nursing Home	Levee	1996	R	25.7	$22,972	$60,530	$83,502
Plemmons	Levee	1996	R	25.3	$20,383	$61,149	$81,532

TABLE 5-18 (continued).
GREEN RIVER FLOOD CONTROL ZONE DISTRICT PROJECTS SINCE 1993

Project Name	Facility Type	Year	Bank	River Mile	GRFCZD[a] Cost	Federal, State and Other Cost Share	Total Cost
Segale (Landward)	Levee	1996	L	15.5	$53,336	$373,353	$426,689
Signature Point Lower	Revetment	1996	R	22.3	$25,060	$149,601	$174,661
Russell Road Lowest	Revetment	1997	R	18.1	$28,068	$185,318	$213,386
Segale Landward	Levee	1997	L	15.5	$148,327	$1,038,287	$1,186,614
Signature Point Upper	Revetment	1997	R	22.3	$51,648	$280,479	$332,127
Strander Bridge	Bridge	1997	-	13.2	—	$10,549	$10,549
Boeing	Revetment	1998	R	17.62	$38,748	$66,198	$104,946
Christian Brothers	Revetment	1998	R	17.15	$40,601	$207,245	$247,846
Desimone	Levee	1998	R	15.4	$48,935	$393,500	$442,435
Russell Road Lower	Revetment	1998	R	19.1	$41,965	$231,688	$273,653
Russell Road Upper	Revetment	1998	R	20.4	$35,705	$200,867	$236,572
Christian Brothers.	Revetment	1999	R	17.15	—	$15,341	$15,341
Desimone	Levee	1999	R	14.45	$136,684	$172,924	$309,608
Narita	Levee	1999	R	22	$80,121	$70,418	$150,539
Pipeline	Levee	1999	R	22	$248,384	$106,538	$354,922
Russell Road Lower	Revetment	1999	R	19.1	$20,660	—	$20,660
Russell Road Upper	Revetment	1999	R	20.4	—	$12,513	$12,513
Boeing Setback Levee	Levee	2000	R	17.5	$395,405	$139,054	$534,459
White Swan	Revetment	2001	L	12.42	$8,176	$39,976	$48,152
Desimone Toe	Levee	2002	R	15.4	$498,957	$64,000	$562,957
Pipeline Toe	Levee	2002	R	22	$219,953	—	$219,953
3rd Avenue South Outfall	Revetment	2003	R	24.4	$614	$33,131	$33,745
Narita Toe	Levee	2003	R	21.15	$403,016	—	$403,016
Segale Toe	Levee	2003	L	15.4	$202,416	$5,000	$207,416
Fenster	Levee	2004	L	32.05	$171,023	$25,000	$196,023
Breda Setback Levee	Levee	2005	R	24.8	$287,843	—	$287,843
Strander Outfall	Levee	2005	L	13.2	—	$22,478	$22,478
Total Cost					**$3,724,837**	**$5,916,648**	**$9,641,485**

a. GRFCZD = Green River Flood Control Zone District

Significant repairs have also been conducted at major levee and revetment segments where sufficient easements were not available to provide for optimal setback reconstruction at stable slope angles. In these cases, slopes were largely repaired in situ with biostabilization measures and extensive rock toe buttress installations. Such repairs commonly incur higher initial costs, lower intrinsic slope stability, and require recurrent damage repair over time. Examples of this category of major levee repair include the 42nd Avenue Revetment and Segale Levee in the City of Tukwila; several segments of the Russell Road

Levee, Okimoto Levee, and Signature Pointe Lower and Upper Revetments; and segments of the McCoy, Plemmons and Nursing Home Levees, all within the Horseshoe Bend 205 Levee reach in the City of Kent.

In addition to work accomplished in the Green River Flood Control Zone District, the King County River Improvement Fund financed the local cost share for a Washington State Department of Ecology Flood Control Assistance Account Program funded repair of the Hamakami Levee near River Mile 36.15 in the middle Green River valley. During a large flood in 1990, the Green River channel avulsed and migrated laterally for approximately one-quarter mile across its floodplain, destroying approximately 300 feet of levee access road and nearly 150 feet of the levee structure itself. An innovative revetment repair employing large woody debris clusters to arrest erosive advance of the new meander bend through adjoining agricultural fields was combined with bioengineered slope protection to stabilize the channel in this reach. The project needed minor repairs following another flood in 1995, but otherwise has performed above expectations to generate exceptional natural large woody debris recruitment, vegetated bar formation and the establishment of numerous side channels.

Other Projects

A number of smaller repairs have been accomplished at sites with localized flood damage or other factors, such as washouts due to drainage running over the slope, outfall culvert construction, and tributary access restoration. These include bioengineered slope repairs to a washed out slope along the White Swan Revetment at River Mile 12.42 in Tukwila, where the Nisqually Earthquake in February 2001 ruptured a high pressure water line. Similarly, emergency repairs were carried out at a location on the Nursing Home Levee at River Mile 28.85, where pumped discharge from a contractor's sediment pond caused slumping of the oversteepened levee embankment. Smaller repairs also include those completed at the 3rd Avenue and Strander Boulevard stormwater outfall locations constructed by the Cities of Kent and Tukwila, respectively.

Development standards enacted by cities within the Green River Flood Control Zone District have led to cooperative development of setback slope stabilization measures and the dedication of related river protection easements by developers of several residential and commercial sites adjoining the Green River. These include the Ranke properties, Family Fun Center and Glacier properties in the City of Tukwila, the Boeing Aerospace Center and Polygon Homes residential subdivision in the City of Kent, and several recent plats in the City of Auburn. While local in character, these efforts contribute to the creation of a narrow but serviceable flood containment corridor bounded by structurally stable levees in major portions of the Green River Flood Control Zone District.

Land Purchases

The Green River Flood Control Zone District has acquired, with FEMA Alternate Project funds, lands adjoining the mouth of Mullen Slough, which flows into the left bank of the Green River at River Mile 21.58, to provide for future restoration of floodplain and fish habitat, consistent with the Green River Flood Control Zone District's mission, the U.S. Army Corps of Engineers' Ecosystem Restoration Project and the Salmon habitat recovery plan for Water Resource Inventory Area 9. The District acquired an additional parcel, adjoining the PD&J Packing Revetments at River Mile 22.05, as a tax lien foreclosure; this parcel subsequently was sold, with approval of the King County Council, to the City of Kent for future development of a riverfront park featuring mainstem river habitat restoration, which is yet to be completed.

King County and the Green River Flood Control Zone District have not pursued any other direct acquisition of lands for flood management purposes in the Green River valley, but a number of easement and open space land acquisitions have been completed in partnership with the King County Parks and

Recreation Division and the Cities of Kent and Auburn. Together with easements dedicated by individual property owners as noted above, such acquisitions are explicitly authorized by Chapter 86.15 RCW to further the Green River Flood Control Zone District's public purposes and mission.

Levee Analyses; Flood Hazard Identification and Mapping

In the early 1980s, local jurisdictions in the Green River valley requested assistance from the Seattle District Office of the U.S. Army Corps of Engineers to study the levee system and help identify, fund and construct needed improvements. The U.S. Army Corps of Engineers study efforts ended in 1982, when it was concluded that the overall system did not qualify for federal participation in the needed improvements. By 1990, the local jurisdictions agreed to activate the taxing authority of the Green River Flood Control Zone District to fund a program to meet ongoing levee repair and maintenance needs. Subsequently, in 1991 and in 1996, the U.S. Army Corps of Engineers raised two segments of the overall levee system to provide adequate freeboard for flood containment. In addition, the Green River Flood Control Zone District has completed over $9.6 million of repairs to damaged levees since 1991, using levy tax revenues, federal grants, and local contributions (Table 5-18). The District also has funded routine levee maintenance and pump station operations during this period. Substantial levee repairs have been accomplished over the past 15 years, but additional high-priority flood protection facility repair needs have been identified that would require funding beyond available levels. These major repairs remain largely unfunded.

When the Green River Flood Control Zone District was activated in 1990, it was generally assumed that despite localized concerns, the overall Green River levee system was soundly built and essentially reliable. That same year, and in years following, extensive flood damage to the levees has occurred, increasingly calling this assumption into question. To address these concerns, the District has sponsored several studies of overall levee improvement needs, including geotechnical slope stability analyses completed in 1996 and a preliminary flood risk assessment completed in 2001. The latter study concluded that the levee system currently provides up to $62 million (2001 dollars) in annual avoided damage. The levee stability analyses, on the other hand, concluded that the majority of the Green River levees were not constructed with adequate factors of safety, based on U.S. Army Corps of Engineers publications EM-1110-2-1913, Engineering and Design–Design and Construction of Levees, and EM-1110-2-1902, Engineering and Design–Slope Stability. The majority of the $9.6 million that the District has spent to date on levee repairs has been to address deficiencies in critically damaged levee segments.

The FEMA Flood Insurance Rate Maps cover flood-prone areas of the Green River valley from River Mile 6.0 in the City of Tukwila to River Mile 45.1 at the upper end of Flaming Geyser State Park, upstream from the City of Auburn. These maps were most recently produced for all areas downstream from State Route 18, at River Mile 34.3, in 1989, and reprinted in 1995 without substantial changes. FEMA has not updated flood mapping information for areas upstream from State Route 18 since 1975. In 1994, King County produced floodplain and FEMA floodway delineations for the middle Green. These maps are used as best available flood data, but were not submitted to FEMA for publication as flood insurance maps. In late 2005, King County executed a contract to acquire all new base data produce a thoroughly integrated restudy and remapping of the entire Green River system, from the mouth to the upstream end of Flaming Geyser State Park. This new aerial photography, topographic and channel survey information can be utilized for an update to the flood study and flood mapping. Updated flood mapping for the Middle Green from SR 18 to Flaming Geyser State Park is scheduled to be completed in 2007 in accordance with current FEMA mapping standards. Additional analyses and updated mapping in portions of the Lower Green River has yet to be scheduled.

King County also completed an analysis and mapping of channel migration hazards in 1993 for the Green River from Central Avenue in the City of Kent, at River Mile 25.3, to the Green River gorge, at River

Mile 45.1. King County adopted the mapped severe and moderate channel migration hazard areas in 1999 by public rule, incorporating them into the King County Critical Areas Ordinance in 2004. They are used in regulating land use in the affected hazard areas in unincorporated King County. Additional flood hazard mapping to identify potential levee failure hazards and associated risks is needed for the lower Green and Duwamish Rivers; this effort began in 2006, in conjunction with the new flood mapping studies, in order to refine earlier approximations with more accurate modeling of potential levee failure locations.

Partnerships

The Green River Flood Control Zone District includes King County and the Cities of Auburn, Kent, Renton and Tukwila. Since 1978, public works department managers and engineering staff of the Green River Flood Control Zone District have typically convened monthly as the Green River Basin Technical Committee to implement interlocal agreements for the coordinated management of floodwaters in the lower Green River and Duwamish River basins. At an annual meeting of the Green River Basin Executive Committee, the Mayors of Auburn, Kent, Tukwila and Renton meet with a member of the King County Council and a representative of the King County Executive to act on recommendations formulated by the Green River Basin Technical Committee. The interlocal agreement directing the work of the Green River Flood Control Zone District mandates that the annual operating budget and work program for the District be approved by the King County Council, which is empowered by Chapter 86.15 RCW as the Board of Supervisors for the District. This committee structure is an effective and essential interlocal program and will require annual staffing and program support to continue.

King County both sponsors and cooperates with other local sponsors responsible for the maintenance of two federally authorized levees on the lower Green River. The first of these is the Tukwila 205 levee system, sponsored by Tukwila, between River Mile 12.6 and River Mile 17.0. Maintenance needs for this project are covered under an interlocal agreement between the City of Tukwila and King County. The second federally authorized levee project covers the Horseshoe Bend 205 Levee between River Mile 24.39 and River Mile 16.15 in the City of Kent, and is sponsored by King County through the Green River Flood Control Zone District. While the federal government was not involved in the original construction of these flood protection facilities, freeboard improvements and significant rehabilitation projects have been carried out in partnership with the U.S. Army Corps of Engineers.

Another partnership with the U.S. Army Corps of Engineers entails the design and construction of a number of projects included in the U.S. Army Corps of Engineers' Ecosystem Restoration Program for the Green River. Most pertinent are several sites identified for habitat restoration in connection with maintenance of flood protection facilities along the mainstem Green River. These include sites at portions of the Segale Levee and adjoining lands along Frager Road, the full length of the 0.8-mile-long Boeing Levee, several Russell Road levee segments, the Rosso Nursery site, and locations at the mouths of Mill Creek, Mullen Slough, NE Auburn Tributary, and the levees at the Pautzke and Fenster sites near the City of Auburn municipal boundary.

5.9.8 Flood Hazard Management Corridor Data

Floodplain inundation maps are available for the entire Green River flood hazard management corridor, based on the Flood Insurance Rate Maps published by FEMA and on the 1993 King County studies of the middle Green. Additional flood risks associated with potential levee failures have also been estimated in two categories, largely within the lower Green River. First, areas immediately landward of the levees where a potential breach could release a surge of deep, high-velocity floodwaters at the failure location were identified. Such conditions could jeopardize the safety of flood patrol crews, emergency response teams, repair crews, local residents and others who might be present at the time of the failure. Such areas were approximated by King County staff for the purpose of evaluating flood risk for this Plan.

Similarly, broader areas along the valley floor that could be inundated with more widespread but slower-moving floodwaters were estimated by County staff, based on known flood stages compared with available topographic mapping data. In other locations, especially along the middle Green River, King County staff also identified tributaries and side channels within the floodplain that can be expected to exhibit deep, fast flows during flooding conditions.

Channel migration zones have also been determined and mapped for the Green River. These extend from Flaming Geyser Park at River Mile 46.2 to the Central Avenue Bridge in the City of Kent at River Mile 25.3. Both severe and moderate channel migration areas have been determined in these reaches, and the mapping has been adopted by King County for regulatory purposes.

Relationships between flooding, flood management levees and revetments, and riparian habitat have been estimated based on a mapping of a minimum riparian buffer width, based generally on the King County Critical Areas Ordinance aquatic-areas buffer for fish-bearing streams such as the Green River. In unincorporated King County and jurisdictions such as the Cities of Auburn and Kent, which regulate a 200-foot-wide shorelines zone, these buffers were drawn along the length of the river at widths measuring 165 feet from the ordinary high water mark. In more developed urban areas, largely within the City of Tukwila and previously developed portions of the City of Kent, these buffers were drawn 115 feet wide. The buffers were used to evaluate the compatibility of existing flood protection facilities with a basic riparian habitat corridor along the riverbank.

5.9.9 Flood Hazard Management Corridor Conditions

An overview of conditions relevant to future flooding and erosion risks in the Green River flood hazard management corridor is provided below. For the Duwamish and lower Green Rivers, ongoing instability of levees and revetments is the primary concern, and potential levee breach and inundation of most of the valley floor would result in extreme consequences. In the middle Green River, discontinuous levees and revetments will continue to experience bank erosion due to lateral channel migration and channel avulsion.

Lower Green and Duwamish

As described above, by the mid-1970s, a nearly continuous system of levees and revetments bordered the lower river, and several disconnected segments extended into the middle Green River valley. These levees were usually constructed at slope angles ranging from 1.5H:1V to 1.75H:1V using dragline cranes to dredge out the levee toe areas, devegetate the channel slopes, remove large woody debris from the channel, shape the riverbanks, and place a minimal thickness of angular riprap armor on the banks. The result was the basic system in place today, with minimal toe buttress structures, oversteepened, sloughing banks, eroding channel margins, minimal or invasive vegetation, and significantly degraded habitat.

Because the downstream portion of the lower Green River channel is severely constrained by levees, floodwaters are contained within a narrow cross section and peak flood levels can be as much as 20 feet above the elevation of the ordinary high water mark. The erosive power of moving water increases as depth increases, resulting in a greater shear force on the riverbed. As a result, the fine-grained channel bed is scoured, including many areas along the channel margins underneath the toe of levee slopes where the riverbank meets the riverbed. Under these conditions, even heavy rock buttress structures can be undermined and fail. Even minor shifting of the riverbed along the channel margins can result in the gradual undermining of the lower portions of over-steepened levee structures. This problem affects many lower Green River levees and results in further slumping and failure of overlying slope areas.

Sediment transport capacity is limited in this low-gradient channel and the materials carried by the river consist exclusively of sands and silts, which are deposited in narrow bands along the mid-slope areas of

the levees when flows recede. These mid-slope sand and silt deposits are largely vegetated with invasive growths of reed canary grass and blackberries. During prolonged periods of high water associated with controlled flow releases from Howard Hanson Dam, these sediment deposits become saturated, adding weight to the already over-steepened banks, and frequently slumping into the river after flows recede. This slumping is especially pronounced on levee segments with slopes in excess of 2.5H:1V where undercutting of the levee toe is present. Portions of the Desimone Levee near River Mile 14.85, where a 400-foot-long levee segment slumped into the river in 1995, exemplify this problem. This failure has not yet been repaired, and additional easement area will likely be required in order to stabilize the levee with setback reconstruction.

Thus, even though it is relatively flat and slow moving, the lower Green River is prone to chronic undercutting erosion and slumping failures; and encroachment of adjacent land uses in the proximity of its over-steepened levees restricts the opportunity to reconstruct the levees with more suitable, flatter, slopes. Despite many repairs that have been completed at substantial cost over the years, many more levee repairs will be required to address current flood risks.

The 1965 levee failure described above resulted in widespread flooding of much of the eastern valley floor. This flood highlights a flooding hazard that requires special consideration throughout the lower Green River valley. Areas affected by the 1965 flood and potential similar events have not been mapped by FEMA as part of the floodplain because they are considered to be protected by levees. However, these areas may also be seriously at risk from flooding in the event of a levee breach.

Transition from Lower to Middle Green River

The upstream portion of the lower Green River is transitional between the rapidly migrating middle Green River, and the more extensively armored portions of the downstream portion of the lower Green River. Channel gradients capable of transporting smaller gravels continue downstream into the lower Green River to about the Central Avenue Bridge at River Mile 25.3 in the City of Kent, which is also the downstream extent of mapped channel migration hazards for the Green River. A number of small levee segments are present in the City of Auburn within this reach, together with several riprap-armored revetments along stretches of the Green Valley Road in unincorporated King County.

Channel migration remains most pronounced in the vicinity of Horsehead Bend, near River Mile 26.8, between the Cities of Auburn and Kent. Additional segments of the riverbank just upstream from this site have continued to migrate, over the past decade in particular, moving up to 150 feet laterally into a corridor dedicated for future recreational trail development and impacting adjoining agricultural properties.

Middle Green

Although Howard Hanson Dam operations have limited flow magnitudes at Auburn to what was a 2-year event before the dam was built, this 2-year event is at the threshold of bank-full flow and is often considered to be “channel-forming” in alluvial systems. The 2-year flow has enough energy to erode the channel bed and banks and move and deposit sediment, leading to continued channel migration. In addition, the frequency and duration of flows at or near this 2-year level have also been increased by dam operations, as larger floods are stored and released at this rate. As a consequence, significant channel migration continues to occur in the middle Green River.

During a single flood in 1990, about 150 feet of the Hamakami Levee and an additional 300 feet of the levee access road at River Mile 36.14 were destroyed, along with nearly two acres of farmland, when the river moved laterally about 360 feet along a channel length of a quarter mile. A meander bend continues to develop just downstream from this site by progressive lateral channel migration. Other active channel

migration is visible in the middle Green River at Metzler-O'Grady Park, near River Mile 39.70, where broad meanders and braiding channels are constantly shifting within a complex of active gravel bars, vegetated riparian floodplains, and remnant side channels. A portion of this reach is called "the Mad Braid" as a consequence of its ever-changing character. Near the downstream end of this site, channel migration hazards threaten the long-term integrity a home near River Mile 38.6. The 1960s-era Loan Levee just downstream, near River Mile 38.1, has also been impacted by channel migration, which has severed the levee access road on several occasions when flows reoccupied a previous floodplain channel.

As these examples indicate, channel migration has influenced flood management efforts much more than flood inundation has along the middle Green River. Since a number of levees in the middle Green are situated in areas affected by potential channel migration, the *1993 King County Flood Hazard Reduction Plan* recommended that they be set back from the channel margins.

5.9.10 Flood Hazard Management Objectives and Strategies

Lower Green and Duwamish

Preliminary risk assessments for the lower Green River indicate that the existing levee system prevents more than $60 million in flood damages each year, on average. The primary objective for the lower river is to maintain the structural integrity of the levee system so that it can continue to provide this essential public service and to protect public safety. At the same time, initial levee stability studies performed at four locations along the lower Green River indicate that the existing levees fail to provide the minimum factors of safety against potential structural levee failures, based on published federal guidelines. A more thorough evaluation of individual levees and a more refined risk analysis are now underway and targeted for completion by 2007, but it is generally anticipated that the results of these investigations will further confirm the preliminary findings. Thus, it is safe to say that a program of major levee rehabilitation and reconstruction is the single overarching need within the lower Green River.

In order to correct the structural deficiencies of the levee system in this reach, the slope geometry of the levees must be modified. The most straightforward remedy is to set the levee fill back away from the top of the riverbank to create an overall levee slope of 2.5H:1V. The slope of most of the existing levees ranges from 1.5H:1V to 1.75H:1V, and the slopes of some segments are even steeper. Such steep slope angles are a primary cause of chronic structural instability and flood protection facility damage.

Additional easement area is frequently required in order to reconfigure damaged levee segments to meet even the minimum recommended slope geometry. It has often been possible to negotiate with property owners to obtain the additional area needed, but not always. Alternative levee repair solutions have been implemented in a few cases where a wider easement could not be secured, but with very high costs and increased long-term maintenance needs. As an example of this, repairs to the federal levee system at River Mile 15.5 on the left bank of the Green River have been constrained to a 2H:1V riverward levee slope angle due to easement restrictions, resulting in the need for later reconstruction of the failed levee toe. Future levee repairs will pose the need for wider easements, including the need to acquire property in some cases. While generally justified by the benefits that would occur as annualized avoided damage, additional easement costs may significantly exceed current annual Green River Flood Control Zone District revenues.

Overall, the approach throughout the lower Green River is centered on the need to provide an adequate area along the riverbank to repair and reconstruct the many damaged levees at a stable slope. Generally speaking, the width required would not exceed 110 feet landward from the aquatic edge of the river channel along each bank. With this setback template in mind, a systematic reconfiguration of the levees can be accomplished throughout the heavily urbanized lower Green River valley. This can be achieved in connection with individual levee repairs and can be incorporated into the development of properties

bordering the existing levee system, including the redevelopment of existing sites over time. A levee setback approach can also be integrated into the relocation of roads, such as Frager and Russell Roads, which currently border the river, and should strongly influence site selection and construction of the Green River Trail system. Levee setbacks should also be required as a standard condition for future redevelopment of urban areas presently abutting oversteepened levees. In some areas, it may not be possible in the near term to obtain the additional easement area needed to reconstruct oversteepened levees in more stable configurations. However, as redevelopment occurs, easement provisions should be made as needed to allow levee reconstruction that ensures the safety of the new development and surrounding area. The timescale and costs involved may present a challenge, but much has already been accomplished in a relatively short time.

In the short term, the existing levee system should continue to be maintained and repaired as needed to protect public safety and the considerable land values and improvements in the floodplains adjacent to the levees. The ongoing short-term maintenance and repair program should be carried out such that it does not preclude long-term opportunities to modify and set back the existing levees.

An assessment of potential damage due to levee breach hazards along the lower Green and Duwamish Rivers, begun in 2006, is scheduled for completion in 2007, and steps should be taken to implement its findings.

Transition Area from Lower to Middle Green River

Flood management recommendations for this upstream portion of the lower Green River emphasize the relocation of encroaching road shoulder revetments and the roadways themselves, together with the creation of a setback levee and thoroughly vegetated riparian buffer along the proposed Green River Trail corridor. This approach will help to accommodate the levels of channel migration present while sufficiently confining the corridor alignment to allow the balance of land uses, present or proposed, through existing zoning and specific development proposals, including trail construction.

Middle Green

The primary strategy for the middle Green River is keyed to the risk to residential structures in channel migration hazard areas. Over the short term, flood protection facilities should be repaired and maintained so as to protect public safety, without precluding long-term opportunities to modify the facilities. The primary long-term goal is to set back existing flood protection facilities and allow unconstrained or less constrained channel migration. Existing at-risk structures would best be acquired and removed. Purchase of at-risk structures and flood protection facility setbacks need to be coordinated with existing acquisition programs and future grant opportunities, and may be coupled with habitat restoration projects or initiatives.

Existing land use designations and policies that protect agricultural practices may also represent an obstacle to full implementation of this strategy. In recognition of acquisition costs, funding limitations, and potentially conflicting agricultural land use policies and provisions, this strategy will likely require a very long-term timeframe for implementation. Still, opportunities exist now for setting back middle Green River flood protection facilities and may be available over the intermediate term as well as the long term (Bauman et al. draft 2005).

5.9.11 Proposed Actions

Proposed projects for the Green River include 13 levee reconstruction projects, one home buyout project, and an opportunity fund for support to emerging salmon habitat recovery projects that are likely to assist in reducing risks. In addition to these projects, it is anticipated that an evaluation of the aging pumping

stations in the lower Green River, scheduled for 2006, may recommend between $2 and $10 million in future retrofit and replacement needs for these flood protection facilities. Acquisition of property interests along the Green River will be informed by two completed studies: *Last Best Places in the Green River Watershed* (King County 2002a) and *Lower Green River Corridor Assessment* (King County 2003.)

Table 5-19 summarizes the start list of proposed flood hazard management actions for the Green River. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-19. The river miles used in the project summaries to identify approximate project locations are based on a 1980 U.S. Army Corps of Engineers Flood Study; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-19
PROPOSED ACTIONS AND COST ESTIMATES FOR THE GREEN RIVER (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
Pump Station Operation	Maintain and operate Black River, P-17 and Segale/Southcenter pump stations in the Green River Flood Control Zone District. Supports recommendation IMP-1.	$2,100,000
Green River Flood Study	Complete flood study and corresponding FEMA Flood Insurance Studies and Flood Insurance Rate Maps for the Green River between River Mile 5.0 and River Mile 45.0. Supports recommendation MAP-1.	$1,000,000
Desimone Levee Project 3	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$650,000
Segale Levee Project 1	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$1,913,000
Briscoe Levee Project 4	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$1,135,000
Nursing Home Levee Project	Rehabilitate levees to reduce the risk of flooding in the lower Green River	$2,438,000
Salmon Habitat Recovery Cost Share	Provide financial support to, and participate in, Salmon Recovery Funding Board and U.S. Army Corps of Engineers Ecosystem Recovery Project habitat projects. Supports recommendation TECH-6.	$1,000,000
Green River Flood Control Zone District Program Management	Provide program management and administration to Green River Flood Control Zone District projects, programs and other related activities. Supports recommendation IMP-10.	$1,000,000
	Total Status Quo Funding	**$11,236,000**

TABLE 5-19 (continued)
PROPOSED ACTIONS AND COST ESTIMATES FOR THE GREEN RIVER (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Enhanced Funding		
Desimone Levee Project 1	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$860,000
Desimone Levee Project 2	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$1,071,000
Desimone Levee Project 4	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$3,491,000
Segale Levee Project 2	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$1,913,000
Brisco Levee Projects 1-3, 5-8	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$14,970,000
Russell Upper Levee Project	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$472,000
Kent Shops Levee Project	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$3,596,000
Narita Levee Project	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$1,913,000
Myer's Golf Levee Project	Rehabilitate levees to reduce the risk of flooding in the lower Green River.	$4,967,000
Middle Green Floodplain Acquisition	Purchase one home and associated property subject to severe flood related hazards.	$1,204,000
	Total Enhanced Funding	**$34,457,000**
	Total Green River	**$45,693,000**

Desimone Levee Project 3

Location Information

Water Resource Inventory Area 9, Green River
River Mile 14.83 to 14.89, Right Bank
Council District 5
Jurisdiction: Tukwila
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$650,000

Problem Statement

The segment of the Desimone Levee that this project addresses has an over-steepened slope at approximately 1.6H:1V to 1.9H:1V and therefore lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. The toe buttress structure appears inadequate or absent. A 400- to 600-foot long portion of the riverward slope slumped up to 12 feet into the water during flooding in 1996, showing this as one of the most critical of all remaining damaged levee reaches throughout the lower Green River. Levee failure here would flood most of the eastern portions of the lower Green River valley, including highly urbanized areas within the historical floodplain. The adjoining river segment lacks adequate instream and aquatic edge habitat structure, such as deep pools, large woody debris, and overhanging cover. The riparian buffer width is inadequate. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass, which presently obscure the remaining slump block. Non-native shade trees have been planted on the landward levee slope along the margins of a parking lot that serves several adjacent office buildings and warehouses.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of levee slopes at a minimum 2.5H:1V slope

angle. The levee toe should be reconstructed using large woody debris structures, and a mid-slope bench/buttress should be constructed. Upper levee slopes should then be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with Policy LG-1 and Project LG-13, and with Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

This project will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. This levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location to achieve stable slope angles. The project is consistent with Policy LG-1 and Project LG-13 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Desimone3.pdf

Desimone Levee Project 4

Location Information

Water Resource Inventory Area 9, Green River
River Mile 15.01 to 15.34, Right Bank
Council District 5
Jurisdiction: Tukwila
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$3,491,000

Problem Statement

The area of this project is immediately downstream and adjacent to previous setback levee reconstruction and stabilization repairs completed in 2001 and 2003. The levee slope within this segment is over-steepened at approximately 1.6H:1V to 1.9H:1V, and therefore lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. The levee toe buttress structure appears to be inadequate. Several locations along the riverward slope have developed localized, minor slumping failures during flooding in 1995 and 1996, showing this as a levee reach of particular concern. Levee failure here would flood most of the eastern portions of the lower Green River valley. The river adjoining this levee segment lacks adequate aquatic edge habitat structure and complexity, such as deep pools, large woody debris and overhanging cover. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass, which presently obscure the localized slump blocks. The riparian buffer width is also inadequate. Non-native shade trees have been planted on the landward levee slope along the margins of a railroad spur-line and parking lots serving adjacent warehouse buildings.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of the riverward levee slope at a minimum 2.5H:1V slope angle. This will require negotiations with local property owners concerning vacation of

the railroad spur line serving these warehouses. This project should include reconstruction of the levee toe, installation of large woody debris structures, excavation of a mid-slope bench/buttress, revegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with Policy LG-1 and Project LG-13, and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee segment will require acquisition of easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained from affected property owners. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. This levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location to achieve stable slope angles. The project will be consistent with Policy LG-1 and Project LG-13 recommendations for this reach from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses, and especially regarding the parking lot and railroad spur-line. On the other hand, a portion of the existing parking lot and the railroad area itself would provide adequate room for the recommended setback.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Desimone4.pdf

Segale Levee Project 1

Location Information

Water Resource Inventory Area 9, Green River
River Mile 15.02 to 15.20, Left Bank
Council District 5
Jurisdiction: Tukwila
Private Lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,913,000

Problem Statement

This levee segment is part of the overall Tukwila 205 federally authorized levee system. The levee here is situated at the upstream end of a tight outer bend that extends downstream along the edge of South 180th Street. The levee abuts a parking lot and railroad spur-line adjacent to a bank building. Levee slope is extremely over-steepened at approximately 1.4H:1V to 1.8H:1V, and therefore lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. No toe buttress structure has ever been constructed in this subreach. Beaver lodge excavation into the lower embankment and localized slumping have been observed since 1990. Levee failure would flood most of the western portions of the lower Green River valley in the City of Tukwila, including most of Southcenter retail and commercial center. The river adjoining this levee segment lacks adequate aquatic edge habitat structure and complexity such as deep pools, large woody debris and overhanging cover. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass. The riparian buffer is also inadequate. A limited number of non-native trees have been planted on the landward slopes along the margins of a parking lot serving an adjacent bank building.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repair of this levee should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of the riverward levee slope at a minimum 2.5H:1V slope

angle. A levee toe buttress should be constructed that includes the installation of large woody debris structures and excavation of a mid-slope bench/buttress. The upper slopes should be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. In addition, the existing degraded habitat functions along this reach will be improved by the levee setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6 and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Major redevelopment of properties adjoining this site has been proposed by the property owner within the City of Tukwila. The levee reconstruction will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, the U.S. Army Corps of Engineers, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and the adjoining property owner. This levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location and riparian plantings and large woody debris placement, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses. Even if acquisition is possible with present constraints, there may be additional acquisition costs. The existing property owner has resisted prior attempts at easement acquisition.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Segale1.pdf

Briscoe Levee Project 4

Location Information

Water Resource Inventory Area 9, Green River
River Mile 16.45 to 16.55, Right Bank
Council District 5
Jurisdiction: Kent
City of Kent and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,135,000

Problem Statement

The levee slope is over-steepened at approximately 1.6H:1V to 1.9H:1V, and therefore lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. A toe buttress structure appears inadequate or absent. A 200- to 300-foot long portion of the riverward slope has developed or activated older tension cracks in the paved trail along the levee crest during flooding in early 2006, showing this as a critically damaged levee reach. Levee failure here would flood most of the eastern portions of the lower Green River valley, including highly urbanized areas within the historical floodplain. The adjoining river segment lacks adequate instream and aquatic edge habitat structure, such as deep pools, large woody debris, and overhanging cover. The riparian buffer width is inadequate. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass, which presently obscure the remaining slump block. Some shade trees have been planted on the landward levee slope along the margins of a parking lot and several office buildings, and a storm drainage system is present along the landward levee toe.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of levee slopes at a minimum 2.5H:1V slope angle. The levee toe should be reconstructed with installation of large woody debris structures,

excavation of a mid-slope bench/buttress, and revegetation with live willow layers and native riparian trees and shrubs. Upper levee slopes should also be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with Policy LG-1, and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee segment will require a setback relocation of the raised levee structure landward from its existing location in order to secure stable angles of repose and meet minimum factors of safety for structural stability of the levee. This project will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Kent, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. This levee reconstruction will be consistent with Policy LG-1 and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Briscoe4.pdf

Nursing Home Levee Project

Location Information

Water Resource Inventory Area 9, Green River
River Mile 25.86 to 26.09, Right Bank
Council District 5
Jurisdiction: Kent
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$2,438,000

Problem Statement

This levee segment is part of the federally authorized Horseshoe Bend Section 205 Levee Project. The levee here is oversteepened throughout, with riverbank slopes in the range of 1.4H:1V to 1.7H:1V, which are inadequate to provide minimum structural stability factors of safety for a number of slope failure modes. One location, at River Mile 25.95, has previously slumped due to the discharge of surface runoff over the slope and down the riverbank. Though temporary repairs were made at this site in 2001, permanent repairs and Endangered Species Act-mandated mitigation measures have not yet been constructed. Several City of Kent parcels and right-of-way for the paved Green River Trail are present in this reach. The landward levee slope angles vary through the reach, with some locations supporting varying levels of native tree cover. The riverward embankment is very steep and is largely dominated by invasive blackberries and reed canarygrass, but with varying amounts of young native maples and alders present in some locations. Smaller rip-rap is occasionally evident along the levee toe, but is also lacking in other locations. The stream aquatic edge habitat is extremely degraded due to lack of large woody debris and overhanging vegetative cover. The width of the riparian buffer is also inadequate.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of the levee at a minimum 2.5H:1V riverward slope angle.

Repairs should include reconstruction of the levee toe, installation of instream large woody debris structures, excavation of a mid-slope bench and toe buttress, and revegetation of the lower bank and bench with live willow layers and native trees and shrubs. Levee upper slopes should also be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. In addition, the existing degraded habitat functions along this reach will be improved by the setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee will require acquisition of easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. The necessary easement areas are located within several City of Kent parcels and some private parcels along the Green River Trail. Levee reconstruction will also require relocation of the City of Kent recreational trail. This project will require coordination with the members of the Green River Flood Control Zone District, the U.S. Army Corps of Engineers, the City of Kent, the Washington Department of Fish and Wildlife, and the Muckleshoot Indian Tribe. This levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location and riparian plantings and large woody debris placement, consistent with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to existing land use and associated infrastructure improvements, such as a surface water pumping station discharging to the river through the levee near the upstream end. Even if the acquisition is possible with present constraints, there may be additional acquisition costs. On the other hand, the City of Kent currently owns several adjoining parcels and the trail right-of-way and would benefit from stabilization of the trail itself.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Nursing.pdf

Desimone Levee Project 1

Location Information

Water Resource Inventory Area 9, Green River
River Mile 14.65 to 14.73, Right Bank
Council District 5
Jurisdiction: Tukwila
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$860,000

Problem Statement

This levee occupies a sharp, outer bend upstream from State Route 181. The levee slope is extremely over-steepened at approximately 1.4H:1V to 1.8H:1V. It lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. Levee failure would flood most of the eastern portions of the lower Green River valley. The levee crest is scarcely ten feet wide over most of this subreach. Previously, large toe rock had been placed to support the levee toe and to prevent undercutting erosion.

In addition to the problem with slope stability, this subreach lacks an adequate riparian buffer and instream habitat structure and complexity such as deep pools, large woody debris, and shade cover. Non-native shade trees are planted into the landward levee slope along the margins of a parking lot serving office buildings. Riverward slopes are largely dominated by invasive blackberries and reed canarygrass.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Incorporate reconstruction of this segment into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of riverward levee slopes at a minimum 2.5H:1V slope angles. Reconstruct the levee toe, install large woody debris structures, excavate a mid-slope bench/buttress, and revegetate with live willow layers and native riparian trees and shrubs.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with Policy LG-1 and Project LG-13, and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

The levee slope reconstruction will require a structural setback relocation and easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. The levee reconstruction will require setback relocation of the raised levee structure landward from its existing location to achieve stable slope angles, and will also be consistent with Policy LG-1 and Project LG-13 recommendations for this reach from the salmon habitat recovery plan for Water Resource Inventory Area 9

Other Information or Needs

Easement acquisition could be problematic due to established land uses.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Desimone1.pdf

Desimone Levee Project 2

Location Information

Water Resource Inventory Area 9, Green River
River Mile 14.73 to 14.83, Right Bank
Council District 5
Jurisdiction: Tukwila
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,071,000

Problem Statement

The levee slope is over-steepened at approximately 1.7H:1V to 2.0H:1V, and therefore lacks adequate structural stability to provide minimum factors of safety for rapid drawdown and intermediate stage modes of slope failure. The crest of this levee has previously experienced settlement in at least two locations, indicating potential subgrade problems. Levee failure would flood most of the eastern portions of the lower Green River valley, including highly urbanized areas. The toe buttress structure appears to be inadequate or absent. The river within this reach lacks adequate aquatic edge habitat structure such as large woody debris and overhanging native vegetation. The bank is vegetated mostly with invasive species, primarily reed canarygrass and blackberries, although a few immature big leaf maples are present. Non-native trees have been planted on the landward levee slope along the margins of a parking lot that abuts office buildings and warehouses adjacent to the levee.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Repairs to this levee segment should be incorporated into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of the levee slopes at a minimum 2.5H:1V slope angle. The levee toe buttress should be reconstructed with installation of large woody debris structures, the excavation of a mid-slope bench/buttress revegetated with live willow layers and native riparian vegetation. The upper levee slopes should also be revegetated.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flooding inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with both Policy LG-1 and Project LG-13, and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

The levee reconstruction will require acquisition of easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained from affected property owners. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. The levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location to achieve stable slope angles, and will also be consistent with Policy LG-1 and Project LG-13 recommendations for this reach from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Desimone2.pdf

Segale Levee Project 2

Location Information

Water Resource Inventory Area 9, Green River
River Mile 15.7 to 15.9, Left Bank
Council District 5
Jurisdiction: Tukwila
Private Lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,913,000

Problem Statement

This levee segment is part of the overall Tukwila 205 federally authorized levee system. The levee here is adjacent to a large warehouse and parking lots. The levee slope is extremely over-steepened at approximately 1.3H:1V to 1.6H:1V slope angles, and therefore lacks adequate structural stability to provide minimum factors of safety for several modes of slope failure. A chain-link fence extends within the levee easement area, hindering equipment access to the levee crest. The levee lacks an adequate toe buttress structure, with some smaller rip-rap visible at low water. Localized slumping and bank erosion have been observed since 1990. Levee failure would flood most of the western portions of the lower Green River valley in the City of Tukwila, including most of Southcenter. Most of the river bank lacks adequate aquatic edge habitat structure and complexity such as deep pools, large woody debris and overhanging cover. The riparian buffer width is inadequate. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass. A limited area of non-native shade trees have been planted on the landward levee slope along the margins of a parking lot.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, primarily businesses.

Proposed Project or Action

Stabilization of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of the levee slopes at a minimum 2.5H:1V slope angle. A levee toe buttress should be constructed with large woody debris structures and excavation

of a mid-slope bench/buttress stabilized and revegetated with live willow layers and native riparian vegetation. The upper levee slopes should also be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. In addition, the existing degraded habitat functions along this reach will be improved by the setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Future major redevelopment of properties adjoining this site has been proposed by the present property owner as part of a large-scale development in the City of Tukwila. Reconstruction of this levee segment will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, the U.S. Army Corps of Engineers, FEMA, the City of Tukwila, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. This levee reconstruction will require setback relocation of the raised levee structure landward from its existing location and riparian plantings and large woody debris placement, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses. Even if acquisition is possible with present constraints, there may be additional acquisition costs. The existing property owner has resisted prior attempts at easement acquisition.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Segale2.pdf

Briscoe Levee Projects 1-3, 5-8

Location Information

Water Resource Inventory Area 9, Green River
River Mile 15.60 to 17.11, Right Bank
Council District 5
Jurisdiction: Kent
City of Kent and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$14,970,000

Problem Statement

Unlike the Briscoe Levee Project 4 site, these segments of the Briscoe Levee have not revealed obvious signs of imminent slope failure. Lower bank slumping and general oversteepening of the riverward levee slopes predominate, however. Most levee slopes are over-steepened at approximately 1.6H:1V to 1.9H:1V, and therefore lack adequate structural stability to provide minimum factors of safety for several modes of slope failure. Robust toe buttress structures appear to be inadequate or absent. A portion of the Project 8 site exhibits unusual settlement and cracking of the paved asphalt trail, most likely due to the presence of large cottonwood roots within the levee prism. Overall, the Briscoe levee throughout exhibits a non-uniform cross section and varying levee crest elevations, raising questions about the quality and consistency of initial construction efforts. Levee failure here would flood most of the eastern portions of the lower Green River valley, including highly urbanized areas within the historical floodplain. The adjoining river segment lacks adequate instream and aquatic edge habitat structure, such as deep pools, large woody debris, and overhanging cover. The riparian buffer width is inadequate. The riverward slopes are largely dominated by invasive blackberries and reed canarygrass, which presently obscure the remaining slump block. Some shade trees have been planted on the landward levee slope along the margins of a parking lot and several office buildings, and a storm drainage system is present along the landward levee toe.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, including both homes and businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of levee slopes at a minimum 2.5H:1V slope angle. The levee toe should be reconstructed with the installation of large woody debris structures, excavation of a mid-slope bench/buttress, and revegetation with live willow layers and native riparian trees and shrubs. The upper levee slopes should also be stabilized.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the setback and installation of large woody debris and native vegetation, consistent with Policy LG-1, and Conservation Hypotheses All-2 and All-6 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee segment will require a setback relocation of the raised levee structure landward from its existing location in order to secure stable angles of repose and meet minimum factors of safety for structural stability of the levee. This project will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Kent, the Washington Department of Fish and Wildlife, the Muckleshoot Indian Tribe and adjoining property owners. This levee reconstruction will be consistent with Policy LG-1 and Conservation Hypotheses All-2 and All-6 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to established land uses.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Briscoe.pdf

Russell Upper Levee Project

Location Information

Water Resource Inventory Area 9, Green River
River Mile 20.42 to 20.46, Right Bank
Council District 5
Jurisdiction: Kent
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$472,000

Problem Statement

This levee segment consists of the raised embankment and trail immediately bordering a sharp curve where Russell Road merges with James Street in Kent, near where the Narita/Kent Shops Levee system adjoining the Riverview Golf Course joins the Green River Trail. The slopes of this levee were partially stabilized and revegetated in 1999. The riverward slope angles range from about 1.5H:1V to 1.9H:1V, and therefore still lack adequate structural stability to provide minimum factors of safety for several modes of slope failure. A partial toe buttress repair and over a dozen pieces of large woody debris were installed in this reach in 1999. Portions of the slope could not be repaired, however, due to limitations on equipment access posed by overhead power lines. The proximity of this flood protection facility to Russell Road has previously prevented levee setback to fully stable slope angles. The overall stability of the toe is also questionable because only portions of the toe were repaired, working from the top of the bank with a dragline. Failure of the levee would result in widespread flooding throughout the eastern portions of the lower Green River valley including highly urbanized portions of Kent and Renton. Because a low vegetated bench could not be established in the slope during the repair completed in 1999, the aquatic edge habitat remains inadequate. The riparian vegetation planted in 1999 has matured somewhat, but the areas that could not be accessed by equipment due to nearby overhead power lines were not adequately revegetated and have remained invaded by non-native vegetation, including blackberries and reed canarygrass.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, including homes and businesses.

Proposed Project or Action

Repairs of this flood protection facility should be incorporated into a reach-length levee setback with the acquisition of sufficient easement areas for full reconstruction of the riverward levee slopes at a minimum 2.5H:1V slope angles. Setback levee reconstruction in this location will require modification or relocation of the existing Russell Road/James Street intersection as well. Levee slope stabilization would include reconstruction of the levee toe buttress, installation of large woody debris structures, excavation of a mid-slope bench/buttress revegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. In addition, the existing degraded habitat functions along this reach will be improved by the setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

This project will require a setback relocation of the raised levee structure landward from its existing location in order to secure stable angles of repose and meet minimum factors of safety for structural stability of the levee. Reconstruction of this levee segment will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. The necessary easement areas would include portions of the City of Kent's roadway at the intersection of Russell Road and James Street, and may impact portions of a small municipal park immediately across the street from the levee site. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Kent, the Washington Department of Fish and Wildlife and the Muckleshoot Indian Tribe. This levee reconstruction will require relocation of the raised levee structure landward from its existing location and the installation of riparian plantings and large woody debris placement, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to the proximity of the existing roadway. Even if acquisition is possible with present constraints, there may be additional easement acquisition costs. On the other hand, the City of Kent currently owns both the street rights-of-way and an adjacent park property on the landward side of the road right-of-way. Reconstruction of this sharp corner may also benefit traffic flow in the area.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Russell.pdf

Kent Shops Levee Project

Location Information

Water Resource Inventory Area 9, Green River
River Mile 20.46 to 20.80, Right Bank
Council District 5
Jurisdiction: Kent
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$3,596,000

Problem Statement

The levee here adjoins the City of Kent's municipal Riverview Golf Course. The levee crest is paved as part of the Green River Trail system. The slopes of this levee range from about 1.7H:1V to 1.9H:1V, and are therefore unstable with respect to rapid drawdown and intermediate flood stage modes of potential levee failure. Failure of the levee would result in widespread flooding throughout the eastern portions of the lower Green River valley including highly urbanized portions of the historical floodplain within the Cities of Kent and Renton. The landward levee slope along the golf course is gently graded, with some locations planted with Douglas fir and other native and non-native trees. This levee segment also lacks adequate riparian buffer width. The riverward embankment is steep and largely dominated by invasive blackberries and reed canarygrass. Smaller rip-rap is evident along the levee toe, but is also absent in some areas. The river along the levee toe lacks adequate instream aquatic edge habitat structure and complexity such as deep pools, large woody debris and overhanging cover.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, including homes and businesses.

Proposed Project or Action

Repair of this levee segment should be incorporated into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of the riverward levee slopes at a minimum 2.5H:1V slope angle. This project would include reconstruction of the levee toe, installation of large woody debris

structures, excavation of a mid-slope bench and toe buttress revegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. In addition, the existing degraded habitat functions along this reach will be improved by the setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee segment will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. The necessary easement areas are located within improved portions of the City of Kent's golf course, and may impact playable tees, greens and fairways, installed lighting, irrigation systems, golf cart paths and other landscaping features. This project will require coordination with members of the Green River Flood Control Zone District, FEMA, the City of Kent, the Washington Department of Fish and Wildlife, and the Muckleshoot Indian Tribe. This levee reconstruction will require relocation of the raised levee structure landward from its existing location and installation of riparian plantings and large woody debris, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to existing golf course land use and associated infrastructure improvements, such as irrigation and lighting systems. On the other hand, the City of Kent currently owns both the golf course and the trail, and would benefit from stabilization of the trail itself.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/maps/Kent.pdf

Narita Levee Project

Location Information

Water Resource Inventory Area 9, Green River
River Mile 20.95 to 21.13, Right Bank
Council District 5
Jurisdiction: Kent
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,913,000

Problem Statement

The levee here adjoins the City of Kent's municipal Riverview Golf course. The levee crest is paved as part of the Green River Trail system. The levee slopes range from approximately 1.3H:1V to 1.6H:1V, and are therefore severely inadequate to provide minimum factors of safety for several modes of levee slope failure. Extensive settlement and cracking are visible for over 1,000 feet along the paved levee crest, indicating significant concern with slumping potential in this reach. Failure of the levee would result in widespread flooding throughout the eastern portions of the lower Green River valley. The landward levee surface along the golf course is gently sloped, with some locations planted with Douglas fir and other native and non-native trees. The riverward embankment is extremely steep and largely dominated by invasive blackberries and reed canarygrass. Smaller rip-rap is evident along some portions of the levee toe, but is also occasionally absent. Aquatic edge habitat lacks structural complexity, such as that provided by large woody debris, and the width of the riparian buffer is inadequate to support native riparian vegetation, especially trees.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, including homes and businesses.

Proposed Project or Action

This levee segment should be incorporated into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of the riverward levee slopes at a minimum 2.5H:1V slope angle. This segment is immediately downstream from previous setback levee reconstruction projects at the Narita

Levee in 2001 and 2004. This project would include reconstruction of the levee toe, installation of large woody debris structures, excavation of a mid-slope bench and toe buttress revegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will be increased within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flood inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the levee setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

This levee reconstruction will require a setback relocation of the raised levee structure landward from its existing location in order to secure stable angles of repose and meet minimum factors of safety for structural stability of the levee. This levee reconstruction will require acquisition of easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. The necessary easement areas are located within improved portions of the City of Kent's golf course, and may impact playable tees, greens and fairways, installed lighting, irrigation systems, golf cart paths and other landscaping features. This project will require coordination with the members of the Green River Flood Control Zone District, FEMA, the City of Kent, the Washington Department of Fish and Wildlife, and the Muckleshoot Indian Tribe. This levee reconstruction will require relocation of the raised levee structure landward from its existing location and installation of riparian plantings and large woody debris, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9

Other Information or Needs

Easement acquisition could be problematic due to existing golf course land use and associated infrastructure improvements, such as irrigation and lighting systems. Even if acquisition is possible with present constraints, there may be additional acquisition costs. On the other hand, the City of Kent currently owns both the golf course and trail, and would benefit from stabilization of the trail itself.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Narita.pdf

Myer's Golf Levee Project

Location Information

Water Resource Inventory Area 9, Green River
River Mile 21.45 to 21.92, Right Bank
Council District 5
Jurisdiction: Kent
Public lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$4,967,000

Problem Statement

The levee here adjoins Kent's municipal Riverview Golf Course, from Meeker Street to the south terminus of Russell Road. The upstream end of this levee segment also adjoins a small apartment complex, and a golf driving range owned by the City of Kent. This subreach is immediately downstream of the Pipeline Levee setback conducted in 2001 and 2003. The levee crest is paved as part of the Green River Trail system. Levee slopes here range from about 1.4H:1V to 1.6H:1V, and are therefore unstable to provide minimum factors of safety for several modes of levee failure. Failure of the levee would result in widespread flooding throughout the eastern portions of the lower Green River valley. Previous levee failures near this location in 1965 did in fact flood the area, which is now highly developed with urban infrastructure and densely configured land uses. The landward levee embankment along the golf course is gently sloped, with some locations planted with non-native trees. The riverward embankment is very steep and is largely dominated by invasive blackberries and reed canarygrass. Smaller rip-rap is occasionally evident along the levee toe, but is also occasionally lacking. The riverward edge of the levee toe lacks adequate aquatic edge habitat structure, such as large woody debris. The levee also lacks adequate riparian buffer widths sufficient to support native riparian vegetation, especially trees.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if levee were to fail suddenly, resulting in deep fast flows in the vicinity of the levee failure;
- Risk to public safety if those driving or working in areas protected by the levee are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate buildings;
- Damage to public infrastructure, including state highways and city streets in the lower Green River valley;
- Impact on regional economy resulting from widespread flooding of dense commercial area;
- Damage to private structures, including homes and businesses.

Proposed Project or Action

This levee segment should be incorporated into a reach-length levee setback reconstruction project with acquisition of sufficient easement area for reconstruction of the riverward levee slopes at a minimum 2.5H:1V slope angle. This project should include reconstruction of the levee toe, installation of large woody debris structures, excavation of a mid-slope bench and toe buttress revegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.

Project Benefits

The existing, unstable levee will be rebuilt in a structurally stable manner. Local flood conveyance capacity will increase within this reach. Highly urbanized portions of the historical lower Green River floodplain will be secured against flooding inundation that might otherwise occur due to catastrophic levee failure. The existing degraded habitat functions along this reach will also be improved by the levee setback and installation of large woody debris and native vegetation, consistent with Conservation Hypotheses All-2 and All-6, and with Policy LG-1 of the salmon habitat recovery plan for Water Resource Inventory Area 9. In addition, long-term flood-fighting, levee repair and maintenance costs will be reduced or eliminated.

Coordination

Reconstruction of this levee segment will require a setback relocation of the raised levee structure landward from its existing location in order to secure stable angles of repose and meet minimum factors of safety for structural stability of the levee. The levee reconstruction will require easement widths in addition to those previously secured for this purpose. There are significant questions concerning the manner in which the required easements may be obtained. The necessary easement areas are located within improved portions of the City of Kent's golf course and driving range, and may impact playable tees, greens and fairways, installed lighting, irrigation systems, golf cart paths and other landscaping features. Additional coordination will also be needed with the owners of the adjoining apartment complex. This levee reconstruction will require setback relocation of the raised levee structure landward from its existing location and riparian plantings and large woody debris placement, consistent with Policy LG-1 from the salmon habitat recovery plan for Water Resource Inventory Area 9.

Other Information or Needs

Easement acquisition could be problematic due to existing developed golf course land use and associated infrastructure improvements, such as irrigation and lighting systems. Other constraints may exist adjacent to the apartment buildings. Even if acquisition is possible within present constraints, there may be additional acquisition costs. On the other hand, the City of Kent currently owns both the golf course and the trail, and would benefit from stabilization of this segment of the Green River Trail.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Myers.pdf

Middle Green Floodplain Acquisition

Location Information

Water Resource Inventory Area 9, Green River
River Mile 38.20 to 38.78, Right Bank
Council District 7
Jurisdiction: Unincorporated King County
Public or Private lands
In Agricultural Production District, may affect Farmland Preservation Program lands

Estimated Cost

$1,204,000

Problem Statement

Previous property owner attempts to address flooding and channel erosion risks in this reach have achieved no measurable success. Flooding and channel erosion conditions have also resulted in successful lawsuits between former owners of these properties. One home at this location occupies an active floodplain channel surface within the severe channel migration hazard zone. Access to the home is compromised by deep, fast-flowing water during floods. Geomorphic studies conducted in the reach by the U.S. Army Corps of Engineers have documented dynamic formation of a large log-jam complex which has temporarily arrested meander advance. Future flood-related changes in the reach have the clear potential to mobilize the jam, thereby reactivating channel advance and placing the home in immediate jeopardy. The site is immediately upstream of the mouth of Burns Creek, and adjoins the upstream terminus of the existing Lone's Levee, which is targeted for setback relocation on the downstream agricultural property. This home is at extreme risk, and the situation needs to be promptly addressed.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded area;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures from both flooding and erosion.

Proposed Project or Action

Purchase and remove the single-family home, remove site fills, and replant native riparian trees and shrubs. This project should be integrated with levee setback and natural area habitat restoration initiatives throughout the adjacent reaches, both upstream and downstream, and at the mouth of Burns Creek.

Project Benefits

This project will eliminate ongoing risks to public safety and the potential for major damage to this home. It will also lead to a number of significant habitat benefits, including restoration of large amounts of high quality instream and riparian habitat. It should be noted that this parcel is immediately downstream from the largest reach of unconstrained riverine habitat in the middle Green River, the Metzler-O'Grady Natural Area, and thus this project affords a rare opportunity to enlarge this existing reach of superb

habitat. This project is consistent with nearby Projects MG-9 and MG-10 from the salmon habitat recovery plan for Water Resource Inventory Area 9, and is also described in the Middle Green River Blueprint.

Coordination

This project should be coordinated with other projects and programs in the adjoining reaches of the middle Green River. A portion of this acquisition may be considered a part of the U.S. Army Corps of Engineers Green/Duwamish Ecosystem Restoration Projects proposed Lones Levee project (MG-9), and is a significant Salmon Habitat Recovery Board project entitled Middle Green River Acquisitions. The Burns Creek Project, which is both a U.S. Army Corps of Engineers Green/Duwamish Ecosystem Restoration Project (MG-10) and a project included in the salmon habitat recovery plan for Water Resource Inventory Area 9, would also be affected by this acquisition. This property includes a portion of Burns Creek just above the mouth on the Green River. This flood risk reduction acquisition and long-term site management plans would need to be coordinated with the agencies proposing these related projects. Coordination with the Trust for Public Lands may be appropriate to accomplish acquisition of this home. Coordination with affected property owners and long-term land mangers will also be needed.

Other Information or Needs

The potential benefits of putting this land into public ownership, beyond meeting the flood risk reduction needs described above, needs to be explored. This property acquisition needs to be evaluated with respect to funding opportunities associated with the identified public benefits.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/NC.pdf

5.10 WHITE RIVER

5.10.1 Overview

The White River is a glacially-borne river system that originates on the northeast face of Mount Rainier, flowing generally north and northwest from where it is joined by its major tributaries, the Greenwater River and Boise Creek, at the community of Greenwater and near Enumclaw, respectively. The river appears white during summer when it carries a suspended load of fine sediments from glacial melting known as glacial flour.

The White River drains an area of about 490 square miles, approximately 30 percent of which lies within King County. Its King County portion flows between the Cities of Enumclaw and Buckley, then through the Muckleshoot Indian Reservation and then along the Cities of Auburn, Algona and Pacific, leaving King County near the City of Sumner to feed the Puyallup River, which enters Puget Sound at Commencement Bay in Tacoma. The White River channel forms a portion of the boundary line between King County and Pierce County from the confluence with the Greenwater River at River Mile 45.8 downstream about 33 river miles nearly to the City of Auburn. Map 5-9 shows the major features of the White and Greenwater basins. An electronic version of this map can be found at:
http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/5-9.pdf

Historically, the bulk of what is now the lower White River flowed northward to join the Green River near Auburn and a smaller portion flowed in the Stuck River to the south to join the Puyallup River. By the late 1800s, public and private interests in Pierce and King Counties were trying to direct the route of the White River in order to minimize flood damage in their own areas (King County 1988 and 1990b). Ongoing disagreement over the river alignment led to legal action between the two counties in the early 1900s that resulted in the White River taking its northern route to the Green River, until November 1906 when a logjam formed that completely diverted the White River south into the former Stuck River. Ongoing flood damage and intervention by the state legislature led to the establishment of the Inter-County River Improvement Agreement by King and Pierce Counties in 1914 for management of flood hazards along the lower portions of the White River. One of the Inter-County River Improvement Agreement's first actions was to construct a concrete structure, called the "Auburn Wall," that made permanent the diversion of the White River south into the Stuck River. The Inter-County River Improvement Agreement efforts have also included land acquisition, extensive channelization of the lower river, sediment and debris removal, and large-scale levee and bank stabilization projects (King County 1993b).

Mud Mountain Dam is a flood control dam located about 7 miles upstream of Enumclaw near River Mile 30 that has had significant effect on flooding in the White River since its completion in 1948. Puget Sound Energy's diversion of flows since 1912 for hydropower generation through Lake Tapps at River Mile 24.3 near Buckley also has had an effect on lower flows of the overall White River flow regime, although the effect has been insignificant with regard to flood magnitudes.

Development generally is concentrated in the downstream end of the basin, where both industrial and residential land uses are common. The lower 11 river miles of the White River, about 6 miles of which are within King County, are lined by revetments and levees in a section that was channelized in the early 1900s through the Inter-County River Improvement Agreement. On the Muckleshoot Indian Tribe Reservation and upstream, the river flows through the White River canyon, a deep and generally undeveloped valley along the King and Pierce county line. Above the dam, the entire watershed is largely undeveloped, although it includes some scattered residential and commercial property in and around the community of Greenwater.

The White River flood hazard management corridor runs from the King and Pierce county line near River Mile 5 upstream to the confluence with the Greenwater at River Mile 45.8, plus the lower 1 river mile of the Greenwater. The corridor includes the river channel, mapped flood hazard areas and a riparian buffer.

5.10.2 Geology and Geomorphology

The White River is a glacial stream with headwaters on the flanks of Mount Rainier. Its basin is underlain by Tertiary bedrock, which is exposed in valley walls downstream of Mud Mountain Dam near Buckley. Continental glaciation that affected the Puget Sound Lowlands also extended into the area that is now the White River basin. However, the geological event that most prominently defines the landscape of the middle and lower White River basin is the Osceola Mudflow, which occurred some 5,700 years ago when a flank of Mount Rainier collapsed and sent a massive mudflow down its slopes and through the White River valley. The mudflow sediments covered the lowlands from Enumclaw to near Auburn with deposits up to 75 feet thick (Dunne 1986), forming the generally flat Enumclaw plateau.

The current-day White River has incised into the surrounding plateau from Buckley to Auburn to form the White River canyon, which makes this part of the White River basin a post-glacial valley. Its valley walls are composed of glacial and non-glacial sediments. Near Auburn, the river exits the canyon at a much lower channel gradient and deposits sediment on the White River alluvial fan from the City of Auburn to the City of Puyallup. Ongoing erosion of coarse sediments within the White River Canyon will continue to deliver sediment that will be deposited along the lower White River alluvial fan.

The river experiences rapid and widespread channel migration by both lateral movement and avulsion, with multiple channel patterns evident through much of the White River canyon. Historical maps and photos also show multiple channels and a braided channel pattern on the White River alluvial fan (Collins and Sheikh 2004), where the channel shifted across its floodplain before channelization efforts around 1912 through the Inter-County River Improvement Agreement.

Overall, the White River is a sediment-rich river, with headwaters draining the glaciers of Mount Rainier and a relatively steep channel gradient upstream of Mud Mountain Dam. Beyond the legacy effects of the Osceola Mudflow, high sediment loads result from the White River's glacial runoff in combination with a steep upper watershed that has been extensively logged and impacted by road construction outside the Mount Rainier National Park (Frissell et al. 1999; Kerwin 1999). Ongoing incision, erosion and channel migration downstream of Mud Mountain Dam ensures a supply of sediment in the lower White River to its confluence with the Puyallup River. In this sediment-rich environment, the river experiences rapid changes in alignment and floodplain boundaries (King County 1993b).

5.10.3 Hydrology and Hydraulics

Most major White River floods occur from November through February. With headwaters on Mount Rainier glaciers, snowmelt also increases White River flows in late summer, but not to a level of flood concern. The primary determinant for flooding characteristics in the White River is the presence and flow control operations of Mud Mountain Dam.

As a sole-purpose flood protection facility near River Mile 30, Mud Mountain Dam reduces peak flood flows and releases the stored water at a lower flow over a longer duration than would occur if the dam were not in place. Mud Mountain Dam is operated by the U.S. Army Corps of Engineers to control floods along the lower Puyallup River. Its operation is targeted to the Puyallup River at the Puyallup gage (USGS #12101500). Although targeted for the Puyallup River, theses dam operations also result in decreased flood flows along the White River relative to pre-dam conditions. Mud Mountain Dam is operated to a target maximum flow of 45,000 cubic feet per second at the Puyallup gage. In addition to

this primary flood control authority directed toward the Puyallup River, the U.S. Army Corp of Engineers operates Mud Mountain Dam to achieve flood benefits on the White River as is feasible. Table 5-20 summarizes White River flow data. Flood frequencies for the White River were obtained from a backwater channel-capacity study by the U.S. Army Corps of Engineers of Engineers completed in 1974 (FEMA 2005).

TABLE 5-20.
WHITE RIVER FLOWS

Recurrence Interval (years)	White River near Auburn Discharge[a] (cubic feet per second)
10	15,870
50	17,600
100	18,370
500	20,700

a. FEMA 2005

The period of record of gage data used to derive values in this table may differ from the period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

Over the course of 90 years, flow control at Mud Mountain Dam and the Puget Sound Energy diversion to Lake Tapps have had a dramatic effect on the natural flow regimes of the basin (Dunne 1986). In this sediment-rich river, such changes in flow regime affect sediment transport capacity, geomorphic processes, channel patterns and fish habitat. Rapid changes in sediment levels and shifting channel locations in turn affect inundation and channel migration flood hazards.

5.10.4 Ecological Context

From its confluence with the Greenwater River to its confluence with the Puyallup River, and including the lower mile of the Greenwater, for a total of about 46 river miles, the White River is a highly dynamic, moderately steep channel with substrates, habitat structure and processes that reflect its glacial origins on Mount Rainier as well as a wide array of human manipulations. Downstream of the White River, the Puyallup River flows for 10.7 miles through a channel confined by levees, with little habitat complexity and poor salmonid spawning substrates (Marks et al. 2004). Although small patches of gravel exist in the lower Puyallup, they are poor quality and the first significant salmon spawning happens slightly upstream of the White River mouth. Commencement Bay, into which the Puyallup empties, is a heavily altered estuary that is highly polluted in places. The majority of the most productive shallow areas have long since been filled.

The White River between the Greenwater and Puyallup Rivers has a history of major human alterations that have affected the quality and quantity of habitat and associated ecological processes. These major alterations, as described above, include 1) the 1914 permanent rerouting of the White River south to the Puyallup River, 2) the 1912 construction of the Puget Sound Energy Diversion dam, which diverts flows and blocks fish passage near River Mile 24, 3) the construction and operation of Mud Mountain Dam near River Mile 30, and 4) the extensive removal of woody debris and channelization of the lower river in the early to mid-1900s. These alterations have resulted in a river with widely varying conditions and ecological processes.

From the upstream end of Mud Mountain Dam Reservoir, at River Mile 35.5, up to the Greenwater River at River Mile 45.8, the White River is largely unconfined by artificial structures and often has braided and complex channels with abundant spawning gravels and woody debris, although the latter is considered undersized (Marks et al. 2004). Much of the riparian area is well-forested with second growth conifers or hardwoods. Exceptions to these conditions exist where State Route 410 lies close to the river, necessitating bank hardening, and at the mouth of the Greenwater and in the lower mile of the Greenwater River, along which bank armoring is present and where there is very little woody debris.

Mud Mountain Dam Reservoir, which stretches from River Mile 29.6 to River Mile 35.5, experiences radical fluctuations ranging from a full reservoir to a mud flat. It affects fish passage and the quantity, quality and transport rate of sediment and woody debris to downstream river reaches.

Between Mud Mountain Dam and the Puget Sound Energy Diversion Dam, from River Mile 29.6 to River Mile 24.3, the river is devoid of migrating salmon due to blockage created by the Puget Sound Energy Diversion Dam. The diversion dam is also where the Buckley fish trap is located and where salmon are collected. The fish are then transported and released above Mud Mountain Dam near the Greenwater River. In this area, the river flows through a narrow and confined canyon below the dam to a wider floodplain where the channel migrates and splits in places. Habitat is generally good except for the presence of large amounts of silt, probably the result of Mud Mountain Dam's transport of finer sediments than would have passed without a reservoir acting as sediment settling basin.

At the Puget Sound Energy Diversion Dam at River Mile 24.3, a sizable portion of the river's flow was removed for about 90 years, such that downstream dewatering was a long-standing, primary concern. Although heavily channelized in places, the bypass reach of the White River, from the Diversion downstream to Derringer at River Mile 3.6, has some areas of high-quality habitat, particularly in the Muckleshoot Indian Tribe Reservation, where damaged levees and revetments have not been repaired or replaced and the channel has been allowed to migrate (Johnson et al. 2003). Marks et al. (2004) note the presence of abundant and excellent spawning gravel and two major side channels serving as valuable habitat in the bypass reach.

The lower 11 miles of the White River is mostly confined by levees and revetments and flows mostly along the developed areas of the City of Auburn, Pacific and Sumner. There is a marked reduction in habitat complexity and spawning gravel in this reach compared to upstream areas (Marks et al. 2004). There are notable exceptions with better habitat conditions, including a large floodplain wetland complex along the left bank immediately downstream of the BNSF Railway bridge in the City of Pacific and a well-forested riparian corridor at the King and Pierce county line.

The Water Resource Inventory Area 10 Citizens Advisory Committee, with input from a Water Resource Inventory Area 10 Technical Advisory Group, concluded that overall the most beneficial actions that could be taken for Puyallup and White River Chinook salmon are those that would restore channel and substrate, stability and habitat diversity. For White River Chinook salmon, the top-ranked beneficial actions are Mud Mountain Dam flow modifications and restoration of normal flow in the bypass reach (Pierce County 2005 and Shared Strategy for Puget Sound 2005). Secondarily, levee setback, floodplain reconnection, redistribution of large woody debris salvaged from Mud Mountain Dam Reservoir and restoration of the lower reach of Boise Creek were noted as important actions.

5.10.5 Salmonid Use

The White River produces Endangered Species Act-listed Chinook salmon—fall and spring stocks—and bull trout, as well as pink, chum, and coho salmon, rainbow, steelhead and cutthroat trout, and mountain whitefish (Kerwin 1999). The White River spring Chinook salmon population has been in a rebuilding

process, with run sizes increasing from historical low levels of the late 1970s (Muckleshoot Indian Tribe 1996 as cited in Kerwin 2001). Small numbers of sockeye salmon are trapped yearly at the White River Diversion/Buckley fish trap, but little is known of their biology or sustainability in the system (Gustafson et al. 1997) and no juveniles have ever been caught (R. Ladley, 1999 as cited in Kerwin 1999). The White River is a part of the Puyallup Core Area for bull trout, which includes the following major rivers and their tributaries: the Puyallup, Mowich, Carbon and White Rivers, including the Clearwater, Greenwater, and West Fork White Rivers, and Huckleberry Creek (U.S. Fish and Wildlife Service, 2004).

5.10.6 King County Facilities, Major Flooding, Flood Damage

The main White River flood protection facility maintained by King County is the channelized portion of the river that is lined by a system of levees and revetments from nearly River Mile 11 downstream to the King and Pierce county line near River Mile 5. These flood protection facilities were built through the Inter-County River Improvement Agreement between King and Pierce Counties in 1914. With the Auburn Wall at approximately River Mile 9.4, the channelized revetment and levee system locks the lower White River channel in place. This system also provides some flood containment from about River Mile 11 down to the mouth, although the current level of containment probably varies due to ongoing sedimentation (Prych 1988) and localized openings or low points in the bank armoring. None of the White River levees are federally certified.

Upstream of Mud Mountain Dam, there are two revetments on the right bank of the Greenwater River that provide bank erosion protection for a row of residential properties.

Historically, the most reliable river gage on the White River is USGS Gage #12100000, White River at Buckley, which was in operation from 1899 to 1938 and from 1977 to 2003. The highest flows recorded at this gage during the 1899 – 1938 period, prior to dam construction, include 23,100 cubic feet per second in December 1917 and 19,000 cubic feet per second in January 1922. In the period of record between 1977 and 2003, the highest recorded flows were 14,300 cubic feet per second in December 1977 and 14,900 cubic feet per second in November 1986. The 1990 and 1995 flood events also resulted in significantly high flows, measuring 13,300 cubic feet per second and 13,900 cubic feet per second, respectively, at the USGS White River at Buckley gage.

Currently, the gage used for flood warning purposes is USGS Gage #12098500, White River near Buckley. Recent high flows recorded at this gage include 14,100 cubic feet per second in January 1990 and 13,200 cubic feet per second in December 1995. Due to the unstable cross-section at this gage location, information provided from this gage during flood events is verified with flow information provided by the U.S. Army Corps of Engineers Reservoir center which manages releases from Mud Mountain Dam.

The channelized system along both river banks, combined with the flood control operations at Mud Mountain Dam, results in overbank flows that occur less frequently than they historically have along the lower White River and in more localized areas. Flood damage along the lower White River occurs more in the form of bank erosion and undermining of existing bank armoring. The floods of 1995 and 1996 caused erosion of some bank armoring at locations along the lower White River. Damage and subsequent repairs are described in the next subsection.

Floods in the 1970s damaged and breached the left bank levee called TransCanada, which is located near River Mile 11 on the Muckleshoot Indian Tribe Reservation. At the request of the Muckleshoot Indian Tribe, levee maintenance has been discontinued and the breached levee has not been repaired. Consequently, overbank flows have access to the south bank floodplain from the site of the breached

levee downstream to the Wilderness Game Park at about River Mile 8, where flood flows can rejoin the White River.

5.10.7 Key Accomplishments Since 1993 King County Flood Hazard Reduction Plan

Flood hazard management actions in the White River basin since 1993 have mainly involved the acquisition of flood-prone homes and land areas important in providing flood storage. One home purchased in 1999 along Boise Creek was the highest repetitive loss structure in King County at that time. Another at-risk home along the White River was acquired in 2002, implementing a recommendation from the *1993 King County Flood Hazard Reduction Plan* (King County 1993b, Appendix B). In total, nearly 160 acres of land and these two at-risk homes have been acquired in the White River basin, preserving flood storage areas and enabling the future implementation of flood protection facility removals and setbacks. Sizable acquisitions setting the stage for future projects include approximately 22 acres along the lowermost left bank of the White River in the City of Pacific, which is essential to the proposed County-Line to A-Street Flood Conveyance Improvement project, and approximately 74 acres along the left bank near Wilderness Park, which is critical for the implementation of the proposed TransCanada Flood Conveyance Improvement project identified in this Plan.

After the 1995 and 1996 floods, several locations experienced some level of flood damage to revetments along the lower White River, but only one site, the White River Trailer Court revetment near A-Street, required immediate repair. This repair project was constructed in 1997 using bioengineering of the bank face with a log and rock toe installation. Other sites had only minor damage that did not warrant the cost of mobilizing work crews, with the exception of the left bank near Roegner Park. This portion of the riverbank along the park was eroded by floodwaters, but in collaboration with the City of Auburn, it was determined that channel monitoring would be conducted rather than implementing a repair, which would have affected the park property and the existing trail alignment. Since 1996, cross sections along this portion of the White River have been surveyed annually by the City of Auburn, and the resulting data have been included in the ongoing channel monitoring program of the King County River and Floodplain Management Program. The 1995 flood event also involved coordination of emergency flood actions at the White River Hatchery flood protection facility. Sandbagging along the flood protection facility prevented floodwaters from overwhelming the site.

5.10.8 Flood Hazard Management Corridor Data

Data available to develop the flood hazard management corridor varies throughout the White and Greenwater Rivers. Some FEMA flood hazard information is available, but it is from the late 1970s and most likely is not representative of current-day flood hazards. Available FEMA flood hazard mapping for the lower White River includes a regulatory floodway boundary between River Mile 6 and River Mile 10 within the City of Auburn. Downstream of the A-Street Bridge at River Mile 6, no floodway has been delineated within the City of Pacific for the White River, but flood elevations for the 100-year flood are estimated. From River Mile 10 to about River Mile 40.5, the FEMA flood hazard maps depict an approximate flood zone with no flood elevations or floodway delineation (FEMA 2005). Flood hazards are not mapped along the White River above River Mile 40.5. Flood hazards also have not been delineated for the Greenwater River. As the best available data, the detailed flood hazard boundaries in the lower White River and the approximate flood zones in the upper reaches of the White River were used for the flood hazard management corridor. However, the boundaries of both types of flood hazards were cross-checked along the river channel and valley using King County's LiDAR-based shaded relief mapping (King County 2003).

Channel migration mapping is not available for the White or Greenwater River, but initial technical work on the White River was completed in 2005. This initial work documents historical channel locations for

the White River from the King and Pierce county line up to Mud Mountain Dam (Collins and Sheikh, 2004). The outer edge of a composite of these historical channel locations, using a series of aerial photos since 1936, identifies the area through which channel migration has occurred during this period of record, but it does not predict future channel migration, as is needed for regulatory delineation of channel migration hazard areas. Because regulatory channel migration hazard area mapping is not yet available, this outer boundary of historical channel locations was used in the flood hazard management corridor to portray an estimate of the extent of the channel migration hazard area. Channel migration mapping for the White River above Mud Mountain Dam and for the Greenwater River has not been initiated but is recommended as future work.

In addition to the formally mapped flood and channel migration hazards, areas of deep fast flows and landslide areas that are known to, or which have, a high potential to affect the river channel were included in the White River flood hazard management corridor. A significant area of deep fast flows occurs along the Red Creek area of the White River just downstream of Mud Mountain Dam. Post-flood field inspections and property owner observations of these conditions were documented by King County staff following the 1995 flood event (Gibbons, 1995).

Riparian area buffers are included in the flood hazard management corridor and are geographically extended where they adjoin steep slopes and where large known landslides could directly affect the river channel. An area where a levee failure could occur along the left bank downstream of the A-Street Bridge is also included in the White River flood hazard management corridor.

The information components described above were graphically presented on recent aerial imagery to generate an overlay of physical hazards that determine the extent of the flood hazard management corridor for the White and Greenwater Rivers. To understand how the various hazard areas are related to and would affect existing or future land development and future flood protection facility projects, the overlay includes land use information on public and private lands and the locations of flood protection facilities. Review of the type of flood hazards, and their physical characteristics along the river such as the severe hazards associated with a floodway area with dense residential development, reveals the areas that are significantly at risk.

5.10.9 Flood Hazard Management Corridor Conditions

The White River flood hazard management corridor includes the following distinct segments:

- The lowermost segment begins at the King and Pierce county line at River Mile 5.5 and continues upstream to just beyond the eastern boundary of the Muckleshoot Indian Tribe reservation at about River Mile 10. As described earlier, this lowermost segment is highly modified, with its channel constricted by levees and revetments.
- The next segment extends from River Mile 10 to about River Mile 23 at the State Route 410 Bridge crossing near the City of Enumclaw. This is a natural and very dynamic portion of the White River that runs through the White River Canyon and has little floodplain development or channel modification.
- The segment above the State Route 410 Bridge crossing includes the White River Diversion and Mud Mountain Dam.
- The uppermost White River segment extends from Mud Mountain Dam up to the confluence of the Greenwater River at River Mile 45.8. Like the segment downstream of State Route 410 Bridge near the City of Enumclaw, this upper watershed portion of the river has sparse floodplain development, although the floodplain and the active channel are encroached upon in several locations by State Route 410.

- The White River flood hazard management corridor also extends up the Greenwater River from its mouth to the residential community at about River Mile 1. The channel has two revetments along the north, King County side, with numerous summer cabins and many year-round residences near the river bank.

In the highly modified channel along the lower White River, flood risks result from a severely constricted channel that is disconnected from its floodplain in an area of ongoing sedimentation. This is most apparent along the river downstream of the A-Street Bridge, where concrete revetments, a short length of levee, and the A-Street and BNSF Railway bridges constrict the channel and local scour has undermined some of the revetment. The densely developed areas along this channel include a subdivision with manufactured homes and other residences that are at high risk. Without improving flow conveyance to accommodate floodwaters by allowing flows to enter the undeveloped floodplain on the left bank, there is an ever-increasing potential for flooding to impact the right bank riverside homes and the park and, for further damage to the aging and degraded concrete revetment along the right bank.

The construction of revetments and placement of fill in the floodplain and channel between the A-Street and R-Street bridges has reduced flood conveyance capacity in this area. With the valley wall protruding from the south side along Oravetz Drive just downstream of the R-Street Bridge, flood flows impinge into the north bank where a junior high school is located. As flows turn from this meander bend, they are directed downstream into the unprotected left bank, eroding the bank and threatening the trails within Roegner Park. These erosive flows could also affect the high school property, which is partly on fill that was placed in an historically highly mobile part of the active channel and floodplain.

There is ongoing sedimentation along the entire channelized segment of the lower White River because of its location on the White River alluvial fan, which is a natural depositional area. This ongoing sedimentation decreases the flood capacity of the channel from R-Street to the King and Pierce county line and beyond, and thereby increases potential flood risks in adjacent developed floodplain areas.

Upstream, from Wilderness Park to the Muckleshoot Indian Tribe Reservation, the channel is actively migrating and floodwaters have breached through the TransCanada levee, which extends from the Williams natural gas pipeline crossing at River Mile 10.5 down to the Wilderness Park levee. The overbank flows, entering the floodplain from several breached locations, travel across public and private land parcels before entering the upstream area of the park. The flows combine into a single, large off-channel and have reentered the river by breaching through the back side of the Wilderness Park levee. A trail embankment with small culverts installed by the City of Auburn after 1996 will continue to receive these flood flows, and future damage to the trail crossing within the park is likely.

The White River near Red Creek, just downstream of Mud Mountain Dam, is also at high risk because of the potential for rapid channel changes through a small residential community. The potential for a life-threatening situation is real, both for residents cut off by floodwaters and for any rescuers who may respond in an emergency evacuation.

The residential complex at the confluence of the White and Greenwater Rivers experienced significant flooding in the 1995 and 1996 events due to rapid channel movement and overbank inundation. This area, along with State Route 410, could also be flooded by water forced out of the Greenwater River channel as a result of the accumulation of logs and debris on the center pier of the State Route 410 bridge.

5.10.10 Flood Hazard Management Objectives and Strategies

Each segment of the White River flood hazard management corridor has varying levels of risk conditions, reflective of its distinct physical hazards and the floodplain development and land uses that they impact.

Resolving and lowering these risks requires different strategies, with incremental objectives implemented in the near-term and over several years.

Because the lower White River is highly modified and constricted, the approach to resolving existing flood risks focuses on actions that result in a greater capacity to accommodate flood flows and sediment loads. The strategy is two-fold: acquire land or flood easements; and follow up with capital improvements to modify levees and retrofit revetments so that the river is reconnected to its floodplain. This approach will provide increased flood conveyance and storage as well as opening up areas to accommodate sediment deposition. The reestablishment of a more naturally functioning floodplain along the lower White River also will provide improved aquatic and wildlife habitat. These objectives are consistent with recommended salmon habitat recovery actions presented in *Water Resource Inventory Area 10 Shared Strategy for Puget Sound*.

The White River upstream of the Muckleshoot Indian Tribe Reservation to State Route 410 is unconstrained, natural and with no significant flood-related risks. This portion of intact floodplain is providing flood attenuation for lower reaches and should continue to be unencumbered by floodplain development. The use of up-to-date flood and channel migration hazard mapping in the application of existing King County code for this area would appropriately preclude future at-risk development. Pierce County could also use this updated mapping for its land use regulations.

The reach above State Route 410 to Mud Mountain Dam has limited existing land development; however, some of the residential structures, such as in the Red Creek area, are very susceptible to flood and erosion hazards. A combination of new flood and channel migration hazard mapping, along with the acquisition of flood-prone homes, will ensure that existing flood conveyance and storage capacity are not reduced and will preclude unsafe development that would be threatened by erosion and inundation by deep fast floodwaters.

The White River above Mud Mountain Dam is an unregulated river and can experience significant, uncontrolled floods. The channel here is encroached upon by the State Route 410 highway. Flood and channel migration hazard mapping are the essential tools necessary to develop approaches for resolving flooding impacts on the highway and precluding future at-risk development. Such mapping would alert existing homeowners to the benefits of acquiring flood insurance for their structures and increase the potential for homeowners to take necessary precautions as floods occur. Achieving a greater understanding of the extent of the flood and erosion risks associated with structures also may increase a property owner's willingness to consider selling.

Flood hazard mapping along the Greenwater River would provide the necessary information to assess the extent of flooding and would help identify structures most at risk from floodwaters. With this information, a more specific strategy could be developed, which may include elevating or removing residences that are at risk.

5.10.11 Proposed Actions

Resolving the existing flood risks along the lower White and Greenwater Rivers through land acquisitions and project implementation will take several years. The proposed actions encompass large-scale projects, a small near-term repair and acquisitions necessary to implement construction projects or remove flood-prone structures. Major construction projects to improve flood conveyance are located in the lowermost reach of the White River, some of which would require easement or fee simple land acquisitions. For the 41st Street setback project, intended to accommodate increased flood conveyance and reduce the potential for overbank flooding, a feasibility analysis is needed to guide the project design. Acquisition of at-risk, flood-prone homes is recommended for the Red Creek area and at the mouth of the Greenwater River.

Table 5-21 summarizes the start list of proposed flood hazard management actions for the White River in King County. The status quo projects are the actions recommended for funding using current River and Floodplain Management Program revenues and grant funding at a level typically received by the program. The enhanced projects address the next set of needs and actions, which will be pursued with additional funding and participation of affected parties and partners. Appendix G identifies the complete list of problems, a subset of which contains a proposed action that would be needed to comprehensively address flood hazard management needs in each basin.

Project summaries for site-specific actions follow Table 5-21. The river miles used in the project summary sheets to identify approximate project locations were generated by a route system algorithm using 2002 King County Streams and Rivers geographic information system base data; left-bank and right-bank notations refer to the river bank as viewed looking downstream.

TABLE 5-21
PROPOSED ACTIONS AND COST ESTIMATES FOR THE WHITE AND GREENWATER RIVERS (2007–2016)

Proposed Action	Description	Estimated 10-Year Cost
Status Quo Funding		
White River Channel Migration Zone Study and Mapping	Prepare channel migration zone study and maps for the White River. Supports recommendation CMZ-1.	$30,000
White River Flood Study	Prepare flood study and corresponding FEMA Flood Insurance Studies and Flood Insurance Rate Maps for the White River. Supports recommendation MAP-1.	$400,000
Greenwater River Flood Study	Prepare flood study and corresponding FEMA Flood Insurance Studies and Flood Insurance Rate Maps for the Greenwater River Supports recommendation MAP-1.	$40,000
County Line to A-Street Flood Conveyance Improvement	Reduce flood-related risk to residential area by purchasing flood-prone property and providing conveyance through an existing levee into adjacent floodplain and wetlands.	$1,193,000
Pacific City Park Revetment Repair	Repair damaged concrete revetment.	$183,000
41st Street Setback Feasibility Analysis	Conduct levee setback feasibility study to protect homes and school.	$25,000
Red Creek Acquisitions	Remove homes subject to flooding and erosion hazards.	$735,000
	Total Status Quo Funding	**$2,606,000**

TABLE 5-21 (CONTINUED)
PROPOSED ACTIONS AND COST ESTIMATES FOR THE WHITE AND GREENWATER RIVERS (2007–2016)

Enhanced Funding		
3rd Place and Pacific City Park Revetment Retrofit	Rehabilitate failing concrete slab revetment by replacing with bioengineered flood protection facility.	$6,447,000
TransCanada Flood Conveyance Improvement	Implement levee modification project.	$1,421,000
White-Greenwater Acquisition	Purchase and remove residential structures subject to flood and erosion hazards.	$785,000
	Total Enhanced Funding	**$8,653,000**
	Total White and Greenwater Rivers	**$11,259,000**

County Line to A-Street Flood Conveyance Improvement

Location Information

Water Resource Inventory Area 10, White River
River Mile 5.5 to 6.20, both banks
Council District 7
Jurisdiction: Pacific
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,193,000

Problem Statement

Flows in this reach are constricted by concrete revetment banks and are partially contained by a short length of left bank levee, the Union Pacific levee, downstream of the A-Street and BNSF Railway bridges. Currently, the active channel is disconnected from its floodplain by the left bank levee, prohibiting sediments from being deposited and flood waters from entering the left, undeveloped, overbank. Flood flows are directed toward the right bank revetment, where residential development is located along the top of the riverbank. During the 1995 and 1996 floods, the lower end of the left bank flood protection facility near the King and Pierce county line was flooded, connecting the river and wetland flows. The White River carries a high sediment load and this reach is a depositional area. River gravels in this area and the downstream reaches had been dredged periodically prior to the mid-1980s. Severe flood conditions combined with increased deposition could exacerbate flood flow impingement into the right bank, resulting in damage to the Pacific City Park concrete revetment and placing the adjacent residential community at-risk of flooding.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to public infrastructure, primarily drainage systems and streets and a flood protection facility;
- Damage to private structures.

Proposed Project or Action

Acquire the remaining private property via fee simple or flood easement purchase to implement this levee modification project. Conduct a floodplain hydraulic analysis and determine current-day base flood elevations to verify the extent of potential flood risk to the right bank residential and park developments. Complete channel migration zone mapping to determine the extent of potential erosion risk. Reconnect the active channel to its left overbank floodplain by breaching the Union Pacific levee, allowing for improved flood flow conveyance into the existing floodplain area and for the restoration of river channel processes through the reach. Replace an existing concrete culvert with a shallow box culvert for flow

reentry into the river channel within Pierce County. This project is also a recommended Water Resource Inventory Area 10 salmon habitat recovery project.

Project Benefits

Acquisition of the three parcels allows for the implementation of a flood protection facility modification that will result in a reduction of the potential flooding of the existing development on the right bank. Flood conveyance and storage of water and sediment in the reach will be improved by accommodating flood flows in the left overbank floodplain area through the reconnection of the active channel to its floodplain. This action will reduce flood risks to the residential and park properties located along the right bank floodplain. This project site is the only remaining significantly sized overbank area available to enhance flood storage and improve conveyance in the lower White River within the Cities of Pacific and Auburn.

Coordination

Although much of the project area is already owned by King County, three private parcels in King County and portions of other parcels in Pierce County are needed under fee simple acquisition or flood easement for project implementation. Property owner willingness is essential to the project's implementation. Coordination with Pierce County via the Inter-County River Improvement Agreement is required. The Muckleshoot and Puyallup Indian Tribal fishery resources staff have been supportive of this proposal. It is a Water Resource Inventory Area 10 salmon habitat recovery project site.

Other Information or Needs

As-built condition should be used to revise the effective FEMA flood insurance rate maps for this reach.

This project is included in the Water Resource Inventory Area 10 Ecosystem Restoration Feasibility Study with the U.S. Army Corps of Engineers and is strongly supported by the Puyallup Tribe of Indians.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Countyline.pdf

Pacific City Park Revetment Repair

Location Information

Water Resource Inventory Area 10, White River
River Mile 5.8 to 6.2, Right Bank
Council District 7
Jurisdiction: Pacific
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$183,000

Problem Statement

The active channel is constricted by concrete revetments on both banks. On the right bank is county-owned property that is leased to the City of Pacific for use as a park with active recreational uses. Prior to the use of the area as a park, the site was a county landfill. No functional riparian buffer exists due to the concrete revetment along the river's edge and the high use by park visitors. A small length of the concrete revetment at the upstream end of the park is broken and undermined along the ordinary high water line. This portion of the revetment is on the outside of the meander and there is the potential for further erosion, which will cause an increased amount of damaged area if not repaired. The park is nearly all within the 100-year floodplain with nearly half of the downstream portion of the park area within the area of historical active channel locations.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure: a city park and the flood protection facility it is protected by.

Proposed Project or Action

Repair a small portion of the existing damaged revetment. Remove portions of the concrete revetment. Place a log and rock toe below the ordinary high water line and restabilize the bank face using bioengineering techniques. Revegetate the upper bank and the top of bank area of the project site with native trees and shrubs. Conduct project scoping and prepare design and permit applications in 2006. Construction is expected in 2007.

Project Benefits

This small repair project would eliminate the potential need later on for a more extensive repair should the concrete revetment continue to be undermined and the extent of damage become more extensive. Repair of the existing damaged section of the revetment is also needed due to the high public use of the park along the river edge. The repair project could be used to demonstrate the resiliency of a bioengineering design approach, and so initiate support for conceptual design of a larger-scale retrofit of the entire concrete revetment.

Coordination

Project timing must be well-coordinated with the city due to annually scheduled park activities. This flood protection facility was built through the Inter-County River Improvement Agreement. Coordination

of the project design and implementation with Pierce County is therefore needed. Integrate design with future revetment retrofit as described in the 3rd place and Pacific City Park Revetment project.

Other Information or Needs:

Historical information about the King County landfill is needed to determine the specific location and types of landfill materials within the project site.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Pacific.pdf

41st Street Setback Feasibility Analysis and Design

Location Information

Water Resource Inventory Area 10, White River
River Mile 7.00 to 7.70, Right Bank
Council District 7
Jurisdiction: Auburn
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$25,000

Problem Statement

The river channel is directed toward the right bank by the valley wall projecting from the southern, left bank. Given this physical feature, the river and flood flows have the potential for lateral migration into the right bank, which contains the City of Auburn's Mt. Baker Junior High School, sixteen single-family residences, a multi-family development and 41st Street, a private road. The existing revetment is composed of sporadically placed concrete rubble and has some minimal vegetation, mainly a single line of maturing cottonwoods with no understory shrubs or saplings. The composition of the revetment materials underneath the concrete rumble is unknown, adding to the uncertainty of the structural integrity to provide erosion protection.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure, including a school, drainage systems and streets;
- Damage to private structures.

Proposed Project or Action

Conduct a feasibility analysis and develop the design for a setback of the existing revetted river bank. Verify whether a flood easement exists for the flood protection facility. Conduct a field investigation to determine the revetment materials, assess the revetment for its level of erosion protection and measure the available landward area that could accommodate a setback while maintaining an adequate width for the private road. Develop a project design that can be used to discuss the proposed setback with the private property owner and the school district. With property owner support, modify the flood protection facility by setting it back farther from the active river channel.

Project Benefits

Repositioning the right bank revetment will provide increased flood flow capacity in this portion of the river, which is highly constrained by the position of the southern valley wall. Added flow area would reduce erosion velocities in the river channel. Retrofitting the flood protection facility by removing unconsolidated rumble and installing a more resilient, bioengineered revetment will increase the level of erosion protection along this outside meander bend. This improved flood protection facility would offer increased erosion protection for the existing residential area, school property and private road.

Revegetation elements of the bioengineered design would not only serve to stabilize the river bank but also would make a significant improvement to the condition of the riparian buffer.

Coordination

Increasing channel velocities along this meander could improve the flow transition and conditions downstream along the Roegner Park area where the river bank is currently in an eroded condition. Implementation of the setback project is dependent upon property owner support and whether there is adequate landward area to shift the road if necessary. This flood protection facility was constructed through the Inter-County River Improvement Agreement and the proposed design should be coordinated with Pierce County. Improvement of the degraded condition of the riparian buffer along this reach is a Water Resource Inventory Area 10 salmon habitat recovery project proposal.

Other Information or Needs

Channel migration hazard mapping and updated flood hazard mapping along this reach is needed to inform property owners about the existing hazard conditions and potential risks and will be used in developing an appropriate design for the setback flood protection facility.

Project Area Map

A map of the project area may be found

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/41st.pdf

Red Creek Acquisitions

Location Information

Water Resource Inventory Area 10, White River and Red Creek
River Mile 25.7 to 27.1, Right Bank
Council District 9
Unincorporated King County
Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$735,000

Problem Statement

This area is located two river miles downstream of Mud Mountain Dam. The river along this reach experiences periodic and rapid river channel migration. In addition, deep fast flows occur in various paths in the right bank floodplain. The extent of inundation and bank erosion can quickly change, threatening several existing residential structures. The Red Creek channel and its confluence are overwhelmed by White River flood flows along this 1.25-mile reach. One home is surrounded by multiple-channel flow paths in the floodplain; another home is immediately adjacent to the mainstem and within the riparian buffer area; a third home is on a low terrace of floodplain, but is in the direct flow path of the right bank mainstem meander; two other homes are positioned on a somewhat higher terrace and may not be directly affected by current flood flows but may lie within a channel migration hazard area and could be at risk in the future.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

In this high hazard area, at-risk residential homes should be acquired and removed. Land areas disturbed during removal of structures should be restored to a natural grade and replanting with native plants. Future development should be prohibited from flood and channel migration hazard zones. A floodplain analysis should be completed to determine current-day base flood elevations to verify the extent of potential flood hazard areas. A channel migration study and mapping should be completed to determine the extent of potential erosion risk. Outreach to property owners is needed to provide information about the existing flood and erosion hazards and to assess the willingness of current property owners to sell at-risk homes.

Project Benefits

Acquisition of the at-risk homes would permanently eliminate the risk to public safety along this reach. Up-to-date flood and channel migration hazard mapping would prevent future at-risk development and direct development to appropriate low risk areas.

Coordination

Property owner willingness to sell the flood-prone homes is essential to implementing this action to permanently eliminate the public safety risk.

Other Information or Needs

The U.S. Army Corps of Engineers has increased its coordination with the Red Creek residents, which has resulted in an improved level of understanding regarding water levels along the Red Creek reach and flow releases from Mud Mountain Dam.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Red.pdf

3rd Place and Pacific City Park Revetment Retrofit

Location Information

Water Resource Inventory Area 10, White River
River Mile 5.8 to 6.4, Right Bank
Council District 7
Jurisdiction: City of Pacific
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$6,447,000

Problem Statement

A subdivision is immediately adjoining the top of the aging and degraded concrete revetment. The homes in this subdivision are very close to flood waters and homeowners have encroached into the 20-foot-wide river protection easement area. Channel constriction in this reach and the location of the homes on the outside of a meander create the potential for flooding to impact these residences. No equipment access to the top of the revetment is available due to the position of the homes on the river bank. No riparian buffer exists due to the concrete revetment and the riverside residences. 16 homes are within the area of the historical active channel location.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Damage to public infrastructure, primarily drainage systems, streets and a flood protection facility;
- Damage to private structures.

Proposed Project or Action

Notify homeowners about the established easement and provide flood preparedness information. Develop a revetment retrofit design to remove degraded concrete slabs, and install a benched, biostabilized riverbank from the A-Street and BNSF Railway bridges down to the existing vegetated bank at the downstream end of the city park. Remove homes located between the top of bank and 3rd Place SE. Re-establish and connect riparian buffer with the adjacent, similar buffer restoration along the city park. See also Pacific City Park Revetment Repair.

Project Benefits

Removing the homes and installing a biostabilized benched riverbank, will permanently eliminate flood risks to the existing top of bank homes and the river channel will have increased capacity to convey flood waters. The newly installed biostabilized bank will link to the existing riparian buffer, providing an improved buffer along the entire reach of the right bank from A-Street to the King and Pierce county line. The project design and installation should be developed to accommodate public recreation needs within

the city park. This site would also provide an excellent opportunity for public education and outreach on flood hazards and natural river systems.

Coordination

The willingness of the property owners to sell their homes and City of Pacific collaboration for work on the revetment within the park area are needed. Improvement of this non-existent riparian buffer is an action recommended in the salmon habitat recovery plan for Water Resource Inventory Area 10. This project should be coordinated with flood hazard management projects proposed for this area.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/third-place.pdf

TransCanada Flood Conveyance Improvement

Location Information

Water Resource Inventory Area 10, White River
River Mile 8.2 to 10.7, Left Bank
Council District 7
Jurisdiction Auburn and Muckleshoot Indian Tribe
Public and Private lands
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$1,421,000

Problem Statement

The TransCanada levee located immediately upstream of the City of Auburn's Wilderness Park extends into the Muckleshoot Indian Tribe Reservation up to the Williams Natural Gas Pipeline crossing at River Mile 10.7. The levee forces the river channel into the northern bluff of the valley wall. The levee was breached in the 1975 flood event and experienced additional erosion in flood events in 1990 and 1995-96. Flood waters now can reoccupy some of the historical floodplain channels that were cutoff from the active channel when the levee was constructed. A portion of the flow path is illustrated in the existing FEMA flood hazard mapping from the western portion of the Muckleshoot Indian Tribe Reservation boundary. Although breached, much of the levee prism remains, constricting portions of the river reach and continuing to force flows into the toe of slope of the right bank valley wall. The overbank flows spread out and travel downstream into the Wilderness Park area, where they funnel into an off-channel to reenter the river through a previously return-flow breached area of the levee. The City of Auburn has constructed the trail over a return-flow breach in the levee and placed two 12-inch culverts, although the off-channel is a quite large trapezoidal flow path with at least a 15-foot bottom width. Overbank flows are expected to continue to enter this off-channel path and may overwhelm the dual-culvert capacity, potentially resulting in damage to the trail embankment or the adjoining trail paths and park land.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Damage to public infrastructure, primarily a park trail.

Proposed Project or Action

Acquire the off-channel floodplain portions of the adjoining undeveloped private parcels and modify the breached portions of the levee to improve flood flow conveyance in the overbank areas of the floodplain. Use existing cross-section data and map the breach locations with global positioning system equipment to initially determine the extent of the existing overbank flow paths. Conduct a project feasibility analysis by developing a hydraulic model and performing a geomorphic assessment of the levee, the breach locations and flow paths. Develop a new trail alignment that eliminates the need for an off-channel crossing. If the trail alignment is not feasible, assess the culvert capacity and replace the culverts to accommodate the expected overbank flow. Enhancing off-channel habitat along this area is a Water Resource Inventory Area 10 salmon habitat recovery plan proposal.

Project Benefits

The existing overbank flow paths are not mapped or quantified. By quantifying and locating the existing flow paths and assessing the hydraulic and geomorphic conditions of the levee, the existing breaches could be modified to accommodate flood flows and decrease the erosive flows currently forced into the right bank toe of slope of the valley bluff. Acquisition of flood hazard areas identified through a hydraulic analysis of the reach would prevent future, at-risk development and also provide the necessary land area to accommodate improved flood flow conveyance along this reach. This improved conveyance would be implemented in conjunction with an upsizing of the existing culverts or realignment of the trail, which would prevent future flood damage to the trail. Improving off-channel areas would be beneficial to salmonids by providing flood refugia. The project feasibility analysis will determine the extent of the risk to downstream developed park property and illustrate the potential enhancements that could be realized by modifying portions of the existing levee and the existing breaches. With the acquisition of the adjoining private parcel and an assessment of modifying the levee within the Wilderness Park at some future time, this reach of the White River could realize a very low flood risk and so reduce flood risks to the park property, and also provide for a higher natural resource value. This is a proposal from the salmon habitat recovery plan for Water Resource Inventory Area 10.

Coordination

Coordination with the Muckleshoot and Puyallup Indian Tribes and the City of Auburn is needed. Property owner willingness is necessary for the acquisition (fee simple or easement) of the privately owned parcels.

Other Information or Needs

This project is also included in the Water Resource Inventory Area 10 Ecosystem Restoration Feasibility Study with the U.S. Army Corps of Engineers.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Transcanada.pdf

White-Greenwater Acquisition

Location Information

Water Resource Inventory Area 10, White and Greenwater Rivers
River Mile 45.85 to 45.9, Right Bank
Council District 9
Unincorporated
Private Land
No Agricultural Production District or Farmland Preservation Program lands

Estimated Cost

$785,000

Problem Statement

On the right bank of the White River at its confluence with the Greenwater River is a residential complex (private home and rental apartments) that has experienced significant flooding and damages in the 1995 flood event. The White River channel eroded into the right bank, allowing flood waters to pass through the property and three structures. The home owner obtained a small business loan of $130,000 to make repairs and construct a flood wall of concrete "ecology blocks" along the river bank. The residential site remains vulnerable to the highly erosive flows along this reach, which could undermine the flood wall. Also, the site could be flooded from the Greenwater River if the State Route 410 bridge pier accumulates significant debris and results in flood waters overtopping the highway.

What Is at Risk

Risks identified in the *2006 King County Flood Hazard Management Plan* Policy G-2 that this project is intended to reduce or eliminate include:

- Risk to public safety if residents are caught unaware of flood conditions or attempt to enter or reenter flooded areas;
- Risk to public safety if fire and rescue personnel are called upon to aid those unable or unwilling to evacuate flooded homes;
- Damage to private structures.

Proposed Project or Action

Acquire the property and remove the at-risk residential and rental structures. Remove the concrete flood wall and restore the riverbank to a natural floodplain condition.

Project Benefits

Removal of the at-risk structures permanently eliminates the risk to public safety. After the structures are removed, the river bank and floodplain area can be restored to a natural condition, improving the riparian habitat at this confluence site.

Coordination

Property owner willingness to sell the property is essential to implementation of this project.

Other Information or Needs

Implementation of this project may facilitate action by Washington State Department of Transportation to replace the State Route 410 bridge over the Greenwater River. A floodplain analysis and channel migration zone mapping for the White and Greenwater Rivers is needed to determine the current-day base flood elevations and flood velocities and to verify the extent of potential flooding and bank erosion.

Project Area Map

A map of the project area may be found at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/flood/fhmp/pdf/Greenwater.pdf