SNOQUALMIE WATERSHED AQUATIC HABITAT CONDITIONS REPORT: SUMMARY OF 1999-2001 DATA

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Department of Natural Resources and Parks
Water and Land Resources Division

LIST OF ABBREVIATIONS AND ACRONYMS

ACOE........ Army Corps of Engineers
AFS .... American Fisheries Society
APD .... Agricultural Production District
C................ Celsius
cfs.............. cubic feet per second
DEM.......... Digital Elevation Model
DNRP........ Department of Natural Resources and Parks
DO............. dissolved oxygen
DOT .... Department of Transportation
ESA........... Endangered Species Act
FPD .... Forest Production District
GIS .... Geographic Information System
GLO .... General Land Office
GPS .... Global Positioning System
LB .... left bank
LIDAR ...... Light Detection and Ranging
LWD .... large woody debris
mm .... millimeters
NOAA....... National Oceanic and Atmospheric Administration
OHWM ..... ordinary high water mark
RB .... right bank
RM .... river mile
SARA........ Snoqualmie Aquatic Resources Assessment
USFS......... United States Forest Service
WDFW...... Washington Department of Fish and Wildlife
WDOE ...... Washington Department of Ecology
WFPB........ Washington Forest Practices Board
WLRD....... Water and Land Resources Division
WRIA........ Water Resources Inventory Area

INTRODUCTION

Scope and Purpose of Report

This report summarizes and interprets data collected in the field from 1999-2001 about habitat conditions for multiple species of salmonids and other aquatic biota in aquatic ecosystems of the Snoqualmie River Watershed, including the mainstem Snoqualmie River and several of its tributaries. This information was collected by King County Water and Land Resources Division (WLRD) staff and consultants. Previously existing information about habitat conditions for fish and other aquatic biota is also summarized from reports on existing conditions in the overall Snohomish River Basin (Water Resource Inventory Area 7 [WRIA 7]).

Until recently, there has been a paucity of data about some areas and issues in the Snoqualmie Watershed. Largely this was because the watershed was located outside of the King County surface water management service area and thus funding was low or nonexistent to do substantive inventory and analysis. In 2000, the King County Council approved the establishment of a Rural Drainage Program that extends surface water management services to the rural areas of the county including the Snoqualmie Watershed. This service area expansion provided additional emphasis and some funding for investigating baseline habitat conditions in the watershed and implementing habitat protection and restoration actions.

Information from this report will be used as part of a larger effort to assess what is currently known and what additional information is needed about the Snoqualmie Watershed in order for King County to proceed with long-term salmon conservation and recovery in the watershed and in WRIA 7 overall, as part of the regional, state, and federal efforts to recover salmon. The report is the first step in framing the questions that need to be answered in the Snoqualmie Watershed portion of the WRIA 7 strategic assessment and in building the Snoqualmie Aquatic Resources Assessment (SARA), which will be a comprehensive technical study program for the Snoqualmie Watershed. King County WLRD staff are currently developing a scope for SARA. The scope will likely include hydrologic mapping and modeling of catchment and subcatchment basins in King County's portion of WRIA 7, geologic interpretation of surficial geology maps, wetland assessment, and biologic assessment (i.e., Snoqualmie River valley floor habitat assessments and salmonid distribution mappings). Implementation of SARA is expected to take place in 2003 and 2004, concurrent with the overall WRIA 7 strategic assessment.

Summary of Previously Existing Information

This section summarizes information about land use, geomorphology, hydrology, water quality, fish populations, and aquatic and riparian habitat in the Snoqualmie Watershed. This information was published prior to the King County WLRD field studies that were conducted from 1999 to 2001.

Figure 1. Snoqualmie Watershed and Snohomish Basin WRIA

The Snoqualmie Watershed comprises 692 square miles and nearly half of the Snohomish River Basin (Figure 1). Approximately 75% of the Snoqualmie Watershed lies within the Forest Production District (FPD). This largely undeveloped headwaters area helps to protect water quality and to maintain hydrologic, sediment, and large woody debris (LWD) functions in waterbodies downstream from the FPD. Most of the Snoqualmie River floodplain downstream of Snoqualmie Falls is zoned for low density agricultural uses, specifically 70.4% for agriculture and 22.2% for rural residential land use.

Between 1980 and 2000, the population in the Snoqualmie Watershed nearly doubled, from just under 20,000 to approximately 40,000 residents. The Puget Sound Regional Council predicts that the population will further increase to over 70,000 residents by 2020 (King County WLRD, 2001).

The major tributaries of the Snoqualmie River begin high in the Cascade Mountains, but none of these streams is fed by glaciers. The Snoqualmie River flows over a relatively unconfined, alluvial floodplain that is divided into two segments by a major bedrock protrusion at Snoqualmie Falls (Pentec Environmental and NW GIS, 1999). As indicated in Figure 2, the river gradient is gentle below the Falls and much steeper above.

The bedrock ledge that forms Snoqualmie Falls resists erosion and traps most of the coarse sediment (bedload) transported from headwater source areas. Above the Falls, sediment deposition is prominent in the South Fork Snoqualmie River, the North Fork Snoqualmie River just above the confluence with the mainstem Snoqualmie, and the mainstem Snoqualmie below the confluence of the North Fork and Middle Fork. The Raging and Tolt Rivers and Tokul Creek supply most of the bedload sediment to the Snoqualmie River below the Falls. Deposition of bedload sediment is concentrated at and just downstream of the confluences of these waterbodies with the Snoqualmie (Booth et al., 1991; Anderson, 2002).

Hydrology and Water Quality

Because a large portion of the Snoqualmie Watershed drains high-elevation areas of the Cascade Mountains, snowmelt strongly influences the hydrology of the watershed. There are two distinct periods of high monthly flows: November, December, and January due to winter rainfall and increased meltwater from rain-on-snow events, and May and June due to snowmelt at high elevations (Figures 3-4). The lowest mean monthly flows occur in August at almost all gauges in the watershed because most of the snow has melted and there is usually little rainfall in western Washington during the summer months. Low elevation subwatersheds such as that of the Raging River do not benefit from a winter snow pack; thus their flows have no springtime increase (Figure 4). Mean monthly flows in low elevation basins increase from September through January as rainfall increases, and then decrease to the low point in August (Pentec Environmental and NW GIS, 1999).

Water quality problems have been identified in several waterbodies of the Snoqualmie Watershed. The mainstem Snoqualmie, South Fork Snoqualmie, and Raging Rivers were included on the Washington Department of Ecology's 1998 Section 303(d) List of Impaired Waterbodies because State of Washington water quality standards were violated for temperature in the mainstem and South Fork Snoqualmie, and for pH in the South Fork Snoqualmie and Raging Rivers (Washington Department of Ecology, 2000). Dissolved oxygen (DO) levels and fecal coliform bacteria counts have not met state water quality standards in the past in the mainstem Snoqualmie River; nutrient levels have been elevated as well. Low gradient reaches of Kimball and Patterson Creeks exhibit low DO levels that violate State of Washington water

quality standards. High fecal coliform counts are a concern in Ames, Cherry, Kimball, and Patterson Creeks, and in the Raging River (City of Snoqualmie, 2001; Pentec Environmental and NW GIS, 1999; Fricke, 1995; Joy, 1994; Ehinger, 1993).

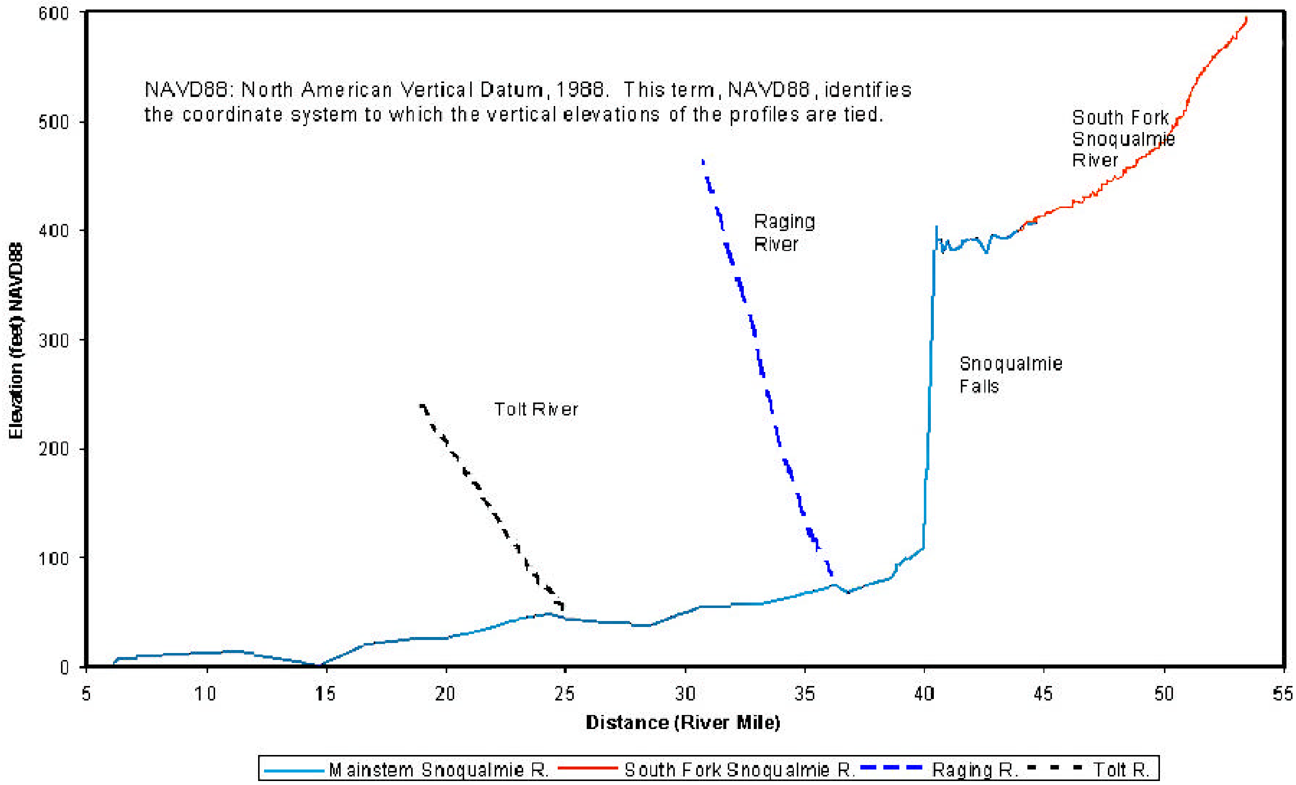

Figure 2. Longitudinal Profiles of Mainstem Snoqualmie River and Selected Tributaries

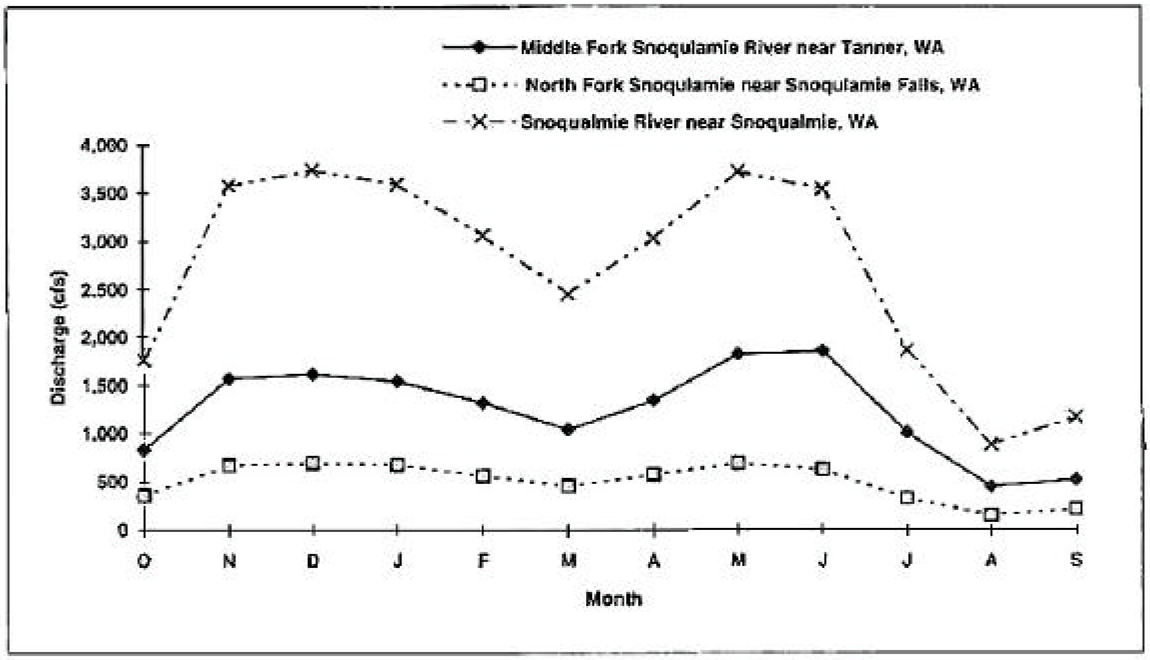

Figure 3. Mean Monthly Stream Discharge, Upper Snoqualmie River Watershed (Pentec Environmental, Inc. and NW GIS, 1999)

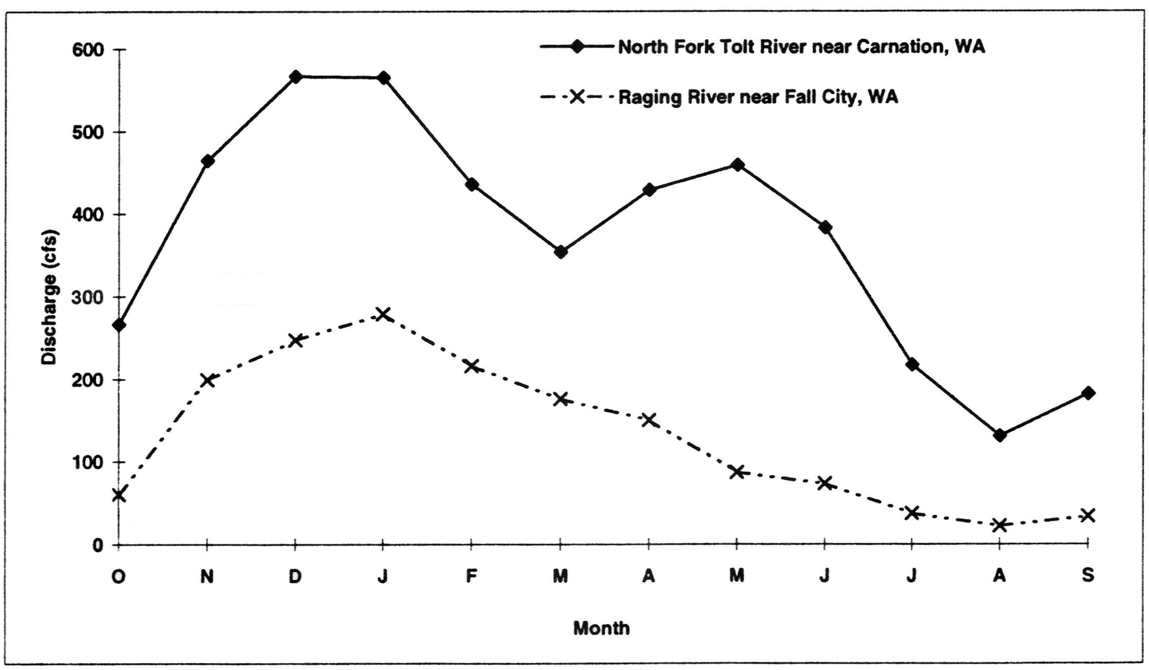

Figure 4. Mean Monthly Stream Discharge in the North Fork Tolt and Raging Rivers (Pentec Environmental, Inc. and NW GIS, 1999)

Groundwater is important in the Snoqualmie Watershed as a source of stream flow during the low flow months, as a potential large-scale source of human water supply for municipalities, and as the primary source of water for rural homes unconnected to regional water supply systems. Two large aquifer systems are located in the Snoqualmie Valley beneath the mainstem Snoqualmie River, one above and one below Snoqualmie Falls. Another aquifer is located beneath the Tolt River delta. Several seepage studies have been conducted to quantify how much groundwater discharge the Snoqualmie River receives directly from the valley aquifers during the dry season. Groundwater could be contributing as much as 22% of the total mean August flow to the Snoqualmie River at the City of Carnation, or 40% of the median seven-day low flow at Carnation (Pentec Environmental and NW GIS, 1999).

Fish Populations

The Snoqualmie Watershed contains some of the healthiest aquatic habitat remaining in King County and supports wild populations of chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), and pink salmon (*Oncorhynchus gorbuscha*), steelhead (*Oncorhynchus mykiss*), rainbow (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*), and native char, i.e., Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) (King County WLRD, 2001). Salmonid spawning in the mainstem Snoqualmie River occurs in the gravel riffles below the confluence with the Tolt River (RM 24), at the confluence with the Raging River (RM 35), and in a section of channel below Tokul Creek (RM 38). These mainstem spawning areas are the same areas supplied with coarse sediment from the Tolt and Raging rivers and Tokul Creek. Chinook and steelhead spawning are concentrated in these areas and in the lower Raging and Tolt Rivers. Pink and chum salmon spawn in the lower Tolt River as well. Pink salmon have historically spawned in the Raging River; some still do. Most coho spawning and some steelhead spawning occurs in the tributary rivers and streams. Table 1 displays known spawning times and locations for anadromous species. Maps that show the distribution of each species within WRIA 7 are available from King County WLRD.

Anadromous fish do not travel above Snoqualmie Falls. However, resident populations of cutthroat, rainbow, and brook trout (*Salvelinus fontinalis*) can be found above the Falls. Native char were found historically as well (Pentec Environmental and NW GIS, 1999). See the section on bull trout surveys for more detail.

Table 1. Wild Salmonid Stocks in the Snoqualmie Watershed
(Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes, 1994; Snohomish River Basin Work Group, 1998)

Species/Stock	Origin	Spawning Times	Spawning Habitat Locations
Chinook salmon/ Snohomish, fall	Native	late September to October	Snoqualmie River from Harris Creek to Snoqualmie Falls Tolt River from mouth to confluence with North and South Forks N. Fork Tolt River—Lower Reach S. Fork Tolt River—from mouth to reservoir Raging River—Lower
Chum salmon/ Snoqualmie	Native	mid-November to mid-January	Snoqualmie River from Harris Creek to Raging River Tolt River—Lower Reach Griffin Creek—Lower Reach Snoqualmie River, in side channel near Fall City
Coho salmon/ Snoqualmie	Mixed	late October to January	Snoqualmie River from mouth to Falls Cherry Creek Tolt River mainstem and lower reach of tributary at RM 5.5 N. and S. Forks Tolt River—lower reaches Tokul Creek—lower reach Raging River Harris Creek Stossel Creek—lower reach Griffin Creek from mouth to headwaters and in unnamed tributary at RM 5.0 Patterson Creek at RM 6.5 Lake Creek Canyon Creek in 1-mile reach Adair Creek—lower reach (Liz Ritzenthaler, Personal Communication, November 2001)
Pink salmon/ Snohomish, odd year	Native	mid-September to October	Snoqualmie River from mouth to Falls Tolt River—lower reach
Steelhead trout/ Tolt, summer	Unknown	February to April	Tolt River from mouth to reservoir North Fork Tolt River—Lower Reach
Steelhead trout/ Snoqualmie, winter	Native	March to mid-June	Snoqualmie River from RM 5 to Falls Cherry Creek—lower reach Raging River and Deep Creek Tokul Creek—lower reaches, Canyon Creek Tolt River—mainstem, N. and S. Forks

Aquatic and Riparian Habitat

Chinook salmon habitat requirements, habitat-forming processes, and factors affecting salmon populations are discussed in the *Initial Snohomish River Basin Chinook Salmon Conservation/Recovery Technical Work Plan* (*Initial Chinook Work Plan*), which was written by the WRIA 7 Technical Committee to provide a technical foundation for chinook salmon conservation and recovery for the Snohomish River Basin. In this document, the Technical Committee identified 34 categories of problems that may contribute to the decline of chinook salmon populations in WRIA 7. The following nine were considered to be the most important habitat problems (Snohomish Basin Salmonid Recovery Technical Committee, 1999):

- Loss of channel area and complexity resulting from bank protection and diking of the river and major tributaries, cutting off the channel from its floodplain.
- Dearth of in-channel large woody debris (LWD).
- High frequencies of redd scour resulting from flood flows.
- Increased sediment input to streams as a result of unnaturally high rates of slope failure and erosion.
- Poor quality riparian forests.
- Loss of wetlands resulting from draining for land conversion that eliminates habitat and reduces water retention.
- In-redd mortality resulting from siltation or water quality contamination.
- Urbanization (road construction, commercial and residential construction, additional bank hardening) that further reduces chinook salmon viability in the basin.
- Artificial barriers (dams, tide gates, diversions, culverts, pump stations) that prevent juveniles from reaching rearing habitat.

As a follow-up to the *Initial Chinook Work Plan,* the WRIA 7 Technical Committee developed a habitat evaluation matrix for chinook salmon (*Snohomish River Basin Chinook Salmon Habitat Evaluation Matrix).* This matrix assesses seven habitat conditions for the 62 subwatersheds of the Snohomish River Basin including the 25 subwatersheds of the Snoqualmie Watershed. Performance criteria from the scientific literature (NOAA, 1996; WFPB, 1997; Gersib et al., 1999; Spence et al., 1996; Bjornn and Reiser, 1991; WDFW and Western Washington Treaty Indian Tribes, 1997; Point No Point Treaty Council and WDFW, 1999) were applied to review existing information and to evaluate each subwatershed as “properly functioning,” “at risk,” or “not properly functioning” for each habitat condition. These habitat conditions are:

- artificial barriers/access to habitat.
- sediment regime.
- baseflow.
- peak flows.
- water quality.
- wetlands/riparian zone and shoreline vegetation/LWD.
- channel/shoreline complexity and floodplain connectivity.

The *Snohomish River Basin Chinook Salmon Habitat Evaluation Matrix* was intended to flag areas of concern. As such, it is not a complete and thorough analysis of all causes and effects that limit suitability of aquatic habitats for the natural production of chinook salmon in WRIA 7. Nor does it pinpoint the precise locations or areal extent of adverse habitat conditions within the watershed.

Table 2 summarizes the habitat conditions evaluations for the Snoqualmie Watershed (Snohomish Basin Salmonid Recovery Technical Committee, 2000). Not surprisingly, the most developed subwatersheds have the largest number of “at risk” and “not properly functioning” habitat conditions evaluations. Issues of concern include:

- degradation of the natural sediment and hydrologic regimes of the mainstem Snoqualmie and many anadromous salmonid-bearing tributaries (e.g., increased delivery of sediments, mass wasting events, reduced baseflows, and increased peak flows).
- water quality parameters that are in violation of state water quality standards.
- degraded or immature riparian vegetation.
- paucity of LWD.
- shoreline hardening causing loss of hydraulic connectivity between river or stream channels and their floodplains.

Since the publication of the *Snohomish River Basin Chinook Salmon Habitat Evaluation Matrix* in June 2000, salmon recovery planning efforts in WRIA 7 have broadened to include all salmonid species. The WRIA 7 Technical Committee has developed a multispecies habitat evaluation matrix (*Snohomish River Basin Salmonid Species Habitat Conditions Review*) for the 62 subwatersheds of the Snohomish River Basin, including the 25 subwatersheds of the Snoqualmie Watershed.

The *Snohomish River Basin Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) modifies and updates the chinook matrix report by assessing existing available information for all species of native salmon, trout, and char found in WRIA 7. Baseflow and peak flows are condensed into one habitat condition that is named “hydrology,” some other habitat conditions are renamed also. The six evaluated habitat conditions are:

- instream artificial barriers to habitat.
- sediment.
- hydrology.
- water quality.
- wetlands/riparian zone and shoreline vegetation/LWD.
- shoreline condition and floodplain connectivity.

Table 2. Chinook Salmon Habitat Conditions Evaluations for Snoqualmie Watershed
(Snohomish Basin Salmonid Recovery Technical Committee, 2000)

Subwatershed	Acres	Artificial Barriers / Access to Habitat	Sediment Regime	Baseflow	Peak Flows	Water Quality	Wetlands / Riparian Zone & Shoreline Vegetation / Large Woody Debris (LWD)	Channel / Shoreline Complexity and Floodplain Connectivity
Snoqualmie River Subwatersheds								
Ames Creek	4,941	Data Gap	NPF	NPF	NPF	AR	AR	NPF
Cherry Creek	17,536	NPF	AR	AR	AR	AR	NPF	NPF
Coal Creek – Lower	4,538	Data Gap	NPF	NPF	NPF	NPF	NPF	NPF
Coal Creek – Upper	9,733	Data Gap	NPF	NPF	NPF	AR	AR	AR
Griffin Creek	11,257	PF	AR	AR	AR	AR	AR	AR
Harris Creek	8,626	AR	NPF	NPF	NPF	AR	AR	AR
Patterson Creek	13,220	AR	NPF	AR	NPF	AR	NPF	AR
Pratt River	18,094	Data Gap	AR	PF	PF	Data Gap	PF	PF
Raging River	20,987	AR	AR	AR	AR	NPF	NPF	NPF
Snoqualmie River – Lower Middle Fork	24,006	AR	PF	AR	PF	AR	NPF	AR
Snoqualmie River – Upper Middle Fork	47,800	AR	AR	AR	AR	AR	NPF	PF
Snoqualmie River – Lower North Fork	23,313	Data Gap	AR	PF	AR	Data Gap	AR	AR
Snoqualmie River – Upper North Fork	39,633	Data Gap	AR	PF	PF	Data Gap	AR	AR
Snoqualmie River – Lower South Fork	15,079	Data Gap	NPF	NPF	NPF	AR	AR	AR
Snoqualmie River – Upper South Fork	40,334	Data Gap	NPF	PF	AR	NPF	AR	AR
Snoqualmie River – Mouth	12,814	AR	NPF	NPF	NPF	AR	NPF	NPF
Snoqualmie River – Mid-Mainstem	15,493	AR	NPF	NPF	NPF	AR	NPF	NPF
Snoqualmie River – Upper Mainstem	9,256	AR	NPF	NPF	NPF	AR	NPF	NPF
Tate Creek	3,028	Data Gap	AR	AR	AR	AR	NPF	AR
Taylor River	19,551	Data Gap	AR	PF	PF	Data Gap	Data Gap	PF
Tokul Creek	21,704	NPF	NPF	AR	AR	AR	PF	AR
Tolt River – Lower	10,606	PF	AR	PF	PF	PF	AR	AR
Tolt River – North Fork	32,596	PF	AR	PF	PF	PF	AR	AR
Tolt River – South Fork Above Dam	11,897	NPF	AR	AR	PF	AR	NPF	AR
Tolt River – South Fork Below Dam	8,190	PF	NPF	AR	AR	PF	AR	AR

Legend
PF – Properly Functioning
AR – At Risk
NPF – Not Properly Functioning

Some performance criteria in the chinook matrix report were also deleted or modified in the multispecies matrix report, based on an updated understanding of conditions in WRIA 7. Each subwatershed in the multispecies matrix report was characterized as "intact," "moderately degraded," or "degraded" for each habitat condition. The terminology was changed from that used in the chinook matrix report to avoid confusion with federal Endangered Species Act (ESA) regulatory language.

Table 3 summarizes the multispecies habitat conditions evaluations for the Snoqualmie Watershed. Where there is insufficient information to make an informed determination at this time, the multispecies matrix report identifies data gaps and areas of concern for future, more thorough evaluation and research. As was the case with the chinook habitat evaluation matrix, the multispecies matrix is not a complete and thorough analysis of all causes and effects regarding the suitability of aquatic habitats for the natural production of salmonids throughout the Snohomish River Basin, nor is it a formal Limiting Factors Analysis or a Biological Assessment under Section 7 of the federal ESA.

Table 3. Multiple Salmonid Species Habitat Conditions Evaluations for Snoqualmie Watershed (Snohomish Basin Salmonid Recovery Technical Committee, 2002)

Subwatershed	Acres	Instream Artificial Barriers to Habitat	Sediment	Hydrology	Water Quality	Wetlands / Riparian Zone & Shoreline Vegetation / Large Woody Debris (LWD)	Channel Stability and Floodplain Connectivity
Ames Creek	4,941	D	DG	I	DG	D	MD
Cherry Creek	17,536	D	DG	I	D	D	D
Coal Creek – Lower	4,538	DG	DG	MD	D	D	D
Coal Creek – Upper	9,733	DG	DG	MD	DG	D	DG
Griffin Creek	11,257	D	D	DG	I	MD	MD
Harris Creek	8,626	D	DG	I	DG	D	MD
Patterson Creek	13,220	D	D	I	D	D	DG
Pratt River	18,094	DG	DG	DG	DG	I	I
Raging River	20,987	D	MD	DG	DG	D	D
Snoqualmie River – Lower Middle Fork	24,006	MD	DG	DG	DG	D	MD
Snoqualmie River – Upper Middle Fork	47,800	DG	DG	DG	DG	I	I
Snoqualmie River – Lower North Fork	23,313	DG	DG	DG	DG	DG	MD
Snoqualmie River – Upper North Fork	39,633	DG	DG	DG	DG	DG	DG
Snoqualmie River – Lower South Fork	15,079	DG	DG	MD	D	D	MD
Snoqualmie River – Upper South Fork	40,334	DG	DG	DG	D	MD	MD
Snoqualmie River – Mouth	12,814	D	DG	I	D	D	D
Snoqualmie River – Mid-Mainstem	15,493	D	MD	MD	D	D	D
Snoqualmie River – Upper Mainstem	9,256	D	MD	MD	D	D	D
Tate Creek	3,028	DG	DG	DG	DG	D	DG
Taylor River	19,551	DG	DG	DG	DG	MD	I
Tokul Creek	21,704	D	MD	DG	I	I	I
Tolt River – Lower	10,606	I	MD	D	I	DG	D
Tolt River – North Fork	32,596	MD	DG	I	I	DG	I
Tolt River – South Fork Above Dam	11,897	MD	D	DG	DG	D	DG
Tolt River – South Fork Below Dam	8,190	I	D	D	I	MD	I

Legend

I – Intact
MD – Moderately Degraded
D – Degraded
DG – Data Gap

LOWER SNOQUALMIE RIVER MAINSTEM

The mission of King County WLRD includes sustaining healthy watersheds and protecting and restoring habitats (King County WLRD, 2002c). In order to accomplish this part of the mission for the Snoqualmie Watershed, it is useful to know the habitat conditions that historically existed as well as the habitat conditions that exist at present.

Historic Habitat Conditions

Under contract to King County, University of Washington geomorphologists researched and analyzed physical habitat conditions for salmonids in the lower Snoqualmie River mainstem (downstream of Snoqualmie Falls to the confluence with the Skykomish River) and valley floor prior to Euro-American settlement (Collins and Sheikh, 2002). The historical (approximately 1870) landscape was reconstructed from archival materials including maps and field notes from General Land Office (GLO) surveys from 1871-1873 and aerial photographs from 1936. These materials were entered into a Geographic Information System (GIS) and in combination with a Digital Elevation Model (DEM) constructed from Light Detection and Ranging (LIDAR) imagery, were used to map the location of the river channel, wetlands, oxbows, and types and sizes of riparian trees and shrubs. LWD removal and recruitment were also analyzed. To evaluate subsequent change, conditions were also mapped from 1936 and 2000 aerial photos. Following is a summary of the findings. The full Collins and Sheikh report, titled *Mapping Historical Conditions in the Snoqualmie River Valley (RM 0—RM 40),* is available on the King County website (http://dnr.metrokc.gov/wlr/waterres/streams/snoqhist.htm).

The lower Snoqualmie River can be subdivided into several morphologically distinct reaches. Throughout most of the study area, Holocene (post-glacial) deposition by the river has built up the river and its meander belt as much as 6 meters above the valley floor. From RM 2-12, the channel is relatively straight with little or no meander belt. Nearly the entire valley is several meters lower in elevation than the riverbanks. Upstream, the meander belt is approximately one kilometer in width, with valley-marginal lowlands narrower than in the downstream reach. Exceptions to this morphology are where the alluvial fans of the Tolt River (RM 23-27), Raging River, and Tokul Creek (RM 35.5-38.5 combined) narrow the meander belt (Collins and Sheikh, 2002).

Historically, wetlands occupied low areas at the margins of the meander belt. Seasonal flooding and tributaries replenished such valley wetlands. Historic records indicate that vegetation in a large wetland complex between about RM 4 and RM 11 was primarily shrubs and small deciduous trees with scattered small spruce trees. Ponds and wetlands also occupied many oxbows created by historic channel avulsions (Collins and Sheikh, 2002).

The riparian forest that existed prior to Euro-American settlement was numerically dominated by hardwoods, including red alder (*Alnus rubra*), willow (*Salix spp.*), vine maple (*Acer circinatum*), big leaf maple (*Acer macrophyllum*), black cottonwood (*Populus balsamifera*), and Pacific crabapple (*Pyrus fusca*). The largest hardwoods were big leaf maple and black cottonwood with an average diameter of 54 centimeters (21 inches), together comprising 33% of the total forest biomass. Numerically, conifers were only 7% of the riparian trees, but comprised 43% of the total forest biomass. Western red cedar (*Thuja plicata*) and Sitka spruce (*Picea stchensis*) were the largest conifers and largest trees overall, with an average diameter of 97 centimeters (38 inches) and 91 centimeters (36 inches) respectively.

Combining LIDAR and georeferenced GLO field data in a GIS layer shows that tree species grew in distinct elevation ranges relative to the riverbank, with spruce, willow, and alder being most tolerant of flooded conditions, growing 1-4 meters below the riverbank elevation. Forest composition varied with distance from the river; alder and willow were more dominant in areas immediately adjacent to stream channels (Collins and Sheikh, 2002).

Cedar, spruce, maple, and cottonwood would have been the most common tree species that historically contributed LWD to the Snoqualmie River because they were the largest tree species in the riparian forest. It was common for the U.S. Army Corps of Engineers (ACOE) to remove LWD from Puget Sound rivers in the late nineteenth and early twentieth centuries. However, there was no mention of LWD in the first ACOE report on the Snoqualmie River in 1880. LWD may not have been abundant enough to impede navigation on the river or may have been removed by settlers prior to 1880. Later ACOE reports indicate that the ACOE removed wood from the Snoqualmie River at irregular intervals between 1887 and 1908. The ACOE did not record the specific locations of this wood in the river prior to removing the wood (Collins and Sheikh, 2002).

Over 40 oxbow features were historically present in the Snoqualmie River valley. Since approximately 1870, only nine additional oxbows have formed on the valley floor. This fact suggests that the migration rate of the Snoqualmie River is generally low. Most oxbows that now exist were created prior to the earliest mapping in around 1870. On the other hand, the total area occupied by valley floor wetlands has decreased substantially over the past 130 years. In 2000, it was only 19% of the presettlement wetland area. Forest cover in 2000 along the Snoqualmie River and in the valley floor was only 16% of its mapped presettlement extent. Between 1870 and 2000, there was a concomitant large increase in agricultural/cleared land and urban areas (Collins and Sheikh, 2002).

King County will use the historical habitat conditions information to help identify and prioritize salmonid habitat protection and restoration projects for the Snoqualmie Watershed portion of WRIA 7. Such projects could include: (1) acquiring land with existing good habitat; (2) planting native vegetation along the riverbanks, oxbow ponds, and wetlands; (3) hydraulically reconnecting the main channel of the river to oxbows and wetlands where such connections have been lost; (4) restoring ditched floodplain tributary creeks; and (5) restoring valley wetlands.

Habitat Conditions Inventories in 2000 and 2001

In the summers of 2000 and 2001, King County WLRD staff performed an inventory of salmonid habitat conditions in the lower Snoqualmie River mainstem from the mouth of Tokul Creek (RM 38) to the King-Snohomish County line (RM 6). Different habitat characteristics were analyzed each year. Figure 5 shows the study area. Washington Trout, a nonprofit salmonid habitat protection and restoration organization located in Duvall, partnered with King County in 2000. The data obtained from these inventories will be used to guide the WRIA 7 strategic assessment, develop the Snoqualmie Watershed portion of the long-term salmonid conservation plan for WRIA 7, identify and prioritize protection and restoration actions in the Snoqualmie River mainstem, and provide baseline data for adaptive management and monitoring.

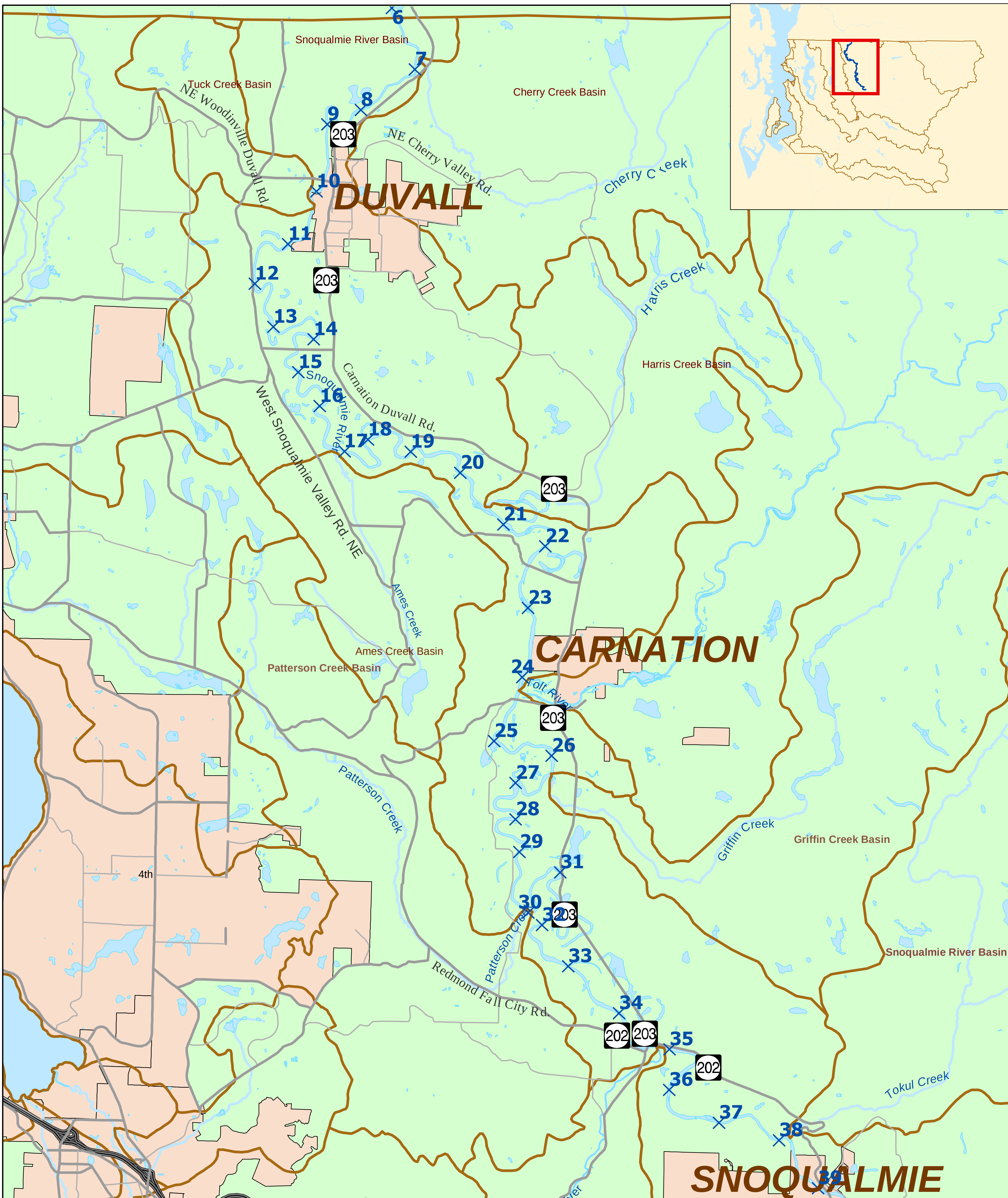

Figure 5.

SNOQUALMIE RIVER SURVEY: Base Map

Map 1 of 1

N

21 River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

0 .3 .6 1.2 1.8 2.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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Methods

The habitat conditions inventories addressed the following questions:

- What is the current condition of the riverbanks with respect to location and type of bank hardening?
- Where are the riverbanks undergoing significant erosion?
- Where can the river be accessed by cattle, people, and vehicles?
- Where are the back channels and tributaries that are still connected to the main channel?
- Where are artificial floodplain and channel modifications located? What types of modifications are present?
- What is the composition, density, and size of the riparian vegetation?
- Where is LWD found in the river at present and what is the type, size, and quality?
- Where are discharge pipes and anthropogenic debris found?
- Where are major pools located and what is their depth?
- Is the temperature of the Snoqualmie River low enough to provide good rearing and prespawning holding habitat for salmon during summer and early fall low flow conditions?

Other questions related to salmonid distribution (species use and relative abundance) in the main channel and habitat conditions in the valley floor (100-year floodplain) will be addressed in fieldwork to be performed in 2003 by King County WLRD and Tulalip Tribes staff.

The habitat conditions inventory in the summer of 2000 focused on physical habitat conditions (bank hardening and erosion, floodplain features, channel modifications, and LWD), riparian vegetation, river access, and dumping and discharge points. Prior to beginning the fieldwork, recent (1996) aerial photos were reviewed to obtain a watershed scale view of King County flood control facilities, other hydromodifications, LWD locations, riparian canopy (presence, amount of cover, types of vegetation), and side channels and oxbows. A data dictionary was developed, listing the features and attributes to be examined in the field (see Appendix A).

Next, King County WLRD and Washington Trout staff received training in the operation of two Trimble Global Positioning System (GPS) Pro XR and TSC1 data collectors. The field team performed a “rehearsal” in order to become familiar with the operation of the GPS equipment in the field and to standardize GPS data collection techniques. For consistency in data collection, the same personnel operated the GPS units throughout the study period. Actual data collection began on August 9, 2000 and continued for two to three days weekly until completion of the habitat conditions inventory on September 12, 2000. King County WLRD provided a raft and Washington Trout provided a canoe. On days when both the raft and canoe were available, the raft crew inventoried habitat conditions on one bank of the river while the canoe crew inventoried habitat conditions on the opposite bank. On days when only one boat was available, the crew inventoried habitat conditions on one bank, then repeated the reach on the other bank another day. Field crew who were not operating the GPS equipment assisted in identifying the start and end points of each habitat feature, recorded supplementary descriptive notes in a field notebook, and photographed key features. Data were downloaded into a computer at the end of each day.

After the conclusion of the summer 2000 habitat inventory, the GPS data were imported to a GIS and map layers were produced for each category of habitat features (bank hardening and erosion, access points, floodplain features, channel modifications, riparian shrubs, riparian trees, LWD, and dumping and discharge points). Summary maps are included and described in subsequent sections of this report. The full set of maps is available in hard copy (King County WLRD, 2002b) and compact disk.

The inventory in the summer of 2001 focused on assessing large pools in the entire lower Snoqualmie River mainstem from the mouth of Tokul Creek (RM 38) to the confluence of the Snoqualmie and Skykomish rivers (RM 0) by canoe. Large pools were defined as pools with a length greater than one channel width. During the month of August, King County WLRD ecologists mapped the location of each pool on laminated Snoqualmie Watershed aerial photos in the field and measured the maximum and residual pool depths using Hondex depth sounders. Digital photos were taken. Pool data were imported into a GIS and map layers were produced.

Water temperature was assessed during both summers. Five temperature loggers were installed in holding pools in the Snoqualmie River mainstem on July 14, 2000. The loggers were tied to rocks and sunk to the bottom of the river in deep pools. The locations of the loggers were:

1. just upstream of the Raging River confluence at RM 35.7.
2. the Neal Road boat launch at RM 32.6.
3. just upstream of the Tolt River confluence at RM 24.8.
4. immediately downstream of “Chinook Bend,” King County open space land near NE Carnation Farms Road at RM 21.1.
5. downstream of the City of Duvall at RM 8.8.

The temperature loggers recorded water temperature every hour from July 14 to September 28, 2000. Four of the loggers were removed on that date (the logger at the “Chinook Bend” location was not recovered) and the data were downloaded. The four temperature loggers were reinstalled in the same locations on June 26, 2001 in order to obtain additional temperature data during the hottest months of the year. Three of these loggers were removed (the logger at RM 24.8 was not recovered) and the data were downloaded on October 19, 2001.

Results and Discussion

For each category of salmonid habitat conditions, the findings and reasons for or implications of these observations are discussed in the following subsections of this report.

Bank Hardening and Erosion

The locations and types of armoring along the toe and top of the banks of the Snoqualmie River are mapped in Figures 6 to 11 and graphed in Figures 12 to 15. The maps include recognized King County flood control facilities as well as other locations. A revetment is a hardened bankline where the top of the bank is at approximately the same elevation as the adjacent land. Riprap is armoring material with a diameter of at least 256 millimeters (mm). Rubble is armoring material with a diameter of less than 256 mm. The locations of levees (structures that are composed of raised fill that is higher than the area landward) were not recorded because the habitat conditions inventory was conducted from the river and field staff did not climb up on the banks.

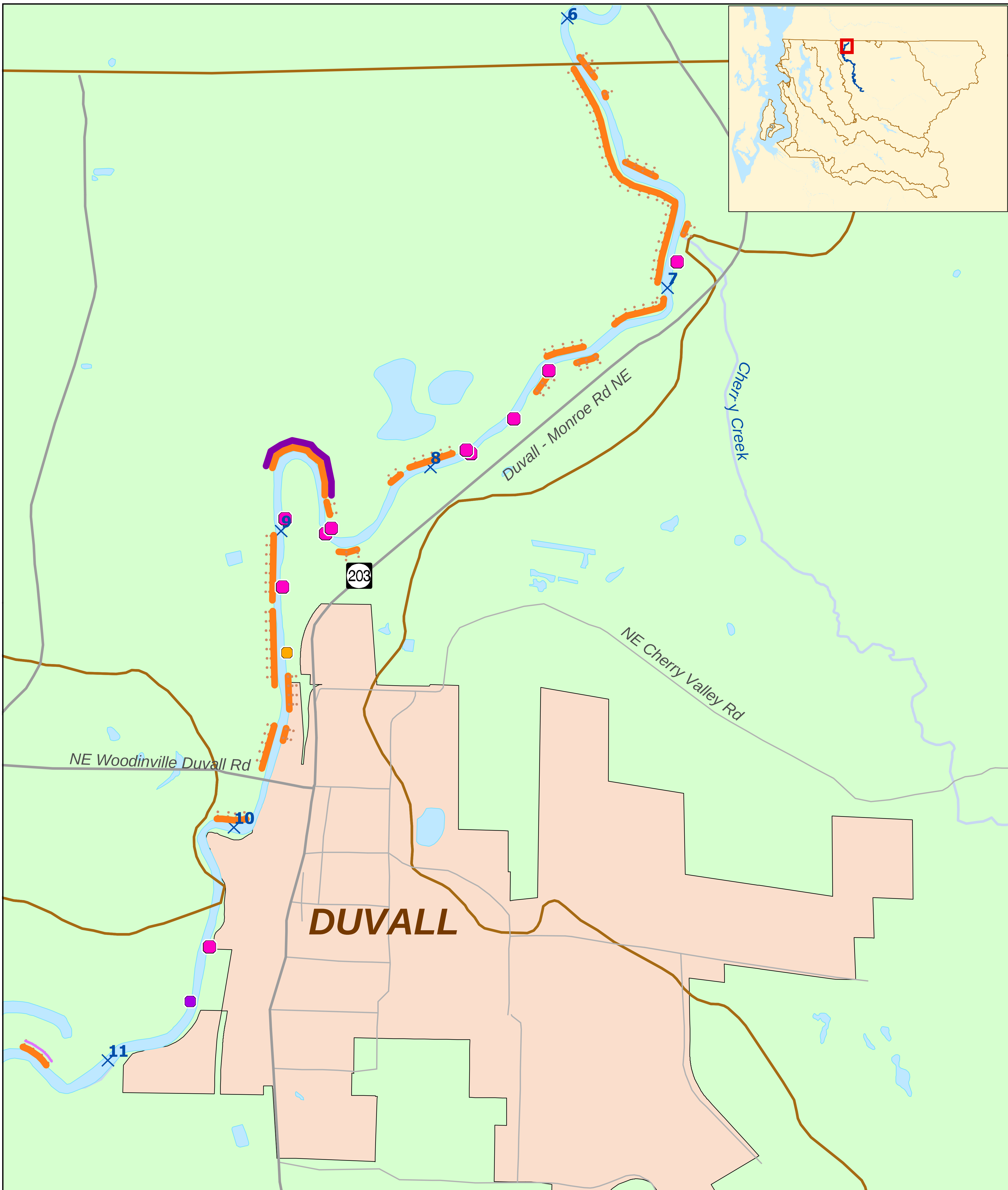

Figure 6.

SNOQUALMIE RIVER SURVEY: Erosional Features & Bank Hardening

Map 1 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Other
Scour
Slump

Toe armor
Rubble (< 256mm)
Rip-Rap (> 256mm)

Upper Bank Armor
Rubble (< 256)
Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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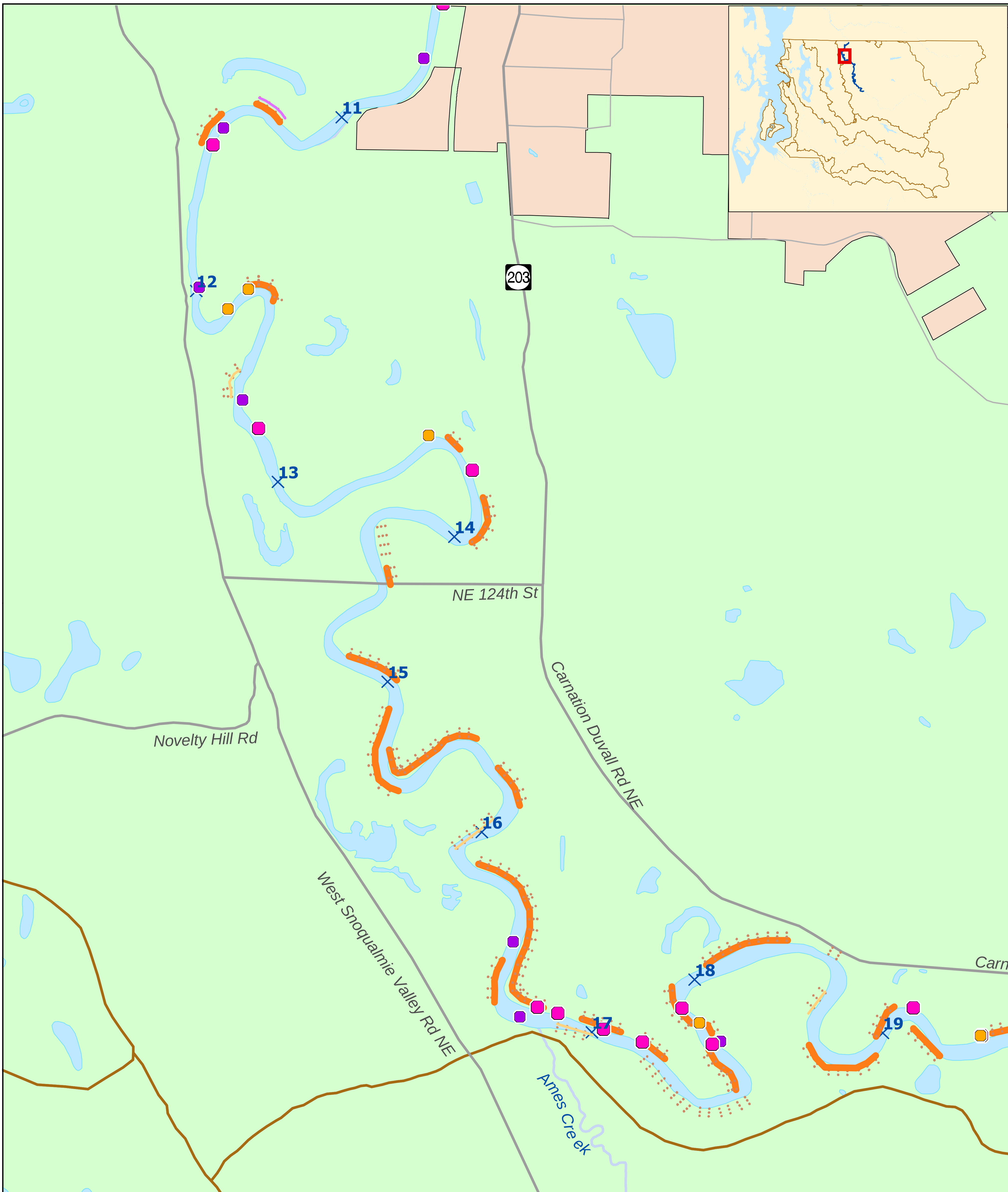

Figure 7.

SNOQUALMIE RIVER SURVEY: Erosional Features & Bank Hardening

Map 2 of 6

N

- 21 River Miles
- Minor Roads
- Major Roads
- DNRP Basin Boundary
- Incorporated Areas

- Other
- Scour
- Slump

Toe armor
- Rubble (< 256mm)
- Rip-Rap (> 256mm)

Upper Bank Armor
- Rubble (< 256)
- Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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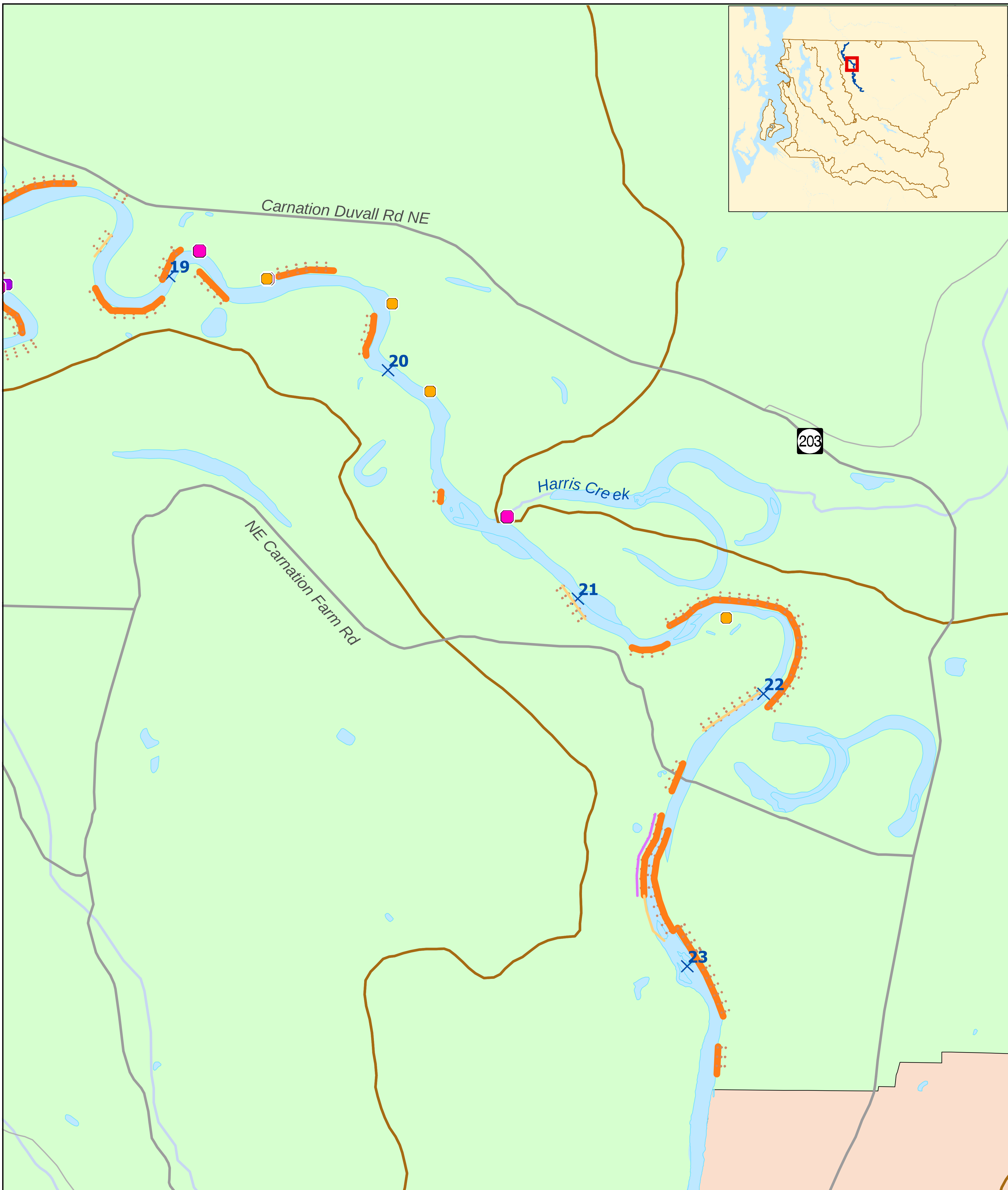

Figure 8.

N

SNOQUALMIE RIVER SURVEY: Erosional Features & Bank Hardening

Map 3 of 6

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Other
Scour
Slump

Toe armor
Rubble (< 256mm)
Rip-Rap (> 256mm)

Upper Bank Armor
Rubble (< 256)
Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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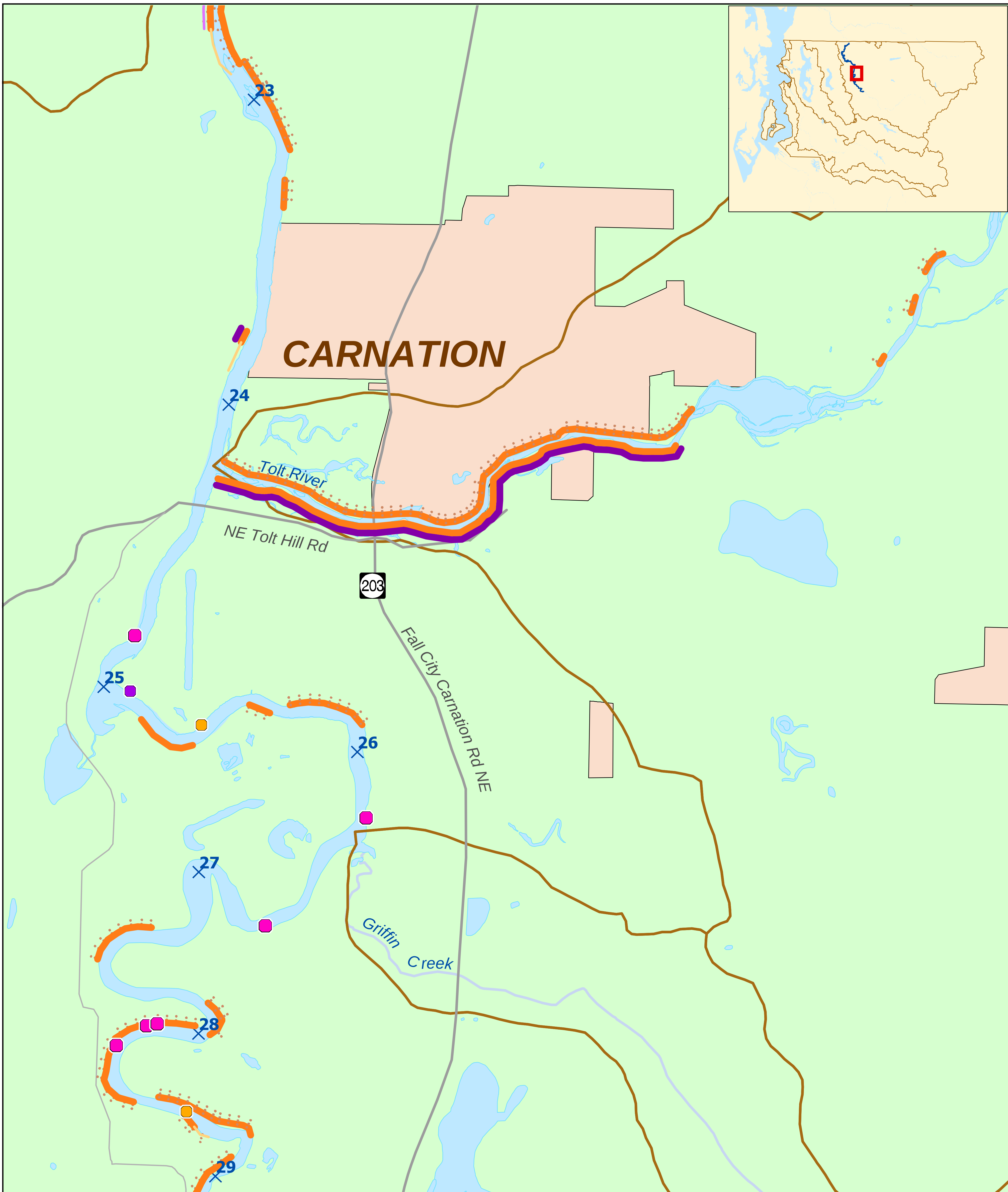

Figure 9.

SNOQUALMIE RIVER SURVEY: Erosional Features & Bank Hardening

Map 4 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Other
Scour
Slump

Toe armor
Rubble (< 256mm)
Rip-Rap (> 256mm)

Upper Bank Armor
Rubble (< 256)
Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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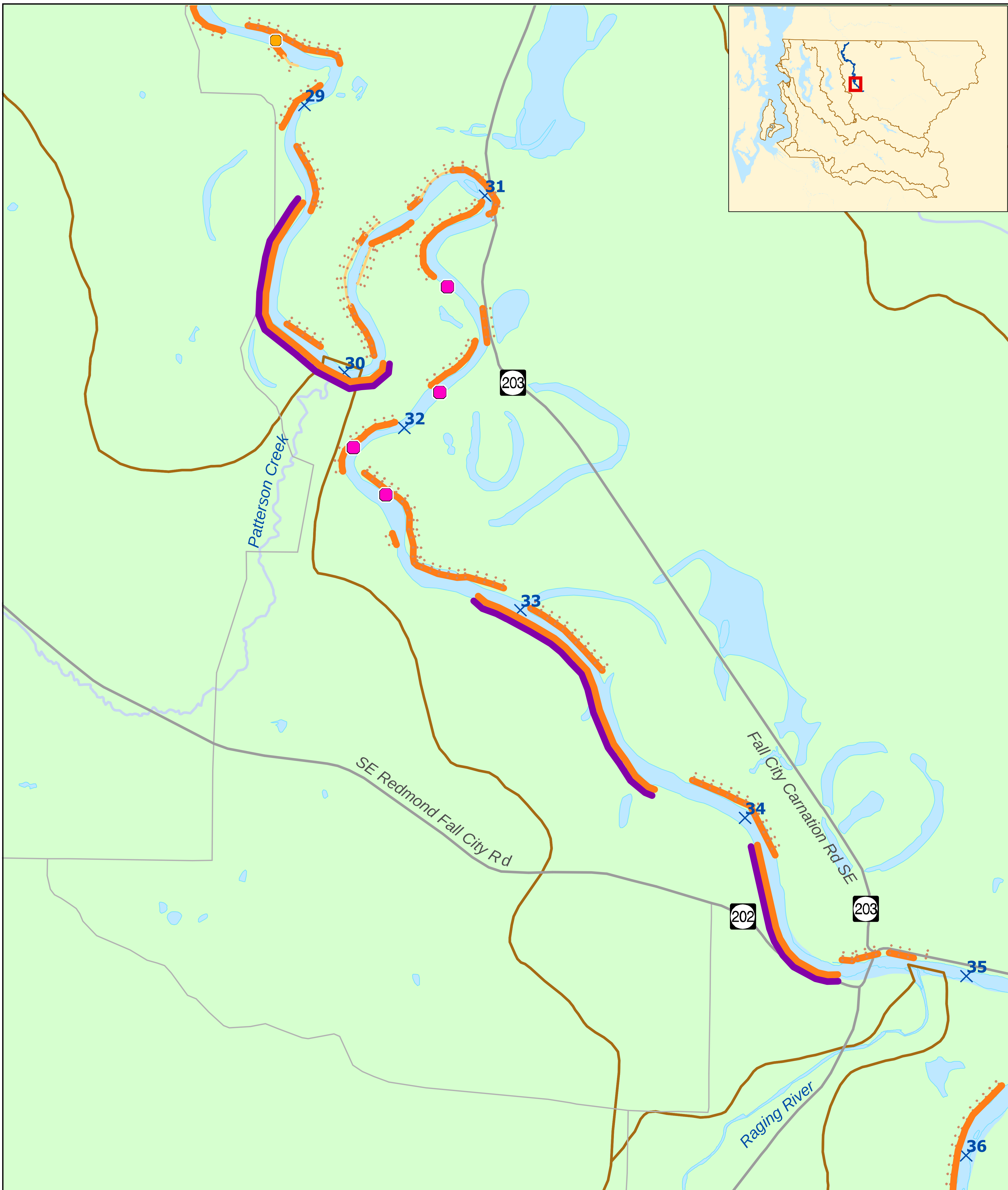

Figure 10.

SNOQUALMIE RIVER SURVEY:
Erosional Features & Bank Hardening

Map 5 of 6

N

21 River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

Other

Scour

Slump

Toe armor

Rubble (< 256mm)

Rip-Rap (> 256mm)

Upper Bank Armor

Rubble (< 256)

Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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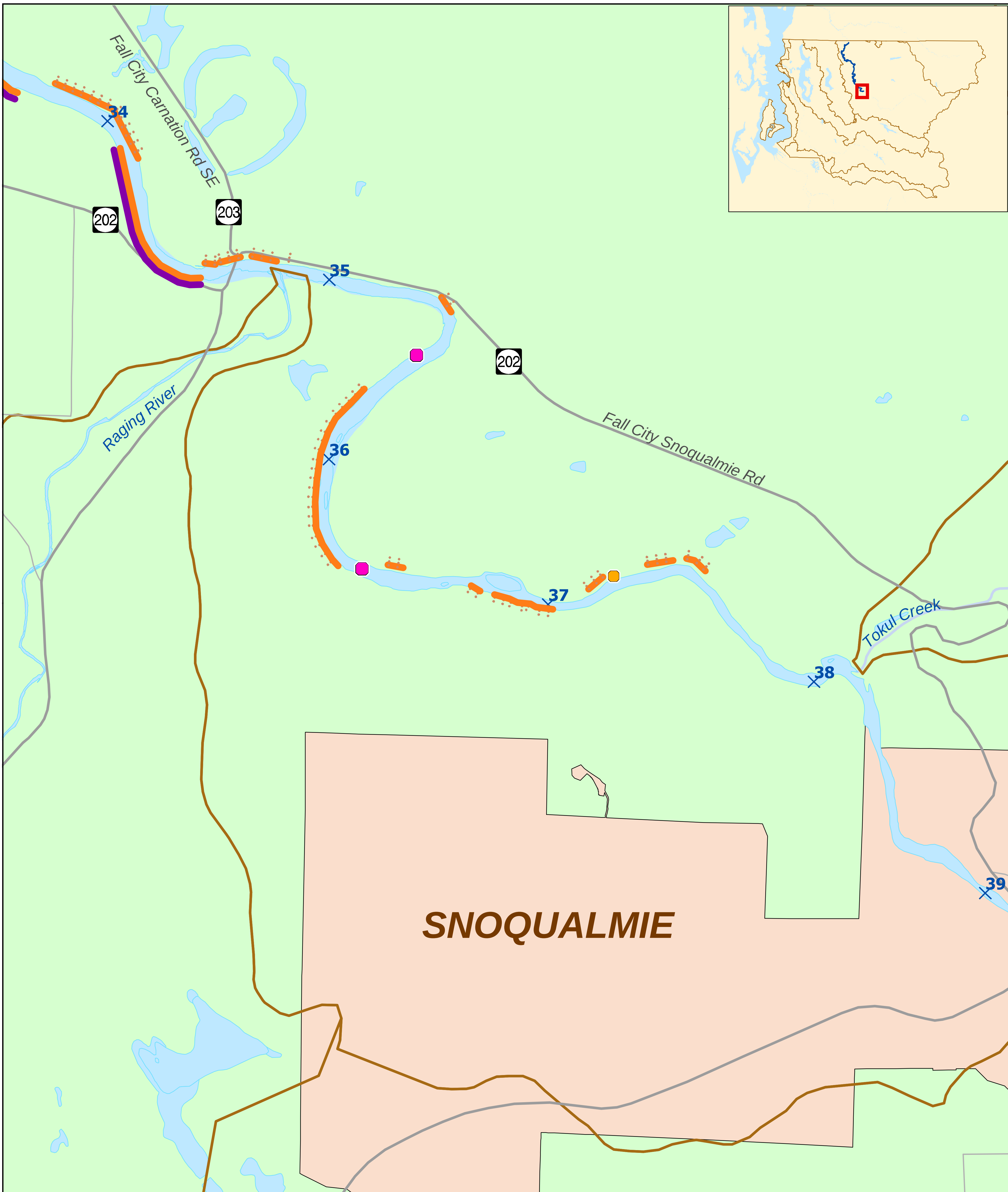

Figure 11.

N

SNOQUALMIE RIVER SURVEY:
Erosional Features & Bank Hardening

Map 6 of 6

21 River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

Other

Scour

Slump

Toe armor

Rubble (< 256mm)

Rip-Rap (> 256mm)

Upper Bank Armor

Rubble (< 256)

Rip-Rap (> 256)

Revetment

0 0.1 0.2 0.4 0.6 0.8 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
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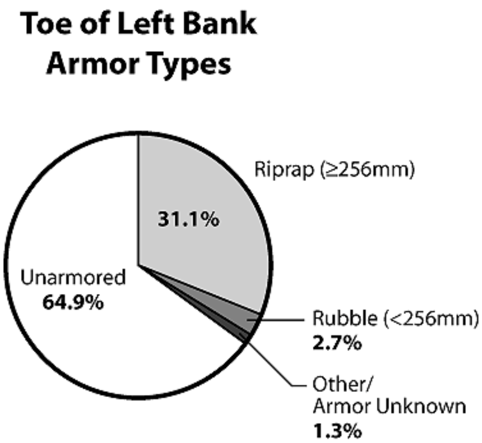

Figure 12.

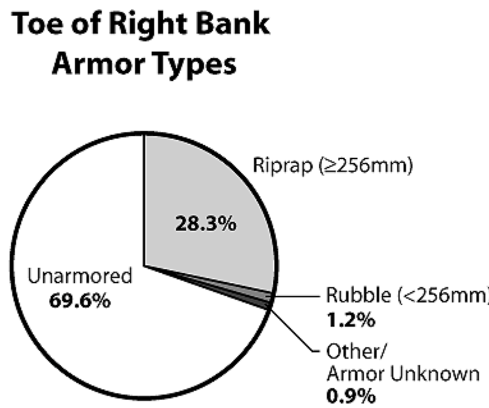

Figure 13.

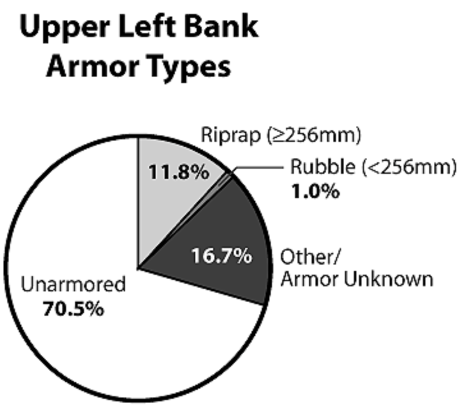

Figure 14.

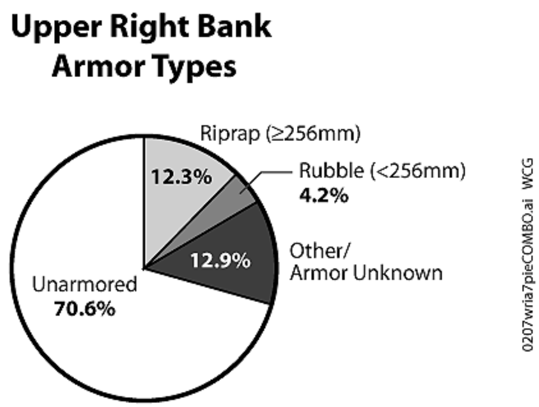

Figure 15.

By disconnecting the main channel of the river from its side channels and inhibiting natural channel migration, bank hardening in the study area limits the creation of summer rearing habitat and winter refuge habitat for salmonids and restricts fish access to off-channel habitat. Other adverse impacts of bank hardening are reducing or eliminating riparian cover, reducing LWD recruitment, eliminating undercut banks and thereby reducing gravel recruitment due to natural bank erosion, and altering the physical characteristics of width, depth, velocity, slope, and roughness within the main channel of the river.

The *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Snoqualmie River mainstem as “degraded” for shoreline condition and floodplain connectivity because bank hardening affects more than 20% of shorelines (NOAA, 1996). In the summer of 2000, there was bank hardening on 35.1% of river

miles on the toe of the left bank (LB—the bank on the left side of the river when looking downstream) and on 29.5% of river miles on the upper LB. There was bank hardening on 30.4% of river miles on the toe of the right bank (RB—the bank on the right side of the river when looking downstream) and on 29.4% of river miles on the upper RB. Riprap was found more frequently than rubble on both banks (Figures 6 to 15). The bank hardening percentages may actually be higher because some bank hardening is covered in silt and partially vegetated and therefore would not have been visible from the river during the habitat conditions inventory. Nevertheless, it remains effective hardening because it arrests channel migration and natural bank erosion critical for forming and rejuvenating habitat (Anderson, 2002).

Figures 6 to 11 also show the location and type of erosional features (i.e., scours and slumps) on the riverbanks. The erosional features shown on the maps were areas of active bank erosion below the ordinary high water mark (OHWM). Scour is the cumulative result of individual grains of sediment being plucked from a river channel by the force of flowing water. Scour can affect the bed or bank of the river and often occurs where natural or artificial irregularities (e.g., logs, boulders, bridge piers) cause local flow acceleration. Slumps are landslides (sliding of a continuous block of soil) that may occur partly or entirely under water. They are often triggered by scour at the toe of the riverbank, or by saturation of the bank by high flows or heavy groundwater seepage.

Scours and slumps are natural, important elements of aquatic ecosystems and contribute spawning gravel and nutrients to rivers and streams. However, excessive bank erosion can degrade habitat conditions by contributing excessive fine sediment, aggrading the channel bed, or filling pools. Bank erosion is accelerated by adjacent bank armoring such as riprap and by altered hydrologic regimes.

The *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Snoqualmie River mainstem as "moderately degraded" for sediment regime (NOAA, 1996) because there was 10% to 20% actively eroding bank in the summer of 2000. Overall, active bank erosion was observed on 11% of the riverbanks in the study area. As might be expected, erosion was observed in areas where the banks were unarmored and was not observed in areas where revetments were present. However, by deflecting water away from a bank, armoring can lead to erosion issues at the next unarmored site downstream and/or across the river from the armored bank. This pattern was observed at many locations throughout the study area. For example, the RB is armored between RM 35.8-36.4 and is eroded downstream at RM 35.5. The LB is armored at RM 8.0 and is eroded directly downstream of the armoring. The RB is armored between RM 21.4-22.1 and is eroded on the LB at approximately RM 21.5. Similarly, the LB is armored between RM 9.3-9.6 and is eroded across the river on the RB at approximately RM 9.5.

<u>Access Points</u>

Figures 16 and 17 show the location of cattle, human, boat, and other vehicle access to the Snoqualmie River. There was a correlation between riverbank erosion and human or cattle access to the river. For example, bank slumping was observed immediately downstream of RM 7 and RM 8, and between RM 9-10 at locations where people could easily walk down the banks to the river. Bank scouring was observed between RM 9-10 and at RM 25.3, again at locations where people could access the river.

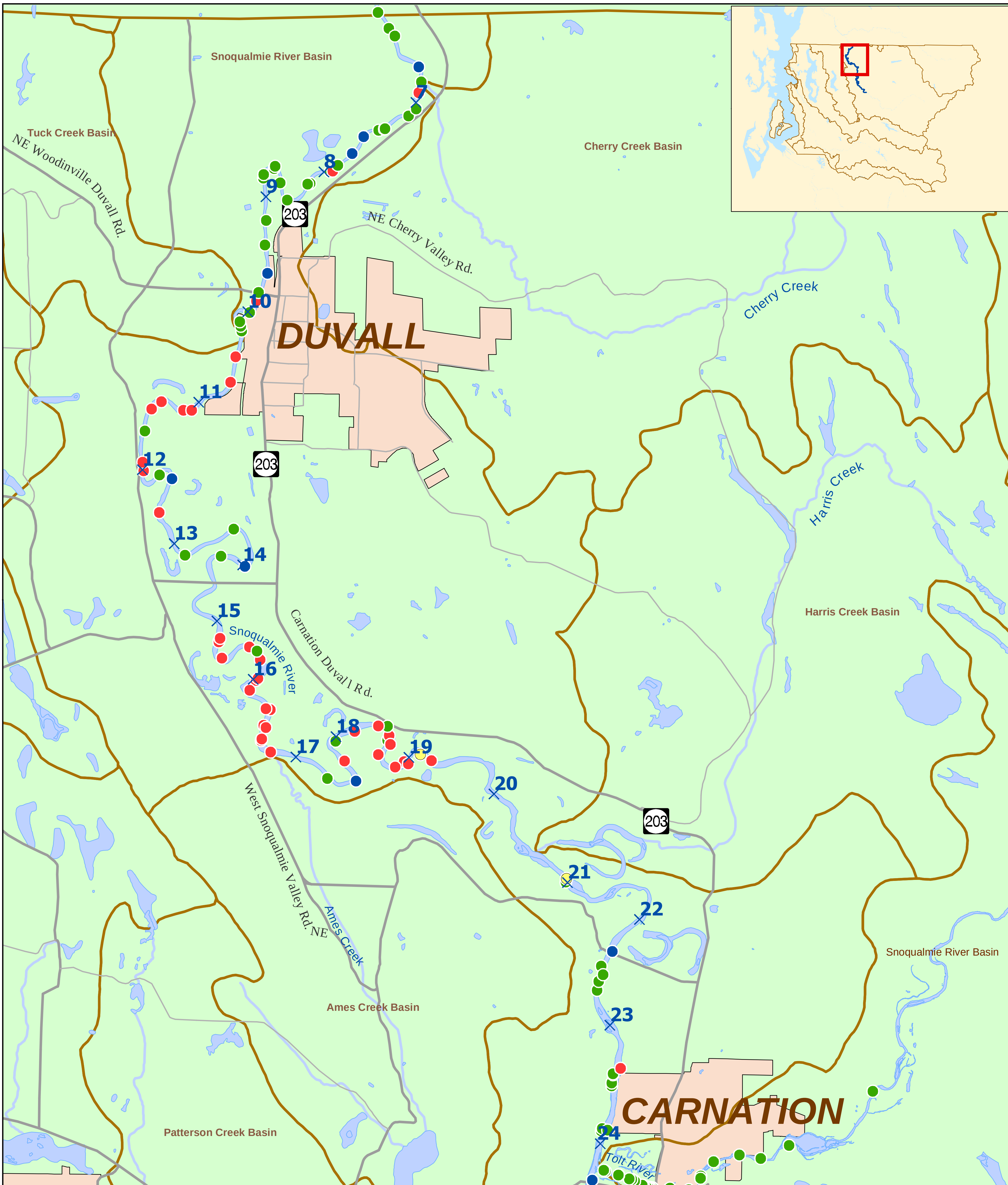

Figure 16.

SNOQUALMIE RIVER SURVEY: Access Points

Map 1 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

CATTLE
HUMAN - BOAT
HUMAN - FOOT
VEHICLE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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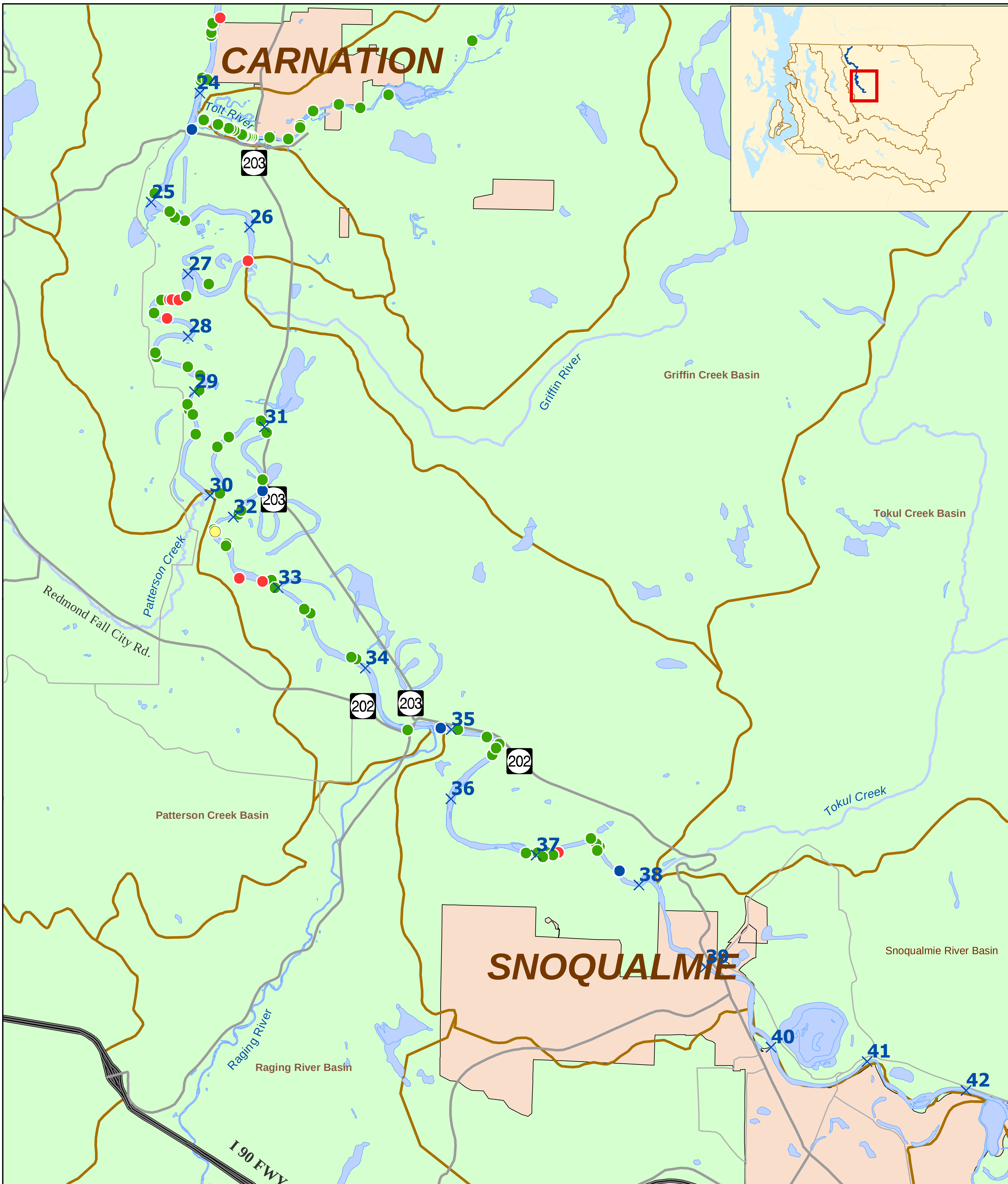

Figure 17.

SNOQUALMIE RIVER SURVEY: Access Points

Map 2 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

CATTLE
HUMAN - BOAT
HUMAN - FOOT
VEHICLE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
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Although there were locations throughout the study area where cattle could access the river, most of the cattle access points were concentrated in the Agricultural Production District (APD) between the City of Duvall and the Harris Creek confluence (RM 10-19). Erosional features and cattle access coincided at RM 10.5, 12, 12.5, 16.5, 16.7, 17.7, and 19. Cows were observed grazing on top of the riverbanks at some locations and wading in the river at others. Horses were occasionally observed as well. For example, on August 31, 2000, the field team counted 17 cows and calves and one bull on the riverbanks, in the river, and on a gravel bar in one area between RM 16.5-16.7.

In addition to causing excessive erosion of riverbanks, loss of riparian vegetation, and destruction of riparian habitat, cattle access to the Snoqualmie River can contribute to nonpoint pollutant loading, especially nutrients (nitrogen and phosphorus) and fecal coliform bacteria. High levels of nutrients can degrade habitat conditions for salmonids and other aquatic biota by reducing DO levels in a waterbody or promoting excessive plant growth that can also reduce DO levels. It is not definitively known if high fecal coliform bacteria counts are a threat for fish, but high counts are a public health threat. Nutrient levels have been elevated, and fecal coliform bacteria counts have violated State of Washington water quality standards in the Snoqualmie River in the past (Fricke, 1995; Joy, 1994; Ehinger, 1993; Joy et al., 1991; Thornburgh et al., 1991). These water quality problems contributed to a rating of "degraded" water quality for the Snoqualmie River mainstem in the *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002).

Floodplain Features

Figures 18 and 19 show the location of floodplain features including the mouths of major tributaries (e.g., Cherry Creek, Harris Creek, and Griffin Creek) and small, unnamed tributaries as well as back channels, water diversion pumps, culverts, and flap gates. A flap gate is a flexible (normally hinged) covering of the outlet of a culvert designed to block high water from entering flood prone areas behind dikes and to allow drainage of water into a river's main channel during normal, nonflood conditions.

Forty-six small, unnamed tributaries and 26 back channels were observed. Tributaries and back channels can provide good edge habitat for summer rearing and winter refuge for salmonids. These valley floor habitat features as well as wetlands and oxbows will be inventoried for habitat conditions and fish use in the summer of 2003.

Most of the water diversion pumps (10 out of 15) were located in the reach between the King-Snohomish County line and the City of Duvall (RM 6-10). The land in this reach is in the APD. It is likely that water is being withdrawn from the Snoqualmie River for irrigating crops and for drinking water for cattle. However, no assessment of diversions was made.

Eight flap gates and 15 culverts were observed throughout the study area. Water diversion pumps, flap gates, and culverts, especially perched culverts, can be barriers to fish habitat. These barriers can adversely affect juvenile and adult salmonids by eliminating or restricting access to upstream rearing and spawning habitat. Fish passage barriers can also cause reduced flow to downstream areas, thereby exacerbating passage problems, reducing the amount of refuge habitat, and decreasing the area and quality of food production for juveniles. Fish passage barriers restrict access to off-channel refuge habitat during high flow events as well (Snohomish Basin Salmonid Recovery Technical Committee, 2002).

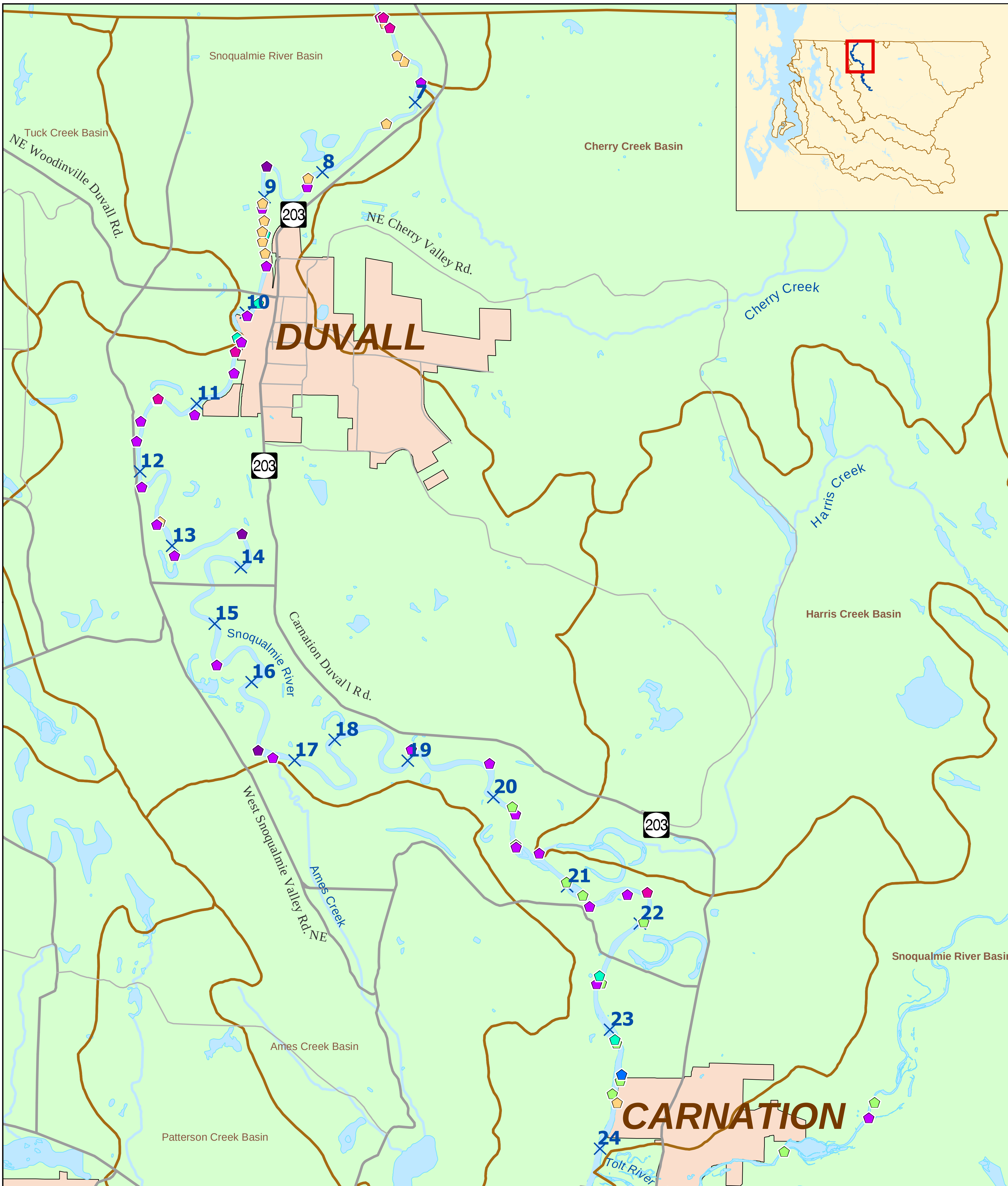

Figure 18.

SNOQUALMIE RIVER SURVEY: Floodplain Features

Map 1 of 2

N

- 21 River Miles
- Minor Roads
- Major Roads
- DNRP Basin Boundary
- Incorporated Areas

- DIVERSIONS (PUMP)
- FLAP GATE
- BACK CHANNEL
- MOUTH OF TRIBUTARY
- OTHER
- PERCHED CULVERT
- SUBMERGED CULVERT

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
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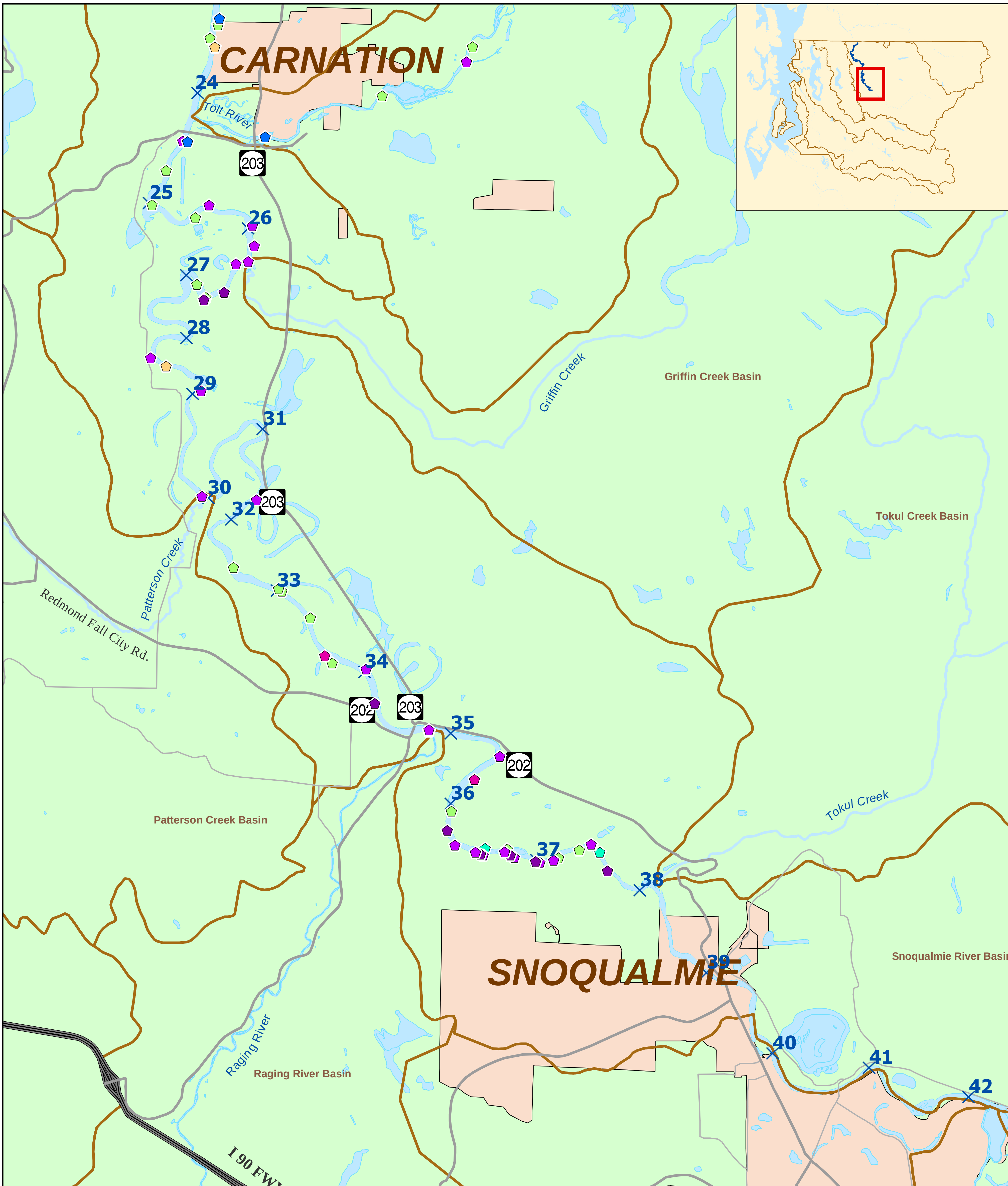

Figure 19.

SNOQUALMIE RIVER SURVEY: Floodplain Features

Map 2 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

DIVERSIONS (PUMP)
FLAP GATE
BACK CHANNEL
MOUTH OF TRIBUTARY
OTHER
PERCHED CULVERT
SUBMERGED CULVERT

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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The King County Department of Transportation (DOT) conducted a culvert survey of the Snoqualmie River mainstem and tributaries that drain directly to the mainstem and are not located in another subwatershed. DOT identified 41 culverts that do not meet the standards for fish passage established by the Washington Department of Fish and Wildlife and therefore are considered to be fish passage barriers (Fritz, 2001). Based on this data, the Snoqualmie River mainstem was rated as "degraded" for instream artificial barriers to habitat in the *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002).

Channel Modifications

Figures 20 and 21 show the locations of channel modifications including barbs, bridge footings, flow deflectors, docks, wooden pilings, utility crossings, and weirs. Barbs are riprap features that are designed to deflect flow away from a bank. Pilings are the remains of old docks that were used in historic boat transportation on the Snoqualmie River. By nailing boards parallel to the river flow, these pilings also function like bank armoring. Barbs and pilings were the most frequently noted structures. Thirty-six barbs were mapped; they were evenly distributed throughout the study area. Forty-six areas of pilings were observed, with the largest concentrations occurring between RM 11-19 and RM 29-38. Docks were observed only at RM 7.5; human access by foot and boat are also indicated at this location (Figure 20).

Riparian Vegetation

Figures 22 to 25 show the location, types, and density of riparian shrubs and riparian trees that were growing on the banks of the Snoqualmie River downstream of Snoqualmie Falls in the summer of 2000 and could be seen from the boats during the habitat conditions inventory. The designation of "non-dense" indicates low or moderate density of the vegetation. The designation of "non-dense" indicates low or moderate density of the vegetation. Several shrub species that are not native to the Pacific Northwest were observed throughout the length of the survey. Of these, Himalayan blackberry (*Rubus discolor*), Japanese knotweed (*Polygonum cuspidatum*), and virgin's bauer (*Clematis spp.*) were prolific. Other invasive species included English ivy (*Hedera spp.*), butterfly bush (*Buddleia davidii*), and yellow tansy (*Tanacetum vulgare*), which is poisonous to livestock if ingested. Purple loosestrife (*Lythrum salicaria*), a very aggressive, nonnative species, was observed in a few locations in the reach between the Tolt River Bridge and Neal Road (RM 24-33). Purple loosestrife is listed as a Class B weed; this means that it is abundant in some areas of Washington State, and controlling the spread of this species is required by law (King County WLRD, 2002a).

Native shrub species that were present included willow, snowberry (*Symphoricarpos albus*), salmonberry (*Rubus spectabilis*), red osier dogwood (*Cornus stolonifera),* Oregon grape (*Berberis nervosa*), elderberry (*Sambucus spp.),* and Indian plum (*Oemleria cerasiformis*). Bracken ferns (*Pteridium aquilinum*), sword ferns (*Polystichum munitum*), and lady ferns (*Athyrium filix-femina*) were also present. Stands of native riparian vegetation were typically composed of several species whereas stands of nonnative shrubs were usually monocultures.

Most of the riparian trees were deciduous, with red alder, vine maple, and black cottonwood found most frequently. Only three areas had more than 30% conifers, i.e., RM 22.4-22.5 on the LB, 36.3-36.5 on the LB, and RM 36.4-36.7 on the RB. Conifers were 5% to 30% of the trees at the following locations: RM 11.5-11.7 on the RB, 18.4-18.6 on the RB, 20.8-21.2 on the LB, 22.5-22.9 on the LB, 24.9-25 on the LB, 26.2-26.3 on the RB, 33.9-34 on the RB, 35.7-36.2 on the RB, 36.4-36.5 on the RB, and 36.7-38 on both banks. Coniferous species included western redcedar, Sitka spruce, grand fir (*Abies spp.*), and western hemlock (*Tsuga heterophylla*).

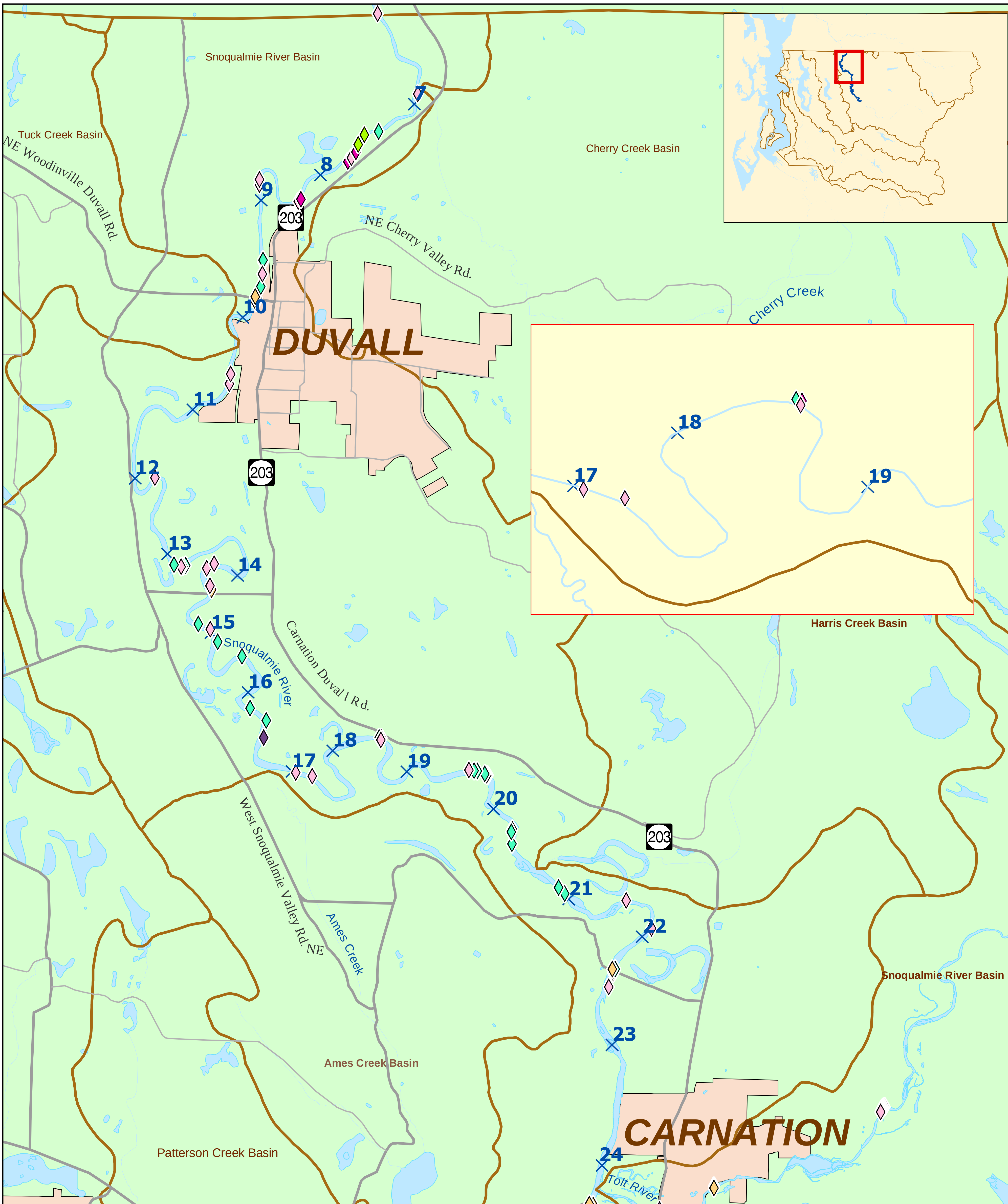

Figure 20.

SNOQUALMIE RIVER SURVEY: Channel Modifications

Map 1 of 2

N

- River Miles
- Minor Roads
- Major Roads
- DNRP Basin Boundary
- Incorporated Areas

- BARB
- BRIDGE FOOTING
- DEFLECTOR
- DOCK
- OTHER
- PILING
- UTILITY CROSSING
- WEIR

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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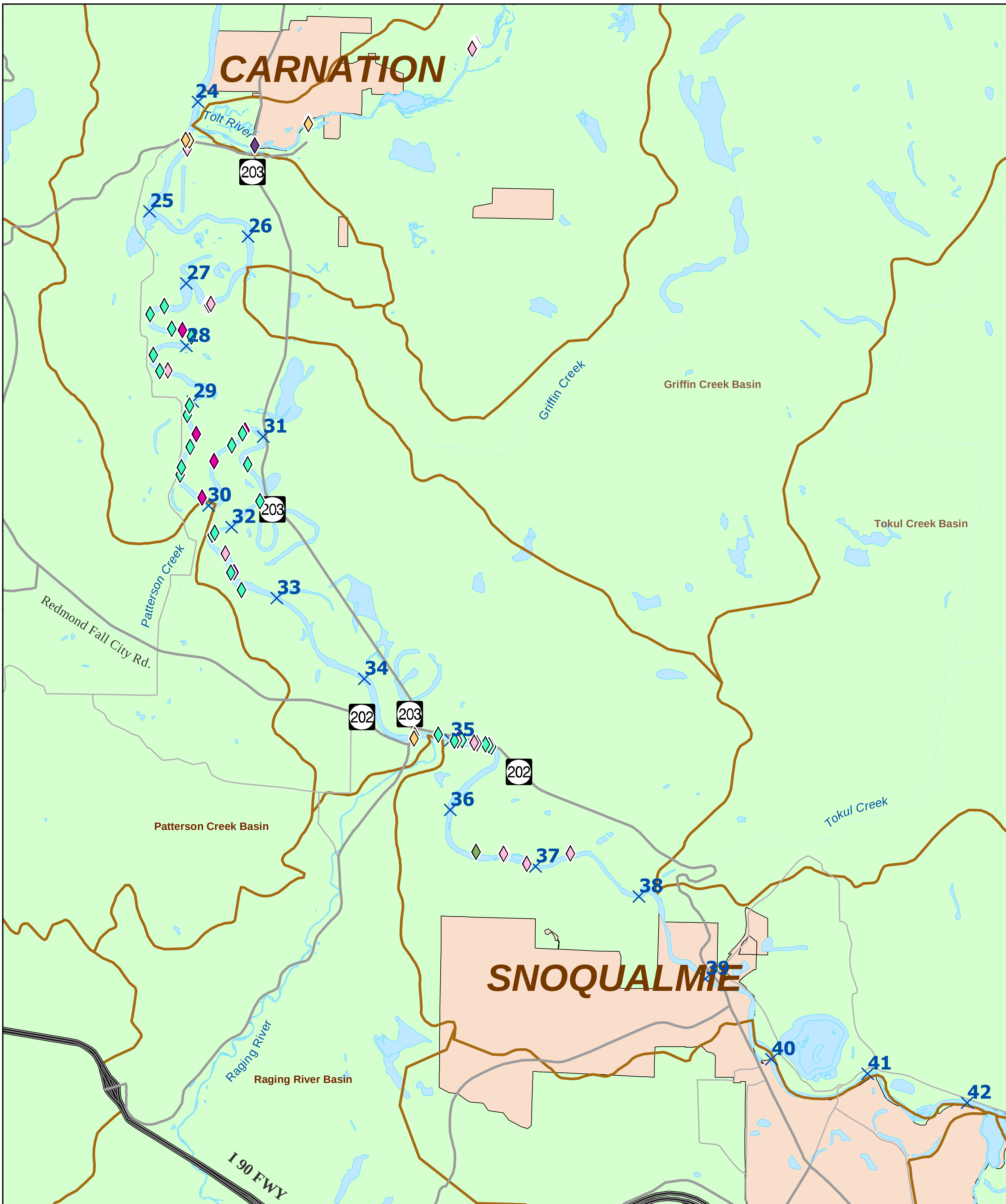

Figure 21.

SNOQUALMIE RIVER SURVEY: Channel Modifications

Map 2 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

BARB
BRIDGE FOOTING
DEFLECTOR
DOCK
OTHER
PILING
UTILITY CROSSING
WEIR

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
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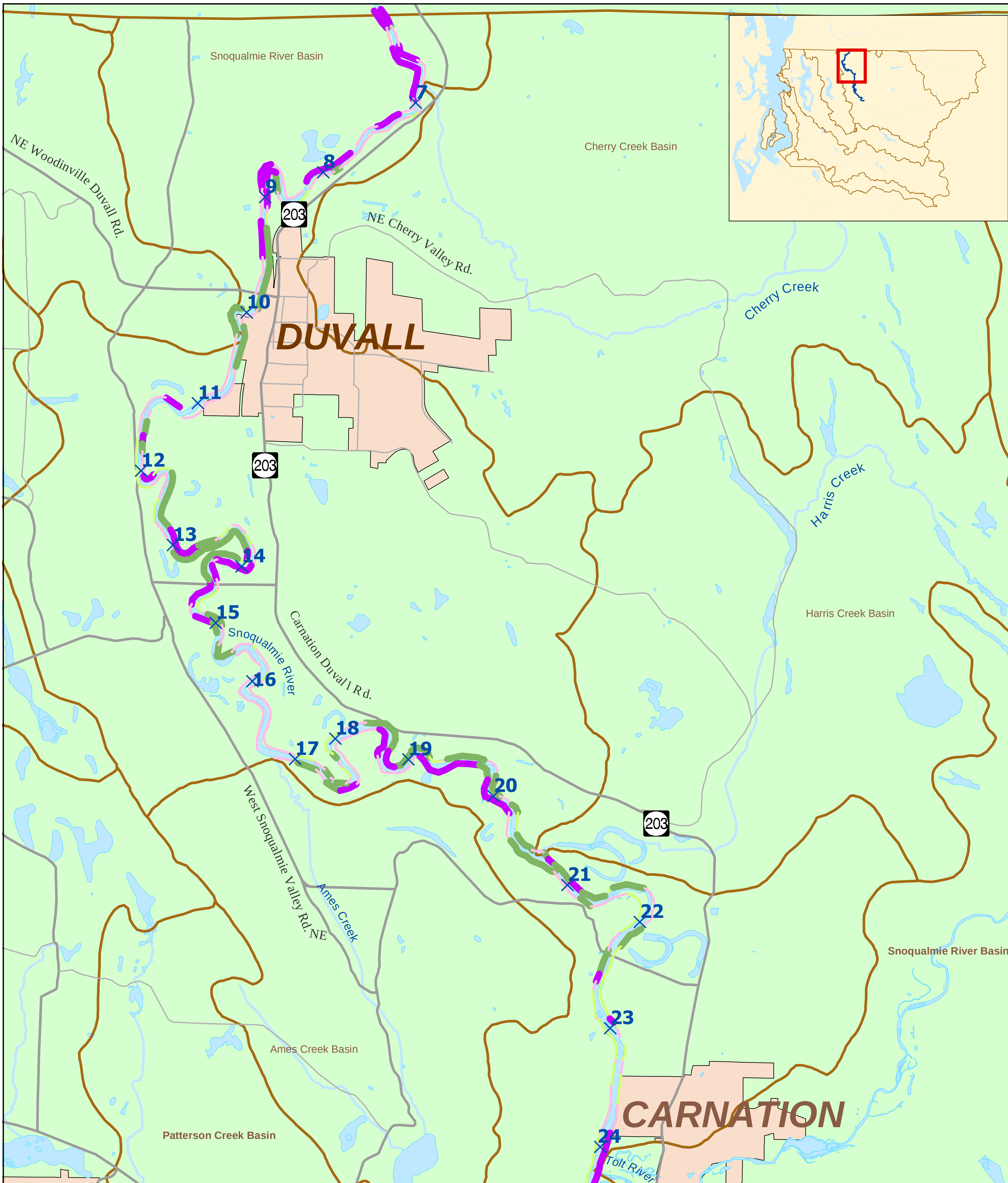

Figure 22.

SNOQUALMIE RIVER SURVEY: Riparian Vegetation - Shrubs

Map 1 of 2

N

21
River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

All Non-Native or Non-Native Dominant	All Native or Native Dominant
NON-DENSE	NON-DENSE
DENSE	DENSE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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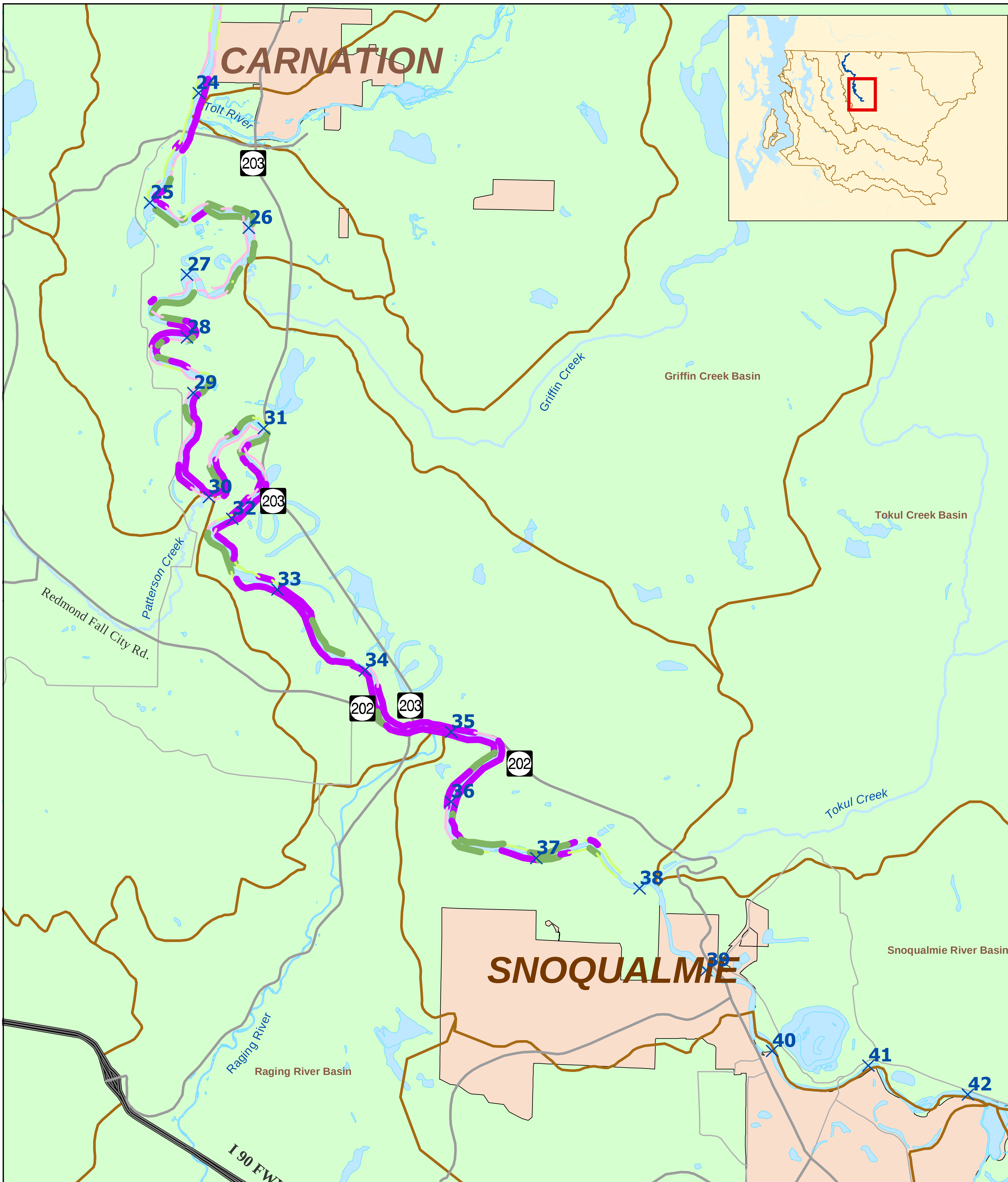
Figure 23.

SNOQUALMIE RIVER SURVEY: Riparian Vegetation - Shrubs

Map 2 of 2



N

21 Legend:
- Miles
- Minor Roads
- Major Roads
- DNRP Basin Boundary
- Incorporated Areas

All Non-Native or Non-Native Dominant
- NON-DENSE
- DENSE

All Native or Native Dominant
- NON-DENSE
- DENSE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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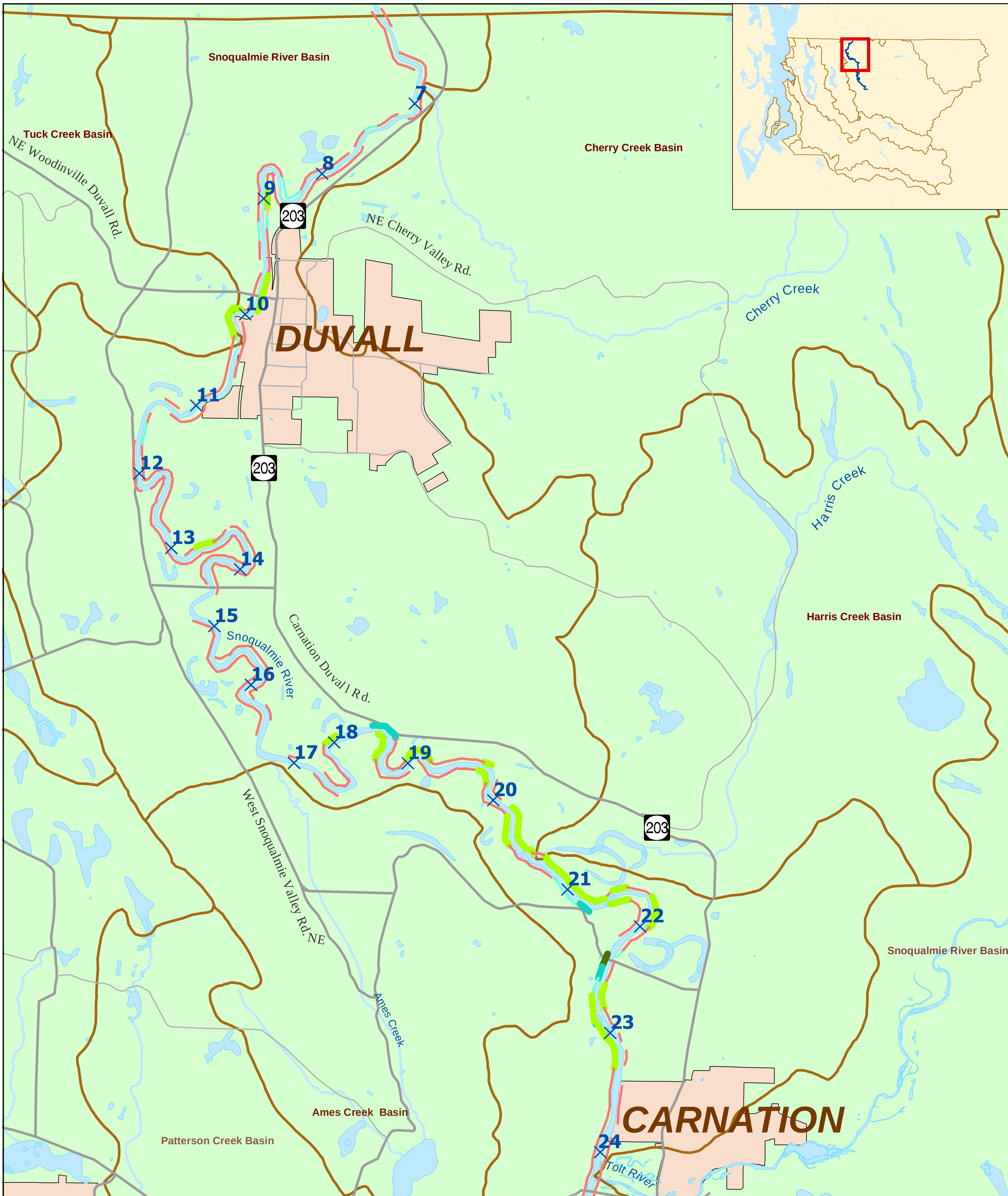

Figure 24.

SNOQUALMIE RIVER SURVEY: Riparian Vegetation - Trees

Map 1 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

All Deciduous
DECIDUOUS, NON-DENSE
DECIDUOUS, DENSE

≤ 30% Coniferous
CONIFEROUS, NON-DENSE
CONIFEROUS, DENSE

>30% Coniferous
CONIFEROUS, NON-DENSE
CONIFEROUS, DENSE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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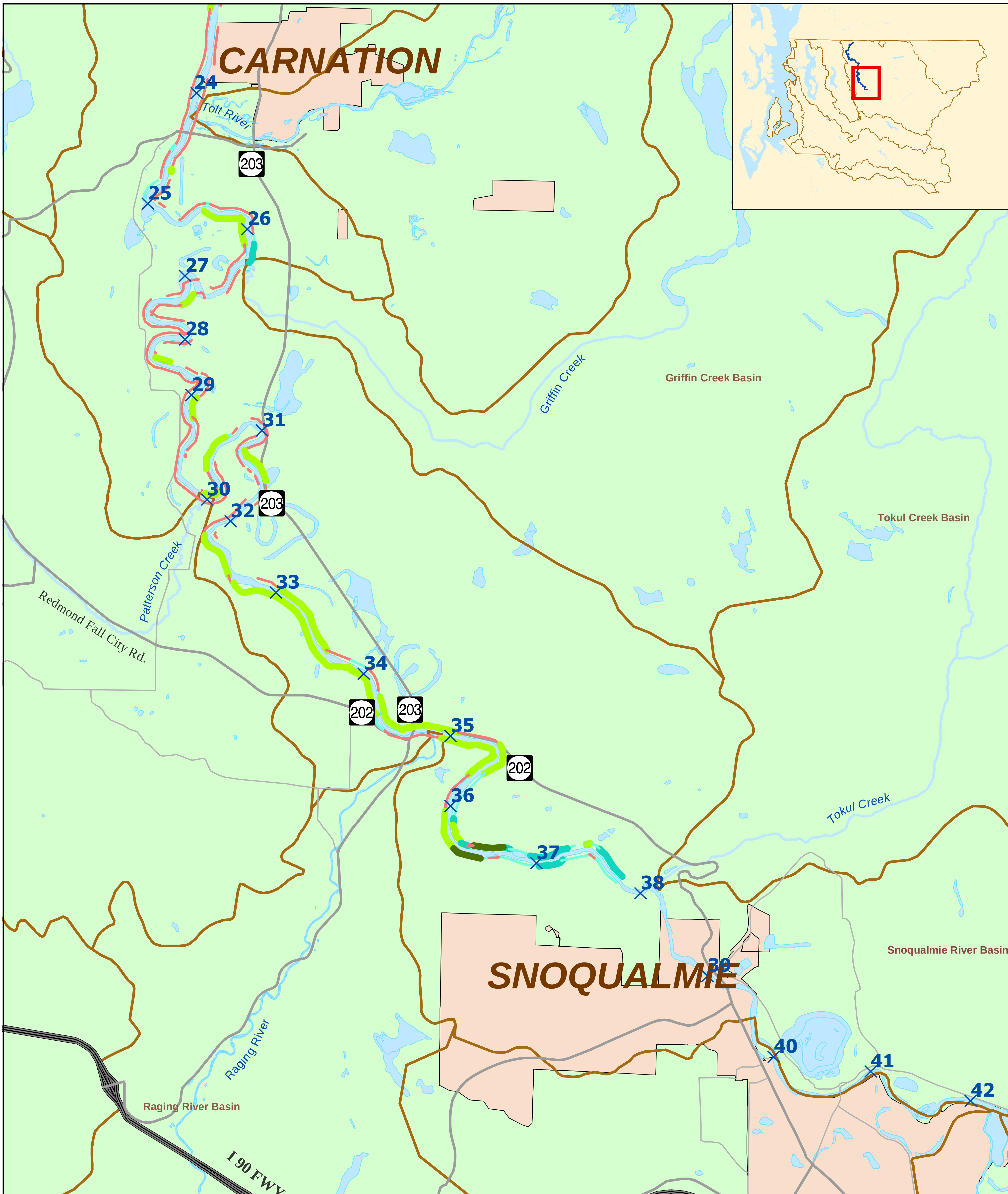

Figure 25.

SNOQUALMIE RIVER SURVEY: Riparian Vegetation - Trees

Map 2 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

All Deciduous
DECIDUOUS, NON-DENSE
DECIDUOUS, DENSE

≤ 30% Coniferous
CONIFEROUS, NON-DENSE
CONIFEROUS, DENSE

>30% Coniferous
CONIFEROUS, NON-DENSE
CONIFEROUS, DENSE

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
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The deciduous and coniferous tree species found in 2000 were similar to the species noted in approximately 1870, but the distribution and size differed. Historically, conifers accounted for 7% of streamside trees and 43% of the streamside biomass. In 2000, fewer than 7% of streamside trees were conifers, and both conifers and deciduous trees were smaller (Collins and Sheikh, 2002). Whereas the average stem diameter (diameter at breast height) of cedar, spruce, maple, and cottonwood trees was greater than 50 centimeters prior to Euro-American settlement, the average diameter of these trees is now less than 30 centimeters; moreover, there are few mature trees (average stem diameter greater than 50 centimeters) downstream of Fall City.

The *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Snoqualmie River as “degraded” for riparian zone and shoreline vegetation because the average stem diameter is less than 30 centimeters (Point No Point Treaty Council and WDFW, 1999). The Snohomish Basin Salmonid Recovery Technical Committee used the concept of one site potential tree height to evaluate the riparian zone. Riparian zone refers to the channel migration zone or OHWM, plus the horizontal distance of one site potential tree height which is the height that a tree could potentially grow to on a particular site (NOAA, 1996). Overall, mature trees are now found along only 1.8% of river miles on the LB and 9% of river miles on the RB of the mainstem Snoqualmie. Conversion of forestland to agricultural and residential land is responsible for this low figure. Loss of riparian vegetation results in decreased riverbank stability, excessive erosion, and reduction of shading which in turn leads to higher water temperatures. A lack of riparian vegetation also limits habitat for a wide variety of wildlife species and insects, on which fish feed. Loss of mature trees in the riparian zone also decreases LWD recruitment into the river, thus reducing the structural and hydraulic complexity of instream habitat. All of these factors combine to adversely affect freshwater life history stages of salmonids and to reduce biological diversity.

Large Woody Debris (LWD)

Instream LWD is an important component of salmonid habitat. By providing cover for fish, LWD protects them from predators and from high, scouring flows. Water scouring around LWD also carves out pools, which provide rearing habitat for juvenile fish and prespawning holding habitat for adults. LWD also delivers sediment and nutrients to aquatic ecosystems and provides structural complexity to river channels, with resulting biological diversity.

Figures 26 to 31 show the location and type of LWD (cut logs, debris jams, logs with rootwads, and rootwads on stumps) found in the Snoqualmie River in the summer of 2000, and indicate whether each piece was above, across, or below the OHWM. Wood embedded in the river channel was included. Because the habitat inventory was conducted during low flow and generally good water clarity conditions, subsurface LWD was observed as well as LWD on the surface of the water and on the riverbanks. A piece of wood was considered to be LWD if it was at least two meters in length and 10 centimeters in diameter (Schuett-Hames et al., 1999; Washington Forest Practices Board, 1997).

The commonest type of LWD observed was the log with rootwad combination. The field team found more LWD in the Snoqualmie River than expected. Concentrations were relatively high between RM 17-21 and RM 24.5-27. However, the summer 2000 inventory still revealed an overall paucity of LWD in the Snoqualmie River. The *Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Snoqualmie River as “degraded” for LWD because there was less than one piece of LWD per 20 meters of river channel (WDFW and Western Washington Treaty Tribes, 1997; Washington Forest

Practices Board, 1997). The field team found 822 pieces of LWD in 32 miles; this translates to an average of 25.7 pieces per mile (1624.6 meters) and 0.32 piece per 20 meters of channel.

Although there were a few locations (e.g., downstream of the Tokul Creek confluence) where large alder and cedar trees were leaning over the river and were potential near-term sources of LWD, in general the degraded shoreline vegetation results in low recruitment of LWD to the Snoqualmie River. Much of the existing LWD appeared to be old, indicating that there had not been recent significant recruitment. Native plant revegetation projects may help to ameliorate this situation in the long-term, once the trees are large enough to restore the natural ecosystem process of LWD recruitment. There may also be opportunities to reintroduce LWD into the river at certain locations as an interim habitat restoration measure until planted trees mature and begin contributing significant volumes of wood to the channel.

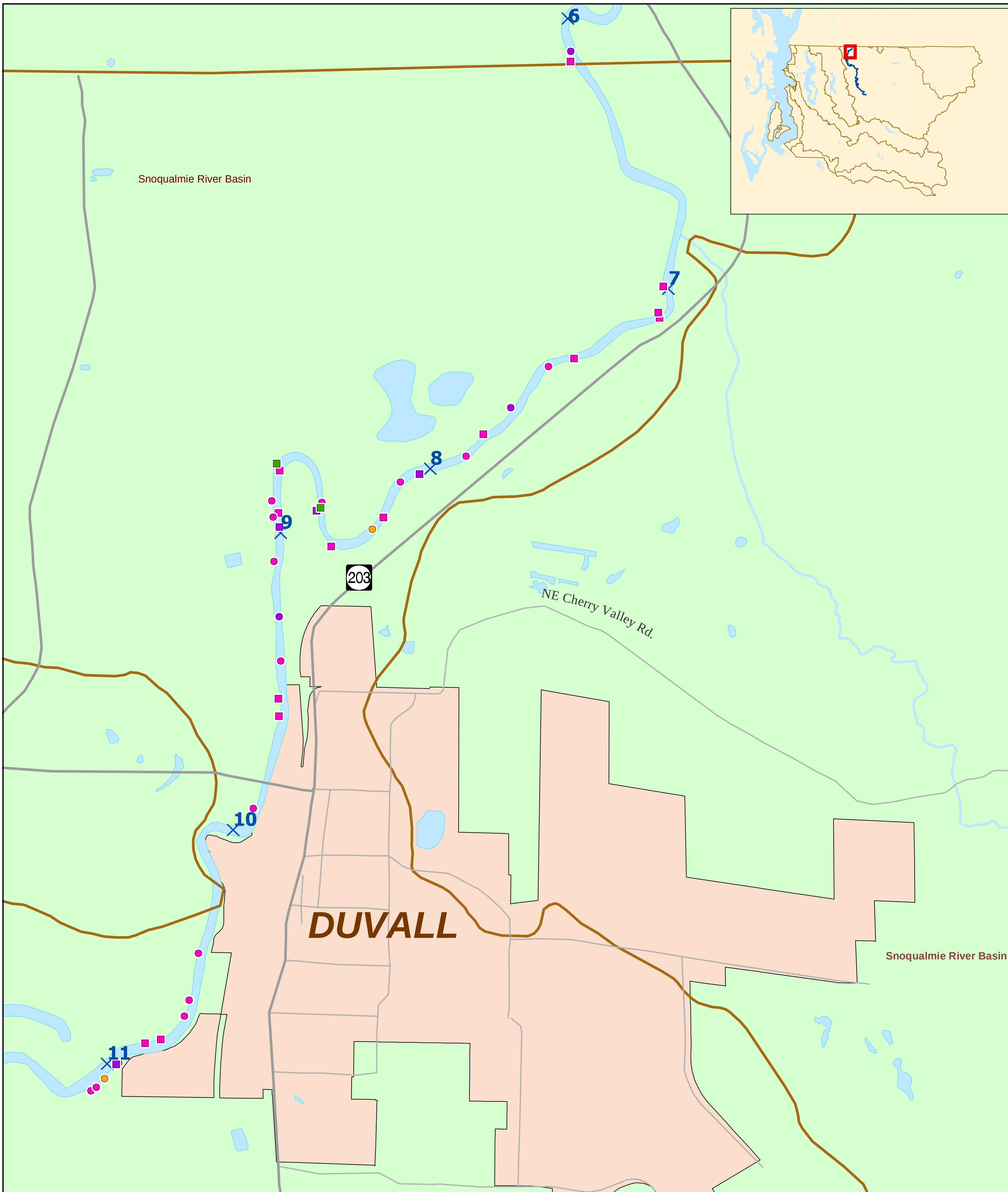

Figure 26.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 1 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long	Debris Jam	Log with Rootwad	Rootwad on Stump
Above OHWM	Above OHWM	Above OHWM	Across OHWM
Across OHWM	Across OHWM	Across OHWM	Below OHWM
Below OHWM	Below OHWM	Below OHWM	

0 0.1 0.2 0.3 0.4
Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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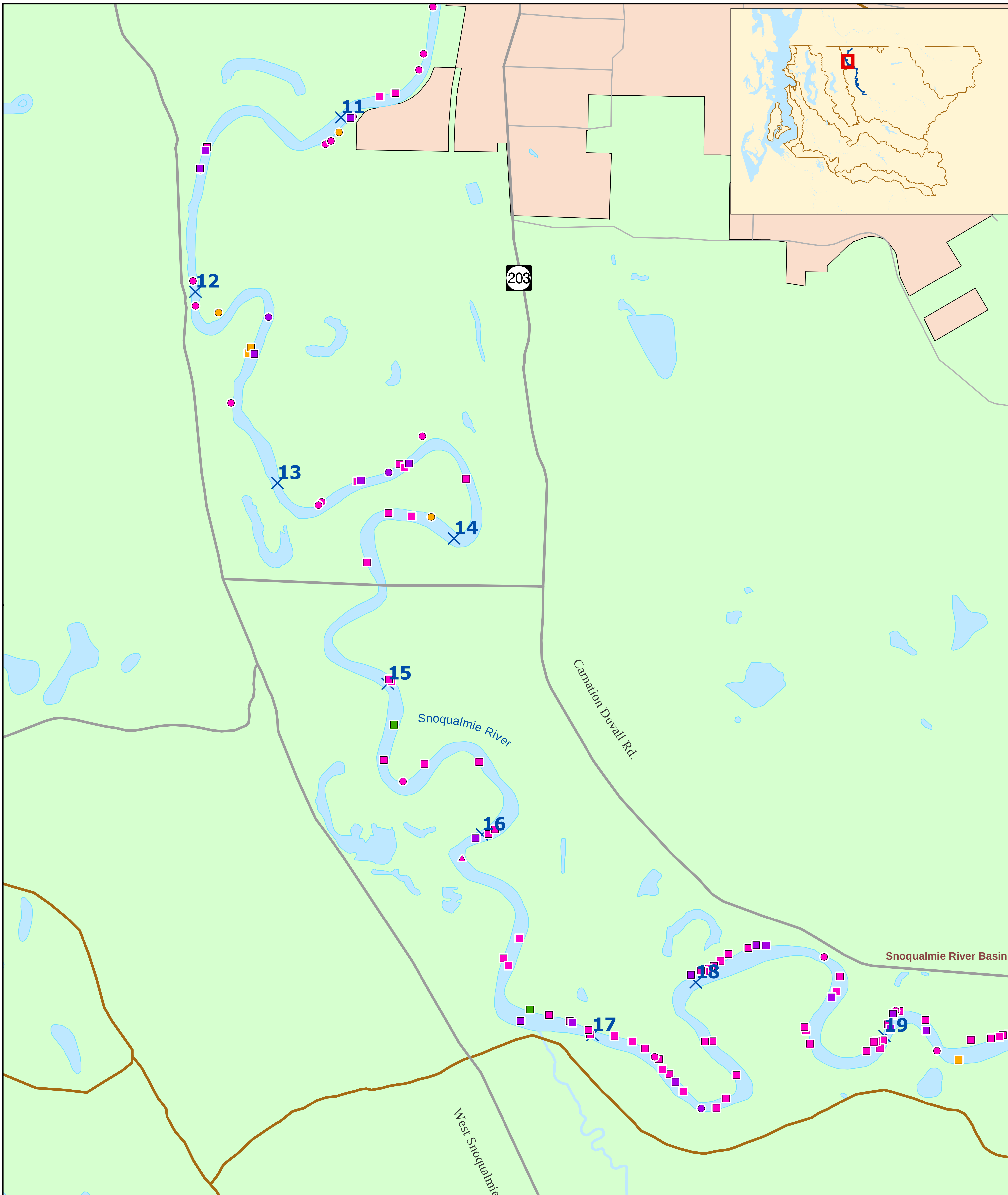

Figure 27.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 2 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long
- Above OHWM
- Across OHWM
- Below OHWM

Debris Jam
- Above OHWM
- Across OHWM
- Below OHWM

Log with Rootwad
- Above OHWM
- Across OHWM
- Below OHWM

Rootwad on Stump
- Across OHWM
- Below OHWM

0 0.1 0.2 0.3 0.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
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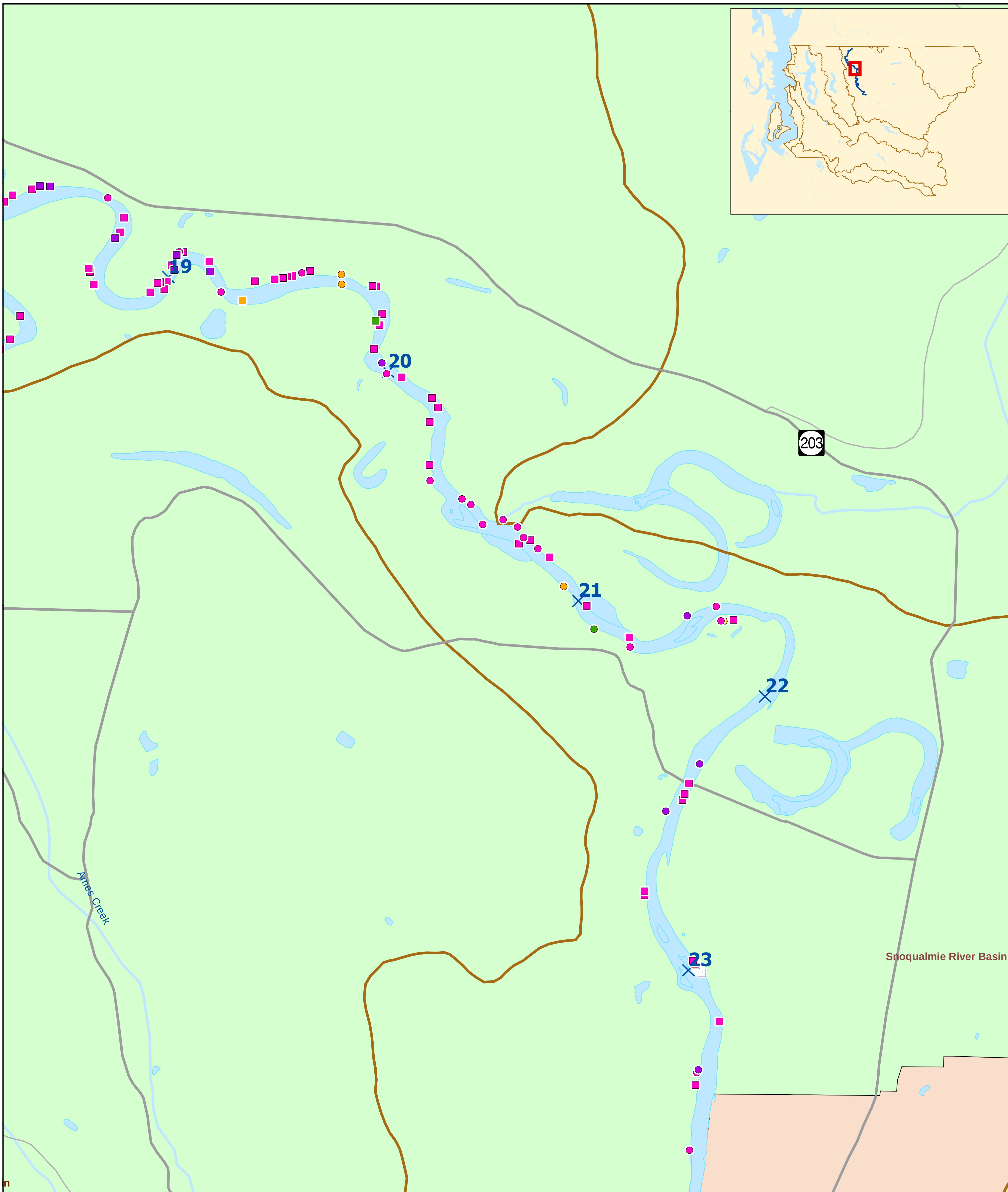

Figure 28.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 3 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long
- Above OHWM
- Across OHWM
- Below OHWM

Debris Jam
- Above OHWM
- Across OHWM
- Below OHWM

Log with Rootwad
- Above OHWM
- Across OHWM
- Below OHWM

Rootwad on Stump
- Across OHWM
- Below OHWM

0 0.1 0.2 0.3 0.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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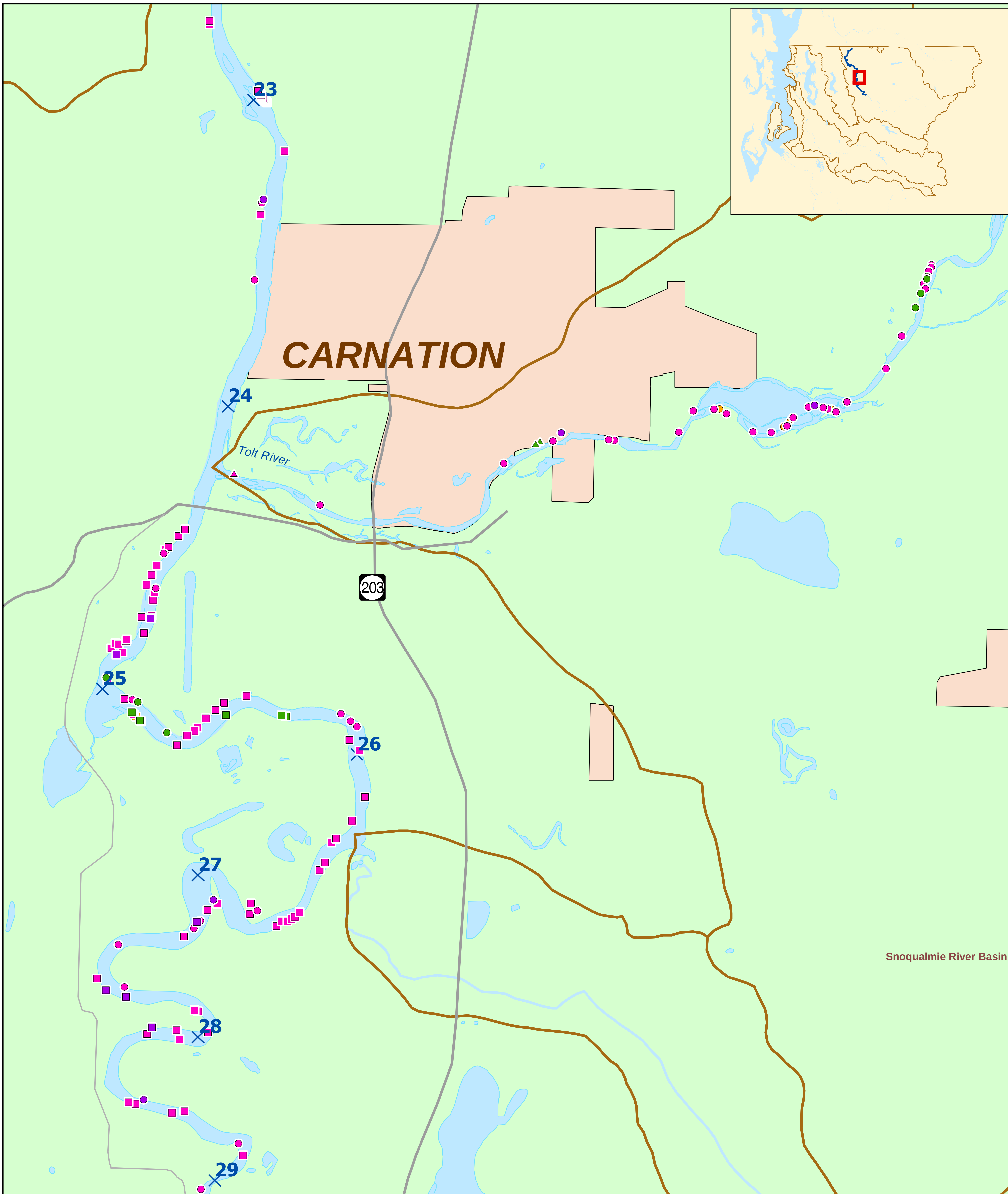

Figure 29.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 4 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long	Debris Jam	Log with Rootwad	Rootwad on Stump
Above OHWM	Above OHWM	Above OHWM	Across OHWM
Across OHWM	Across OHWM	Across OHWM	Below OHWM
Below OHWM	Below OHWM	Below OHWM	

0 0.1 0.2 0.3 0.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:

Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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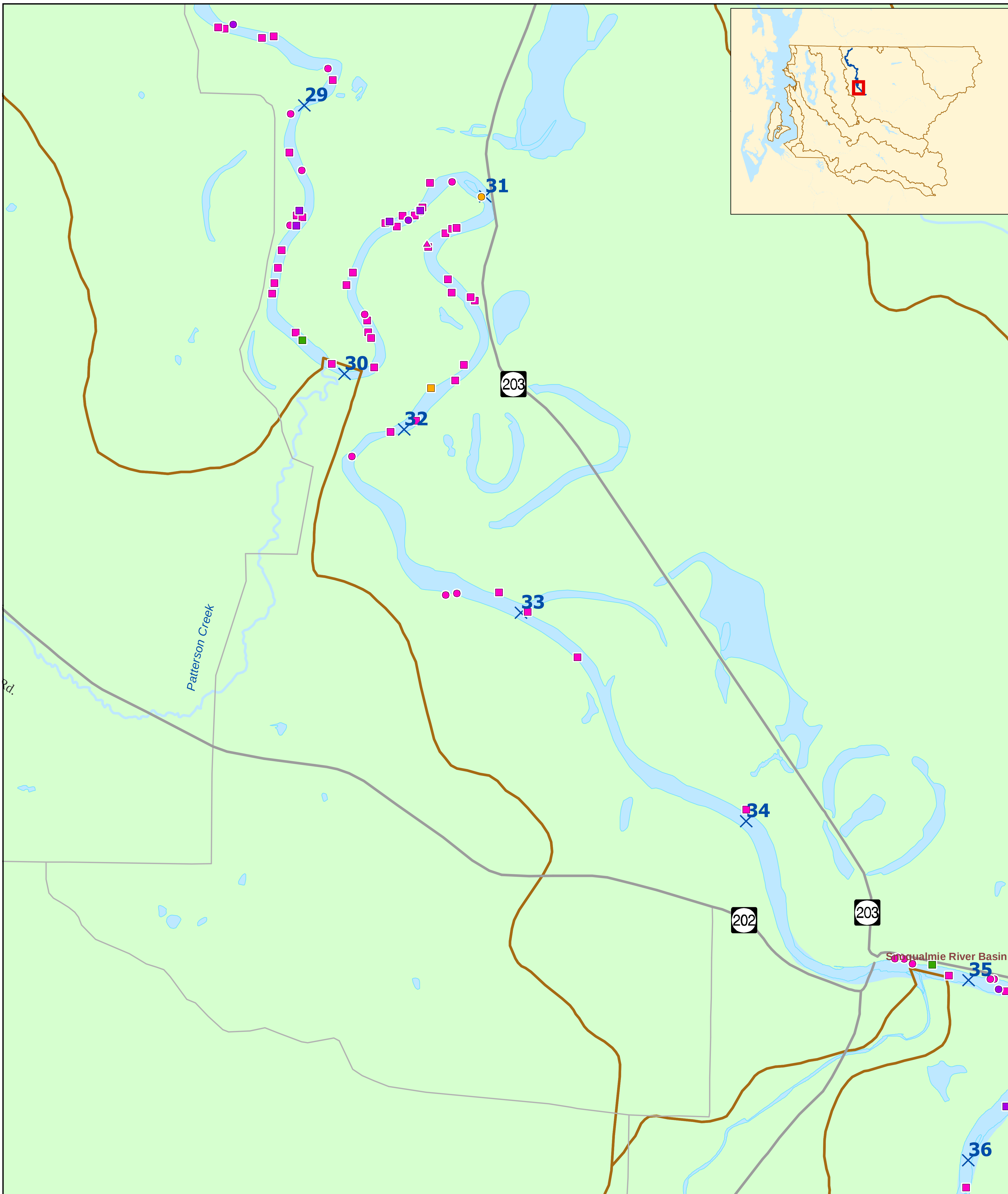

Figure 30.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 5 of 6

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long
- Above OHWM
- Across OHWM
- Below OHWM

Debris Jam
- Above OHWM
- Across OHWM
- Below OHWM

Log with Rootwad
- Above OHWM
- Across OHWM
- Below OHWM

Rootwad on Stump
- Across OHWM
- Below OHWM

0 0.1 0.2 0.3 0.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
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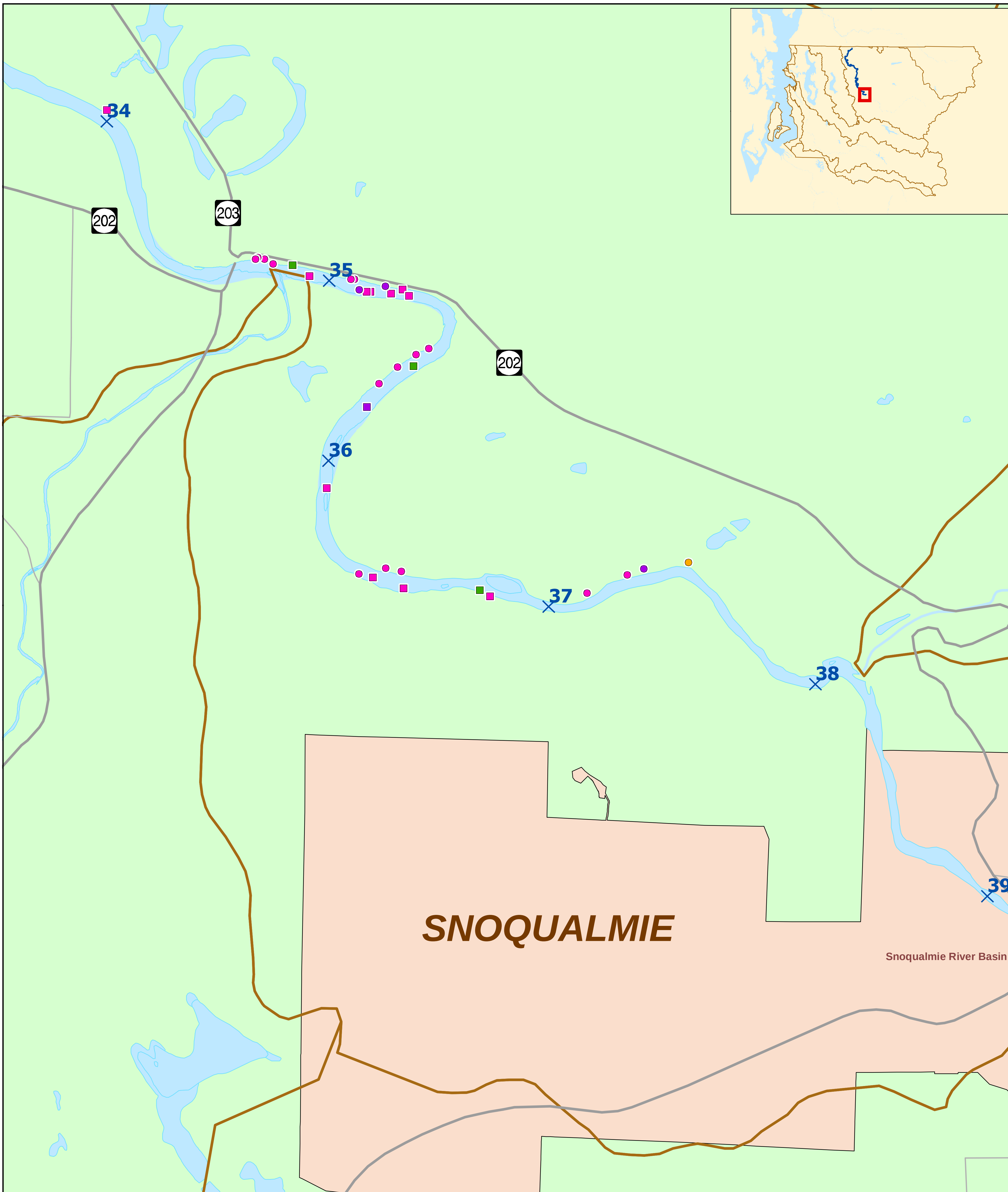

Figure 31.

SNOQUALMIE RIVER SURVEY: Large Woody Debris

Map 6 of 6

N

21
River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

Cut Log > 15 Ft. Long
- Above OHWM
- Across OHWM
- Below OHWM

Debris Jam
- Above OHWM
- Across OHWM
- Below OHWM

Log with Rootwad
- Above OHWM
- Across OHWM
- Below OHWM

Rootwad on Stump
- Across OHWM
- Below OHWM

0 0.1 0.2 0.3 0.4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
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Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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Dumping and Discharge Points

Figures 32 and 33 show the location and type of dumping and discharge points and anthropogenic debris found in the Snoqualmie River in 2000. Cars and car parts, tires, machine and metal parts, and various types of yard waste were identified. At several locations, an unknown liquid was discharging from pipes into the river or seeping into the river. These are potential point sources of pollution. Source tracing and educating the responsible landowners on best management practices (BMPs) will help to alleviate this problem. In general, visible water turbidity increased in the downstream reaches of the Snoqualmie River, especially between RM 6-11. Possible sources of this turbidity are runoff from agricultural land, urbanization, and algal growth.

Miscellaneous Observations

Although this habitat inventory did not focus on identification of aquatic biota, the field team observed great blue herons (*Ardea herodias*), songbirds such as American robins (*Turdus migratorius*), tree swallows (*Iridoprocne bicolor*), and yellow-bellied sapsuckers (Sphyrapicus *varius),* and occasional bald eagles (*Haliaeetus leucocephalus*) using the riparian trees for roosting and perching. The field team also observed large concentrations of live freshwater mussel beds (*Margaritifera falcata*) at two locations: immediately downstream of Neal Road between RM 31-32, and immediately upstream of the City of Duvall between RM 11-12. Numerous cutthroat trout (*Oncorhynchus clarki clarki*) and whitefish (*Prosopium williamsoni*) were seen throughout the Snoqualmie River as well. Sockeye salmon (*Oncorhynchus nerka*) spawners were observed in two locations: near the Neal Road boat launch at RM 31.4 and near RM 18, where a female was observed building a redd. This finding was surprising because WRIA 7 is not known to support populations of wild sockeye salmon.

Large Pools

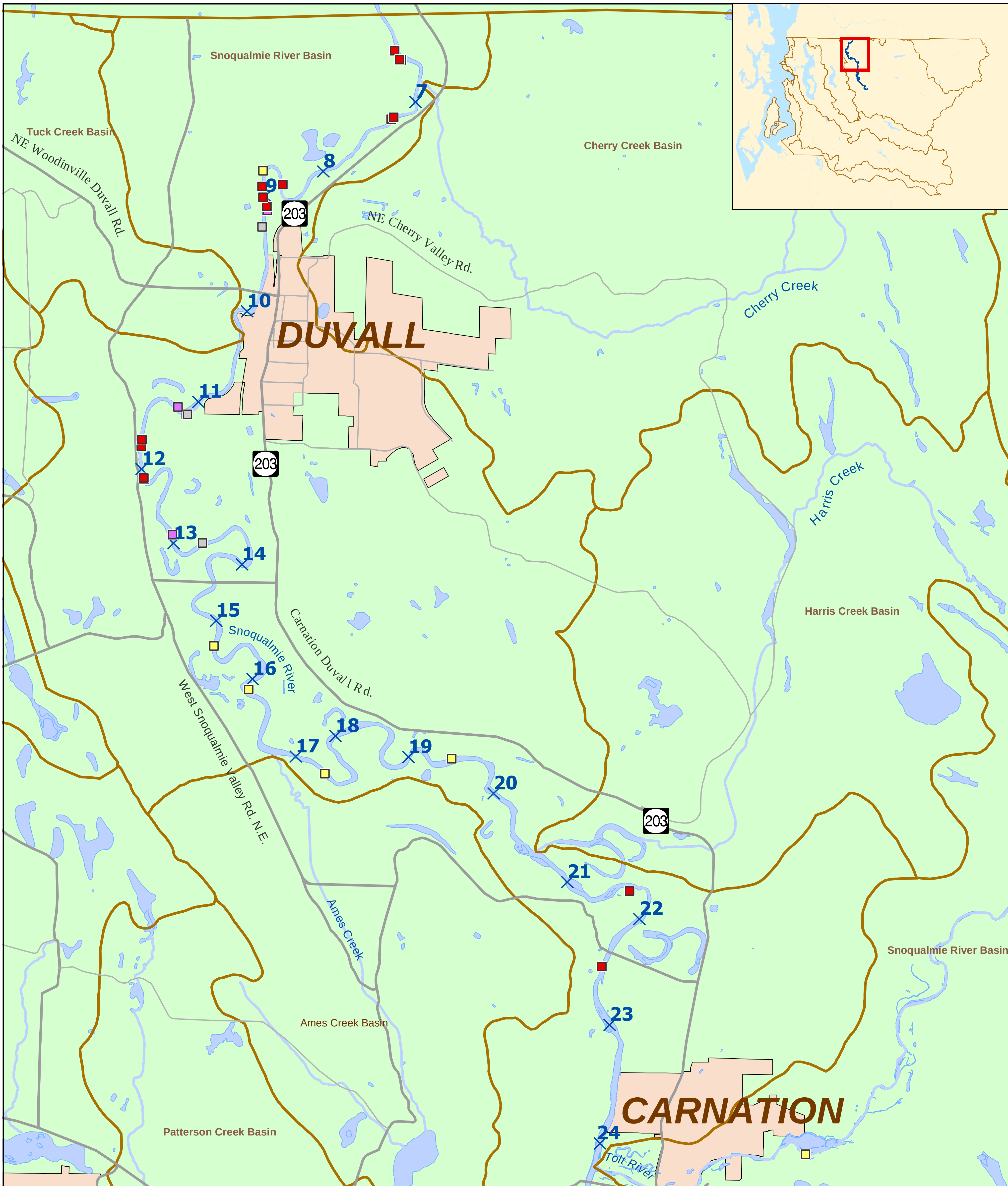
Figures 34 to 36 show the locations of large pools in the King County portion of the Lower Snoqualmie River mainstem in the summer of 2001. In all, 70 large pools, at least as long as the river is wide, were recorded in the 35 mile reach between the mouth of the Snoqualmie River and the confluence of the Snoqualmie and Raging Rivers for an average of two large pools per mile. Many of these pools were several channel widths in length. The frequency of pools and the overall area of pool habitat suggest good rearing, refuge, and prespawning holding habitat for salmonids.

Table 4 indicates that 67 large pools were recorded between the King County line and the confluence of the Snoqualmie and Raging Rivers (RM 6-35) for an average of 2.3 large pools per mile. Between RM 6-35, the Snoqualmie River has five distinct morphological reaches. RM 6-13 is a deep and stable channel with little history of avulsion. This reach is called “County Line to Duvall” and has a very uniform, trough-like streambed with few distinct pools. In the summer of 2001, there were only 1.7 pools per river mile and the pool area (percentage of river area occupied by pools) was only 30.4%. The Snoqualmie River picks up increased gradient and velocity and has a uniform streambed as the river flows over the Tolt River delta, RM 22-25. The pool spacing in this reach was only 1.7 pools per mile, and the pool area was only 25.3%. The Raging River delta, RM 32-35, is also a reach of increased velocity and gradient, does not have a uniform streambed, and averaged 2.0 pools per mile. The percent pool area could not be calculated for this reach because tailout depths were not recorded for three of the six pools and therefore residual depths could not be determined. The two meandering reaches, near Duvall downstream of the Tolt River delta, and near Carnation between the Tolt and Raging River deltas, had nonuniform streambeds with frequent pools. The Duvall Meanders reach had 2.8 large pools per mile, with a 55.3% pool area. The Carnation Meanders reach had 2.7 large pools per mile, with fully 63.7% of the river area occupied by pools.

Figure 32.

SNOQUALMIE RIVER SURVEY: Dumping Sites

Map 1 of 2



N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

CAR OR PARTS
YARD WASTE
UNKNOWN LIQUID
OTHER
TIRES

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Erosional Features: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

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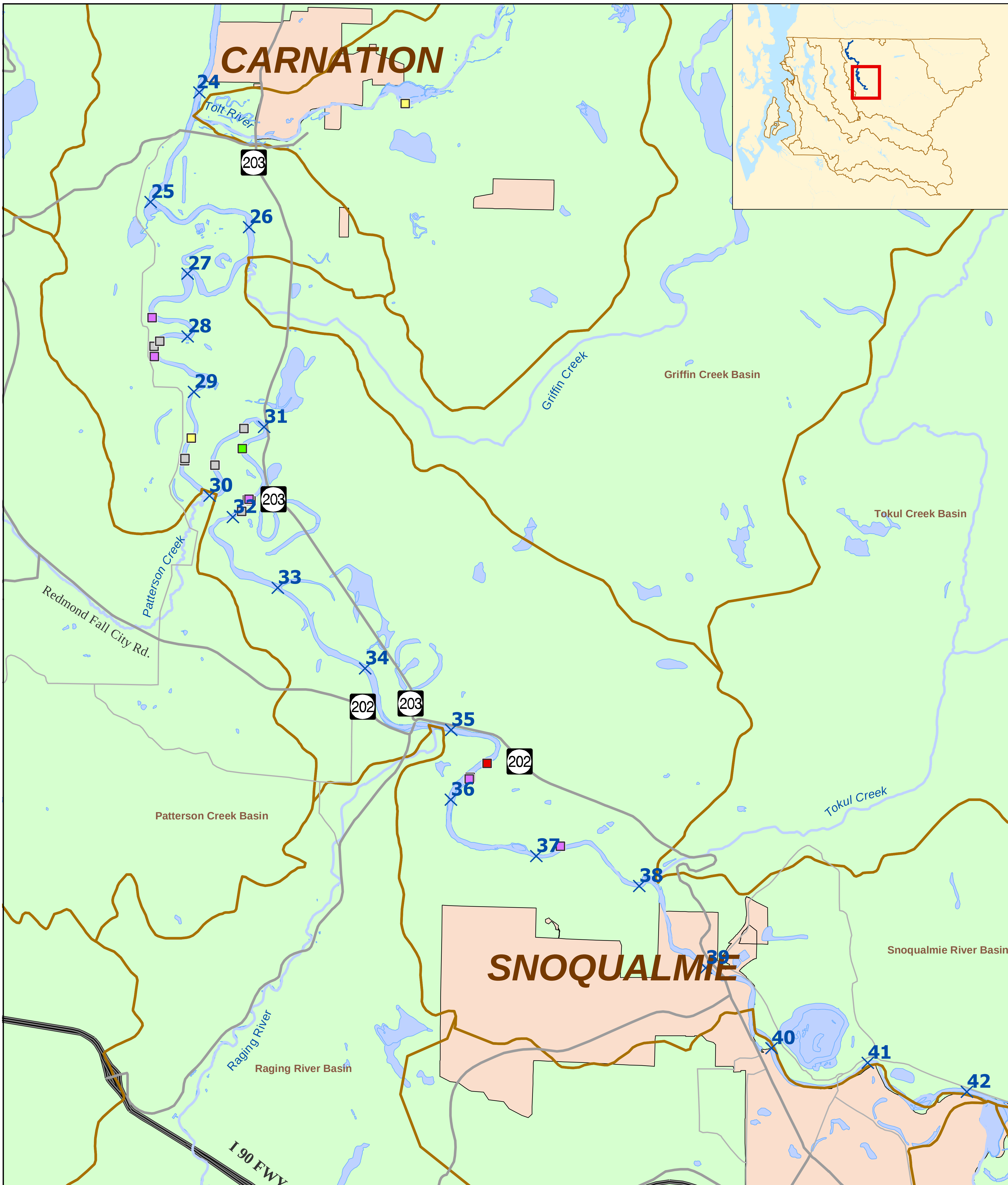

Figure 33.

SNOQUALMIE RIVER SURVEY:
Dumping Sites

Map 2 of 2

N

21 River Miles
Minor Roads
Major Roads
DNRP Basin Boundary
Incorporated Areas

CAR OR PARTS
YARD WASTE
UNKNOWN LIQUID
OTHER
TIRES

0 0.5 1 2 3 4 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
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CJG & CAC, July 2002
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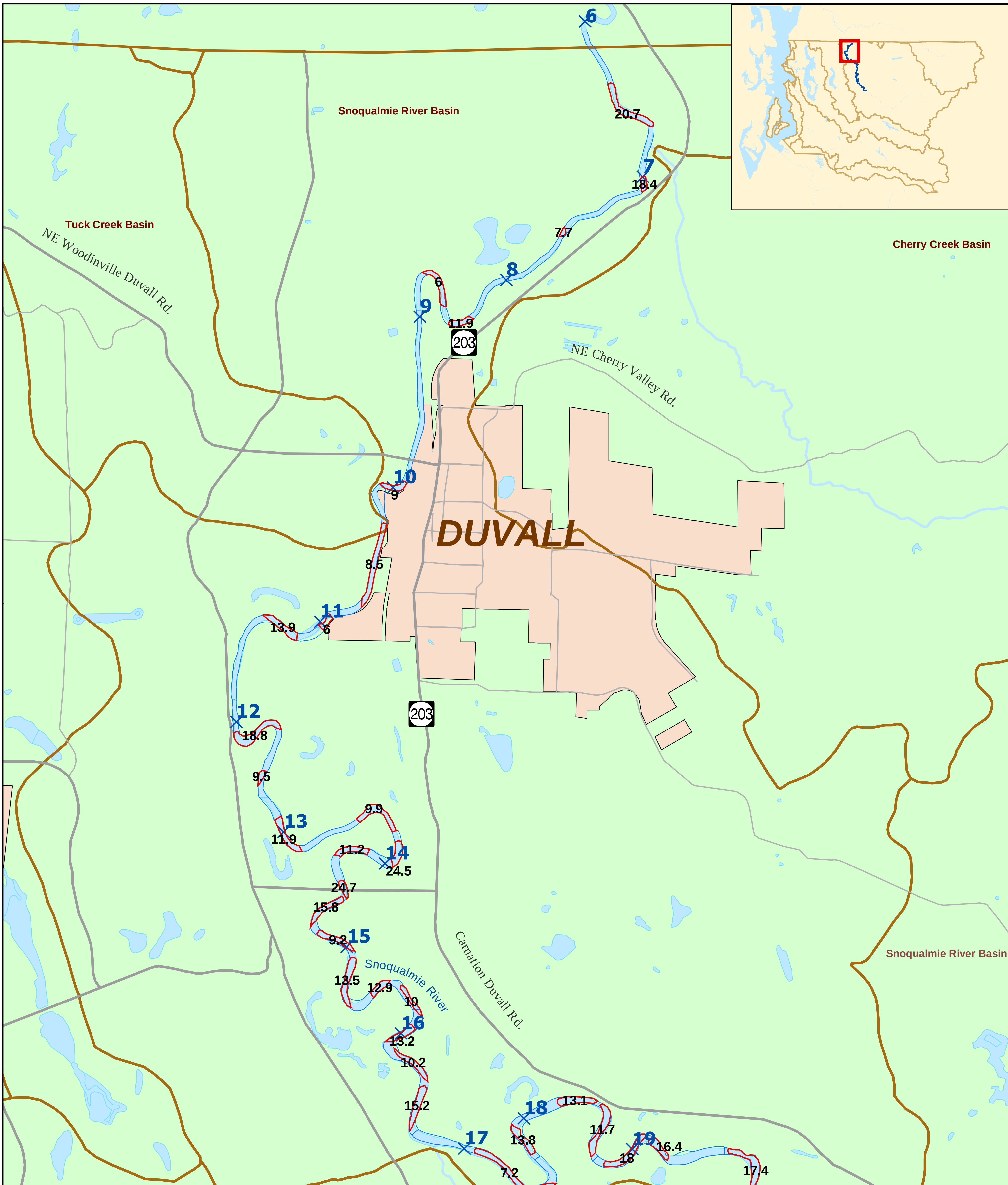

Figure 34.

SNOQUALMIE RIVER SURVEY: Location of Large Pools Map

Map 1 of 3

N

21 River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

11.9 Large Pools (Residual Large Pool Depth Measured in Feet)

Major Streams

Open Water

0 .15 .3 .6 .9 1.2 Miles

King County
Department of Natural Resources and Parks
Water and Land Resources Division

DATA SOURCE NOTES:
Large Woody Debris: KC DNRP & Washington Trout survey, 2000
Waterbodies: KC DNRP & WA DOE Hydrography Project, 1997
River Miles: Generated from waterbody routes in waterbody layer
Basin Boundaries: KC DNRP Basin Planning, 1997

PRODUCED BY:
Department of Natural Resources & Parks
GIS unit
CJG & CAC, September 2002
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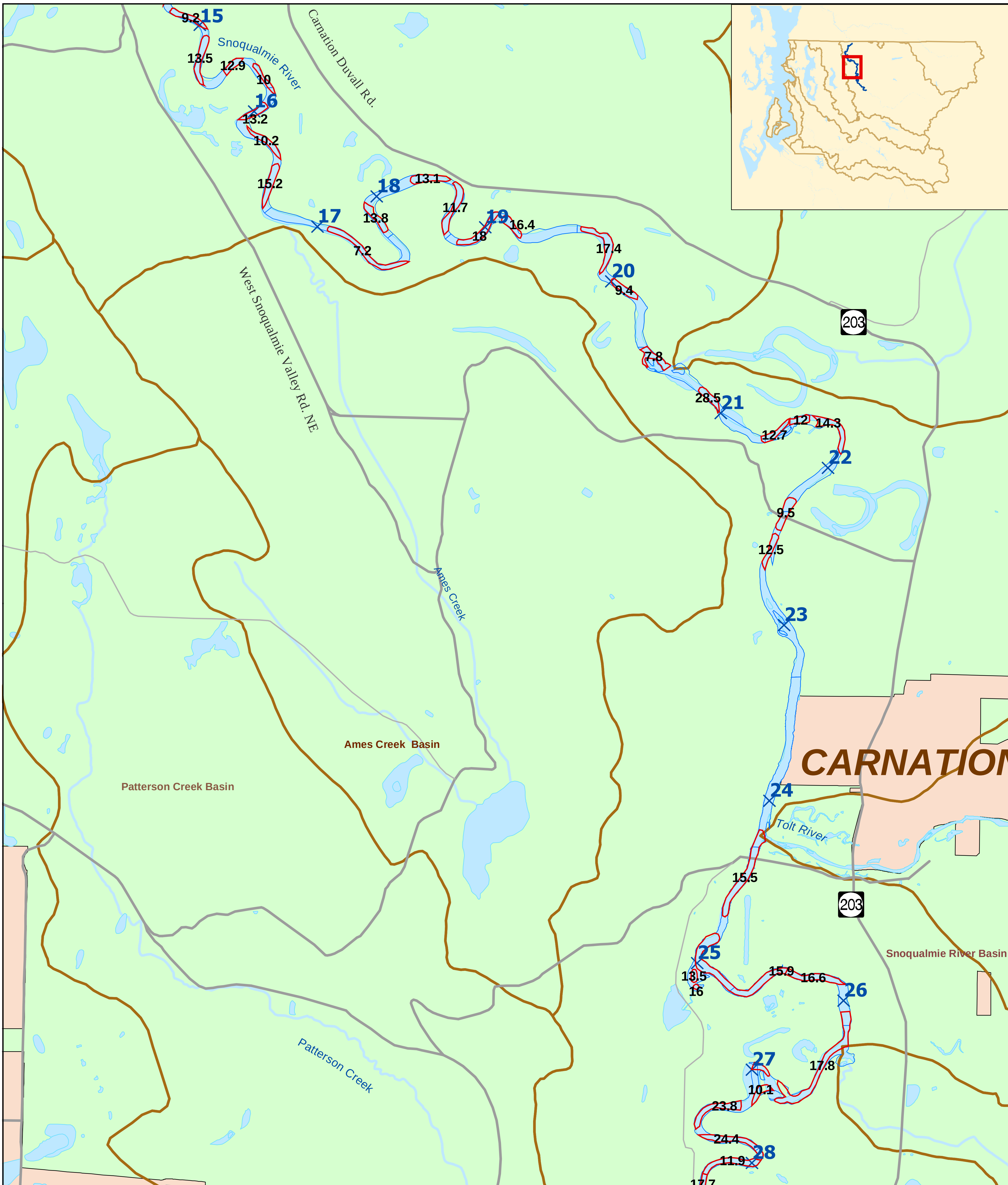

Figure 35.

SNOQUALMIE RIVER SURVEY: Location of Large Pools Map

Map 2 of 3

N

21 River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

11.9 Large Pools (Residual Large Pool Depth Measured in Feet)

Major Streams

Open Water

0 .15 .3 .6 .9 1.2 Miles

King County
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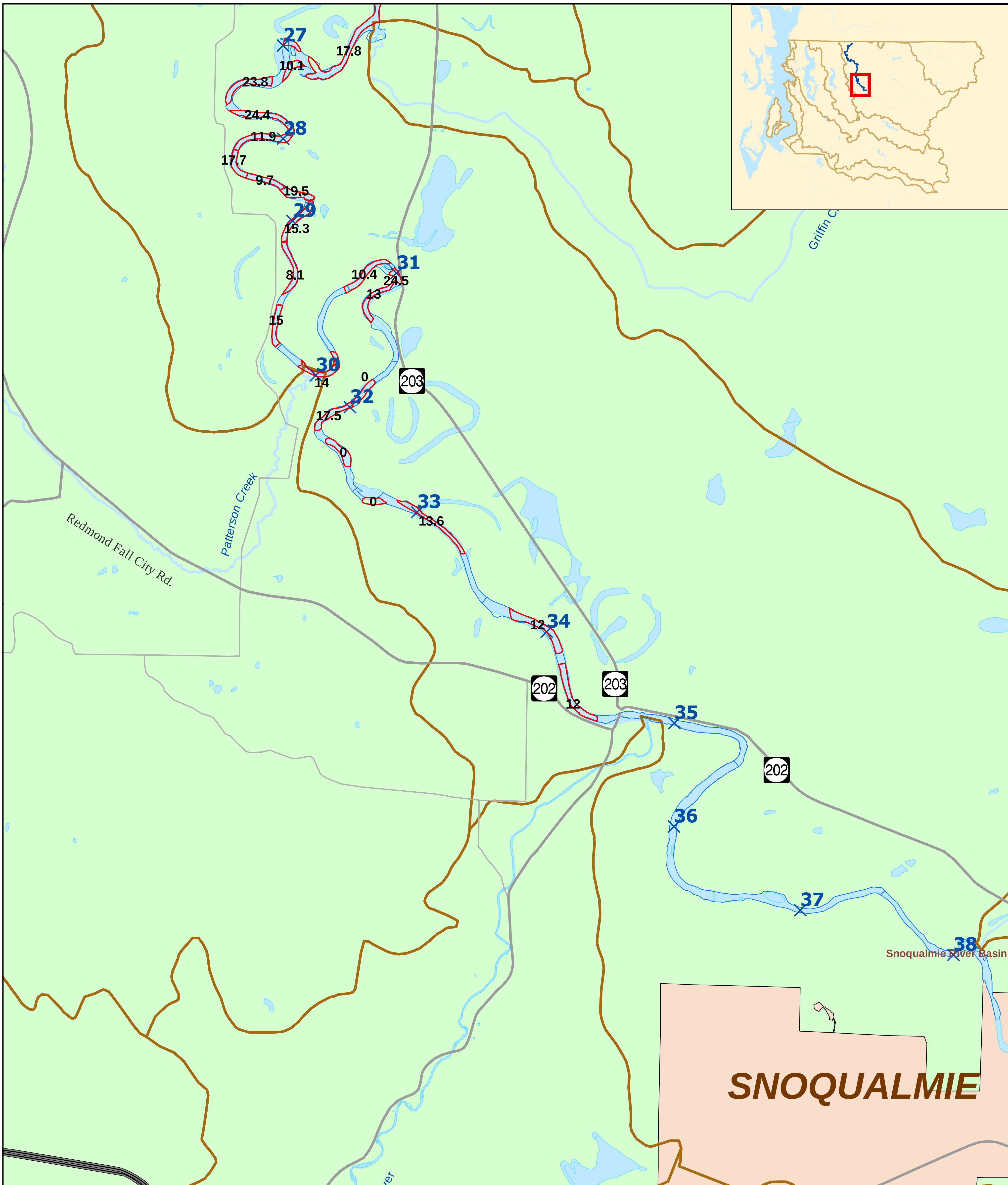

Figure 36.

SNOQUALMIE RIVER SURVEY: Location of Large Pools Map

Map 3 of 3

N

21 — River Miles

Minor Roads

Major Roads

DNRP Basin Boundary

Incorporated Areas

11.9 — Large Pools (Residual Large Pool Depth Measured in Feet)

Major Streams

Open Water

0 .15 .3 .6 .9 1.2 Miles

King County
Department of Natural Resources and Parks
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Residual large pool depth was consistent throughout the Snoqualmie River. Pools averaged 14.1 feet (4.3 meters) of residual depth, and ranged between 6.0 and 28.5 feet (1.8 and 8.7 meters). The average residual depth in the different morphological reaches ranged from 11.9 feet (3.6 meters) in the "County Line to Duvall" reach to 15.9 feet (4.9 meters) in the Carnation Meanders reach.

Two pools had a maximum depth of 30 feet (9.2 meters). Almost all of the pools were formed by scour along the riverbanks. A few pools were dammed behind accumulated sediment, such as just upstream of the Tolt River delta. None of the large pools had been formed by logjams.

Table 4. Frequency, Residual Depth, and Area of Pools in Mainstem Snoqualmie River (RM 6-35) in Summer 2001

River Mile	Reach	Pools	Pools/ mile	Range Residual Depth Feet (meters)	Average Residual Depth Feet (meters)	% Pool area
6-13	County Line to Duvall	12	1.7	6.0-18.8 (1.8-5.7)	11.9 (3.6)	30.4
13-22	Duvall Meanders	25	2.8	7.2-28.5 (2.2-8.7)	14.1 (4.3)	55.3
22-25	Tolt River Delta	5	1.7	9.5-16.0 (2.9-4.9)	13.4 (4.1)	25.3
25-32	Carnation Meanders	19	2.7	8.1-24.5 (2.5-7.5)	15.9 (4.9)	63.7
32-35	Raging River Delta	6	2.0	12-17.5 (3.7-5.3)	13.8 (4.2)	N/A
6-35	**All**	**67**	**2.3**	**6-28.5 (1.8-8.7)**	**14.1 (4.3)**	**42.0**

Temperature

Temperature loggers recorded the water temperature at the bottom of deep pools at four locations in the Snoqualmie River every hour from July 14 to September 28, 2000, and at three locations in the Snoqualmie River every hour from June 26 to October 19, 2001. The exact locations are described in the Methods Section of this report.

Both hourly and average monthly water temperatures increased progressively downstream in both 2000 and 2001, with Duvall being the warmest and the Raging River mouth being the coolest (Figures 37 to 40, Tables 5 to 8). The difference between minimum and maximum monthly temperatures ranged from 5.3 to 6.6°C at each site in 2000 and from 2.7 to 7.5°C at each site in 2001 (Table 6). Since all temperatures were measured at the bottom of deep pools, these measurements may not depict actual average water column or surface temperatures.

Table 5. Seven-Day Moving Average Temperature (°C) in Mainstem Snoqualmie River in Summer 2000 and Summer 2001

	7-day moving average	
	2000	2001
Duvall	20.5	17.2
Tolt River Mouth	19.8	N/A
Neal Road	19.2	16.5
Raging River Mouth	18.4	16.0

Table 6. Minimum and Maximum Temperatures (°C) in Mainstem Snoqualmie River in Summer 2000 and Summer 2001

	2000					
	July 14 - 31		August		Sept 1 - 28	
	min	max	min	max	min	max
Duvall	14.9	21.2	15.5	21.2	11.3	17
Tolt River Mouth	14.2	20.5	14.7	20.5	11.1	16.6
Neal Road	13.2	19.7	13.3	19.9	10.5	16.3
Raging River Mouth	12.7	19	13.4	19.2	10.5	15.8

	2001							
	June 26 - 30		July		August		September	
	min	max	min	max	min	max	min	max
Duvall	12.4	15.7	13.3	19.5	13.9	20.8	12.5	18.5
Neal Road	11.6	14.3	12.6	15.4	13.3	20.8	11.2	17.6
Raging River Mouth	11.4	14.2	12.4	15.2	13.1	20.1	11.4	17.5

Table 7. Average Temperature (°C) by Month in Mainstem Snoqualmie River in Summer 2000 and Summer 2001

	2000			
	July 14 - 31	August	Sept 1 - 28	
Duvall	17.3	17.8	14.4	
Tolt River Mouth	16.7	17.3	13.9	
Neal Road	16.1	16.4	13.4	
Raging River Mouth	15.8	16.1	13.2	
	2001			
	June 26 - 30	July	August	September
Duvall	13.7	16.7	17.7	15.6
Neal Road	12.8	15.4	16.6	14.4
Raging River Mouth	12.6	15.2	16.3	14.2

Table 8. Number of Hours that Temperature $\geq$ 18°C in Mainstem Snoqualmie River in Summer 2000 and Summer 2001

	2000	2001
	hours at or above 18°C	hours at or above 18°C
Duvall	393	469
Tolt River Mouth	317	N/A
Neal Road	175	171
Raging River Mouth	116	120

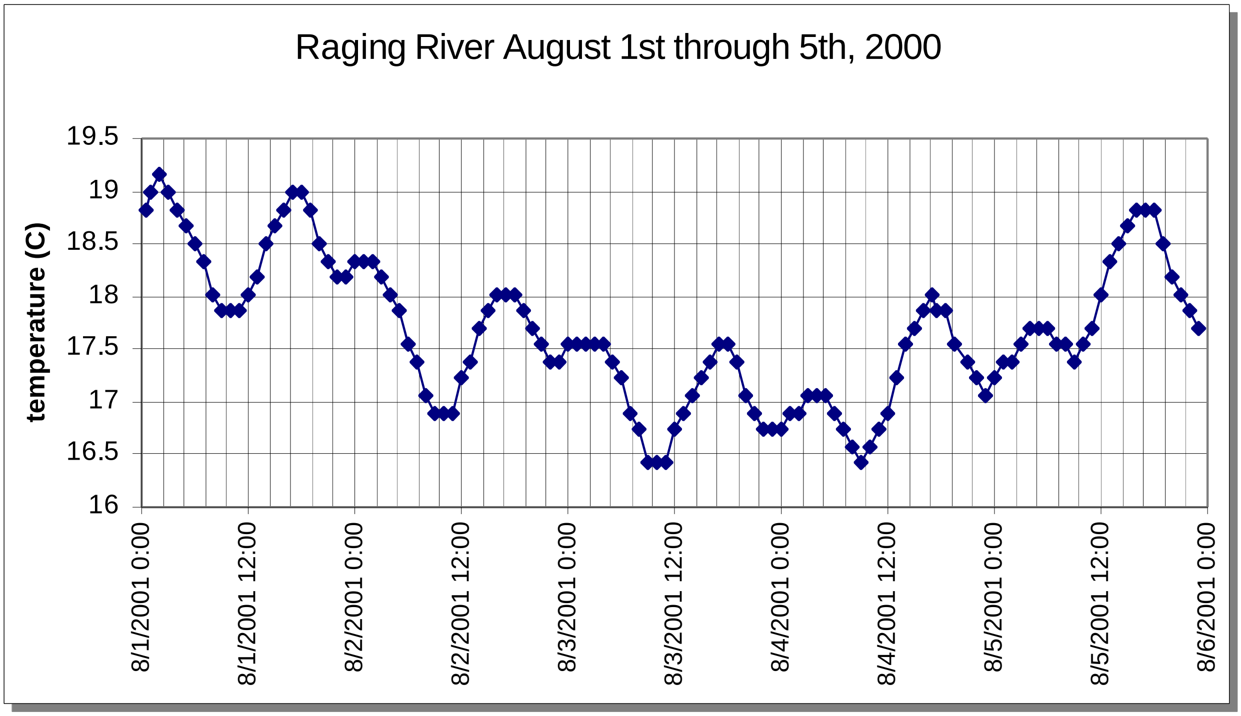

Figure 37. Diurnal Temperature Measurements at Raging River Site, August 1-5, 2000

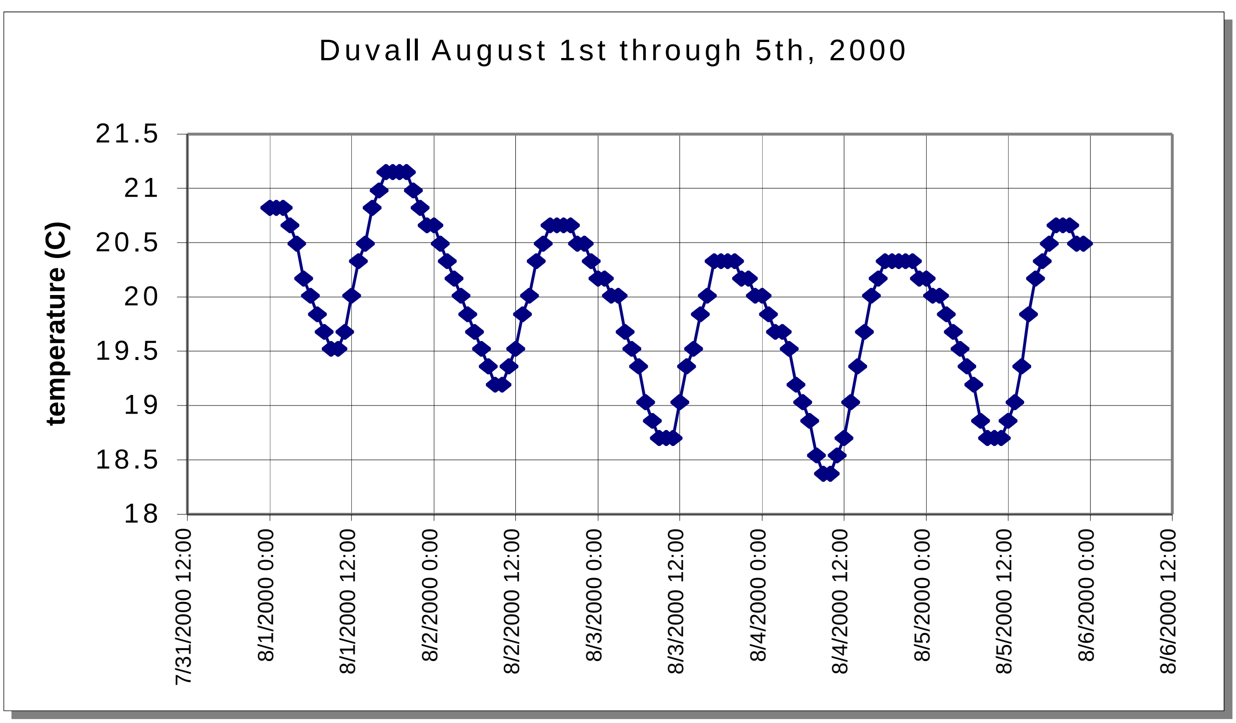

Figure 38. Diurnal Temperature Measurements at Duvall Site, August 1-5, 2000

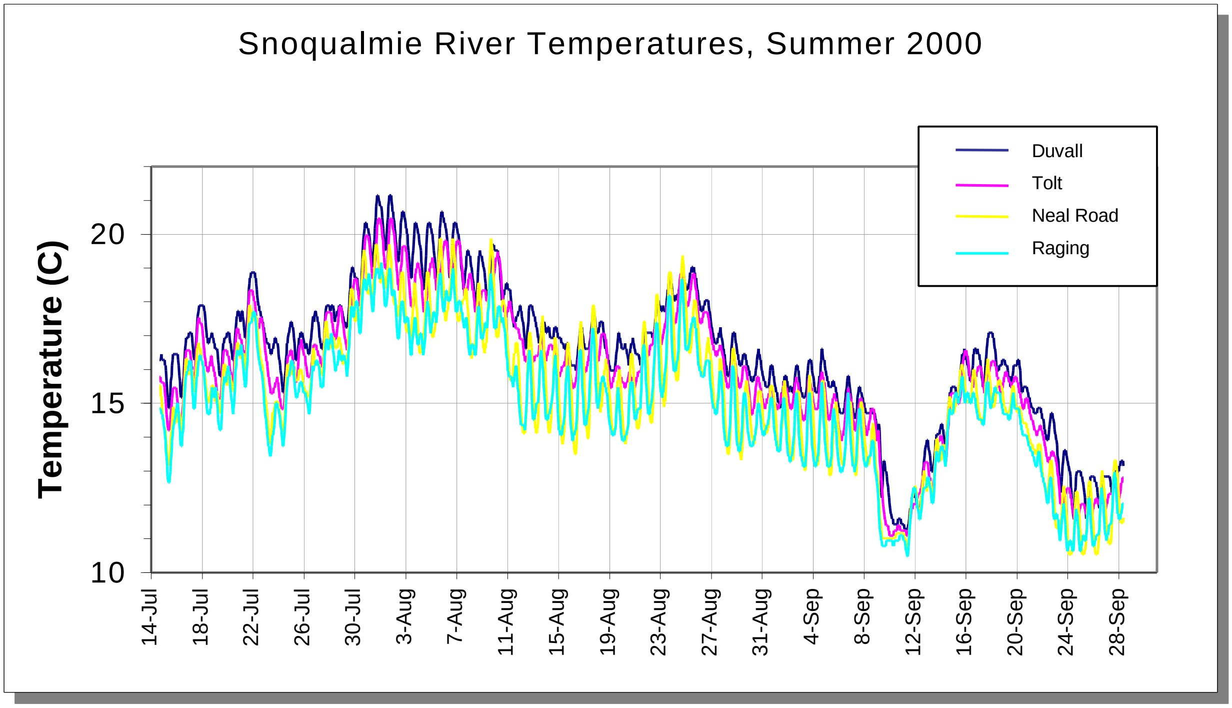

Figure 39. Snoqualmie River Temperature Measurements, Summer 2000

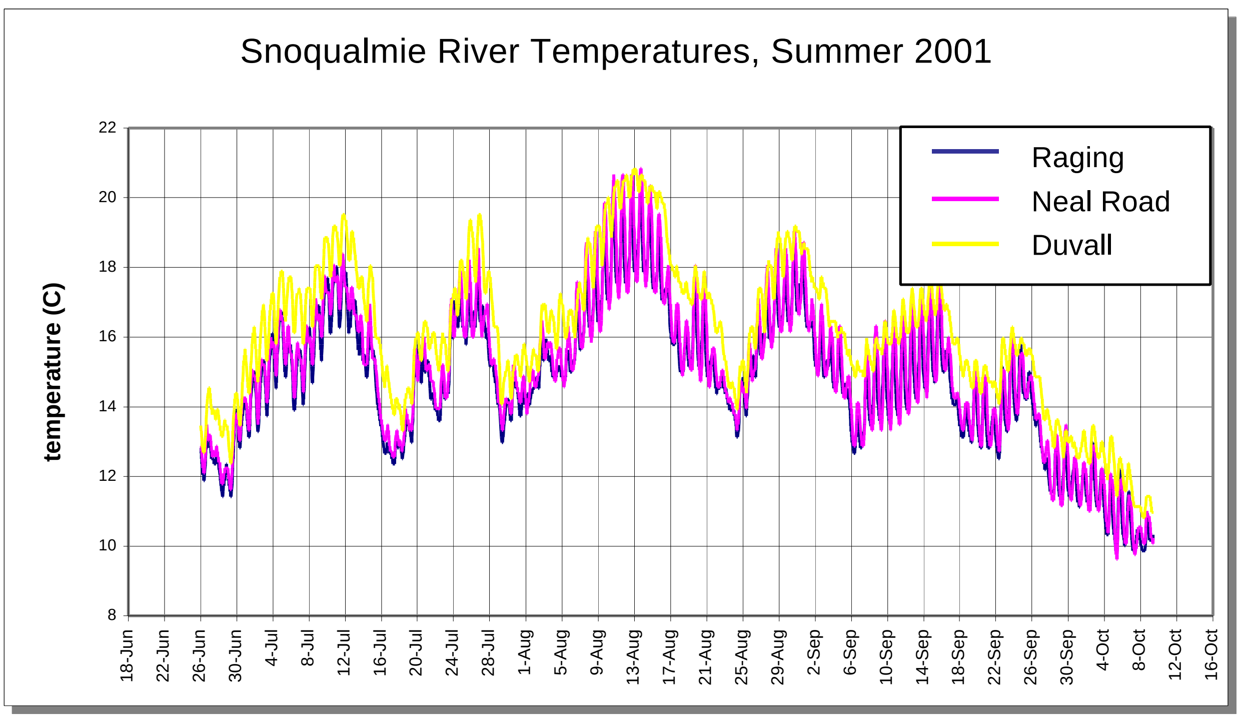

Figure 40. Snoqualmie River Temperature Measurements, Summer 2001

Examination of diurnal fluctuations in temperatures at each site revealed that the time for peak temperature differed at each site. The Raging River site peaked around 6 PM daily, the Neal Road site peaked around 5 PM daily, and the Duvall and the Tolt River sites peaked around 10 PM. These findings correlate with the water depth of the loggers. The Raging River and Neal Road temperature loggers were in only about 8 feet of water, while the Tolt River and Duvall loggers were in over 10 feet of water. The hottest time of the day for summer air temperatures is around 3 to 5 PM. It may be that water temperature on the surface peaks in the late afternoon and the warmer water slowly mixes with the bottom of the water column resulting in later peak temperatures registering on the loggers in the deeper pools.

The logger at the Raging River site showed two separate temperature peaks per day. The second, more minor peak occurred approximately 12 hours after the primary temperature peak. This second peak was only slightly noticeable on colder days, but was evident on warmer days. This pattern appeared at the Neal Road site as well, but was less evident than at the Raging River site.

The first week of August is statistically the warmest week of the year in western Washington (University of Washington, 2002). Figures 37 and 38 show temperatures recorded from August 1 to 5 in 2000 at the Raging River and Duvall sites. The seven-day average daily maximum temperature from August 1 to 7 in 2000 (Table 5) ranged from 18.4° to 20.5°C, exceeding the 17.8°C threshold for “degraded” water quality for salmonid rearing as defined by the Snohomish Basin Salmonid Recovery Technical Committee. The seven-day average daily maximum temperature from August 1 to 7 in 2001 (Table 5) ranged from 16.0 to 17.2°C. Therefore, each site was “moderately degraded” for water quality for salmonid rearing, i.e., within the “moderately degraded” range of 13.9 to 17.8°C (Snohomish Basin Salmonid Recovery Technical Committee, 2002).

Water temperatures at or above 18°C, temperatures dangerous to salmonid survival (Berman, 1998), were recorded for over 300 hours each summer at the Duvall site and at the Tolt River mouth site in 2000 (Table 8). Overall, the water temperatures during the summer months in 2000 and 2001 were in a temperature range that is considered limiting to salmonid rearing (Berman, 1998; Bjornn and Reiser, 1991). The mainstem Snoqualmie River is on the final 1998 303(d) list based on exceedances of the state water quality criterion for temperature (Washington Department of Ecology, 2000). Lack of riparian cover and presence of low gradient causing slow moving water in the channelized lower reaches of the river contribute to elevated temperature. The summer 2000 habitat conditions inventory showed that even where there is a dense riparian canopy, the trees rarely overhang the river by more than 5 feet. The Snoqualmie River is too wide for the riparian vegetation to have a significant shading effect. Clearcutting in headwaters areas of the Snoqualmie Watershed may also be influencing water temperatures in downstream areas (i.e., the lower mainstem Snoqualmie River).

TRIBUTARIES TO LOWER SNOQUALMIE RIVER MAINSTEM

University of Washington Temperature Survey (1999-2001)

King County WLRD staff and Snoqualmie Watershed residents participated in a Puget Sound Lowland stream temperature monitoring study that was designed by the University of Washington Center for Urban Water Resources Management (CUWRM) and Center for Streamside Studies. The goals of the study were to determine if stream temperatures during the middle of the historically hottest week of the year (i.e., first Wednesday of August) are in compliance with State of Washington water quality standards for temperature and to determine the influence of riparian canopy and urban development on stream temperatures.

Methods

In the Snoqualmie Watershed, four tributaries to the Lower Snoqualmie River mainstem were selected for temperature measurements in 1999 to 2001: Harris, Griffin, and Patterson Creeks, and the Raging River. King County WLRD staff and Snoqualmie Watershed residents monitored temperature at several sites in Harris and Patterson Creeks, and in the Raging River on August 4, 1999, August 2, 2000, and August 1, 2001. Temperature in Griffin Creek was also monitored on the 1999 and 2001 dates. To ensure accuracy of temperature measurements, each team calibrated their thermometer in an ice-water bath early in the afternoon of the monitoring day. Temperature measurements were collected once at each site between 3 and 5 PM, which is statistically the hottest part of a summer day. At each site, a data sheet was filled out indicating site number, location, air temperature, water temperature, riparian canopy, flow conditions, water depth, and estimated water flow speed. The project cover sheet and a field sampling site data form are found in Appendix B. Completed cover and data sheets were submitted to the University of Washington research team for compilation with temperature data from streams in other Puget Sound Lowland watersheds. Following is a summary of the findings for the four tributaries to the lower Snoqualmie River. The report of the entire study, including descriptions of the specific monitoring sites for the Snoqualmie River tributaries, can be accessed through the CUWRM web site (http://depts.washington.edu/cuwrm/).

Results and Discussion

Table 9 indicates the number of temperature monitoring sites and the mean, minimum, and maximum temperatures recorded for each tributary on the monitoring day of each monitoring year. The overall mean temperature for each tributary on the three monitoring days is also shown.

Table 9. Summary of Temperature Survey Data in Snoqualmie River Tributaries

Tributary	1999 Number of Sites	1999 Mean Temperature	1999 Range (degrees C)	2000 Number of Sites	2000 Mean Temperature	2000 Range (degrees C)	2001 Number of Sites	2001 Mean Temperature	2001 Range (degrees C)	Overall Mean Temp.
Raging River	4	17.6	15–19.5	5	20.8	16.5–24.5	6	15	13–16	**17.6**
Patterson Creek	9	15.6	15–16	8	16.1	15–17	5	13.2	13–13.5	**15.2**
Griffin Creek	7	17.1	11–20	*no measurements*			7	14.3	11–16.5	**15.7**
Harris Creek	4	19.1	17–22	8	17.4	14–21	7	14.8	13–20.5	**16.8**

Juvenile salmonids rear in the Raging River and in Patterson, Griffin, and Harris Creeks during the summer months. The optimal temperature for rearing is 10 to 13.9°C (50 to 57°F) for species other than bull trout and less than 10°C for bull trout (Bjornn and Reiser, 1991). These temperatures were exceeded at most monitoring sites on all four tributaries. The overall mean temperature for each tributary also exceeded the optimal temperature range. Some temperature measurements in the Raging River, Griffin Creek, and Harris Creek also exceeded 18°C, thereby violating the State of Washington water quality standard for temperature in Class A waterbodies. Water temperatures that are this high can affect salmonid survival and can also have sublethal physiological and behavioral effects such as decreased growth rate, decreased enzymatic activity needed for smoltification, less resistance to disease, and increases in disease virulence (Berman, 1998). The effects of habitat perturbations during freshwater rearing of salmonids can persist into the marine phase of the life cycle. Therefore, sublethal temperatures experienced during any one life stage may have repercussions for individual fitness and ultimately population and species viability (Holtby, 1988).

There was no consistent correlation between water temperature and the presence or absence of riparian canopy in the four streams. At a few sites (e.g., Raging River 2000, Patterson Creek 1999, Griffin Creek 2001, and Harris Creek 2000), temperatures were lower when the stream was fully shaded by riparian vegetation. However, at other sites, water temperatures in full shade were higher than temperatures in partial shade or full sun. Groundwater influx may have been a confounding factor at these sites.

Water temperatures were higher at the downstream sites than the upstream sites in the Raging River on the monitoring days in 2000 and 2001. The range was from 16.5°C at the most upstream site to 24.5°C at the most downstream site in 2000 and from 13°C at the most upstream site to 16°C at the most downstream site in 2001. These temperature measurements follow the same pattern that was observed with the temperature logger data in the mainstem Snoqualmie River in the summers of 2000 and 2001. However, this pattern was not observed in the other tributaries; underground spring input may be a complicating factor in those systems.

High summer water temperatures in tributaries to the Snoqualmie River are a factor contributing to the high summer water temperatures in the mainstem Snoqualmie that were cited earlier in this report. The mainstem Snoqualmie is warm, in part because the tributaries are warm. To reduce temperatures, solutions must be found starting high in the headwaters to ensure that feeder tributaries are well-shaded and riparian canopy is restored to the maximum extent practicable all the way downstream in the watershed.

Stream Walks in 2001

In summer 2001, King County WLRD staff began a qualitative habitat inventory of tributaries to the Snoqualmie River. Fieldwork conducted in 2001 included reaches of the Raging River (RM 0-8.2), Tolt River (RM 2.8-5.9), and Griffin Creek (RM 0-3.1). The survey of the Snoqualmie River tributaries was modeled after a survey performed for the Cedar River Watershed in the early 1990s, in which baseline data were collected in qualitative form for most of the watershed.

Methods

Parameters observed for the Snoqualmie tributaries included riparian vegetation, LWD, substrate type, bank hardening and erosion, presence of pools, fish, wildlife, and benthic macroinvertebrates, adjacent land use, and general habitat condition. Two-person field teams walked each tributary and took notes and photographs on the above parameters about every 0.1 mile. The information from these stream walks will be used to make habitat and aquatic resources management decisions in King County and to identify potential areas for conservation or restoration. The information will also provide a baseline for developing a quantitative monitoring program to detect trends in habitat quality over time and for adaptive management as habitat protection and restoration actions are implemented in the Snoqualmie Watershed. Furthermore, the data will be shared with the WRIA 7 Technical Committee and used to inform the strategic assessment and the long-term salmon conservation and recovery plan for WRIA 7.

Results and Discussion

The dates of the stream walks were August 27 and 29 for the Raging River, September 5 for Griffin Creek, and October 2 for the Tolt River. Field observations are summarized and interpreted below. More detailed field notes are available upon request from King County WLRD (Boles, 2001).

Raging River (RM 0-8.2)

The Raging River is confined in a narrow channel between containment levees for the lower 1.3 river miles before it flows into the Snoqualmie River. This reach is choked with sediment and gravel bars are built up as much as 4 feet above the summer low-flow channel. The riverbed is higher than the surrounding topography as gravel has accumulated within the levees, and the gravels are generally embedded with fine sediments. Riparian vegetation through this reach is dominated by invasive shrubs. However, tall cottonwoods align the RB of the channel and provide shade. Habitat conditions are poor with relatively fast flows as the wetted stream navigates around the tall gravel bars. There is no LWD or other types of cover in this reach, and very little slow water habitat. Therefore, salmonid rearing and refuge habitat is limited here.

Upstream from the containment levees, the habitat conditions in the Raging River improve greatly, except for specific areas around RM 6.2 and 7.5 where land development has confined the river and the riparian forest has been removed. However, in most other locations where there is development on the Raging River, the residents have left healthy riparian vegetation on their

properties. Many of the homes have mature trees and native shrubs on their properties, and lawns are contained to small areas that do not extend to the edge of the river. Some invasive nonnative trees and shrubs were also seen above RM 1.3. The upstream extent of butterfly bush invasion was at RM 5.0 and the farthest upstream sighting of Japanese knotweed was at RM 7.4.

A logjam at RM 7.8 comprised most of the LWD encountered in the survey. Bank hardening occurred sporadically. Typically, banks are hardened with riprap, but an approximately 200 foot long revetment comprised of LWD was found on the RB at RM 5.1.

The substrate was cobble (64-256 mm diameter) dominated and gravel (2-64 mm diameter) subdominated for most of the surveyed river; these gravels provide potential material for spawning salmon to construct redds. A landslide on the RB at RM 3.7 was contributing a lot of fine sediment to the river. Alders growing in the area appeared to be about 10 years old, possibly dating the origin of the slide or the last big movement of the mass. The embeddedness of fine sediments in the substrate appeared to be the most impacting feature to fish habitat in the Raging River.

The overall observations of LWD were consistent with previous findings. Logging, residential development, recreation, and road construction have reduced the amount of mature forested riparian area and therefore the potential for LWD recruitment in the lower Raging River. LWD that was formerly present in the river was removed for flood protection and navigation purposes (Herrera Environmental Consultants, 1995). The *Snohomish River Basin Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Raging River as “degraded” for LWD based on the paucity of LWD (i.e., less than 0.2 piece LWD per channel width which generally ranged from 10 to 20 meters wide).

Griffin Creek (RM 0-3.1)

A wetland complex at the mouth of Griffin Creek provides excellent slow-water habitat for fish in both Griffin Creek and the Snoqualmie River. Juvenile salmonids rear and take refuge from predators in this area. However, horses were observed grazing near the mouth of Griffin Creek, so all of the streambanks were trampled and riparian vegetation was absent in the summer of 2001. Even so, the waters in this area were observed to support a high density of fish. Habitat at this location would benefit from planting of riparian vegetation and fencing the land to prevent animals from grazing the banks.

The mouth of Griffin Creek to RM 0.7 is adjacent to agricultural land that is downstream of the SR 203 crossing. This reach of Griffin Creek has a history of dredging and straightening. The substrate was predominantly fine sediment, with some coarser sediment up to cobble-sized.

LWD placed by King County in this reach in 1998 (see section on Restoration Project Monitoring for details) has moved during high flow events, and has concentrated in a few areas. Some of the LWD has collected in naturally occurring small jams. A fence post in the creek at RM 0.2 indicates that some recent channel avulsion has occurred. In the summer of 2001, riparian vegetation was predominantly invasive, except for where plantings had occurred. The plantings were still very immature so the riparian density was very poor. There were very few trees. Beaver (*Castor canadensis*), blacktail deer (*Odocoileus hemionus*), and some sculpins (*Cottus spp.*) and other fish were observed in this reach.

RM 0.8-1.6 has a lower stream gradient than the reaches of the creek upstream from here. The sediment sizes are mixed as the coarser materials deposit in the channel as the gradient decreases.

This reach is developed with homes on both banks, so has occasional revetments on both banks. In the summer of 2001, at least 50% of the riparian vegetation in this reach was invasive shrubs and was mowed for yards. Some dense pockets of native, riparian vegetation were present, including some mature deciduous and coniferous trees. Water withdrawal pipes, rock weirs, and diversion structures occurred sporadically.

RM 1.6-2.7 encompasses the upper extent of home development. Stream gradient increases as the creek moves down the hillslope, so the substrate is generally coarser and is dominated by gravel and cobbles. Some step pool morphology and deep scour pools create good fish habitat. Riparian vegetation was generally good to excellent with thick, mostly deciduous trees and native shrubs. In places the riparian vegetation was cleared or consisted entirely of invasive shrubs including blackberries, Japanese knotweed, and even bamboo (species unknown). Occasional LWD was found in this reach of Griffin Creek.

RM 2.7 to 3.1 is located within the FPD. Small tributaries on the RB deposit deltas of fine sediments washed down from East Griffin Creek Road NE. The riparian vegetation was generally excellent, with occasional patches of immature but native vegetation. Channel spanning LWD jams occurred frequently. They sort sediment, scour pools, and provide excellent cover and refuge habitat. Fish (most likely juvenile coho) were observed in pools created by these LWD jams.

Tolt River (RM 2.9-5.8)

This reach is upstream of the narrow containment levees and covers the upper extent of residential land development on the Tolt River. A property at RM 5.8 contains the furthest upstream house.

Riparian areas on the Tolt River have been consistently cleared by land development. Bank hardening occurs on the properties developed with homes, and at the King County facility at RM 2.8. On lots without homes, the riparian vegetation was generally very good, with mature trees and dense native shrubs. Cottonwood and big leaf maple were the most frequently occurring deciduous trees. Conifers occurred infrequently, but were observed to overhang the river in places, providing cover. Invasive plants, particularly butterfly bush and blackberries, occurred infrequently in the healthy riparian areas and frequently on developed properties.

Mayflies (Order *Ephemeroptera*), caddisflies (Order *Trichoptera*), and stonefly (Order *Plecoptera*) exoskeletons were observed in the substrate, which is cobble (64-256 mm diameter) dominated and gravel (2-64 mm diameter) subdominated. However, fine sediments embedded the gravels throughout the reach. This observation is consistent with previous findings. The *Snohomish River Basin Salmonid Species Habitat Conditions Review* (Snohomish Basin Salmonid Recovery Technical Committee, 2002) rates the Lower Tolt River as “moderately degraded” for sediment, based on the occurrence of 12% to 17% surface fine sediments in spawning areas (Washington Forest Practices Board, 1997).

LWD was prevalent throughout the river in the summer of 2001. There were a few jams with excellent salmonid rearing and refuge habitat at RM 3.3, 5.2, and 5.8. The channel was braided in locations throughout this reach, with smaller side channels containing slow water fish habitat, which is especially valuable as refuge during high water events. Instream habitat was generally very good in this reach of the Tolt River, with over-wintering habitat, off-channel habitat, and deep pools occurring regularly. A bedrock outcrop at RM 5.2 had scoured a large, deep pool with an adjacent LWD jam. Some of the pools were being used by fish, presumably juvenile coho.

Pink salmon were observed spawning throughout the reach. Chinook spawners were observed at a couple of sites in the reach and chinook carcasses occurred throughout. Pink and chinook salmon were observed spawning in the same pool tailout at RM 3.3.

Restoration Project Monitoring

Three restoration projects completed by King County in the Snoqualmie Watershed were monitored for fish use during 2000 and 2001. The projects were on the Tolt River, Griffin Creek, and Patterson Creek, and involved stream habitat improvement and native vegetation plantings. A culvert placed in a levee on the Tolt River reconnected the existing Frew side channel to the mainstem Tolt River for fish access. This project also involved LWD addition to the side channel and the excavation of ponds at the downstream extent of the project area. A fencing and LWD addition project on Griffin Creek was designed to keep livestock out of the creek, improve instream habitat through the creation of pools for salmonid rearing and refuge, and discourage channel dredging by the property owners. The Korn project on Patterson Creek involved the construction of off-channel ponds and addition of LWD to the ponds and adjacent reach of the creek. Each of these three project sites was monitored for fish use every other month throughout the year to track the seasonal use of the habitat by juvenile and spawning salmon. The monitoring results will be summarized in an upcoming report by King County.

POTENTIAL NEAR-TERM HABITAT PROTECTION, RECONNECTION, AND RESTORATION OPPORTUNITIES

The data collected in the Lower Snoqualmie River mainstem and tributary habitat inventories and the tributary temperature data have informed the development of the WRIA 7 Near-Term Action Agenda (Snohomish Basin Salmon Recovery Forum, 2001). Furthermore, the data will be applied by King County and the WRIA 7 Technical Committee in identifying specific habitat protection, reconnection, and restoration actions for the Snoqualmie Watershed as part of the long-term WRIA 7 salmonid conservation plan. Protection projects include acquisitions and conservation easements. Reconnection projects include removing or retrofitting culverts, levees, revetments, and other structures that block fish passage or disconnect rivers from floodplain and watershed processes. Restoration projects include improving salmonid habitat in instream, riparian, and upland areas (e.g., native plant revegetation), as well as acquisitions and conservation easements that preserve future restoration options.

Lower Snoqualmie River Mainstem Project Ideas

The Near-Term Action Agenda includes several project ideas that could be implemented in the next two to five years to protect and improve habitat conditions for salmonids in the Snoqualmie River. These project ideas are not a comprehensive list of opportunities and generally pertain to the following mainstem reaches: the confluence with Harris Creek to the confluence with the Tolt River (approximately RM 21-24), immediately upstream and downstream of the confluence with Griffin Creek (approximately RM 26-27), and the confluence with the Raging River and immediately downstream (RM 34-35). These reaches were identified as focus areas, which are areas that support high levels of spawning, rearing, holding, and/or refuge for chinook salmon. Riparian habitat conditions in the focus areas were rated as fair to good (Snohomish Basin Salmon Recovery Forum, 2001). The habitat inventory data for the focus areas are consistent with this rating. The data show a moderate amount of bank hardening, few erosional features, few cattle access points, few artificial floodplain features but many back channels and tributaries, relatively moderate to high concentrations of LWD, more native than nonnative shrubs, and moderate to high riparian tree density including some larger trees.

For the reach between the mouths of Harris Creek and the Tolt River, there are several floodplain reconnection opportunities (Snohomish Basin Salmon Recovery Forum, 2001). King County WLRD is beginning a feasibility study to determine the habitat benefits to salmonids that would result from removing a levee on the LB of the County-owned “Chinook Bend” property at RM 22.6. Likely benefits include increasing the complexity of the main channel, restoring the river’s capacity to develop side channels and capture LWD, and decreasing the redd scour that could be caused by the channel constriction that exists at present.

Other potential floodplain reconnection projects include:

- Improving the connection between Harris Creek oxbows in public (WDFW) ownership and the Snoqualmie River by removing bank hardening and restoring the river’s ability to migrate.
- Restoring the main channel of the Snoqualmie River on the RB at RM 23.3 by setting back the levee and allowing back channel formation.

- Enhancing a remnant side channel on the LB at RM 24.2 within the 450-acre King County Tolt MacDonald Park by removing bank hardening and thereby restoring its connection to the Snoqualmie River.

The vegetation in Tolt MacDonald Park is currently a mixed second growth forest dominated by black cottonwood; Himalayan blackberry and other nonnative plants have invaded portions of the park following initial clearing efforts (Lucchetti et al., in review). Other project opportunities in the reach between RM 21-24 are native vegetation planting in the riparian corridor of the park and restoring native vegetation and removing barriers to channel migration and fish passage in the WDFW-owned Stillwater Wildlife Unit (Snohomish Basin Salmon Recovery Forum, 2001). Historical information about riparian vegetation species on the banks of the mainstem Snoqualmie River (Collins and Sheikh, 2002) should be applied to selecting the combination of trees and shrubs for native plant revegetation projects at these and other locations.

Despite extensive bank hardening within Tolt MacDonald Park, a set of large swales and side channels still exists. Considerable additional restoration could be accomplished by reconnecting and restoring more of the off-channel habitats that remain cut off from the mainstem Snoqualmie and lower Tolt Rivers in and near the park. Baseline and trend monitoring of habitat conditions in this area would provide useful background information for designing reconnection and restoration projects as well as for evaluating the success of such projects after they are implemented. Parameters to be included in baseline and trend monitoring are vegetation maturity and forest complexity (patchiness, snags, woody debris on the forest floor, instream and off-channel LWD loadings), the amount and type of aquatic habitats, and fish and wildlife use and diversity (Lucchetti et al., in review).

Two project opportunities have been proposed for the reach immediately upstream and downstream of the confluence of the mainstem Snoqualmie River with Griffin Creek. These include improving the surface water connection between the river and an oxbow on the LB at RM 27.9, and acquiring land inside the large LB river bend to allow improved connections between the river and several oxbow and wetland habitats.

Approximately 33% of the riparian area at the confluence of the mainstem Snoqualmie River with the Raging River is in public ownership. There are opportunities to modify flood and erosion control facilities to enhance instream and riparian habitat at this location. Potential acquisition and floodplain reconnection projects in this reach include enhancing the connection between the mainstem channel and an existing small side channel at RM 35 by retrofitting a small culvert in the LB levee, and acquiring land at RM 34.3, then removing part or all of the existing RB levee to increase the frequency and amount of flow through an existing side channel (Snohomish Basin Salmon Recovery Forum, 2001).

In addition to the three reaches described above, the Snoqualmie River mainstem habitat inventory data will help identify other river reaches where habitat conditions are good (i.e., mostly native vegetation, relatively mature trees, presence of LWD, tributaries, and back channels, little or no bank hardening, few channel modifications and other artificial structures, and little or no cattle access). Additional habitat protection, reconnection, and restoration opportunities will be identified for the Snoqualmie Watershed portion of the long-term WRIA 7 salmonid conservation and recovery plan.

King County WLRD staff have reviewed the cattle access data from the summer of 2000 and are in the process of working with the landowners to identify and develop defined access points that will allow regrowth of trampled riparian vegetation, help to prevent excessive erosion of

riverbanks, and benefit water quality, thereby contributing to improved salmonid habitat conditions at affected locations.

Tributaries Project Ideas

The *Snohomish River Basin Chinook Salmon Near Term Action Agenda* (Snohomish Basin Salmon Recovery Forum, 2001) includes project ideas that could be implemented in the next 2 to 5 years to protect and improve habitat conditions for salmonids in the Raging River, Griffin Creek, and the Tolt River.

The mouth of the Raging River and the mouth of Griffin Creek were identified as focus areas for chinook salmon. An acquisition/floodplain reconnection opportunity exists in the lower Raging River from RM 0.4 to the mouth. Levees constrain this reach of the river and prevent the main channel from meandering. Development is much less dense along the RB, where there are several houses and a golf course. Where there are willing landowners, land could be acquired in this reach. The levees could then be set back, relocated or removed in order to restore natural delta processes and hydraulic connectivity between the Raging River and its floodplain (Snohomish Basin Salmon Recovery Forum, 2001).

Potential restoration projects in Griffin Creek are:

- Improving the quantity and quality of bank edge habitat in the wetland complex at the mouth of the creek by planting native riparian vegetation.
- Placing LWD in the wetland complex at the mouth of the creek to provide diverse cover for juvenile fish (Snohomish Basin Salmon Recovery Forum, 2001).

The Tolt River mainstem (RM 0-8.2) and South Fork (RM 0-1.6) was identified as a focus area because the river provides high quality spawning habitat for about 20% of the chinook salmon that return to the Snoqualmie Watershed to spawn. The channel location shifts over time, creating dynamic and diverse habitats within the active channel, and productive side-channel habitats. Riparian habitat conditions in this focus area were rated as fair to good (Snohomish Basin Salmon Recovery Forum, 2001). This rating is consistent with the initial habitat inventory conducted on the Tolt River in 2001, as there was little bank hardening, few erosional features, few artificial floodplain features but many back channels and tributaries, relatively high concentrations of LWD, more native than nonnative shrubs, and moderate to high riparian tree density including some larger trees in these reaches.

The lowest 1.6 miles of the Tolt River are constrained by levees. However, King County and the City of Seattle are investigating the feasibility of relocating or reconfiguring these flood control facilities in order to reconnect the historic floodplain area and side channels to the main channel of the river while preserving flood protection and the integrity of key bridges. See the “Other New Field Studies” section of this report for more details on this project.

Another potential opportunity in the lower Tolt River is to acquire land where there are willing landowners; some of the land in this reach is residential, while other areas are held in large, single-ownership forest tracts. Numerous side channels that wind through the floodplain and offer habitat diversity would then be protected. Acquiring undeveloped land behind dikes would preserve the option to set back or remove the dikes in the future (Snohomish Basin Salmon Recovery Forum, 2001).

Other protection or restoration projects in the Snoqualmie River tributaries will be identified as the stream walks continue in the summer of 2002. Areas of good habitat, (i.e., mostly native vegetation, relatively mature trees, presence of LWD, side channels and back channels, little or no bank hardening, few channel modifications and other artificial structures, and little or no cattle access) will be noted for potential acquisition and protection. Areas with good opportunities for restoration, such as a perched culvert that could be replaced thus restoring connectivity and fish passage, will be identified and flagged.

OTHER NEW FIELD STUDIES (2000-2001)

This section summarizes the results of other field studies that were initiated in the Snoqualmie Watershed by King County WLRD in 2000 and 2001. The information obtained from these studies is new information about the Snoqualmie Watershed. The full products of these studies are available from King County WLRD.

Aerial Photography

In 2000, King County WLRD contracted to have aerial photos taken of the entire county including the Snoqualmie Watershed. These high quality images replace the last set taken in 1996. The aerial images were used to characterize current habitat conditions in the focus areas that were identified in the *Snohomish River Basin Chinook Salmon Near Term Action Agenda* (King County WLRD, 2001). Information about current habitat conditions was then applied to identify specific project ideas for near-term habitat protection and restoration actions in the focus areas.

In late March and early April of 2001, a second and more comprehensive set of photos was taken when the King County photographer flew over the Snoqualmie Watershed in a two-person airplane and shot approximately 2000 low-elevation, oblique aerial photos. Photographs were taken of the entire Snoqualmie River mainstem including the North, Middle, and South Forks, the Tolt and Raging Rivers, and the following creeks: Cherry, Tuck, Adair, Harris, Stossel, Ames, Griffin, Langlois, Patterson, Tokul, and Tate. The early spring time period was selected so that the photography could take place before leaves reappeared on the deciduous trees and blocked views of the river and stream channels.

These photos are in the process of being analyzed for channel configuration, riparian vegetation, wetlands, LWD, and other riparian habitat features. By the end of 2002, the photos will also be accessible in electronic format. Information from the photos will be used to guide habitat inventories in future years.

Bull Trout Surveys

On November 1, 1999, the U.S. Fish and Wildlife Service listed coastal/Puget Sound bull trout as "threatened" under the federal ESA (Federal Register, 1999). In order to comply with federal and state recovery efforts and develop local conservation plans, it is necessary to know where and when bull trout are found. Therefore, King County WLRD implemented a Bull Trout Sampling Program in 2000 to identify existing bull trout populations and habitats in King County waters. The goal of this pilot sampling program was to sample areas with suitable habitat for bull trout spawning and rearing but where the occurrence of self-sustaining populations of this native char has not been proven. Bull trout prefer clean, cold water (temperatures of 4 to 6°C for spawning and egg incubation and 6 to 9°C for rearing) with abundant, clean spawning gravel and good rearing habitat cover such as clean cobbles and boulders and abundant LWD (Spence et al., 1996; Rieman and McIntyre, 1993).

King County implemented the protocol developed by the American Fisheries Society (AFS) for the detection of both juvenile migratory and stream-resident char (Berge and Mavros, 2001). In January 2000, U.S. Forest Service (USFS) and WDFW biologists reported seeing native char near the mouths of the Tolt and Raging Rivers and in the mainstem Snoqualmie River between these

two tributaries. Because some bull trout are freshwater resident fish that spend their entire lives in rivers, streams, or lakes, populations of bull trout also have the potential to be present above Snoqualmie Falls.

In the fall of 2000, electrofishing and snorkel surveys were performed on the North, Middle, and South Forks of the Snoqualmie River above Snoqualmie Falls (Figure 41) to search for bull trout and Dolly Varden, a closely related species of native char. King County WLRD, USFS, and University of Washington biologists partnered in this effort. Rainbow trout, cutthroat trout, rainbow and cutthroat hybrids, sculpin, and brook trout were found, but neither bull trout nor Dolly Varden were detected (Berge and Mavros, 2001).

Thermographs were installed at a total of 10 locations in the upper North, Middle, and South Forks of the Snoqualmie River to determine if water temperatures were suitable for bull trout, especially for egg incubation. In late 2002, the temperature data will be downloaded and analyzed to determine if waters of the Snoqualmie Forks are cold enough for successful incubation, spawning, and rearing in the areas sampled in 2000. If the water temperatures are low enough, then this information will be used to prioritize additional areas in which to conduct future bull trout surveys (Berge and Mavros, 2001).

Inclement weather in the fall of 2000 prevented nighttime snorkeling in the South Fork of the Snoqualmie River and in Denny Creek, one of its tributaries. In the fall of 2001, these snorkeling surveys proceeded. No native char were found, although there were sightings of brook trout, rainbow trout, and cutthroat trout (Berge, Personal Communication, 2002).

Lack of detection does not mean that bull trout and other native char are absent, but does indicate that if they are present, their potential density in the upper watershed is low. The AFS sampling protocol gives a confidence interval of 80% for absence of bull trout. Although native char are found in adjacent watersheds such as the Skykomish Watershed and below Snoqualmie Falls, it appears that a remnant population does not exist upstream of Snoqualmie Falls (Berge and Mavros, 2001).

Lower Tolt River Floodplain Reconnection Site Analysis

King County and the City of Seattle are investigating the feasibility of removing, setting back, or otherwise reconfiguring the existing levees in the lower Tolt River in order to reconstruct a more diverse channel configuration that would improve salmonid habitat, especially for chinook salmon. The *Lower Tolt River Floodplain Reconnection Site Analysis Characterization of Existing Conditions* (Parametrix, Inc., 2001) examines baseline physical and biological habitat conditions for salmonids in the lowest reach of the Tolt River that is constrained by levees and in the unconstrained reach of the river immediately upstream (RM 0-3.75 for both reaches). The unconstrained reach serves as a reference area for habitat conditions that could occur naturally in the constrained reach if levees were to be removed or set back. When linked with hydraulic modeling, comparison of these two reaches provides an indication of potential channel morphology and predicts likely salmonid habitat improvements if river levees are altered or removed to facilitate restoration of natural ecosystem processes.

The project team reviewed and analyzed existing data about habitat conditions in the Tolt River and collected new data, specifically chinook spawner redd counts in fall 2000. Following is a summary of the key findings on hydrology, channel complexity, sediment transport, and chinook salmon spawning and rearing in the Tolt River and an explanation of next steps in the study.

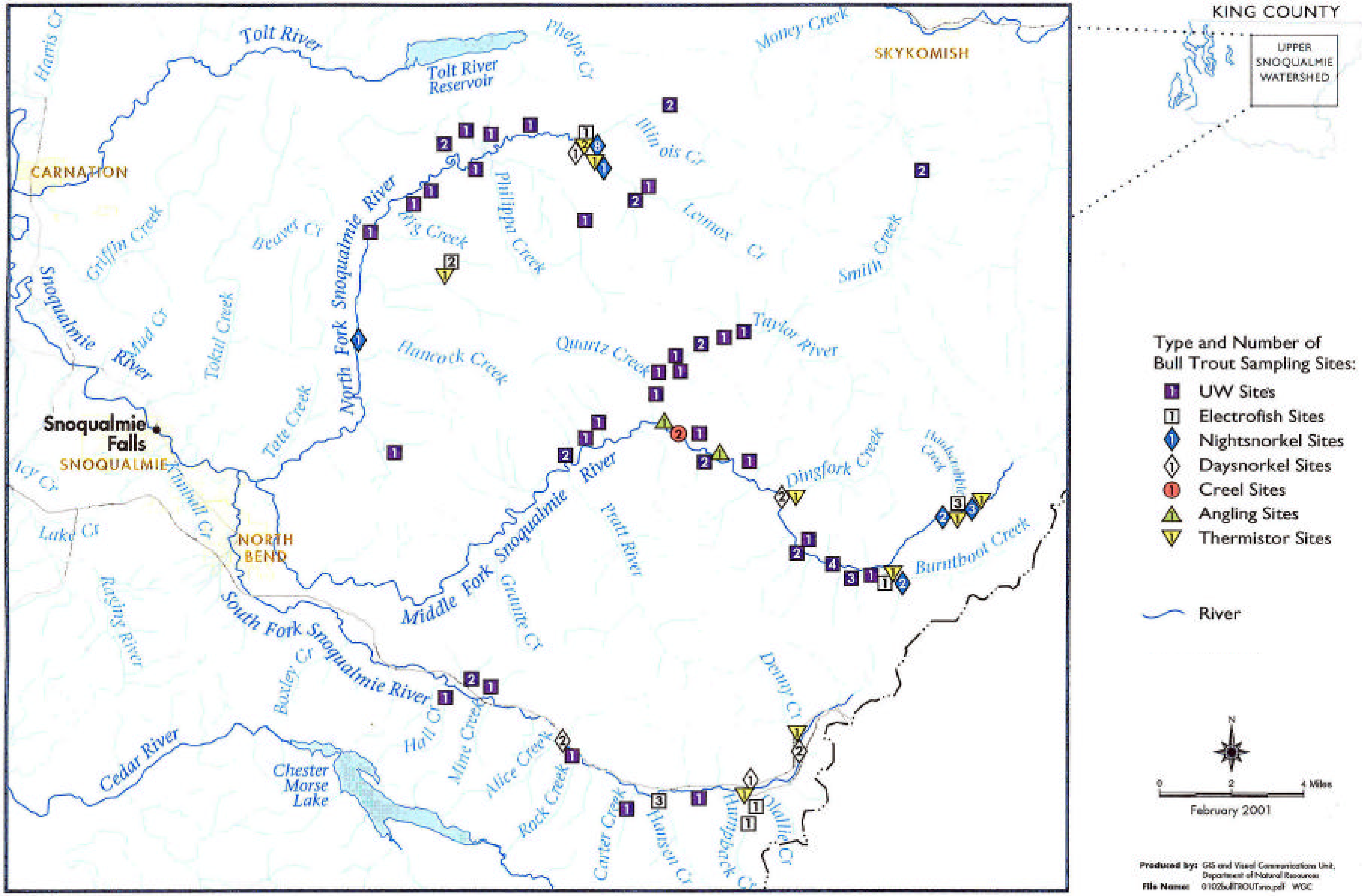

Figure 41. Bull Trout Sampling Sites in the Upper Snoqualmie Watershed

The two-year peak flow at the mouth of the Tolt River is 7,900 cubic feet per second (cfs) which is 223.7 cubic meters per second and the 100-year event is 22,000 cfs (623 cubic meters per second). Historic minimum flows in the Tolt River were 60-70 cfs (1.7-2.0 cubic meters per second) at its mouth. More typical low flows during the chinook spawning period of mid-September through October are about 150 cfs (4.2 cubic meters per second).

Levees along the lower Tolt River below the trail bridge (RM 1) constrain the river channel but do not prevent flooding except for small, frequent events. Levees upstream of the trail bridge do provide effective flood control (Parametrix, Inc., 2001).

Channel complexity has been greatly reduced in the leveed reach of the Tolt River. Unconstrained reference reaches have many more side channels than the leveed reaches and therefore more optimum salmonid spawning and rearing habitat. Because the main channel of the Tolt River is connected to its floodplain in the reference reaches, there is greater channel complexity. This results from river migration across the floodplain, as well as increased influence of LWD jams (Parametrix, Inc., 2001).

Coarse sediments that exit the Tolt River are deposited in the mainstem Snoqualmie River between RM 22-24.5. This deposition provides a gravel spawning area for 20% of the fall chinook salmon that spawn in the mainstem Snoqualmie as well as winter-run steelhead trout, pink salmon, and chum salmon. The average rate of sediment bedload supply to the leveed reach of the Tolt River is 6,036 cubic meters (7,900 cubic yards) per year. The leveed channel reach is predicted to gradually fill in by another meter over the next 30 years, mostly during moderate to large floods. The reason for this is that the constrained portion of the channel has less floodplain area for sediment storage from upstream, so the riverbed elevation is rising faster than in the reference reaches upstream. The riverbed within the leveed reach has risen since dredging was discontinued in the late 1960s. The streambed of floodplain channels is currently at 1 to 2 meters lower elevation than the mainstem Tolt channel bed elevation in some places. If levees with large toe rock were not present, channel migration would naturally occur here including potential channel shifting into the existing floodplain channels currently outside of the levees (Parametrix, Inc., 2001).

Chinook redds were counted in the leveed and reference reaches of the lower Tolt River in fall 2000. Only two redds were seen in side channels; this low number of redds was possibly a result of the combination of low flows and scarcity of side channel habitat. Most redds in the mainstem Tolt were at the edge of the wetted channel due to the presence of somewhat smaller sediment particle sizes in these areas. Many were located on the shaded LB side of the river, and near cover such as downstream from LWD accumulations or under overhanging riparian vegetation (Parametrix, Inc., 2001).

Approximately 20% of all chinook spawning in the Snoqualmie River watershed occurs in the Tolt River. However, the leveed reach of the Tolt River currently provides only marginal habitat for chinook reproduction because of decreased channel complexity, concentrated flows, disconnection of side channels from the main channel, deposition of excessively coarse and suboptimally sized spawning gravel, and limited LWD recruitment and supply. Inadequate LWD holding results in a reduced numbers of pools for juvenile rearing and adult holding areas prior to spawning as well as fewer channel avulsions that create floodplain and bar side channels (Parametrix, Inc., 2001).

The full report on the lower Tolt River floodplain reconnection site analysis is available in hard copy or compact disk format from King County WLRD. This report will be followed by a final summary report that will describe project goals and objectives, identify project alternatives, and evaluate their feasibility (Parametrix, Inc., 2001).

SUMMARY AND CONCLUSIONS

Although the Snoqualmie Watershed has healthy aquatic habitat compared to the more urbanized watersheds of King County, recent habitat inventories and temperature surveys conducted on the mainstem Snoqualmie River and several tributaries showed that there are impaired habitat conditions at many locations. In the summer of 2000, only a few reaches of the mainstem Snoqualmie were found to have simultaneous good conditions for a suite of habitat features (i.e., little or no bank hardening, erosion, and cattle access; presence of side channels and back channels; few channel modifications and other artificial structures; mostly native vegetation; relatively mature trees; and presence of LWD). These good habitat conditions were found at approximately RM 8-9 (RB), 10-11 (both banks), 19.3-21.3 (LB), 22-22.5 (RB), 24-25 (LB), and 37-38 (both banks). Large pools were also found in these reaches in the summer of 2001 (the presence of pools in RM 37-38 is unknown because the pool survey ended at RM 35).

A total of 8.5 river miles on the mainstem Snoqualmie (i.e., 13% of the 32 river miles that were inventoried on each bank of the river for a total of 64 river miles) exhibited good habitat conditions for all habitat features. The remaining 87% of river miles had one or more habitat problems (i.e., extensive bank hardening and erosion; many cattle access points; few or no side channels and back channels; many channel modifications and other artificial structures; sparse or mostly nonnative vegetation; and limited or no LWD).

In the summer of 2000, bank hardening was observed on 35.5% of river miles on the toe of the LB, 29.5% of river miles on the upper LB, 30.4% of river miles on the toe of the RB, and 29.4% of river miles on the upper RB of the mainstem Snoqualmie River. By disconnecting the main channel of the river from its side channels and inhibiting natural channel migration, bank hardening limits the creation of summer rearing habitat and winter refuge habitat for salmonids and restricts fish access to off-channel habitat. Bank hardening also accelerates the natural process of bank erosion on adjacent or opposite unprotected banks; excessive erosion can degrade habitat conditions by contributing excessive fine sediment to the river, aggrading the channel bed, or filling pools. Scours, slumps, and other erosional features were observed at many locations directly downstream or on the opposite bank from revetments.

Riverbank erosion also correlated with human or cattle access to the Snoqualmie River. Although there were locations throughout the mainstem Snoqualmie where cattle could access the river, most of the cattle access points were concentrated in the APD between RM 10-19. In addition to causing excessive erosion of riverbanks and loss of riparian vegetation, cattle access can degrade water quality for fish and for people by contributing nutrients, sediments, and fecal coliform bacteria to the river. King County WLRD staff are working cooperatively with landowners to identify and develop defined access points that will allow regrowth of trampled riparian vegetation, help to prevent excessive erosion of riverbanks, and benefit water quality, thereby contributing to improved salmonid habitat conditions at affected locations.

Several types of floodplain features were observed in the mainstem Snoqualmie including the mouths of several major tributaries, 46 small, unnamed tributaries, and 26 back channels. Tributaries and back channels can provide good edge habitat for summer rearing and winter refuge for salmonids. On the other hand, other types of floodplain features such as water diversion pumps, flap gates, and culverts can be barriers to fish habitat. Banks and pilings were the most frequently noted channel modification structures on the mainstem Snoqualmie. These

structures can adversely impact salmonid habitat quality by increasing habitat quantity for predatory and invasive species and by altering the river's natural scour pattern, thereby affecting sediment transport.

Several shrub species that are not native to the Pacific Northwest were observed on the banks of the mainstem Snoqualmie River in the summer of 2000. These invasive species included Himalayan blackberry, Japanese knotweed, virgin's bauer, English ivy, butterfly bush, yellow tansy, and purple loosestrife. Native shrub species that were present included willow, snowberry, salmonberry, red osier dogwood, Oregon grape, elderberry, and Indian plum. Most of the riparian trees were deciduous, with red alder, vine maple, and black cottonwood found most frequently. Conifers such as western redcedar, Sitka spruce, grand fir, and western hemlock were found at some locations. Riparian tree species in 2000 were similar to historic species (those noted in the 1870s), but the percentage of conifers is now lower and the trees are now smaller. Mature trees (i.e., trees with an average stem diameter greater than 50 cm) are now found along only 1.8% of river miles on the LB and 9% of river miles on the RB of the mainstem Snoqualmie.

Although more LWD was found in the mainstem Snoqualmie River than expected, there was still an overall dearth of wood in the river (i.e., less than one piece per 20 meters of river channel). There were a few locations where large alder and cedar trees were leaning over the river (e.g. immediately downstream of the Tokul Creek confluence) and were potential near-term sources of LWD. However, the generally degraded riparian vegetation results in low recruitment of LWD to the river.

River segments with one or more of the above habitat problems lack the floodplain connectivity and complex structure that is important for forming and sustaining high quality salmonid habitat. Furthermore, data from the temperature loggers showed that the temperature of the Snoqualmie River is not low enough to provide good rearing and pre-spawning holding habitat for salmon during summer and early fall low flow conditions. However, future efforts will explore the potential for localized cool temperature refuge (such as from springs or cold water tributaries) that may not be obvious from the sampling to date.

Data from the University of Washington temperature survey that was conducted during the hottest part of the summer (the middle of the first week of August) in 1999 to 2001 showed that the temperature of the Raging River, and Griffin, Harris, and Patterson Creeks at that time was not low enough to provide optimal rearing conditions for salmonids (Bjornn and Reiser, 1991). Some temperature measurements in the Raging River, Griffin Creek, and Harris Creek exceeded 18°C, thereby violating the State of Washington water quality standard for temperature in Class A waterbodies. If sustained, temperatures that are this high can be lethal to salmonids and can have sublethal physiological and behavioral effects as well (Berman, 1998). High summer water temperatures in tributaries to the Snoqualmie River contribute to high summer water temperatures in the mainstem Snoqualmie. To reduce water temperatures, solutions must be found starting in the headwaters to ensure that feeder tributaries are well shaded and riparian canopy is protected and restored to the maximum extent practicable throughout the watershed.

Aside from high temperatures, habitat conditions were generally good in the summer of 2001 in the inventoried reaches of the Raging River, Griffin Creek, and Tolt River that were upstream of confinement levees, other bank hardening, and residential land uses. Between RM 1.3-8.2 of the Raging River, good habitat conditions included native riparian vegetation, some LWD, and cobble and gravel substrate. Between RM 2.7-3.1 of Griffin Creek, dense native riparian vegetation recruited a high frequency of LWD to the stream. Habitat conditions were good between RM 1.6-2.7 as well, with mostly high-density native riparian vegetation, pools, and a

gravel and cobble substrate. On the Tolt River (RM 2.9-5.8), instream habitat was generally good, with mature and dense native trees and shrubs, high frequency of LWD, pools, and side channels. The reaches with good habitat conditions in the mainstem Snoqualmie, Raging, and Tolt Rivers and Griffin Creek should be targeted for habitat protection actions in the Snoqualmie Watershed portion of the WRIA 7 salmonid conservation plan.

The results of the habitat inventories on the mainstem Snoqualmie River and several tributaries highlight four of the nine most important habitat problems that were identified by the WRIA 7 Technical Committee. These were loss of channel area and complexity resulting from bank protection, disconnecting the channel from its floodplain; dearth of LWD; increased sediment input to rivers and streams as a result of unnaturally high rates of erosion; and poor quality riparian forests.

Aquatic habitats critical to salmonids are the product of natural ecosystem processes acting throughout watersheds and particularly within riparian areas along rivers and streams. At the watershed level, the major processes that affect physical and chemical attributes of aquatic ecosystems are (Spence et al., 1996):

- hydrology - pertains to precipitation in the form of rain and snow and to migration of river and stream channels across their floodplains.
- sediment transport - pertains to redistribution and sorting of sediment based on energy gradients.
- heat energy transfer - pertains to river and stream temperatures.
- nutrient cycling - pertains to delivery of nutrients to rivers and streams from trees falling in the water and from decaying salmon carcasses.
- LWD recruitment - related to size and density of riparian vegetation.

Large-scale disruption and acceleration of natural ecosystem processes has occurred in WRIA 7 since the 1850s (i.e., beginning of Euro-American settlement). Human activities such as logging, road building, flood control actions, and conversion of forest land to agricultural and residential land have changed the way that water, sediment, and wood move through the Snoqualmie Watershed (Snohomish Basin Salmonid Recovery Technical Committee, 1999). Data from the habitat inventories and temperature surveys described in this report suggest that sediment transport, heat energy transfer, nutrient cycling, and LWD recruitment have been altered from natural conditions (hydrology was not examined in these field studies) and, in turn, have adversely affected aquatic habitat quality. For example, bank hardening on the mainstem Snoqualmie River and its tributaries is often related to erosional features on the opposite or adjacent banks. Excessive erosion alters the natural sediment regime of the river and can contribute fine sediments to the channel substrate. Lack of mature, native riparian vegetation along the mainstem Snoqualmie and its tributaries contributes to the dearth of LWD, and high summer and early fall temperatures in the river. Low LWD recruitment into the river will impact nutrient cycling in the river as well.

In order to be effective in the long-term, salmonid conservation and recovery efforts in the Snoqualmie Watershed need to assess and take into account the natural ecosystem processes that create instream habitat structure. Habitat protection, reconnection, and restoration projects need to focus on restoring these processes rather than just addressing the symptoms of observed impaired habitat conditions. For example, instream habitat would benefit from forest retention in headwaters areas of the Snoqualmie Watershed, native plant revegetation of riparian zones, and

removal of invasive plants along the mainstem Snoqualmie River and its tributaries. Historical data should be consulted on the composition of the mainstem riparian plant community in order to determine which species of native vegetation to plant along the banks. Healthy riparian buffers will provide LWD for the rivers and streams of the Snoqualmie Watershed, which will lead to more nutrient cycling and to more and better quality habitat for juvenile salmonid rearing and refuge and adult salmonid holding prior to spawning. The shade provided by riparian vegetation will help to moderate summer water temperatures (i.e. will help to restore a more natural heat energy transfer regime). The roots of riparian vegetation will reduce the amount of unnatural bank erosion, thereby helping to restore natural sediment transport. Because natural ecosystem processes are interrelated, restoring one process will help to restore others.

The 1999-2001 field studies provided qualitative information about baseline habitat conditions in the Snoqualmie Watershed. This is not a final or comprehensive picture of habitat conditions in the watershed. Before definitive conclusions can be drawn and a salmonid conservation plan can be developed, more in depth and quantitative research and habitat inventories need to be conducted. Some high priority information needs for the Snoqualmie Watershed include:

- Quantitative surveys of habitat conditions in specific reaches of rivers and streams.
- Snoqualmie River valley floor habitat assessments.
- Temperature stratification assessments in large pools of the mainstem Snoqualmie River.
- Wetland assessments, including location, functions, and values.
- Juvenile salmonid distribution mapping.
- Hydrologic mapping and modeling of stormwater catchment and subcatchment basins.
- Geologic interpretation of surficial geology maps.

Information that is obtained from the above investigations and from monitoring habitat quality trends over time will be included in updates to this report.

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APPENDIX A: DATA DICTIONARY FOR SNOQUALMIE RIVER HABITAT CONDITIONS INVENTORY

```
UPSTREAM END OF BANK  Point Feature
   BANK               Menu, Required
      RIGHT BANK
      LEFT BANK
   TYPE               Menu, Required
      REVETMENT
      ARMORED UNKNOWN
      UNARMORED
      VERTICAL BULKHEAD
      LEVEE
      OTHER
   TOE ARMOR          Menu
      RIP-RAP (>256mm)
      RUBBLE (<256mm)
      BIO-ENGINEERED
      NONE
      OTHER
   UPPER BANK ARMOR   Menu
      RIP-RAP (>256mm)
      RUBBLE (<256mm)
      UNKNOWN
      BIO-ENGINEERED
      NONE
      OTHER
   HEIGHT             Menu, Required
      <5' ABOVE OHWM
      5'-10' ABOVE OHWM
      >10' ABOVE OHWM
   SLOPE              Menu, Required
      STEEPER THAN 60 DEG
      45 TO 60 DEG
      FLATTER THAN 45 DEG
   CONDITION          Menu
      NEW CONSTRUCTION
      OLDER
   NOTES              Text, Maximum Length = 72

FLOODPLAIN MOD'S      Point Feature
   BANK               Menu, Required
      RIGHT BANK
      LEFT BANK
   TYPE               Menu, Required
      PERCHED CULVERT
      SUBMERGED CULVERT
      MOUTH OF TRIBUTARY
      MOUTH OF BACK CHAN
      ADJACENT WETLAND
      FLAP GATE
      DIVERSIONS (PUMP)
      OTHER
   NOTES              Text, Maximum Length = 72

CHANNEL MOD'S         Point Feature
   BANK               Menu, Required
      RIGHT BANK
      LEFT BANK
      MID CHANNEL
   TYPE               Menu, Required
      PILING
      BRIDGE FOOTING
      DEFLECTOR
      UTILITY CROSSING
      WEIR
      DOCK
      BARB
      OTHER
   NOTES              Text, Maximum Length = 72

RIPARIAN VEG (100FT)  Point Feature
   BANK               Menu, Required
      RIGHT BANK
```

```
      LEFT BANK
   TREE DENSITY         Menu, Required
      NONE
      SPARSE
      MODERATE
      DENSE
   TREES                Menu
      ALL DECIDUOUS
      <5% CONIFEROUS
      5-30% CONIFEROUS
      >30% CONIFEROUS
   SHRUB DENSITY        Menu, Required
      NONE
      SPARSE
      MODERATE
      DENSE
   SHRUBS               Menu, Required
      NONE
      ALL NON-NATIVE
      NON-NATIVE DOMINANT
      NATIVE DOMINANT
      ALL NATIVE
   DOMINANT FORM        Menu, Required
      TREES
      SHRUBS
      GRASSES
      TREES AND SHRUBS
      TREES AND GRASSES
      SHRUBS AND GRASSES
      OTHER
   TREE MATURITY        Menu
      YES
      NO
   OVERHANG             Menu, Required
      NONE
      0-5 FT
      >5 FT
   NOTES                Text, Maximum Length = 72

ACCESS POINT            Point Feature
   BANK                 Menu, Required
      RIGHT BANK
      LEFT BANK
   USER                 Menu, Required
      HUMAN - FOOT
      HUMAN - BOAT
      CATTLE
      VEHICLE
   NOTES                Text, Maximum Length = 72

LWD                     Point Feature
   NUMBER OF PIECES     Numeric, Decimal Places = 0
   NUMBER OF PIECES     Numeric, Decimal Places = 0   Minimum = 1, Maximum = 99, Default Value
   TYPE                 Menu, Required
      LOG WITH ROOTWAD
      ROOTWAD ON STUMP
      CUT LOG >15 FT LONG
      DEBRIS JAM
      OTHER
   LOCATION             Menu, Required
      BELOW OHWM
      ACROSS OHWM
      ABOVE OHWM
   SPECIES              Menu, Required
      CONIFER
      DECIDUOUS
      BOTH
      UNKOWN
   DIAMETER             Menu, Required
      1-2 FT
      2-3 FT
      >3 FT
   DOES IT FORM A POOL?     Menu, Required
      YES
```

```
      NO
   NATURALLY PLACED?  Menu, Required
      YES
      NO
      UNKNOWN
   NOTES              Text, Maximum Length = 72

EROSION               Point Feature
   BANK               Menu, Required
      RIGHT BANK
      LEFT BANK
   TYPE               Menu, Required
      SCOUR
      SLUMP
      DUMPING
      OTHER
   MATERIAL SIZE      Menu, Required
      BOULDER (>256mm)
      COBBLE (64-256mm)
      GRAVEL (2-64mm)
      SAND (.064-2mm)
      SILT/CLAY (<.064mm)
   LENGTH IN FEET     Numeric, Decimal Places = 0
   LENGTH IN FEET     Numeric, Decimal Places = 0    Minimum = 1, Maximum = 9999, Default Va
   HEIGHT             Numeric, Decimal Places = 0
   HEIGHT             Numeric, Decimal Places = 0    Minimum = 0, Maximum = 999, Default Value
   NOTES              Text, Maximum Length = 72

DUMPING & DISCHARGE   Point Feature
   BANK               Menu, Required
      RIGHT BANK
      LEFT BANK
   TYPE               Menu, Required
      LANDSCAPE REFUSE
      LIQUID UNKNOWN
      CAR
      TIRE
      FILL DIRT
      SEWAGE
      OTHER
   NOTES              Text, Maximum Length = 72
```

APPENDIX B.
STREAM TEMPERATURE SURVEY COVER SHEET AND FIELD SAMPLING SITE DATA FORM

Center for Urban Water Resources Management
Department of Civil & Environmental Engineering
University of Washington, Box 352700
Seattle, WA 98195
206-543-7923

STREAM TEMPERATURE SURVEY

AUGUST 2, 2000 3-5 pm

Dear Survey-er:

Many thanks for your assistance on this year's survey. This is the third annual effort , which we are using to better characterize the temperature conditions in the region's streams and creeks. This project is being coordinated with a variety of other stream-temperature and stream-habitat studies by agencies and organizations throughout Puget Sound, and our data is being used both to identify the conditions that cause high stream temperatures and to evaluate the significance of high temperatures in comparison to other potential stresses on aquatic habitat. Some of the results from the first two years of this study can be viewed on the "RESEARCH" page of the Center's web site, **http://depts.washington.edu/cuwrm/**.

We have benefited tremendously from the experience of volunteers from the past two years, which you will see reflected in the package. You should find the following information:

1. **A "COVER SHEET."** This gives us contact information for you, and calibration information about your thermometer. Plan on spending about 10 minutes at your kitchen sink! The information is really important, however—from past years, we know we can trust our data to within about ½ degree C if this part is done (and if not, we really can't use it). Make sure this sheet comes back to us with your field forms.

2. **A list of sites to visit.** In almost all cases, we are starting with the routes from last year, minus those localities where access was difficult or impossible. We are *renumbering* all sites: the new numbers, which we would like you to record on your field form, are three letters (for the stream system) and then a number. For reference, last year's numbers are also listed—they are 2 letters (generally, the initials of last year's volunteer) followed by a number. The directions to the site (if available) are straight off of last year's field form—otherwise, just follow the map (see below).

   The sites are generally listed in order of their visiting last year. It will probably work that way for you too, but if you know a better route then take it. We are again including (1) sites that may have no water, and (2) sites that you have *already* visited earlier in the route—please measure these all over again. You may also cross paths with another volunteer during the course of the 2 hours. It is part of our evaluation of data replicability, so do make independent measurements!

3. **A map,** courtesy of Thomas Brothers. Use it to plan your route, but if there are directions on the previous sheet, they will in most cases be more precise.

4. A **"FIELD SAMPLING SITE DATA FORM,"** one per site. It's a little simpler than last year's; you shouldn't need more than about 3-5 minutes per site. Go for the fastest, deepest water you can reach (safely!). **BE SURE TO FILL IN THE SITE NUMBER!**

Get it all back to us, or to your coordinator, as soon after August 2nd as you can. Many thanks!

Derek Booth, CUWRM

Center for Urban Water Resources Management
Department of Civil & Environmental Engineering
University of Washington, Box 352700
Seattle, WA 98195
206-543-7923

STREAM TEMPERATURE SURVEY

COVER SHEET

This sheet records basic information about you and about your thermometer. We'd like the information about you so that if any questions arise about your data we can reach you directly. The information about your thermometer is necessary to assign an error band to each data point—no instrument is perfect and so all results have some uncertainty. We would like to be as careful as possible in specifying that uncertainty, so that the results will be as useful as possible.

FIELD DATA COLLECTOR

Name____

Affiliation______________________________________

Phone number(s) __________________________________

Fax number______________________________________

Email address____________________________________

Your contact person for this survey________________________

INFORMATION ABOUT YOUR THERMOMETER

Type (*e.g.*, mercury, alcohol, digital)________________________

°F or °C ________________

Your qualitative estimate of accuracy (*e.g.*, "laboratory grade," "cheap," etc.)____________

Please *calibrate* your thermometer before going out to make measurements. This can be done in your kitchen in about 10 minutes. Take an ice cube tray's worth of ice cubes, empty them into a medium-sized jar, and add water so about one half of the ice cubes are covered. *Do not put in so much water that the ice starts to float!* If they do, a small pocket of dense but warmer (4 °C) water will collect at the bottom of the jar. Wait a few minutes for the ice to warm up; as long as you have both ice and water coexisting in the jar, the water temperature is fixed at the freezing point. Immerse your thermometer in the water between the ice cubes and read the temperature once it stabilizes (it should be pretty close to 0 °C or 32 °F). Record that number here, to the nearest degree (F) or ½ degree (C):

[   ]

When you measure temperatures in the field, please DO NOT apply any correction before recording your results. Just let us know on *this* sheet how well your thermometer registers the freezing point of water.

STREAM TEMPERATURE SURVEY
FIELD SAMPLING SITE DATA FORM
Wednesday, August 4, 1999, 3:00-5:00 PM

Please fill out one sheet for *each* station that you visit. Remember we have not been able to visit every site beforehand, and so if you are not able to locate the exact site indicated on your map (or that site does not exist) please find and use the nearest stream crossing. In addition, if you have time and have the opportunity to make additional measurements elsewhere, please do so!

Your Name ______________________________

Stream ______________ **Site Number** ______________ **Time** __________

Location (upstream of bridge at 232nd St, east of 35th Ave SW at 160th SW 103rd St, etc.):
*(ALSO, WHAT IS THE NEAREST TOWN?)*______________________________

____

1. Measure air temperature near stream, but not over it, and not in direct sunlight.

Air Temperature: [ ] **°C or °F**

2. Assess reach conditions (check one box under each heading)

<u>Flow conditions in reach</u>:

- ☐ Free-flowing stream
- ☐ Sluggish flow
- ☐ Intermittent flow
- ☐ Stagnant pool(s)
- ☐ No water (and so no T to measure!)

Riparian canopy extending from site <u>approximately 100 m upstream</u>:

- ☐ Open, stream in full sun
- ☐ Partial, shrubs dominant
- ☐ Partial, trees dominant
- ☐ Closed, stream in full shade

3. Assess site where water temperature is measured (listed in order of preference)

<u>Flow conditions</u>:

- ☐ Swift flow
- ☐ Sluggish flow
- ☐ Stagnant

<u>Location across channel</u>:

- ☐ Center/deepest part of channel (i.e., thalweg)
- ☐ Along side of main current

4. Measure water temperature for 1 minute in fastest flow possible at ½ of the total water depth (circle units or otherwise specify). Quickly estimate the depth and speed of the flow. ***EVEN IF THERE IS NO WATER, turn in this sheet for this station!***

Water Temperature (the "sampling point"): [ ] °C or °F

Estimate **total water depth at the sampling point (centimeters or inches):** [ ] **cm** or in.

Estimate **flow speed at the sampling point (meters or feet per second):** [ ] **m/s** or ft/s

Dry off thermometer after use so it is ready for the next site's air temperature reading!

Mail all completed forms to: Derek Booth, Box 352700, University of Washington, Seattle WA 98195 or return them to your coordinator.