APPENDIX C.
KING COUNTY FLOOD RISK ASSESSMENT

INTRODUCTION

The King County Flood Risk Assessment is used to determine potential losses from a flood event in terms of life, property, economy and environment. The assessment required the systematic use of all available information to determine how each flood hazard may affect King County, how often flood events can occur and the potential severity of their consequence. The information in this risk assessment was used in development of the *Flood Hazard Management Plan* to support the decision-making process. Three steps were used in generating this analysis:

- Identify the flood hazard
- Determine impacts of the flood hazard
- Analyze vulnerability.

The Disaster Mitigation Act of 2000 is federal legislation that emphasizes planning for disaster events before they occur. It addresses local and state mitigation planning and requires that plans be completed before Hazard Mitigation Grant Program funds are available to communities. This is intended to reduce the risk of repetitive disaster damage on communities and establish long-term solutions to impacts from disasters. The Disaster Mitigation Act requires a local government to assess its risk from natural hazards that may impact it. Creation of this risk assessment completes this task for the flood hazard.

Planning Context

The risk assessment is a key element of the overall planning process prescribed by programs such as the Disaster Mitigation Act, the Community Rating System, the Flood Mitigation Assistance Grant Program, and the Washington State Flood Control Account Assistance Program. This process provides a loss estimation that identifies the effects of the flood events in monetary terms. The loss estimation informs the public, policy-makers and decision-makers about the tangible effects of disaster events on communities. The risk assessment can identify specific issues that will help determine areas that should be focused on and provide information to aid policy makers in comparing benefits and costs of possible mitigation strategies and establishing priorities for those strategies.

The information used in the preparation of this risk assessment was the best available at the time of this assessment. As is pointed out frequently in this plan, there is a need for new and updated information regarding flooding extent and location in King County. This risk assessment may identify vulnerabilities that appear to not be addressed by actions identified by the *Flood Hazard Management Plan*; however, this is not the case. Some vulnerabilities will need to be reevaluated once new information and technology become available.

Methodology

The risk assessment was developed with guidance provided in the Federal Emergency Management Agency's (FEMA's) local mitigation planning guide, *Understanding Your Risks, Identifying Hazards and Estimating Losses* and Section 510 of the 2006 Community Rating System Coordinator's Manual. The assessment augments information provided in the main body of the Plan to ensure that programmatic requirements prescribed under federal and state planning programs are met. Specifically, it addresses the following planning requirements:

- **Identify the flood hazard**—A detailed description of the extent and location of flooding by basin is presented in Chapter 5 of the Plan.
- **Profile the flood hazard**— The risk assessment performed for each basin is reach-based, segregating each basin into segments with similar flood-related characteristics, such as land use, geomorphology or hydrology. Profiling the flood hazard was determined with the following information:
  - **Past Events**—This provides detailed information, where available, on past flood events, including dollar estimates of losses.
  - **Flood Characteristics**—Flood characteristics are analyzed in two categories. Basin flow characteristics describe drainage, the 100-year flow at various gage stations and the flow for the flood of record. Basin flood characteristics describe land use, estimated depth of flooding, presence of channel migration zones as defined by King County and estimated warning time by reach. Land use by reach is evaluated in terms defined by the King County Comprehensive plan.
- **Vulnerability Analysis**—Vulnerability was determined using Geographic Information System (GIS) overlays of the King County floodplain and anecdotal information from County, state and other public sources. Vulnerability from flooding was analyzed based on impacts on life, safety and health, structures, natural and environmental areas, future development and economic areas.
  - **Public Health and Safety**—This is a discussion of how flooding affects public health and welfare. This is defined in terms of regulated floodplain area and length of unmapped floodplain.
  - **Critical Facilities**—This identifies the critical facilities and infrastructure that are vulnerable to flooding, using GIS overlays and anecdotal information.
  - **Land Use and Structures**—GIS methods were used to determine the estimated number of parcels and structures in the floodplain. The following criteria were used to identify floodplain parcels:
    - Parcels with 50 percent or more of their land area in the floodplain
    - Parcels with improvements with an assessed value of $50,000 or greater

    King County's GIS data indicated the structure on a property is likely to be located in the floodplain for parcels with 50 percent or more of their land area within the floodplain. There is some level of error in this assumption but it is an appropriate assumption based on available information and technology. Improvements on these parcels were then surveyed for assessed values of $50,000 or more. This threshold was determined based on an evaluation of housing values in King County. These are the structures that would be most impacted by flooding. The corresponding flood vulnerability was then estimated applying FEMA's flood loss estimation tables to these approximate values for structures. It should be noted that this analysis focused on building values and did not include the value of contents or functional down time. It was not possible to perform analysis to this detail based from the information available.
  - **Environment**—An ecological review of each basin is presented in Chapter 5 of the Plan.
  - **Development Trends**—This identifies vacant lands zoned as residential or commercial in the floodplain and buildable lands to determine which parcels may be at risk in the future.

- **Economy**—This consists of a very brief discussion of what drives the economy in the basin and what is vulnerable to flooding. No detailed analysis of the economic impact of flooding was performed for this risk assessment. It is the County's intentions to perform a more detailed analysis using FEMA's HAZUS program in the future. For this risk assessment, an anecdotal approach was used to evaluate the economic impact of flooding in each basin. This evaluation was based primarily on historical flooding in the basin. The following classifications of potential impacts were assigned for planning purposes:
  - *Significant Impact*—Flooding in the basin would have a major countywide economic impact.
  - *Moderate Impact*—Flooding in the basin would have an economic impact on citizens in the basin, but not severely impact the countywide economy.
  - *Minimal Impact*—Flooding in the basin would not cause significant economic impact in the basin or countywide.
- **Repetitive Loss**—This identifies all properties in the basin that have repeatedly been flooded, as identified by FEMA.
- **Insurance Analysis**—A flood insurance policy analysis was performed for each basin to identify possible flood risks beyond those known in identified floodplains. The concept of this analysis was to plot the location of flood insurance policies in the basin to identify possible pockets of coverage outside known floodplains. This could indicate a flood risk be considered under the scope of the Plan.

Data Sources

The risk assessment was developed based on existing information from various sources, including several planning documents King County has developed. A large part of the analysis required the use of data from King County's GIS system. Other technical information, including river flow data, was taken from data developed by the U.S. Geological Survey (USGS). The outputs generated for this risk assessment represent those generated from FEMA loss estimation tools and planning guidance.

Repetitive Loss Properties

Repetitive loss properties require special attention in terms of flood mitigation planning. A repetitive loss property as defined by FEMA is a property insured under the National Flood Insurance Program that, since 1978 and regardless of changes in ownership during that period, has experienced any of the following:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period since 1978
- Three or more paid losses that equal or exceed the current value of the insured property.

The main identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by those policies. The Community Rating System program, which King County is a part of, requires that repetitive loss properties be identified. A repetitive loss area is the portion of a floodplain where buildings that meet FEMA's definition of repetitive loss properties are clustered together.

How to Use This Risk Assessment

This risk assessment is organized by drainage basin within King County. This follows the approach the County uses in the management of its floodplains, and thus better enables this assessment to provide the degree of information necessary to augment the County's floodplain management activities. The risk assessment methodology was followed for each of the following basins:

- South Fork Skykomish River Basin
- Snoqualmie River Basin
- Sammamish River Basin
- Cedar River Basin
- Green River Basin
- White River Basin

Basin specific information is analyzed for each of these basins in the following sections.

SOUTH FORK SKYKOMISH RIVER BASIN PROFILE

The South Fork Skykomish River basin lies predominantly in the northeast portion of King County and is a part of Water Resource Inventory Area 7. The King County portion of the South Fork Skykomish drains 234 square miles of mountainous terrain within the forest production zone and Alpine Lakes Wilderness Area. Major tributaries within King County include the Foss, Tye, Miller, and Beckler Rivers.

Hazard Profile

Past Events

Table 1 summarizes the history of flood events for the South Fork Skykomish River Basin since 1990. Peak flows are listed in cubic feet per second (cfs). The most severe recent flood event was the November 1990 flood. The flow data used is collected in the Snohomish County portion of the Skykomish River. Most of the data in Table 1 is from gage data collected in Snohomish County.

TABLE 1.
SOUTH FORK SKYKOMISH BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Peak Flow (cfs)[a]	Type of Damage	Estimated Cost
11/26/1990	Yes/#883	102,000	Overbank flooding causing damage to both public and private property. Stream bank erosion.	$1.4 million for entire County
02/19/1995	No	44,100	Overbank flooding. No significant property damage reported	No information available
12/03/1995	Yes/#1079	79,600	Overbank flooding causing damage to both public and private property. Levee damage.	$ 1,141,498 in public property damage
02/10/1996	Yes/#1100	74,400	Overbank flooding causing damage to both public and private property. Stream bank erosion. Levee damage.	$215,142 in public property damage
10/20/2003	Yes/#1499	86,500	Public property damage only.	

a. Flow estimates based on USGS #12134500

Flood Characteristics

Tables 2 and 3 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. None of the flood events so far have surpassed the 100-year flood flow at the Goldbar gage. Observed flooding depths for this basin vary from less than 1 foot to 6 feet. King County considers the South Fork Skykomish River to have channel migration potential, and regulates this region under the channel migration zone provisions of the King County Critical Areas Ordinance.

King County provides no flood warning on the South Fork Skykomish River System. The only available flow data is collected near the City of Goldbar in Snohomish County, which is significantly downstream from hazard areas in King County. The available data is not useful for providing flood warning to residents in these area.

TABLE 2.
SOUTH FORK SKYKOMISH RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)
Index	12133000	43.0	535	74,700	Recent Data Not Available

TABLE 3.
SOUTH FORK SKYKOMISH RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
South Fork Skykomish	Clustered residential, National Forrest.	0 - 6 Feet	Yes	No Warning Time

Vulnerability Analysis

Public Safety and Health

Flooding in the South Fork Skykomish River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption caused by flooding have been significant. The South Fork Skykomish River is generally clean and free-flowing, with a very steep gradient and numerous rock cascades of white water in the King County portion. The steep gradient produces deep and high velocity flows that can be extremely dangerous for public heath and safety. Several small communities have development within the floodplain, and deep flooding over State Route 2 has the potential to isolate these communities from the rest of the county.

Table 4 shows the length of unmapped floodplain in King County for the South Fork Skykomish River basin. Since there is no mapped floodplain in these areas, the risk of flooding to the public may be more significant during severe events and may need to be monitored closely. This is especially true for communities having ingress and egress on only one road.

TABLE 4.
UNMAPPED FLOODPLAIN IN THE SOUTH FORK SKYKOMISH RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	78
Total unmapped floodplain	67
Unmapped floodplain—incorporated areas	0
Unmapped floodplain—unincorporated King County	67

Critical Facilities

Critical facilities in the South Fork Skykomish River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 5 lists the critical facilities in the South Fork Skykomish River basin. All of these facilities are considered to be vulnerable to the impacts of flooding. The degree of vulnerability for the public health and safety facilities identified in Table 5 varies. Damage to existing King County flood control facilities from the 1990 floods totaled $192,000. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Mitigation Plan* to proactively mitigate impacts on identified critical facilities when opportunities arise. Several of the facilities listed in Table 5 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 5.
CRITICAL FACILITIES IN THE SOUTH FORK SKYKOMISH BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Skykomish Police Substation	Town of Skykomish	16.3	X	
City Hall	City of Skykomish	16.3	X	
Skykomish K to 12 School	Skykomish School District	16.1	X	
Levee (Town of Skykomish left bank)[a]	King County	16.2		X
Fire Station 1	City of Skykomish	16.2	X	X
Railroad Line and Bridges	Burlington Northern	Length	X	
State Route 2 and bridges	Washington State	Full length		X

a. This is a training levee that protects the school

Land Use and Structures

The predominant land use in the South Fork Skykomish basin is forest use. Fifty percent of the basin is protected wilderness; 43 percent is zoned for forest production; 6 percent is in rural residential use; and approximately 1 percent is in urban use (King County 2002c). Development in the basin has been limited, but much of it has occurred in the floodplain. There are several developments in the Town of Skykomish, the unincorporated communities of Grotto and Baring and scattered residential subdivisions. During the November 1990 flood event, several riverfront homes were affected by severe bank erosion (King County 1993b).

FEMA floodplain mapping shows 1,146 acres of mapped floodplain in the South Fork Skykomish River basin, all of it along the South Fork Skykomish mainstem. A floodplain study of the South Fork Skykomish was completed in 1998. The total area of regulatory floodplain for the South Fork Skykomish River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. A channel migration study is in progress for portions of the South Fork Skykomish River. Approximately 86 percent of the South Fork Skykomish River basin regulatory floodplain is in unincorporated King County. Table 6 shows the area of regulatory floodplain.

Within the South Fork Skykomish River basin floodplain there are a total of 170 parcels. This is approximately 4 percent of the total number of parcels in King County floodplains (4,738). There are structures at risk from flooding on 36 of these parcels. The depth of flooding varies with location. Table 7 summarizes estimated flood loss potential. Of the 36 structures in the South Fork Skykomish River basin floodplain, 33 are residential and 3 are commercial.

TABLE 6.
SOUTH FORK SKYKOMISH RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	2,113
Incorporated Areas	207
Total	**2,320**

TABLE 7.
PARCELS IN THE 100-YEAR FLOODPLAIN IN THE SOUTH FORK SKYKOMISH BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
South Fork Skykomish	170	36	1,597	$1,797,300	$7,535,600	$9,332,900	$2,109,968

a. The number of structures in each reach is an estimate generated as described in the introduction to this risk assessment.

Development Trends

The South Fork Skykomish River basin has maintained a rural land use environment. Significant development has not and likely will not occur in this area because a large portion of it is protected wilderness area and forest production area. Future land use is projected to be similar to current land use conditions. Only a small increase in households is projected for the 2001 through 2022 planning period (King County 2004).

An assessment of buildable and potentially buildable lands was completed to help determine future risk in the South Fork Skykomish River basin. Vacant lands from King County Assessor's data were used to determine potentially buildable lands in the floodplain. Table 8 summarizes the number of vacant lands susceptible to 100-year flood flows for the South Fork Skykomish River basin.

TABLE 8.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN IN THE SOUTH FORK SKYKOMISH BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
293	778	$7,791,100

Economic Impact

Based on existing land use and past experience, flooding along the South Fork of the Skykomish River would have nominal economic impact within the basin, due primarily to the lack of significant population density within the basin. There are no major employment centers in this basin, but the loss of use of transportation corridors to major employment centers elsewhere in the County could have some economic impact within the basin. Due to the low population density, this potential impact is not considered significant. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be minimal.

Repetitive Loss Areas

There are tem repetitive loss properties in the South Fork Skykomish River basin, one of which has been mitigated, as summarized in Table 9. Five of the unmitigated properties are located near Baring, Washington, and the remaining four are scattered along the length river. All of these parcels are single-family residences located in the floodway, and it is concluded that the cause of repetitive flooding for all of them is overbank riverine flooding, as reflected by the mapping for the basin.

TABLE 9.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SOUTH FORK SKYKOMISH BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
9	2.39	$72,000	$672,000

Insurance Analysis

Flood insurance statistics can help identify vulnerability by regionally isolating areas where claim activity is high and a high rate of flood insurance is in force. Table 10 summarizes insurance statistics that can be used to help identify vulnerability within the South Fork Skykomish River Basin.

TABLE 10
FLOOD INSURANCE STATISTICS FOR THE SOUTH FORK SKYKOMISH RIVER BASIN

Number of flood insurance policies in force within the basin	54
Number of policies within a mapped floodplain	49
Number of policies outside of a mapped floodplain	5
Estimated number of structures in mapped floodplains	36
Estimated percent of at risk structures with flood insurance coverage	91
Percent of flood insurance coverage outside of a mapped floodplain	9

Based on a review of this data, the following observations can be made:

- Based on the approximate number of structures in the floodplain and the insurance coverage in force within the floodplain, insurance coverage as a form of mitigation appears to be adequate in this basin.
- With approximately 17 percent of the flood insurance policies in this basin qualifying as repetitive loss, flood insurance programmatic mechanisms such as “Increased Cost of Compliance” could be promoted as a form of flood hazard mitigation in this basin.
- The low percent of insurance coverage outside the floodplain indicates no apparent flood risks not currently mapped or identified by King County.
- The County’s ongoing promotion of flood insurance through its public outreach strategy appears to be working in this basin and should be continued.

SNOQUALMIE RIVER BASIN PROFILE

The Snoqualmie River basin covers northeast King County and drains to the Snohomish River and ultimately to Puget Sound. It is a part of Water Resource Inventory Area 7. The watershed includes the Tolt River, Raging River, Miller River, Tokul Creek, Griffin Creek, Harris Creek, Patterson Creek, and other tributaries.

Hazard Profile

To provide additional detail of the characteristics of flooding in Snoqualmie Basin, the analysis is separated into six reaches:

- Upper Snoqualmie Reach—Headwaters to Snoqualmie Falls
- Fall City Reach—Base of Snoqualmie Falls to Fall City
- Raging River Reach—Raging River Headwaters to Fall City
- Carnation Reach—Fall City to Carnation
- Tolt River Reach—Tolt River headwaters to Carnation
- Duvall Reach—Carnation to Snohomish County line

Past Events

Table 11 summarizes the history of flood events for this basin since 1990. The most severe recent flooding event was the November 1990 flood. There has been millions of dollars worth of damage in the Snoqualmie River basin as result of flood events.

Flood severity is identified in terms of phases. Table 11 shows events that reached Phase III or above. Below are the phases of flooding for the Snoqualmie River.

- Phase I—The flow is greater than 6,000 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase II—The flow is greater than 12,000 cfs and lowland flooding will occur. Several roads will be overtopped or closed (Neal Road, SE Reinig Road, West Snoqualmie River Road NE, Snoqualmie Meadowbrook Road, and Mill Pond Road).
- Phase III—This is considered moderate flooding and exhibits flows greater than 20,000 cfs. Flooding of varied depth will occur in the entire Snoqualmie area. Fall City-Carnation Road, Tolt Hill Road and Novelty Flats Road will be overtopped or closed.
- Phase IV—This is extreme flooding. Flow is greater than 38,000 cfs and some residential areas may experience dangerous high velocities and flooding of homes. Roads that may be overtopped or closed are Woodinville-Duvall Road, State Route 203 between Duvall and Carnation, Moon Valley Road, and South Fork Road.

Flood Characteristics

Tables 12 and 13 summarize observed flooding characteristics typical for this basin. These tables reflect the range of flood conditions by identifiable reach or stream for planning purposes only. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Flood depths in this basin can vary from less than 1 foot to 6 feet, with significant velocities depending on extent and location within the basin.

TABLE 11.
SNOQUALMIE RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/10/1990	Yes/#852	IV/48,522	Overbank flooding causing damage to both public and private property. Channel avulsion.	$4.9 million for entire county
11/1990	Yes/#883	IV/50,100	Overbank flooding causing damage to both public and private property. Channel avulsion.	$5.6 million for entire county
11/7/1995	Yes/#1079	IV/49,350	Overbank flooding causing damage to both public and private property. Channel avulsion.	$ 683,612 in public property damage
01/1996	Yes/#1100	IV/44,430	Overbank flooding causing damage to both public and private property. Channel avulsion.	$1,598,304 in public property damage
01/1997	Yes/#1159	III/>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	No information available
03/1997	Yes/#1172	III/>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	$647,005
10/1997	No	III/>20,000	No significant damage reported to public or private property.	No information available
11/1999	No	IV/>38,000	Overbank flooding. No major damage to public or private property reported	No information available
12/2000	No	III/>20,000	No significant damage reported to public or private property.	No information available
01/2003	No	III/>20,000	No significant damage reported to public or private property.	No information available
03/2003	No	III/>20,000	No significant damage reported to public or private property.	No information available
10/21/2003	Yes/#1499	III/32,700	Overbank flooding causing damage to both public and private property. Channel avulsion.	Individual assistance only; approximately $68,748 countywide

TABLE 12.
SNOQUALMIE RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)
North Fork	12142000	9.2	64.0	27,200 [a]	02/26/1932; 15,800 cfs
Middle Fork	12141300	55.6	154.0	43,000 [a]	12/02/1977; 30,200 cfs
South Fork	12143400	17.3	41.6	15,000 [a]	11/23/1986; 8,450 cfs
Snoqualmie @ Snoqualmie.	-	40.0	375	79,100 [b]	11/24/1990; 78,800 cfs
Snoqualmie @ Carnation	-	23	603.0	91,800 [b]	11/24/1990; 65,200 cfs
Raging @ Fall City	12145500	2.75	30.6	6,970	11/24/1990; 6,220 cfs
North Fork Tolt	12147500	11.7	39.9	10,300	12/15/1959; 9,560 cfs
South Fork Tolt	12148000	6.8	19.7	9,160	23/15/1959; 6,500 cfs
Tolt @ Carnation	12148500	8.7	81.4	18,800	12/15/1959; 17,400 cfs

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)

a. FEMA 2005. Period of record of USGS gage data used to derive values in table may differ from period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

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

TABLE 13.
SNOQUALMIE RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Upper Snoqualmie	Mixed land use. Commercial, Industrial, Residential. Urban area land uses from the Cities of North Bend and Snoqualmie. Upper areas of this reach predominately national forest.	6 feet or greater with measurable velocity	Yes	2-4 hours
Fall City	Urban residential, light commercial, agricultural	6 feet or greater with measurable velocity	No	4 hours
Raging River	Rural Residential, National Forrest	Shallow Flooding 0-6 feet, with measurable velocity	Yes	No Warning
Carnation	Mixed land use. High density residential, commercial, industrial and agricultural	Shallow Flooding 3-6 feet	No	12+ hours
Tolt River	Rural residential, agricultural, National Forrest	Shallow Flooding 0-6 feet, with measurable velocity	Yes	2 hours
Duvall	Agricultural and open space uses	6 feet or greater with measurable velocity	No	24 hours

Vulnerability Analysis

Public Safety and Health

Flooding in the Snoqualmie River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption cased by flooding have been a recurrent problem.

The Cities of Snoqualmie and North Bend have been urbanizing since 1980. Significant growth is expected throughout the basin. Between 1980 and 1999, the population in the basin went from approximately 20,000 to approximately 38,000 (King County 2002c). The Puget Sound Regional Council predicts that the population in the Snoqualmie basin will grow from its current estimated level of approximately 40,000 to over 70,000 residents by 2020 (King County 2001).

Table 14 shows the length of unmapped floodplain in the Snoqualmie River basin. The risk of flooding to the public may be more significant in these areas during severe event, requiring close monitoring.

TABLE 14.
UNMAPPED FLOODPLAIN IN THE SNOQUALMIE RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	1,341
Total unmapped floodplain	1,017
Unmapped floodplain—incorporated areas	19
Unmapped floodplain—unincorporated King County	999

Critical Facilities

Critical facilities in the Snoqualmie River basin were identified using GIS. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 15 lists the critical facilities in the Snoqualmie River basin. All of these facilities are considered to be vulnerable to the impacts of flooding. In the 1990 flood, King County levees and revetments sustained $660,000 worth of damage. The degree of vulnerability for the public health and safety facilities identified in Table 15 varies. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Management Plan* to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 15 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 15.
CRITICAL FACILITIES IN THE SNOQUALMIE RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Snoqualmie City Hall	City of Snoqualmie	41.0	X	
North Bend City Hall	City of North Bend	South Fork—2.5	X	
North Bend Elementary	North Bend	South Fork—2.5	X	
Two Rivers High School	Snoqualmie Valley	South Fork—2.5	X	
Administration/Transportation (Snoqualmie Valley)	Snoqualmie Valley	40.8	X	
Mt. Si High School	Snoqualmie Valley	42.0	X	
Snoqualmie Elementary	Snoqualmie Valley	42.0	X	
Snoqualmie Middle School	Snoqualmie Valley	42.0	X	
Wastewater Treatment Plant	North Bend Treatment Plant	North Fork—2.0	X	
Wastewater Treatment Plant	Snoqualmie Treatment Plant	40.2	X	
Police Department	City of North Bend	South Fork—1.0	X	

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
State Patrol District 2 North Bend Detachment	City of North Bend	South Fork—2.5	X	
Fire Station 87	Fire District 38—North Bend	South Fork—2.5	X	
Fire Station 28	Snoqualmie	41.0	X	
Tolt River Dam	City of Seattle	South Fork Tolt – 8.5	X	X
S. Fork Levee at N. Bend	King County	South Fork - 2.0-3.0		X
Tolt River levee @ Carnation	King County	Tolt– 0.0-1.0		X
Raging River Levee @ Fall City	King County	Raging – 0.0-1.0		X

Critical facilities can also include critical infrastructure, such as roads whose closure could cause isolation and evacuation problems during flood events. Isolation is a key issue for flood preparedness and response in this basin. King County has determined that the following major roadways and stream crossings (bridges or culverts) would be impassable during a 100-year flood event:

- Neal Road
- SE Reinig Road
- West Snoqualmie River Road NE (Walker Road)
- Snoqualmie Meadowbrook Road
- Mill Pond Road.
- Fall City-Carnation Road
- Tolt Hill Road.
- Novelty Flats Road.
- Woodinville-Duvall Road
- SR 203 between Duvall and Carnation
- Moon Valley Road, South Fork Road

Land Use and Structures

The major portion of the Snoqualmie River basin floodplain is in unincorporated King County, with small but significant portions in the cities of North Bend, Snoqualmie, Duvall and Carnation. Development throughout the incorporated portions of the Snoqualmie River floodplain is mainly commercial and residential. Agricultural and residential development predominates in unincorporated King County along the lower and upper portions of the river.

FEMA floodplain mapping shows 22,129 acres of mapped floodplain in the Snoqualmie River basin. This includes the Raging and Tolt River, the three Forks of the Snoqualmie River and the mainstem of the Snoqualmie River. Approximately 97 percent of this, or 21,408 acres, is along the Snoqualmie River mainstem. Table 16 defines the mapped floodplain in terms of incorporated and unincorporated King County. A floodplain study of the mainstem of the Snoqualmie River is nearly complete and will update the floodplain and floodway data in 2006. Studies and new floodplain boundaries for the Forks and the Raging and Tolt Rivers were completed during the past 10 years.

TABLE 16.
SNOQUALMIE RIVER BASIN MAINSTEM AREA

	FEMA-Mapped Floodplain Area (acres)
Mainstem Unincorporated	18,502
Mainstem Incorporated	2,906
Mainstem Total	**21,408**
Snoqualmie River Basin Total	***22,129***

The total area of regulatory floodplain for the Snoqualmie River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. Results of a channel migration study on the Tolt River and portions of the Snoqualmie River are included in the area of regulatory floodplain. Approximately 86 percent of the Snoqualmie River basin regulatory floodplain is in unincorporated King County. Table 17 shows the area of regulatory floodplain.

TABLE 17.
SNOQUALMIE RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	41,244
Incorporated Areas	6,689
Total	**47,933**

The cities of North Bend and Snoqualmie have significant residential development. During the 1990 flood, both cities suffered significantly from flood damage. Most structures in the City of Snoqualmie suffered substantial damage.

Approximately 75 percent of the Snoqualmie basin is in the forest production district. Most of the Snoqualmie River floodplain below Snoqualmie Falls is within the agricultural production district. As timber harvesting in the basin has decreased, the timber companies have been slowly selling off their land. Much of that land could be developed, but there have been some efforts to conserve it. The potential for high density development in incorporated areas is increased by the presence of vested lots and plats.

Within the Snoqualmie River basin floodplain there are a total of 1,880 parcels. This is approximately 40 percent of the total number of parcels in King County floodplains (4,738). There are structures at risk from flooding on 867 of these parcels. The depth of flooding varies depending on location. Table 18 summarizes estimated flood loss potential. Of the 867 structures in the Snoqualmie River basin floodplain, 772 are residential structures and 95 are commercial.

TABLE 18.
PARCELS IN THE 100-YEAR FLOODPLAIN IN THE SNOQUALMIE RIVER BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
Upper Snoqualmie	953	473	1,845	$92,036,300	$145,218,100	$237,254,400	$58,087,240
Fall City	265	105	4,240	$31,127,400	$32,376,800	$63,504,200	$12,950,720
Raging River	67	33	82	$3,794,000	$8,865,000	$12,659,000	$2,482,200
Carnation	176	97	2,488	$20,050,700	$24,543,900	$44,594,600	$10,860,675
Tolt River	143	52	1,230	$14,353,700	$15,010,800	$29,364,500	$4,203,024
Duvall	276	107	4,729	$36,010,400	$32,866,800	$68,877,200	$13,146,720
Basin Totals	**1880**	**867**	**14,614**	**$197,372,500**	**$258,881,400**	**$456,253,900**	**$101,730,579**

a. The number of structures in each reach is an estimate generated as described in the introduction to this risk assessment.

Development Trends

Much of the urbanization of the watershed has been contained in high density incorporated areas. While urban areas constitute only about 3 percent of the total watershed area, they make up a significant portion of some subwatersheds including Coal Creek (50 percent), mainstem Snoqualmie (15 percent), Patterson Creek (10 percent), and Cherry Creek (6 percent). The potential for high density development is increased by the presence of vested lots and plats, particularly in the Patterson and Ames Creeks areas (King County 2002c).

An assessment of buildable and potential buildable lands was completed to help determine future risk in the Snoqualmie River basin. Vacant lands from King County Assessor's data were used to determine potential buildable lands in the floodplain. Table 19 summarizes the number of vacant parcels susceptible to 100-year flood flows for the Snoqualmie River basin.

TABLE 19.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN
SNOQUALMIE RIVER BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
1,053	9,240	$124,672,290

Economic Impact

With the largest floodplain in King County, the Snoqualmie basin has experienced significant economic impact from flooding. It is estimated that 34 percent of the $25,215,505 in countywide flood damage from federally declared flood events since 1990 occurred in this basin. The Snoqualmie basin contains approximately 66 percent of the mapped floodplain in all of unincorporated King County and 35 percent of the at-risk structures. Although this basin is not a major employment center although is a significant commercial agricultural community, flooding can have an economic impact on employment for the County because many of the basin's residents are not able to get to work due to road closures and isolation caused by flooding. Functional down time of roads is a major economic factor in this basin. No

detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Snoqualmie and North Bend are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

The Snoqualmie River basin has 46 repetitive loss properties, 27 of which have been mitigated. Table 20 summarizes the number of unmitigated repetitive loss properties in the basin. These properties are not clustered together. Of the 19 properties, all are single-family residential. All but one property lies within a mapped 100-year floodplain, so it is concluded that the main cause of repetitive flooding for this basin is overbank riverine flooding reflected by the mapping for the basin.

TABLE 20.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SNOQUALMIE RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
19	403	$3,021,500	$4,090,100

Insurance Analysis

Table 21 summarizes insurance statistics that can be used to help identify vulnerability in the Snoqualmie River Basin.

TABLE 21.
FLOOD INSURANCE STATISTICS FOR THE SNOQUALMIE RIVER BASIN

Number of flood insurance policies in force within the basin	559
Number of policies within a mapped floodplain	388
Number of policies outside of a mapped floodplain	171
Estimated number of structures in mapped floodplains	867
Estimated percent of at risk structures with flood insurance coverage	44
Percent of flood insurance coverage outside of a mapped floodplain	31

Based on a review of this data, the following observations can be made:

- It is estimated that less than 50 percent of the structures in this basin have flood insurance coverage in force as a form of property protection/mitigation.
- With the high number of repetitive loss properties in this basin, the promotion of flood insurance could impact mitigation opportunities in this basin by leveraging programmatic insurance mechanisms such as “Increased Cost of Compliance.”
- With a relatively high percentage of flood insurance coverage outside of the floodplain, an analysis of where these policies lie and why they are in force could be performed to determine future needs for mapping and hazard identification.

- The County's ongoing public information strategy that includes elements that promote flood insurance as a form of property protection should be continued or enhanced in this basin.

SAMMAMISH RIVER BASIN PROFILE

The Sammamish River originates at Lake Sammamish and drains a 240-square-mile watershed that includes 97 square miles of the Lake Sammamish basin, 50 square miles in the Bear Creek basin and 67 square miles of the combined Little Bear, North, and Swamp Creek basins.

Hazard Profile

To provide additional detail of the characteristics of flooding in the Sammamish River basin, the analysis of this basin is separated into the following reaches:

- Issaquah Creek Reach—Issaquah Creek headwaters to Lake Sammamish
- Upper Sammamish Reach—Lake Sammamish at Issaquah to River Mile 15.3
- Lower Sammamish Reach—River Mile 15.3 to Lake Washington
- Evans Creek Reach—Evans Creek headwaters to confluence with the Bear Creek in Redmond
- Bear Creek Reach—Bear Creek headwaters to confluence with Sammamish River in Redmond

Past Events

Table 22 summarizes the history of flood events for the Sammamish River basin. The data collected is mainly from Issaquah Creek.

TABLE 22.
SAMMAMISH RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
12/1/1995	Yes/#1079	IV/1,240	Overbank flooding causing both public and private property damage within the Issaquah Creek Basin.	$5.2 million for entire county
01/1997	No	IV/1,240	Flooded farmland. No reports of significant public or private property damage.	No information available

Severity of historical floods is listed in terms of phases in Table 22. Below are the phases of flooding for Issaquah Creek.

- Phase I—This is considered an internal alert and has a flow of 200 cfs.
- Phase II—The flow is greater than 500 cfs.
- Phase III—This indicates a moderate flooding event and exhibits flows greater than 800 cfs.
- Phase IV—This is considered extreme flooding and the flow is greater than 1,000 cfs.

So far there have no been flood events surpassing the 100-year flood flow at the Hobart gage. Nine of the last 10 events on Issaquah Creek have been Phase IV events.

Flood Characteristics

Tables 23 and 24 summarize observed flooding characteristics typical for this basin. These tables reflect the range of flood conditions by identifiable reach or stream for planning purposes only. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives

appropriate for the level of risk for that stream or reach. Table 23 shows events that reached above Phase III at the Hobart gage for Issaquah Creek unless otherwise indicated. Warning time estimates were not available for the Sammamish River basin. Table 23 shows the calculated 100-year flow for each gage. King County collects gage information only on Issaquah Creek. Observed depths of flooding in this basin range from less than 1 foot to 8.5 feet.

TABLE 23.
SAMMAMISH RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs) [a,b]	Flood of Record, Date & Peak Flow (cfs)
Sammamish River @ Mouth	12122000	5.6	99.6	4,300	-
Issaquah Creek @ Mouth	12121600	1.2	55.6	3,960	01/09/1990; 3,200 cfs

a. FEMA 2005.

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

TABLE 24.
SAMMAMISH RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Issaquah Creek	Urban residential, rural residential, Commercial, agricultural	6-8.5 feet with measurable velocity	No	3-4 Hours[a]
Upper Sammamish	Urban Residential, light commercial	Shallow flooding 0-3 feet	No	No Warning
Lower Sammamish	Agricultural, Recreational/Open Space, Urban residential	Shallow flooding 0-3 feet	No	No Warning
Evans Creek	Rural Residential/Urban Residential	Shallow flooding 0-3 feet	No	No Warning
Bear Creek	Rural Residential/Urban Residential	Shallow flooding 0-3 feet	No	No Warning

a. Flood warning system on Issaquah Creek is operated by the City of Issaquah.

Vulnerability Analysis

Public Safety and Health

Flooding in the Sammamish River basin has a variety of potential impacts on life, safety and health. Table 25 shows the length of unmapped floodplain in the Sammamish River basin. Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely.

TABLE 25.
UNMAPPED FLOODPLAIN IN THE SAMMAMISH RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	744
Total unmapped floodplain	255
Unmapped floodplain—incorporated areas	101
Unmapped floodplain—unincorporated King County	154

Critical Facilities

Critical facilities in the Sammamish River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 26 shows the critical facilities in the Sammamish River basin. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Management Plan* to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 26 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 26.
CRITICAL FACILITIES IN THE SAMMAMISH RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Flood Control Weir	Army Corps of Engineers	14.0		X
Redmond City Hall	City of Redmond	11.5	X	
Redmond Police Department	City of Redmond	11.5	X	
Support Service Center	Lake Washington School District	10.8	X	X
Metro Sewer Line[a]	Seattle Metro		X	
Hollywood Pump Station	King County			X

a. Considered a critical site due to its public health impacts

Land Use and Structures

In recent decades, substantial development has occurred in the Sammamish River basin. Extensive commercial and residential developments have been constructed throughout the floodplain. There are also several parks and other recreational facilities. Land uses in the upper 10 miles are mainly recreational and agricultural as well as urban commercial, specifically in the Cities of Redmond and Woodinville. The lower 5 miles include significant residential and commercial developments as well as some open space areas.

FEMA floodplain mapping shows 5,281 acres of mapped floodplain in the Sammamish River basin, including Lake Sammamish. Approximately 35 percent of this, or 1,824 acres, is along the Sammamish River mainstem. Table 27 defines the mapped floodplain in terms of incorporated and unincorporated areas.

TABLE 27.
SAMMAMISH RIVER BASIN MAINSTEM AREA

	FEMA-Mapped Floodplain Area (acres)
Mainstem Unincorporated	664
Mainstem Incorporated	1,161
Mainstem Total	**1,824**
Sammamish River Basin Total	***5,281***

The total area of regulatory floodplain for the Sammamish River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. No channel migration area has been mapped in the Sammamish River basin. Approximately 51 percent of the Sammamish River basin regulatory floodplain is in unincorporated King County. Table 28 shows the area of regulatory floodplain.

TABLE 28.
SAMMAMISH RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	5,008
Incorporated Areas	4,780
Total	**9,788**

Within the Sammamish River basin floodplain there are a total of 710 parcels. This is approximately 16 percent of the total number of parcels in King County floodplains (4,738). There are structures at risk from flooding on 363 of these parcels. The depth of flooding varies with location. Table 29 summarizes estimated flood loss potential. Of the 363 structures in the Sammamish River basin floodplain, 219 are residential structures and 144 are commercial.

Development Trends

The Sammamish River basin has been urbanizing rapidly since the 1950s. Future development is expected to continue throughout the Sammamish basin. Bellevue, Issaquah, Kirkland and Redmond have designated potential annexation areas, some of which are within the floodplain.

An assessment of buildable and potential buildable lands was completed to help determine future risk in the Sammamish River basin. Vacant lands from King County Assessor's data were used to determine potential buildable lands in the floodplain. Table 30 summarizes the number of vacant parcels susceptible to 100-year flood flows for the Sammamish River basin.

TABLE 29.
PARCELS IN THE 100-YEAR FLOODPLAIN IN THE SAMMAMISH RIVER BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
Issaquah Creek	245	130	459	$93,556,700	$79,454,600	$173,011,300	$34,165,478
Upper Sammamish	58	33	85	$16,639,000	$14,123,600	$30,762,600	$3,107,192
Lower Sammamish	248	126	771	$126,868,800	$300,403,900	$427,272,700	$66,088,858
Evans Creek	59	22	161	$3,715,700	$5,300,100	$9,015,800	$1,166,022
Bear Creek	100	52	122	$35,548,600	$85,871,800	$121,420,400	$18,891,796
Basin Totals	**710**	**363**	**1598**	**$276,328,800**	**$485,154,000**	**$761,482,800**	**$123,419,346**

a. The number of structures in each reach is an estimate generated as described in the introduction to this risk assessment.

TABLE 30.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN
SAMMAMISH RIVER BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
386	1,806	$126,757,300

Economic Impact

Historically, flooding has not caused significant property damage in this basin, aside from significant public and private property in the City of Issaquah in December 1995. This basin is fairly urbanized, with population centers in the Cities of Issaquah, Redmond, and Bothell. Within these population centers are businesses that employ many of the citizens of King County. However, past history shows that flooding in this basin has not shut down commerce for any prolonged period of time or had any measurable impact on tax base. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be minimal.

It is the working assumption of this Plan that cities such as Issaquah, Redmond and Bothell are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

Repetitive loss areas are not numerous in the Sammamish River basin. Table 31 summarizes the repetitive loss properties in the Sammamish River basin. Both properties are located on Issaquah Creek, but they are not clustered together. One is a single-family residential property and the other is a mobile home. Both lie within a mapped 100-year floodplain, so it is concluded that the cause of repetitive flooding for this basin is overbank riverine flooding reflected by the mapping for the basin.

TABLE 31.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SAMMAMISH RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
2	7.59	$332,000	$502,000

Insurance Analysis

Table 32 summarizes insurance statistics that can be used to help identify vulnerability within the Sammamish River Basin.

TABLE 32.
FLOOD INSURANCE STATISTICS FOR THE SAMMAMISH RIVER BASIN

Number of flood insurance policies in force within the basin	134
Number of policies within a mapped floodplain	39
Number of policies outside of a mapped floodplain	95
Estimated number of structures in mapped floodplains	363
Estimated percent of at risk structures with flood insurance coverage	11
Percent of flood insurance coverage outside of a mapped floodplain	71

Based on a review of this data, the following observations can be made:

- It is estimated that only 10 percent of the at-risk structures within the floodplain have insurance coverage in this basin. This is well below the national average of 18 percent.
- With a high percentage of flood insurance coverage outside the floodplain, an analysis of where these policies lie and why they are in force could be performed to determine future needs for mapping and hazard identification.
- The County's ongoing public information strategy that includes elements that promote flood insurance as a form of property protection should be continued or enhanced in this basin.

CEDAR RIVER BASIN PROFILE

The Cedar River flows west from the Cascade Mountains and then turns north to enter the south end of Lake Washington. The Cedar River is approximately 36 miles long from its mouth at Lake Washington in the City of Renton to Chester Morse Lake.

Hazard Profile

To provide additional detail of the characteristics of flooding in the Lower Cedar, the analysis of this basin is separated into five reaches:

- The Cedar River Reach—Headwaters to Landsburg diversion dam
- Lower Mainstem Reach— Landsburg diversion dam to Renton City Limits
- The Renton Reach—Renton City Limits to Interstate 405
- The Boeing Reach—Interstate 405 to Lake Washington
- Lake Washington Reach—The Lake Washington drainage basin, including May Creek

Past Events

Table 33 summarizes the history of flood events for the Cedar River basin since 1990. The most severe recent flooding events were the 1990, 1995 and 1996 federally declared disaster events.

TABLE 33.
CEDAR RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/09/1990	No	IV/5,308	Landslides and road damage due to flooding on small streams	Information not available
11/22/1990	Yes/#883	IV/10,800	Overbank flooding causing damage to both public and private property. Levee failure	$1.4 million for entire County
11/30/1995	Yes/#1079	IV/6,750	Overbank flooding causing damage to both public and private property.	$882,965 public property damage ($5.2 million for entire county
02/10/1996	Yes/#1100	IV/5,510	Overbank flooding causing damage to both public and private property. Levee failure	$1,385,193 in public property damage ($7.4 million for entire county

Severity is identified in terms of phases. Table 33 shows events that reached Phase III or above at the Landsburg gage. Below are the phases of flooding for the Cedar River:

- Phase I—The flow is greater than 1,000 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase II—The flow is greater than 2,800 cfs and Jones Road near 156 Street NE will be overtopped.
- Phase III—This is a moderate flooding event that exhibits flows greater than 3,500 cfs. This generally indicates that there is a strong chance of Lower Dorre Don and Byers Road being overtopped.

- Phase IV—This is considered extreme flooding and the flow is greater than 4,200 cfs. Some residential areas may experience dangerous high flows and home flooding. The Renton Airport experiences flooding and State Route 169 may be overtopped and closed.

Flood Characteristics

Tables 34 and 35 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Table 35 also shows warning time in terms approximate amount of lead time county officials have to initiate warning procedures within the reach. These warning times are estimates based on the length of travel time from gage to gage where available and practical experience based on observed conditions.

TABLE 34.
CEDAR RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs) [a]	Flood of Record, Date & Peak Flow (cfs)
Cedar Falls	12116500	33.2	84.2	8,930	11/24/1990; 12,300
Landsburg	12117500	23.4	121.0	10,300	11/18/1911; 14,200
Renton	12119000	1.6	184.0	12,000	11/24/1990; 10,600

a. Final Flood Frequency Analysis Curve For Year 2000 Floodplain Mapping on the Lower Cedar River march 2000 include with King county's submittal to FEMA for a revised Flood Insurance Study for the Cedar River. Period of record of USGS gage data used to derive values in table may differ from period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

TABLE 35.
CEDAR RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Cedar River	Open Space, Agricultural, Forest	1-6 feet	No	No Warning
Lower Mainstem	Rural Residential	1-6 feet	No	1.5 to 6 hours
Renton	Residential, Commercial, Some Open Space	3-6 feet	No	6 hours
Boeing	High density, Industrial, Commercial	1-3 feet	No	6 hours
Lake Washington	Forest, Rural Residential	3-6 Feet	No	0.5 to 1.5 Hours

Vulnerability Analysis

Public Safety and Health

Flooding in the Cedar River basin has a variety of potential impacts on life, safety and health. The mainstem Cedar upstream of the City of Renton is relatively narrow and steep. Flow velocities are generally high, and at many locations, the river approaches the steep valley walls at sharp angles, eroding the bases of several tall cliffs and at times, inducing landslides. The river's slope flattens in the city, reducing both its flow velocity and its sediment carrying capacity.

Due to the valley's steep gradient, flood flows are generally very fast along the Cedar River. Given the heavy residential use of the valley bottom, these high velocities represent significant threats to health and safety. Flows can be made even more hazardous by the significant amount of logs and debris, generally carried by floods (King County 1993b). In one neighborhood during the November 1990 flood, floodwaters carried several trees out of the channel and piled them in two large jams on the riverbank, nearby crushing a garage and a residential structure.

The Renton reach of the mainstem Cedar has a wider floodplain and gentler channel gradient. These characteristics contribute to sediment deposition and repeated flooding. Between River Miles 1 and 3, channel capacity had been restricted by the encroachment of fill that was placed through the years by adjacent commercial operations (King County 1993b).

Table 36 shows the length of unmapped floodplain in the Cedar River basin. Since mapping is not available in these floodplain areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. The lower Cedar River is highly urbanized and parts of the upper Cedar are beginning to urbanize. As more areas begin to urbanize the need for accurate floodplain mapping in unmapped areas becomes essential to minimize effects on public safety and health. King County has adopted comprehensive regulations to deal with the impacts of new development in the floodplain (see Appendix B of this Flood Hazard Management Plan). The impact of this regulatory program should hold in check the possible increase in vulnerability due to new development in this basin.

TABLE 36.
UNMAPPED FLOODPLAIN IN THE CEDAR RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	774
Total unmapped floodplain	624
Unmapped floodplain—incorporated areas	110
Unmapped floodplain—unincorporated King County	514

Critical Facilities

Critical facilities in the Cedar River basin were identified by anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 37 lists the critical facilities in the Cedar River basin. In Renton there are several roads and bridges in the floodplain as well as public facilities such as City Hall, a public library and the Renton Airport. However, since the Cedar River dredging project was implemented in the City of Renton, the area near the Renton Airport is generally considered at less risk from flooding. As long as there is periodic dredging of the channel, this is expected to remain so. Severe flood damage was experienced during the November 1990 floods, in which damage to river facilities totaled $1.2 million. Other than the public facilities in the City of Renton, there are no other identified critical facilities within the currently mapped Cedar river floodplain.

Critical facilities can also include critical infrastructure such as roads that could cause isolation and evacuation problems during flood events. King County has determined that the following major roadways and stream crossings (bridges or culverts) would be impassable during a 100-year flood event:

- Dorre Don Road
- Arcadia Road

TABLE 37.
CRITICAL FACILITIES IN THE CEDAR RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Levees and Revetments[a]	King County	NA		X
Landsburg Dam	City of Seattle	21.7		X
Cedar Falls Powerhouse	City of Seattle	33.7		X
Masonry Dam	Seattle Public Utilities	35.7		X
Leachate Line[b]	King County	At Rainbow	X	

a. There are several critical levees and revetments along the length of the Cedar River that overtop or could be subject to failure.
b. Considered a critical site due to its public health impacts.

Land Use and Structures

Land use in the Cedar River basin is dominated by forest uses (60.6 percent). The other main uses are residential; 21.3 percent can be classified as low-density development, 7.7 percent as medium and 0.9 percent as high density development. High-density development is located primarily in the Cities of Renton and Maple Valley. Damage in the City of Renton during the November 1990 flood was estimated to be $5 million.

FEMA floodplain mapping shows 2,556 acres of mapped floodplain in the Cedar River basin. Approximately 65 percent of this, or 1,661 acres, is along the Cedar River mainstem. Table 38 defines the mapped floodplain in terms of incorporated and unincorporated King County. A new flood study of the Cedar River, completed by King County has been reviewed by FEMA and will update the FIS floodplain and floodway data in late 2006.

TABLE 38.
CEDAR RIVER BASIN MAINSTEM AREA

	FEMA-Mapped Floodplain Area (acres)
Mainstem Unincorporated	1,355
Mainstem Incorporated	306
Mainstem Total	**1,661**
Cedar River Basin Total	***2,556***

The total area of regulatory floodplain for the Cedar River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. A channel migration study is currently being completed for the Cedar River but it is not included in the area of regulatory floodplain because it has yet to be finalized. Approximately 63 percent of the Cedar River basin regulatory floodplain is in unincorporated King County. The area of regulatory floodplain in the Cedar River basin is reflected in Table 39.

TABLE 39.
CEDAR RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	3,184
Incorporated Areas	1,913
Total	**5,097**

Within the Cedar River basin floodplain there are a total of 463 parcels, approximately 9 percent of the total number of parcels in King County floodplains (4,738). There are structures at risk from flooding on 219 of these parcels. The depth of flooding varies with location. Table 40 summarizes estimated flood loss potential. Of the 219 structures in the Cedar River basin floodplain, 200 are residential structures and 19 are commercial.

TABLE 40.
PARCELS IN THE 100-YEAR FLOODPLAIN IN THE CEDAR RIVER BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
Boeing	1	1	164	$65,619,600	$13,629,200	$79,248,966	$2,988,424
Renton	27	12	1032	$1,934,800	$1,852,600	$3,788,471	$518,728
Lower Mainstem	322	164	402	$18,079,700	$28,001,300	$46,081,888	$7,840,364
Upper Cedar	113	42	631	$16,842,675	$31,670,325	$48,513,786	$9,342,746
Basin Totals	**463**	**219**	**2229**	**$102,476,775**	**$75,153,425**	**$177,633,111**	**$20,690,262**

a. The number of structures in each reach is an estimate generated as described in the introduction to this risk assessment.

Development Trends

The greater part of the Cedar River floodplain is in unincorporated King County, with a smaller portion in the City of Renton. There is commercial, industrial and residential development throughout the incorporated areas of the Cedar River floodplain. Residential development has also occurred in unincorporated King County along the upper floodplain, which is likely due to its proximity to Renton. Renton is expected to annex portions of the land along the Cedar River. There is expected to be a significant amount of growth in Renton during the 2001 to 2022 planning period (King County 2005).

An assessment of buildable and potential buildable lands was completed to help determine future risk in the Cedar River basin. Vacant lands from King County Assessor's data were used to determine potential buildable lands in the floodplain. Table 41 summarizes the number of vacant parcels susceptible to 100-year flood flows for the Cedar River basin. King County and City of Renton regulations currently in effect strive to limit the impact of new development on the floodplain and the impact of flooding on new development.

TABLE 41.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN
CEDAR RIVER BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
278	820	$46,052,600

Economic Impact

Based on existing land use and past experience, flooding along the Boeing and Renton reaches of the Cedar River would have the most severe economic impact within the basin. Both of theses reaches contain the major population centers in the basin, and the Boeing reach contains areas of major employment for the entire County. The functional down time associated with the flooding typical for this basin could have a significant financial impact on the region. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Renton are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

There are 17 repetitive loss properties in the Cedar River basin , five of which are mitigated. Table 42 summarizes the unmitigated repetitive loss properties in the Cedar River basin. The 12 unmitigated properties are located in no consistent location in the basin and all are single-family residential properties. They all lie within a mapped 100-year floodplain, so it is concluded that the cause of repetitive flooding for this basin is overbank riverine flooding reflected by the mapping for the basin.

TABLE 42.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE CEDAR RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
12	7.83	$931,000	$1,287,000

Insurance Analysis

Flood insurance statistics can help identify vulnerability by regionally isolating areas where claim activity is high and a high rate of flood insurance is in force. Table 43 summarizes insurance statistics that can be used to help identify vulnerability within the Cedar River Basin. Based on a review of this data, the following observations can be made:

- The estimated percentage of flood insurance coverage for structures at risk is well above the national average (18 percent).
- With a relatively high percentage of flood insurance coverage outside the floodplain, an analysis of where these policies lie and why they are in force could be performed to determine future needs for mapping and hazard identification.

- The County's ongoing public information strategy that includes elements that promote flood insurance as a form of property protection should be continued in this basin.

TABLE 43.
FLOOD INSURANCE STATISTICS FOR THE CEDAR RIVER BASIN

Number of flood insurance policies in force within the basin	287
Number of policies within a mapped floodplain	138
Number of policies outside of a mapped floodplain	149
Estimated number of structures in mapped floodplains	219
Estimated percent of at risk structures with flood insurance coverage	63
Percent of flood insurance coverage outside of a mapped floodplain	52

GREEN RIVER BASIN PROFILE

The Green/Duwamish River is a 93-mile long river system that originates in the Cascade Mountains at an approximate elevation of 4,500 feet. The headwaters are in the vicinity of Blowout Mountain and Snowshoe Butte, about 30 miles northeast of Mount Rainier (King County 2002b). The river basin is part of Watershed Resource Inventory Area 9.

Hazard Profile

For the purposes of this risk assessment, the Green River basin can be divided into five reaches:

- The Upper Green River reach —Headwaters to the Howard Hanson Dam at River Mile 64.5
- The Gorge Reach—Howard Hanson Dam to Flaming Geyser park at River Mile 45.2
- The Middle Green River reach—Flaming Geyser Park at River Mile 45.2 to Auburn city limit at River Mile 31.8
- The Lower Green River reach—Auburn city limit at River Mile 31.8 to confluence with the Black River at River Mile 11.
- The Mill Creek reach—Mill Creek headwaters to confluence at Tukwila

Past Events

Historically, there have been several severe flooding events in the Green River basin, with records dating back to 1933. Table 44 summarizes the history of flood events for this basin since 1990. The most severe recent flooding event was the February 1996 flood.

Severity is identified in terms of phases. Table 44 shows events that reached Phase III or above at the Auburn gage. Below are the phases of flooding for the Green River.

- Phase I—The flow is greater than 5,000 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase II—The flow is greater than 7,000 cfs and lowland flooding in the valley upstream of Auburn will occur.
- Phase III—This is a moderate flooding event and exhibits flows greater than 9,000 cfs. This generally means that flooding of varied depths will occur in the valley upstream of Auburn and lower Mill Creek. Roads that may be overtopped are SE Green Valley Road and West Valley Road.
- Phase IV—This is considered extreme flooding and the flow is greater than 12,000 cfs. Levees may exhibit seepage or weaken from saturation.

Flood Characteristics

Tables 45 and 46 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Table 46 also shows warning time in terms of length of time from gage to gage where available. This is shown as the time that it takes peak flows to travel downstream from one gage to the next. Table 45 also shows the calculated 100-year flow for each gage.

TABLE 44.
GREEN RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/09/1990	No	III/10,800	No significant public or private property damage reported for this event	Information not available
11/09/1990	Yes/#883	III/10,200	Overbank flooding. Property damage to both public and private property. Levee damage.	$5.6 million for entire county
11/22/1990	Yes/#896	III/11,500	Overbank flooding. Property damage to both public and private property. Levee damage.	$1.4 million for entire county
02/19/1991	No	III/10,300	No significant public or private property damage reported for this event	Information not available
02/19/1995	No	III/9,450	No significant public or private property damage reported for this event	Information not available
12/01/1995	Yes/#1079	III/11,700	Overbank flooding. Property damage to both public and private property. Levee damage.	$2,402,374 in damage to public property
02/10/1996	Yes/#1100	IV/12,400	Overbank flooding. Property damage to both public and private property. Levee damage.	$1,728,704 in damage to public property
03/20/1997	Yes/#1172	III/9,290	No significant public or private property damage reported for this event	Information not available
11/26/1999	No	III/9,200	No significant public or private property damage reported for this event	Information not available
12/16/1999	No	III/9,130	No significant public or private property damage reported for this event	Information not available

TABLE 45.
GREEN RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)[a,b]	Flood of Record, Date & Peak Flow (cfs)
Howard Hanson Dam	12105900	63.8	221.0	Maximum flow release to meet target of 12,000 cfs at Auburn	12/21/1960; 12,200 (pre-dam)
Auburn	12113000	32.0	399.0	12,000 (as regulated by Howard Hanson Dam)	11/23/1959; 28,100 (pre-dam)
Tukwila	12113350	NA	440.0	12,400	01/31/1965; 12,100

a. FEMA (2005)

b. Affected by regulation at the Howard Hanson Dam

TABLE 46.
GREEN RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Upper Green	Forestry, flood control	1-6 feet	Yes	No Warning
Gorge	Forestry, Open Space/Recreation	Up to 20 feet with measurable velocity contained in gorge channel	Yes	Not applicable. Nothing to warn.
Middle Green	Agricultural, Rural Residential	Shallow Flooding; 1 – 3 feet	Yes	8 hours
Lower Green	Urban Residential, Commercial, Light Industrial	1 – 6 feet	No	12 hours
Mill Creek	Some agricultural, mixed rural and urban residential	Up to 12 feet in Johnson Creek vicinity, 1 – 6 feet everywhere else	No	No warning

Vulnerability Analysis

Public Safety and Health

Flooding in the Green River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption caused by flooding have been significant. The river's historical floodplain on the Lower and Middle Green River includes the Southcenter commercial area and much of the region's industrial and warehouse capacity. The Middle Green River is a broad valley. The Middle and Lower Green River areas are protected by the Howard Hanson Dam and extensive flood containment levees and pumps. The Upper Green River is steep with high velocity flows.

Table 47 shows the length of unmapped floodplain in the Green River Basin. Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. There are significant amounts of development throughout the Green River valley. It is home to several commercial and industrial centers and has a growing residential population. With this growth, it is likely that public health and welfare will be at risk from flooding. The population in the Green River basin, estimated to be 564,000 in the 2000 census, is mostly concentrated in the lower end of the basin, but the fastest rate of population increase is in the suburban cities and nearby unincorporated areas east of Seattle (King County 2002b).

TABLE 47.
UNMAPPED FLOODPLAIN IN THE GREEN RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	1,276
Total unmapped floodplain	1,058
Unmapped floodplain—incorporated areas	90
Unmapped floodplain—unincorporated King County	966

Critical Facilities

Critical Facilities in the Green River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 48 lists the critical facilities in the Green River basin. King County has established policies in both its Regional Hazard Mitigation Plan and the Flood Hazard reduction Plan to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 48 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 48.
CRITICAL FACILITIES IN THE GREEN RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Kent Junior High	Kent School District	10.0	X	
Fire Station 14	City of Renton	1.0	X	
Neely O'Brien Elementary	Kent School District	20.0	X	
Tukwila Fire Station	City of Tukwila	13.0	X	
Pipeline #5 (Water Supply)	King County		X	
Levees[a]	King County and private property owners			X
Howard Hanson Dam	Army Corps of Engineers	64.5		X

a. Various levees along the Green River are in need of repair. Further analysis will be done to determine which should be repaired.

Land Use and Structures

Land use in the Green River basin varies significantly among the lower, middle and upper portions. The land in the Upper Green River is primarily forestland. The Middle Green River is primarily farmland and a mix of urban and rural residential. The major land uses are residential (50 percent), forestry (27 percent) and agriculture (12 percent) (King County 2005). Several large state and county parks abut the river in this segment. The Lower Green River contains less farmland and is mainly urban. Except for occasional stretches of parkland, a mixture of residential, commercial and industrial land uses are the main land uses. Residential development (50 percent), industrial development (17 percent), and commercial development (10 percent) are the primary uses along the Lower Green River.

FEMA floodplain mapping shows 8,753 acres of mapped floodplain in the Green River basin. Approximately 44 percent of this, or 3,821 acres, is along the Green River mainstem. Table 49 defines the mapped floodplain in terms of incorporated and unincorporated King County. A floodplain study of the Lower and Middle Green River has been initiated in 2006 and will be used to update the floodplain and floodway data.

TABLE 49.
GREEN RIVER BASIN MAINSTEM AREA

	FEMA-Mapped Floodplain Area (acres)
Mainstem Unincorporated	2,465
Mainstem Incorporated	1,357
Mainstem Total	**3,821**
Green River Basin Total	***8,753***

The total area of regulatory floodplain for the Green River basin includes all portions of the Flood Insurance Rate Map's flood zones and King County's regulatory floodplain and floodway map that include most current floodplain studies. A channel migration study is completed for portions of the Green River, and the results are included in the area of regulatory floodplain. The area of regulatory floodplain is shown in Table 50. Approximately 57 percent of the Green River regulatory floodplain is in unincorporated King County.

TABLE 50.
GREEN RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	11,744
Incorporated Areas	8,715
Total	**20,459**

Within the Green River basin floodplain there are a total of 1,161 parcels. This is approximately 25 percent of the total number of parcels in King County floodplains (4,738). There are 496 parcels with structures at risk from flooding. Of these, 312 are residential structures and 184 are commercial. The depth of flooding varies with location. Table 51 summarizes estimated flood loss potential.

TABLE 51.
PARCELS IN THE 100-YEAR FLOODPLAIN IN THE GREEN RIVER BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
Upper Green	1	1	1	$50,000	$229,000	$279,000	$20,000
Gorge	53	32	351	$4,994,000	$6,794,000	$11,788,436	$2,717,600
Middle Green	422	220	1470	$26,525,000	$44,871,000	$71,398,112	$9,871,620
Lower Green	549	196	1955	$67,511,700	$842,829,800	$910,344,200	$235,992,344
Mill Creek	137	48	740	$239,666,400	$43,356,500	$283,023,825	$12,139,820
Basin Totals	**1161**	**496**	**4516**	**$338,697,100**	**$937,851,300**	**$1,276,554,573**	**$260,741,384**

a. The number of structures in each reach is an estimate generated as described in the introduction.

Development Trends

The Green River basin has been urbanizing since the 1970s. In the 1990s, Black Diamond, Enumclaw and Covington experienced rapid growth. Land development estimates indicate that the largest areas of future development will be in the Lower and Middle Green River areas.

An assessment of buildable and potentially buildable lands was completed to help determine future risk in the Green River basin. Vacant lands from King County Assessor's data were used to determine potentially buildable lands in the floodplain. Table 52 summarizes the number of vacant parcels susceptible to 100-year flood flows for the Green River basin.

TABLE 52.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN
GREEN RIVER BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
610	3,669	$175,737,200

Economic Impact

Based on existing land use and past experience, flooding along the middle and lower reaches of the Green River would have the most severe economic impact in the basin. Theses reaches contain the major population/employment centers in the basin and in the county. The river flows in the lower reaches of the Green River are contained by levee systems, and costs associated with flood fighting and levee repair have been the highest of all basins in King County. Such costs can have an impact on the tax base in the long run. The functional down time associated with the flooding typical for this basin could have a significant financial impact on the region. No detailed analysis of this potential impact was performed for this risk assessment although a risk analysis on levees will be performed beginning 2007. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Auburn, Kent, Renton and Tukwila are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

Based on the County's review of repetitive loss data provided by FEMA, there is one repetitive loss property in the Green River basin that has been mitigated by a stormwater drainage project. The property is single-family residential. This property is currently not mapped in the 100-year floodplain which means that the flooding was likely due to storm water drainage problems.

Insurance Analysis

Flood insurance statistics can help identify vulnerability by regionally isolating areas where claim activity is high and a high rate of flood insurance is in force. Table 53 summarizes insurance statistics that can be used to help identify vulnerability within the Green River Basin. Based on a review of this data, the following observations can be made:

- It is estimated that only 7 percent of the at-risk structures in the floodplain have insurance coverage in this basin. This is well below the national average of 18 percent.

- With a high percentage of flood insurance coverage outside of the floodplain (67 percent), an analysis of where these policies lie and why they are in force could be performed to determine future needs for mapping and hazard identification.
- The County's ongoing public information strategy that includes elements that promote flood insurance as a form of property protection should be continued or enhanced in this basin.

TABLE 53.
FLOOD INSURANCE STATISTICS FOR THE GREEN RIVER BASIN

Number of flood insurance policies in force within the basin	113
Number of policies within a mapped floodplain	37
Number of policies outside of a mapped floodplain	76
Estimated number of structures in mapped floodplains	496
Estimated percent of at risk structures with flood insurance coverage	7
Percent of flood insurance coverage outside of a mapped floodplain	67

WHITE RIVER BASIN PROFILE

The White River is a glacially-fed river system that originates on the northeast face of Mount Rainier and is a part of Water Resource Inventory Area 10. The White River flows in northwest from its headwaters and then turns south to join with the Puyallup River near the City of Sumner. The Puyallup River flows for 10 miles through the Cities of Puyallup and Tacoma to Commencement Bay in south Puget Sound. The White River drains an area of approximately 494 square miles (King County 2002d).

Hazard Profile

The analysis of this basin is separated into five reaches:

- Upper White/Greenwater Reach—Basin divide to Mud Mountain Dam
- Boise Creek Reach—Boise Creek headwaters to confluence with the White River
- Dams Reach—Mud Mountain Dam to SR 410
- Natural Reach—SR 410 to upper end of levee protected channel
- Lower White—Upper end of levee protected channel to King County/Pierce County line

Past Events

Historically, there have been several severe flooding events in the White River basin. Table 54 summarizes the history of flood events for this basin since 1990.

TABLE 54.
WHITE RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/11/1990	No	IV/13,000	No significant public or private property damage reported for this event	No information available
12/02/1995	Yes/#1079	IV/15,000 @ Auburn	Overbank flooding. Property damage to both public and private property.	$304,054 in damage to public facilities
02/10/1996	Yes/#1100	III/10,600	Overbank flooding. Property damage to both public and private property.	$20,213 in damage to public facilities
12/30/1996	No	III/>8,000	No significant public or private property damage reported for this event	No information available

Severity is identified in terms of phases. Table 54 shows events that reached Phase III or above at the Buckley gage, unless otherwise indicated. Below are the phases of flooding for the White River:

- Phase I—The flow is greater than 2,500 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase II—The flow is greater than 6,000 cfs and Red Creek area residents may experience overtopped roads and high water.
- Phase III—This is moderate flooding and exhibits flows greater than 8,000 cfs. Red Creek area residents may experience dangerous, high velocities, debris flow, and residential flooding.
- Phase IV—This is considered extreme flooding. The flow is greater than 12,000 cfs and there is likely to be significant overbank flooding, possibly inundating areas of State

Route 410 and Sumner. Area residents may experience dangerous high velocities and debris flows.

Flood Characteristics

Tables 55 and 56 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach.

TABLE 55.
WHITE RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flow (cfs) [a]	Flood of Record, Date & Peak Flow (cfs)
Buckley	12098500	27.9	401.0	17,600 (maximum release from Mud Mountain Dam)	12/01/1933; 28,000 (pre-dam)
Auburn	12100496	6.30	464.0	18,370	02/10/1996; 15,000
Greenwater	12097500	1.10	73.5	5,776	12/02/1977; 10,500

a. FEMA 2005.

TABLE 56.
WHITE RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Channel Migration Zone (yes/no)	Approximate Warning Time
Upper White/ Greenwater	Low density Residential, Forestry	Shallow Flooding, 0-3 feet	No	No warning
Boise Creek	Low density Residential, Agricultural	Shallow Flooding, 0-3 feet	No	No warning
Dams	Low density Residential, Agricultural	6 feet or greater with measurable velocities	No	2-4 hours
Natural	APD, recreational-open space, Agricultural	Shallow flooding 0-6 feet with some measurable velocity	No	2-4 hours
Lower White	Mixed Use: Urban residential, commercial, industrial	Shallow flooding,0-6 feet with some measurable velocity	No	4-5 hours

Vulnerability Analysis

Public Safety and Health

Flooding in the White River basin has a variety of potential impacts on life, safety and health. The large amount of sediment carried by the White River affects its drainage pattern and can cause flooding in the

valley lands near the cities of Auburn and Pacific. In this area, the gradient lessens, the velocity slows and the sediments and debris tend to settle out onto the floodplain (King County 1993b). Additionally, much of the lower White River in the Auburn and Pacific area has been channelized, and overbank flows occur only in rare events.

Table 57 shows the length of unmapped floodplain in King County for the White River basin. Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. This is more of a concern in areas that are becoming more urbanized, such as the lower White River near Auburn and Pacific.

TABLE 57.
UNMAPPED FLOODPLAIN IN THE WHITE RIVER BASIN

Description	Length (miles)
Total streams, lakes major rivers and tributaries	311
Total unmapped floodplain	229
Unmapped floodplain—incorporated areas	13
Unmapped floodplain—unincorporated King County	216

Critical Facilities

Critical Facilities in the White River basin were identified by using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.). Table 58 lists the critical facilities in the White River basin.

Land Use and Structures

Approximately 175 square miles in the White River basin is owned and managed by the Mount Baker-Snoqualmie National Forest. Another 90 square miles of the basin is part of Mount Rainier National Park. In this upper portion, the basin is mainly undeveloped but includes some scattered residential and commercial property around Greenwater (King County 1993b). In the lower areas of the basin, there are some agricultural lands and a mix of residential, commercial and industrial uses closer to and in the cities. Upstream of the Muckleshoot Indian Reservation, the river is unconstrained and the valley is mostly undeveloped (King County 1993b).

FEMA floodplain mapping shows 3,025 acres of mapped floodplain in the White River basin. Approximately 74 percent of this, or 2,246 acres, is along the White River mainstem. Table 59 defines the mapped floodplain in terms of incorporated and unincorporated King County. One of the major risks in the White River basin is that there are significant channel migration hazards related to the river's significant sediment load and debris local, especially in the upper basin. Floodplain maps for the White River are outdated and do not reflect recent changes in several channel locations.

The total area of regulatory floodplain for the White River basin includes all portions of the FEMA flood zones. A channel migration study will be completed on the White River but is not currently included in the area of regulatory floodplain. About 91 percent of the regulatory floodplain in the basin is in unincorporated King County. Table 60 shows the area of regulatory floodplain.

TABLE 58.
CRITICAL FACILITIES IN THE WHITE RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Facility
Pump Station	King County—Wastewater Treatment Division	6.5	X	
Natural Gas Pipeline[a]	Williams	10.8	X	
Water Supply Pipeline #1[b]	Tacoma Public Utilities	23.3	X	
Water supply well-field[c]	City of Auburn	Approximately 9.0	X	
Auburn Wall[d]	King County—Water and Land Resources Division	8.1		X
Riverside High School[e]	Riverside High School	6.5	X	
Mount Baker Middle School[f]	Mount Baker Middle School	7.0	X	
Abandoned Land Fill[g]	King County	6.0	X	

a. Pipeline exposed in 1995 flood. In 2003, Williams replaced crossing with new pipeline well-below expected scour depth.
b. In 2003, TPU replaced crossing with the new pipeline well-below expected scour depth.
c. Only a major avulsion would affect the well-field
d. This facility protects the City of Auburn from any potential avulsion into the historic White River channel.
e. This is on the left bank and is built on fill and will likely be in a moderate channel migration zone.
f. This is on the right bank and is built on fill and will likely be in a moderate channel migration zone.
g. Considered a critical site due to its potential public health impacts.

TABLE 59.
WHITE RIVER BASIN MAINSTEM AREA

	FEMA-Mapped Floodplain Area (acres)
Mainstem Unincorporated	1,937
Mainstem Incorporated	308
Mainstem Total	**2,246**
White River Basin Total	***3,025***

TABLE 60.
WHITE RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	5,500
Incorporated Areas	550
Total	**6,050**

Within the White River basin floodplain there are a total of 175 parcels. This is approximately 4 percent of the total number of parcels in King County floodplains (4,738). There are structures at risk from flooding on 64 of these parcels. The depth of flooding varies depending on location. Table 61 summarizes estimated flood loss potential. Of the 64 identified structures in the White River basin floodplain, 61 are residential structures and 3 are commercial.

TABLE 61.
PARCELS IN THE MAPPED 100-YEAR FLOODPLAIN IN THE WHITE RIVER BASIN

Reach	Parcels	Structures[a]	Total Area (acres)	Assessed Land Value	Assessed Value Improvements	Total Assessed Value	Estimated Flood Loss Potential
Upper White/ Greenwater	0	0	0	0	0	0	$0
Boise Creek	64	33	247	$4,643,000	$6,943,000	$11,586,000	$1,527,460
Dams	29	11	117	$1,579,100	$3,246,860	$4,825,960	$1,298,744
Natural	65	19	251	$3,837,100	$4,635,300	$8,472,400.00	$1,297,884
Lower White	17	1	2	$227,900	$147,100	$375,000	$41,188
Basin Totals	**175**	**64**	**617**	**$10,287,100**	**$14,972,260**	**$25,259,360**	**$4,165,276**

a. The number of structures in each reach is an estimate generated as described in the introduction to this risk assessment.

Development Trends

The majority of the White River basin is in unincorporated King County, with a smaller portion in the cities and the Muckleshoot Indian Tribe Reservation. There is commercial, industrial and residential development throughout the incorporated areas of the White River floodplain. The majority of development is along the White River in the Auburn and Pacific area. This area has significant potential for new residential, commercial and industrial development.

An assessment of buildable and potentially buildable lands was completed to help determine future risk in the White River basin. Vacant lands from King County Assessor's data were used to determine potentially buildable lands in the floodplain. Table 62 summarizes the number of vacant parcels susceptible to 100-year flood flows for the White River basin.

TABLE 62.
VACANT LANDS IN THE 100-YEAR FLOODPLAIN
WHITE RIVER BASIN

Number of Vacant Parcels	Total Area (acres)	Total Land Value
215	2,348	$23,664,345

Economic Impact

The economic impact for this basin is based on a review of historical flooding, the inventory of structures at risk, and current land use in the basin. The current land use is predominantly open space, forestry and agricultural in the upper reaches, and the urbanized lower reaches are channelized and protected by flood

control facilities. The safety provided by flood control facilities is dependent on the functionality and integrity of the facilities at the time of a flood event. Failure of a flood control facility in this basin could have a measurable economic impact within the basin due to functional downtime, flood fighting costs and facility repair. However, since these costs have not been significant during past events, King County considers the possible economic impact of typical flooding in this basin to be minimal.

Repetitive Loss areas

There currently are no repetitive loss properties in this basin. However, at one time, this basin included a single property with the most flood insurance claims of any property in the County. This property was located along the Boise Creek reach of this basin, and was mitigated through a property acquisition by King County in 2000.

Insurance Analysis

Flood insurance statistics can help identify vulnerability by regionally isolating areas where claim activity is high and a high rate of flood insurance is in force. Table 63 summarizes insurance statistics that can be used to help identify vulnerability within the White River Basin.

TABLE 63.
FLOOD INSURANCE STATISTICS FOR THE WHITE RIVER BASIN

Number of flood insurance policies in force within the basin	17
Number of policies within a mapped floodplain	11
Number of policies outside of a mapped floodplain	6
Estimated number of structures in mapped floodplains	64
Estimated percent of at risk structures with flood insurance coverage	17
Percent of flood insurance coverage outside of a mapped floodplain	35

Based on a review of this data, the following observations can be made:

- The flood insurance statistics for this basin mirror the low vulnerability of structures identified in the land use and structures analysis.
- The estimated percent of flood insurance coverage for at-risk structures is comparable to the national average (18 percent).
- Although the percent of flood insurance coverage is fairly high, which can be attributed to the low number of policies in force, there appears to no apparent indication of flood risks not currently mapped or identified by King County due to the presence of flood insurance policies.
- The County's ongoing public information strategy that includes elements that promote flood insurance as a form of property protection should be continued in this basin.