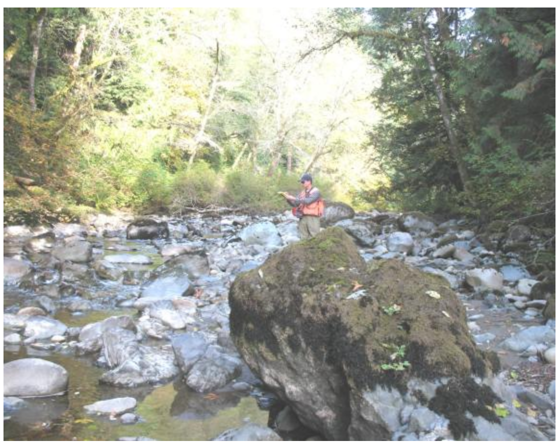
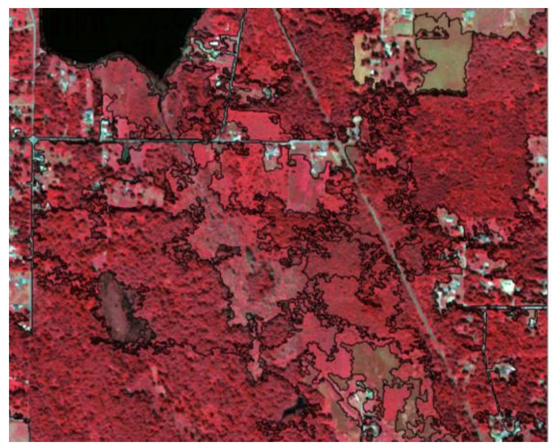
Snohomish County
September 2008

Critical Area Monitoring and Adaptive Management Plan





Snohomish County Public Works Department, Surface Water Management

Snohomish County Department of Planning and Development Services

Table of Contents

Table of Figures, Maps & Tables

FIGURES

MAPS

TABLES

EXECUTIVE SUMMARY

This monitoring and adaptive management program was developed to support Snohomish County's Critical Area Regulations (CAR) in order to meet the requirements of the Washington State Growth Management Act (GMA). The CAR, monitoring and adaptive management program, and critical area restoration programs are the central elements of Snohomish County's overall program to prevent net loss of critical area functions and values.

The monitoring program, designed to detect changes in critical areas in a timely fashion, consists of three main components: (1) assessment of changes in land cover indicators using primarily remote sensing[1] methods; (2) assessment of changes in shoreline conditions along major rivers and lakes; and (3) assessment of select ecological indicators through a "treatment" and "control" study design to evaluate the effectiveness of code provisions in protecting aquatic environments. The monitoring plan is focused on Wetlands and Fish & Wildlife Habitat Conservation Areas (FWHCA) because the CAR contains greater flexibility in approach to protection of these types of critical areas, and thus greater uncertainty.

The adaptive management component, designed to provide greater certainty that the conservation goal will be achieved, will evaluate whether changes in indicators were related to the regulations for Wetlands and Fish & Wildlife Habitat Conservation Areas and whether modifications to regulations or other County programs are needed to prevent a net loss of critical area functions and values.

[1] Remote sensing is the acquisition of data about the earth's surface from planes and satellites

1. INTRODUCTION

1.1 Overview

This document describes Snohomish County's critical area monitoring and adaptive management program. The introductory chapter provides an overview of the County's general requirements under the Washington State Growth Management Act to protect critical areas and the County's overall approach to meeting this requirement through its General Policy Plan, Critical Area Regulations (CAR), restoration programs, and the critical area monitoring and adaptive management program. The remaining chapters describe the elements of the monitoring and adaptive management program.

1.2 Growth Management Act Requirements

Washington State's Growth Management Act (GMA – chapter 36.70A RCW) requires Snohomish County to protect and manage the functions and values of critical areas. The GMA identifies critical areas as Wetlands, Fish and Wildlife Habitat Conservation Areas, Frequently Flooded Areas, Critical Aquifer Recharge Areas and Geologically Hazardous Areas. To protect and manage these areas, the County has included critical area protection policies in its General Policy Plan (GPP) and adopted science-based Critical Area Regulations.

The introduction to the Natural Environment Chapter of the 2006 Snohomish County GPP describes the following elements of a multifaceted approach to environmental protection:

> *"…planning, intergovernmental coordination; development of regulation; enforcement; and improved protection of ecological functions and values through non-regulatory incentive-based means, such as voluntary enhancement and restoration, public education and other voluntary activity; and monitoring and adaptive management."*

The GPP contains specific policies in each of these areas to direct the County's efforts to protect the natural environment.

In October of 2007, the County Council adopted revised Critical Area Regulations in chapters 30.62A (Wetlands and Fish & Wildlife Habitat Conservation Areas), 30.62B (Geologic Hazard Areas) and 30.62C SCC (Critical Aquifer Recharge Areas). The County's flood hazard regulations (chapter 30.65 SCC) remained unchanged. CAR revisions were based on the State's guidelines for the designation and protection of critical areas contained in section 365-190-080 WAC and the Best Available Science requirements of section 365-195-905 WAC. In addition, the County has a number of other existing environmental protection and restoration programs that directly or indirectly manage, protect or restore critical areas.

The County's overall goal is to protect critical area functions and values through the net effect of regulations and environmental programs. Achievement of this goal will be measured and supported by the monitoring and adaptive management program, which will indicate whether or not changes are needed to regulations or other County programs, and outline the process for making adjustments. Figure 1 shows the relationship of CAR, non-regulatory restoration and enhancement actions, and the monitoring and adaptive management program.

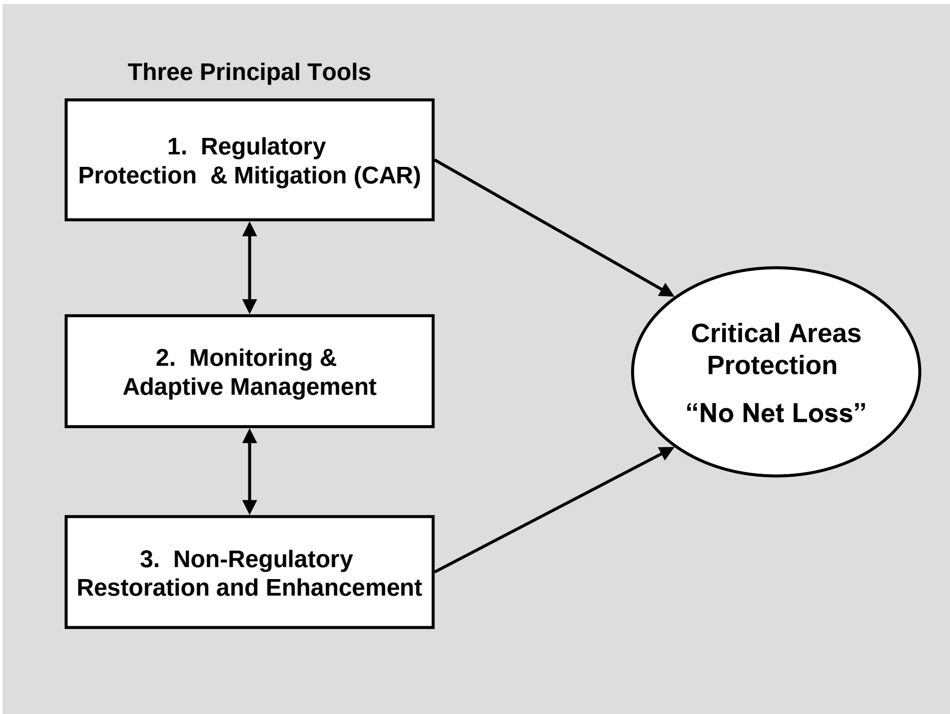


Figure 1 Conceptual Model of Snohomish County's Critical Area Program

1.3 Critical Area Regulations and County Restoration Programs

The primary line of protection for critical areas is the implementation and enforcement of the Critical Area Regulations. Snohomish County's CAR contains standard science-based requirements such as buffers of prescribed widths. CAR also allows alternative or innovative approaches to critical area protection provided that the alternative or alternative approach achieves the same level of protection. The intent of these alternatives is to maximize protection of the functions and values through a tailored approach. A more tailored approach accommodates site specific conditions and allows flexibility to protect critical area functions and values, while balancing other County objectives such as maintaining property rights, a viable agricultural community and a healthy economy.

While alternative and innovative approaches allowed under the CAR may occur in many types of designated critical areas, they principally will impact Fish and Wildlife Habitat Conservation Areas (FWHCA) and Wetlands. Thus, the monitoring plan focuses on FWHCA and Wetlands. The alternative and innovative approaches allowed in the Wetland and FWHCA regulations include:

use of buffer reductions as incentive for specific mitigation measures; innovative development design to encourage use of low impact development and implementation of watershed management or salmon recovery plans; and use of best management practices (BMPs) for minor development and agricultural activities. Table 1 provides a comprehensive list of alternative and innovative approaches.

Allowed Buffer Impacts:
○ Innovative development
○ Reasonable use exception
○ Fencing reduction
○ Separate tract reduction
○ Averaging
○ Habitat corridor reduction
○ Other mitigation measures from Table 5
○ SFR exception
○ Fee in lieu – via County parks
○ Buffer loss/replacement
○ Innovative development
○ Minor development activity
○ Reasonable use exception
○ Ag BMP
Allowed Wetlands Impacts:
○ Fill mitigation
○ Enhancement mitigation
○ Wetland banking
○ Innovative development design

Table 1 Alternative and Innovative Approaches Allowable under the CAR

Potential environmental impacts that may result from alternative and innovative approaches include a reduction in mature riparian forest cover, reduction in total riparian forest cover (including younger trees and shrubs), increased impervious surface within and outside of riparian and buffer areas, loss of wetlands, modification of shorelines and stream banks, and associated water quality and habitat impacts.

In addition to the mitigation measures required in the regulations, impacts to functions and values will be further offset by the County's on-going non-regulatory restoration and enhancement actions. The goal of the Critical Area Conservation Program is to protect critical area function and values in areas under the County's jurisdiction.

The program also strives to support salmon recovery efforts by promoting improvement of habitat conditions in focus areas identified in the Puget Sound Salmon Conservation Plan (2005). Restoration program elements will include outreach and technical assistance to increase voluntary planting and wetland enhancement (e.g. native plant and community partners stewardship programs) and County-led restoration actions such as riparian planting, removal of invasive species, placement of large woody debris in streams and rivers, riparian fencing, wetland creation, fish-passage barrier removal, side-channel reconnection, improved stormwater infiltration, and water quality pollution reduction. The County will also continue to manage critical area impacts by means of other land use codes (e.g., shorelines master program, drainage, grading and other development codes), acquisition of conservation properties, and protection and mitigation measures in road planning and construction. These actions will be prioritized and implemented consistent with the salmon recovery strategies outlined in the Puget Sound Salmon Recovery Plan (2005), the County's NPDES municipal stormwater management program, and other regulatory and strategic efforts.

1.4 Monitoring and Adaptive Management Program Overview

The status and trends of critical area functions and values for FWHCA and Wetlands will be assessed through a three-part monitoring approach. The first component consists of analyses of riparian conditions, impervious surface and wetland extent using remote sensing data (aerial images and maps) with field-verification throughout the area under the County's jurisdiction. Specific riparian and wetland indicators were selected because they are directly regulated through the CAR, and because they are leading indicators of change, which exert a strong influence on critical area functions and values. The second part of the monitoring program involves assessing shoreline conditions along major rivers and lakes. The third component is designed to evaluate the effectiveness of riparian buffer provisions of the code over the longer term in protecting riparian functions, water quality and in-stream habitat.

This three-part monitoring approach will balance the need to detect change over a short time frame (components 1 and 2) with the need to evaluate a range of functions and values over a longer time frame (component 3). Initial monitoring results will establish the baseline for the selected environmental indicators, and subsequent monitoring will track changes.

If changes in environmental indicators exceed adaptive management thresholds, programmatic or regulatory adjustments will be implemented through the adaptive management framework. Adaptive management is a formal process of evaluating data relative to established goals or benchmarks, incorporating new information, and taking actions based on the results. Key hypotheses or management questions, levels of change that will trigger a response and the form of the response are established at the outset; monitoring activities are designed to yield the information needed.

Snohomish County is using the six-step monitoring and adaptive process outlined in Figure 2 as the conceptual framework. The six steps are (1) problem assessment, (2) plan development, (3) implementation, (4) monitoring, (5) evaluation, and (6) adjustment. Step 1 consists of the official recognition by the County and the State of the need to protect critical area functions and values.

Step 2 consists of the development and adoption of the GPP, CAR, underlying Best Available Science (BAS), restoration programs, and this monitoring and adaptive management program. Step 3 consists of the implementation of the elements of Step 2. Steps 4 through 6 encompass of the monitoring, evaluation and adjustment process described in this document.

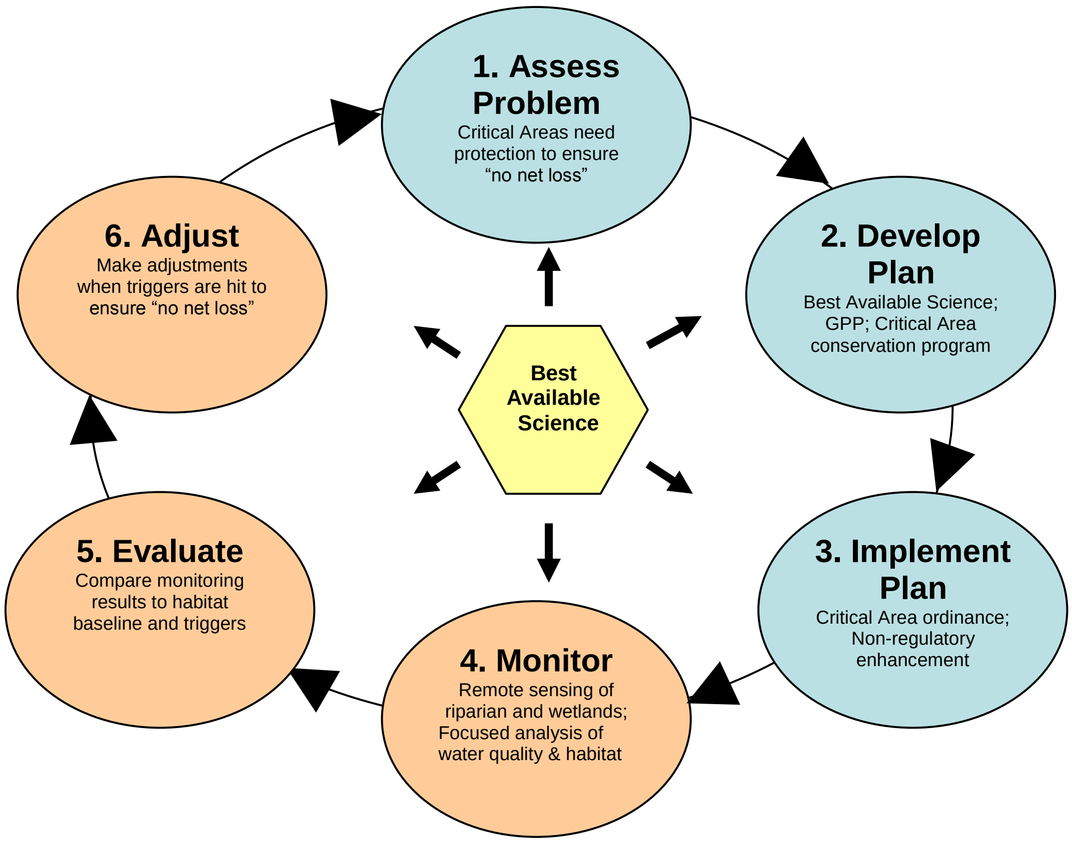


Figure 2 Monitoring and Adaptive Management Framework

1.5 Key Management Questions

The monitoring and adaptive management program has been designed to inform the following key management questions and sub-questions:

1. Are gains or losses of functions and values occurring in Fish and Wildlife Habitat Conservation Areas and Wetlands?
2. If loss is occurring, what and where are programmatic adjustments needed to protect functions and values in FWHCA and Wetlands?
    a) Are losses of functions and values occurring not as a result of County actions, but rather actions taken outside the County's jurisdiction?
    b) Are losses of functions and values occurring in a specific land use or geographic area?
    c) Are losses of functions and values resulting from code violations?

d) Are losses of functions and values occurring despite the County's programmatic approach to managing critical areas?

The order of questions follows the sequence outlined in the monitoring and adaptive management framework (Figure 2). The monitoring plan (step 4) is designed to answer the first question. The second question frames the evaluation process (step 5), and the sub-questions inform source identification and the process for program adjustment (step 6).

Together the questions and answers to them guide the adaptive management response. For example, if no change in critical area functions and values or a gain is observed (question 1), no further action would be required. If a loss is observed, the answers to the evaluation sub-questions (question 2) direct treatment toward the root cause to correct problems identified through referral, enforcement, public outreach and code adjustment.

1.6 Best Available Science

Best Available Science (BAS) is the technical foundation for all six steps of Snohomish County's Critical Area Monitoring and Adaptive Management Plan. Section 365-195-905 WAC outlines the key characteristics of BAS as follows:

- Peer review by other persons who are qualified scientific experts in that scientific discipline. Publication in a professionally-reviewed scientific journal is usually appropriate; this does not include newspaper articles or popular journals.
- Follows a replicable method. The methods are standardized in the pertinent scientific discipline or, if not, the methods have been appropriately peer-reviewed to assure their reliability and validity.
- Reaches logical conclusions and reasonable inferences. The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.
- Uses appropriate statistical or quantitative methods for analysis.
- Appropriately frames conclusions with respect to the prevailing body of pertinent scientific knowledge, and adequately references assumptions, analytical techniques, and conclusions with citations to relevant, credible literature and other pertinent existing information.

The County's BAS document (Revised Draft Summary of Best Available Science for Critical Areas, March 2006) contains a comprehensive review of the state of the science applicable to Snohomish County regarding functions and values associated with critical areas. The BAS document provided the basis for selecting measures to assess functions and values with precision and accuracy to support timely management decisions.

1.7 Work Plan and Schedule

In 2007 the County began the monitoring and adaptive management program with the development of a monitoring and adaptive management plan, assembly of a project team, and acquisition of high-resolution satellite imagery from the Quickbird satellite at the time of code adoption. Additional tasks included post-processing of satellite imagery, refinement of Geographic Information System (GIS) data layers essential for the analysis, reconnaissance, purchase of field gear, and coordination between Public Works and Planning and Development Services departments on the evaluation and adjustment process. Tasks and department roles and responsibilities in subsequent years are summarized in Table 2 and 3, respectively.

Table 2 Monitoring, Evaluation and Adjustment Schedule

Steps	Monitoring and Adaptive Management Cycle 2008	2009	2010
Monitoring			
Monitoring Component 1	Improve hydrography; acquire winter satellite image; finalize imagery classification protocol; conduct field verification; prepare report summarizing baseline dataset including an assessment of accuracy and precision	Acquire and process a second summer image; Gather additional field data to verify results.	Acquire and process a second winter satellite image. Gather additional field data to verify results.
Monitoring Component 2	Survey major river and lake shorelines to establish baseline.	Fill in remaining gaps in shoreline survey as needed.	Resurvey shorelines and report results.
Monitoring Component 3	Refine sampling design and study questions; select sites; begin data collection.	Collect data on chemical/biological/physical indicators using a replicable method.	Collect data on chemical/biological/physical indicators using a replicable method.
Evaluation			
	Refine permit review process (PDS). Prepare report summarizing baseline data collection (SWM).	Provide update on monitoring results to date. (SWM)	Evaluate changes in landcover and shoreline conditions and prepare monitoring report (SWM)[1].
Adjustment			
	Refine adjustment process; refine trigger levels as needed based on literature review and replicate surveys.	Continue to refine adjustment process as needed.	Produce adaptive management report (PDS). Adjust program based on results relative to triggers (referral; education; enforcement; mitigation; code adjustment).

[1] PDS is the lead for evaluation and ground-truthing related to permits

Table 3 Public Works SWM and PDS Roles and Responsibilities

Public Works SWM	Planning and Development Services
1. Complete effectiveness monitoring • remote sensing • shorelines • paired catchments study 2. Evaluate changes in indicators relative to baseline conditions and adaptive management thresholds 3. Produce monitoring reports summarizing baseline conditions, changes, a discussion of probable causes, and an assessment of data accuracy and completeness	1. Complete implementation monitoring • permits issued • enforcement actions taken • buffer reduction location/extent 2. Provide data to SWM on the location and area of buffer reductions and exemptions allowed under the CAR to aid in evaluation 3. Produce adaptive management reports recommending and summarizing changes made to protect critical areas based on monitoring results

2. MONITORING

2.1 Overview

As described above, the monitoring program will have three basic components: (1) assessment of changes in land cover indicators through remote sensing methods; (2) assessment of changes in shoreline conditions along major rivers and lakes; and (3) assessment of select ecological indicators to evaluate the effectiveness of code provisions related to riparian buffers. All elements are designed to inform the central management question:

> ***Are gains or losses of functions and values occurring in fish and wildlife habitat conservation areas and wetlands?***

This chapter describes the hypothesis, guiding principles, monitoring indicators, and study design. The CAR monitoring program is part of broader County monitoring efforts, which include monitoring required for Shorelines Master Plan compliance, ESA salmon recovery planning support and NPDES permit compliance. The CAR monitoring program directly supports Shoreline Master Plan compliance. Monitoring efforts to support ESA salmon recovery planning and NPDES permit compliance are complimentary, but are also distinct because they are designed to inform different questions. Protocols for CAR monitoring are included in Appendices A and B.

2.2 Hypothesis

A statistical test of a hypothesis involves stating it to favor either acceptance or rejection. In this case, the 'null' or assumed hypothesis for the program is that County regulations and programs are adequate to protect critical area functions and values. The statistical analysis will be conducted to accept the null hypothesis unless there is reasonably strong evidence to reject it.

Hypotheses have also been developed for each of the monitoring plan components.

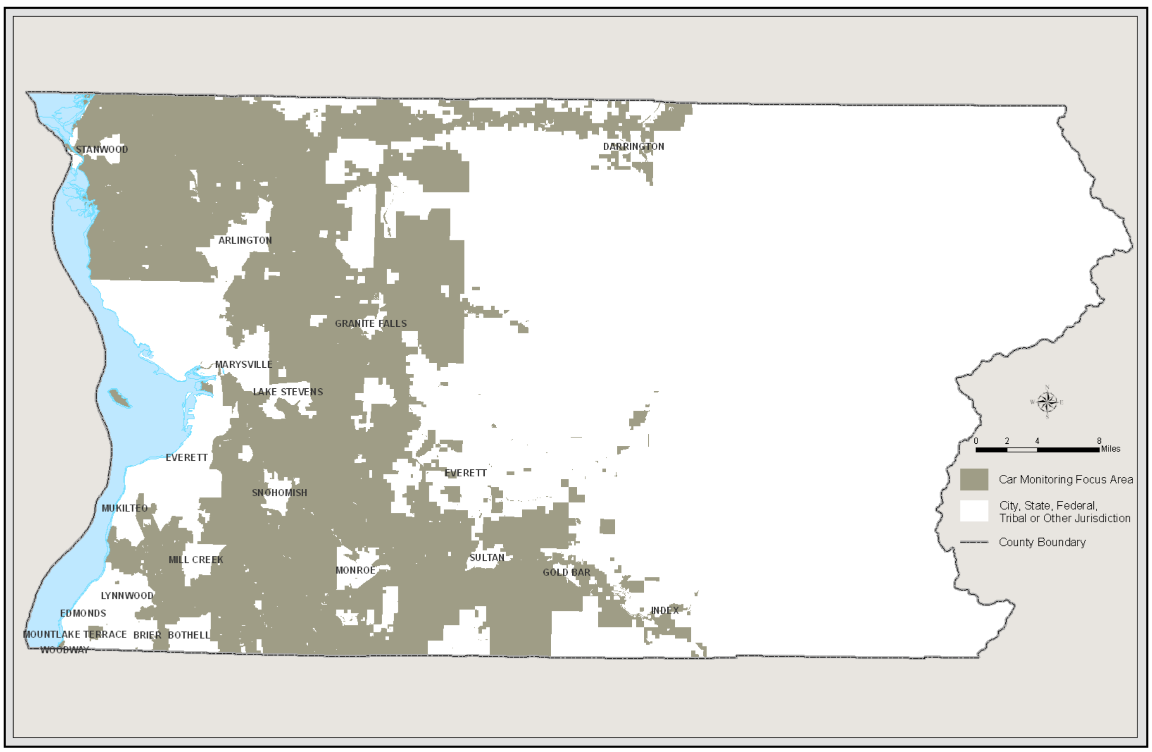
1. Riparian forest conditions and wetland extent will remain at current levels.
2. Shoreline conditions along major rivers and lakes will remain at current levels.
3. Indicators of functions and values in stream drainages undergoing new development will not differ significantly from those in similar but undeveloped drainages.

2.3 Guiding Principles

The following principles will guide implementation of the monitoring program:

1. Monitoring sampling design, protocols, and analysis will be developed and implemented using peer-reviewed BAS.
2. The spatial extent of monitoring will be the area under Snohomish County's jurisdiction and will exclude federal and state forest lands, cities, and tribal trust land (Map 1).
3. Monitoring will focus on evaluation of functions and values of Wetlands and FWHCA.

4. The hypotheses stated above will be tested based on monitoring indicators representing measurable functions and values of critical areas.
5. Permissions will be obtained from private landowners prior to field sampling on private property.
6. Some functions and values as measured by environmental indicators may be sub-sampled. In situations where a census survey is not possible, a randomized sampling design will be used to gather a representative sample so that results can be extrapolated to the broader population with known certainty.
7. Field sites will be over-selected in the random sample to address property access issues. Crews may be unable to sample some locations because landowner consent has not been granted or due to safety concerns.
8. The monitoring program will have its own adaptive management process. Indicators may be adjusted and sample design refined to ensure that the program remains consistent with BAS and meets its goals and objectives as efficiently and effectively as possible.



Map 1 County Jurisdiction and the Approximate Spatial Extent of CAR Monitoring Program

2.4 Monitoring Indicators

Proposed monitoring indicators were selected to track changes in critical area functions and values based on the following criteria summarized from Reid and Furniss (1998):

1. High sensitivity to changes.
2. Accurate and precise with a high signal-to-noise ratio[2].
3. Comprehensive in representing a range of functions and values of concern.
4. Documented methodology and performance measures in the scientific literature.
5. Cost effective means to obtain results of high statistical power.

Table 3 summarizes the indicators selected to monitor trends in critical area functions and values based on these criteria. Indicators are categorized as related to wetlands, to the riparian portion of FWHCA, or to the aquatic portion of FWHCA. Table 3 also presents functions and values associated with each critical area, performance criteria from the scientific literature, and monitoring plan components.

Performance criteria provide a context of ecological function for each indicator and may be used to summarize the status of conditions by watershed as part of baseline characterization. It is important to note, however, that they are not triggers for adaptive management action in this plan. Triggers are based on changes from baseline conditions at the time of code adoption and are described below in Chapter 3 - Evaluation.

This list of monitoring indicators represents our preferred approach at the time of publication. Refinement of the study design through peer review continues. The County may refine the list as needed to remain consistent with BAS and program goals as part of the adaptive management process. For example, the County will evaluate the use of indices of riparian and wetland functions that combine multiple indicators such as riparian width, tree height, invasive species and connectivity. An advantage of indices is that they provide a framework for summarizing a broader range of functions and values into one result, and they tend to have a normal distribution, thus making statistical analysis more straightforward. A disadvantage is that they can mask downward trends in individual indicators. These issues will be explored further through discussions with regional experts in monitoring and statistics.

[2] Signal-to-noise ratio is the ratio of relevant or useful information (signal) to irrelevant information (noise).

Table 4 Critical Area Monitoring Indicators

Critical Areas	Function and Values	Indicators[1]	Performance Criteria			Source	Monitoring Plan Component
			Properly Functioning	At Risk	Degraded		
Wetlands	Fish and wildlife habitat; habitat for locally important and threatened species; runoff absorption, pollution assimilation, water quality maintenance, floodwater storage and attenuation; stream base-flow, groundwater	Wetland area by type (open water, emergent, scrub/shrub, forested)	>80% historic wetlands intact	50-80% historic wetlands intact	<50% historic wetlands intact	NOAA Pathways and Indicators, 1996	One
FWHCA – Riparian (including lakes and marine shorelines)	Fish and wildlife habitat; habitat for locally important and threatened species, large woody debris recruitment, nutrients, water quality maintenance, stream bank stabilization	% mature forest cover	None reported	None reported	None reported	None reported	One
		%young forest cover	None reported	None reported	None reported	None reported	One
		% total vegetation cover (mature evergreen, medium evergreen, deciduous,, scrub-shrub)	>80% riparian reserves intact	70-80% riparian reserves intact	<70% riparian reserves intact	NOAA Pathways and Indicators, 1996	One
		% total impervious area (TIA)[2]	<7% TIA	7-12% TIA	>12% TIA	Summary of reports referenced in Spence *et al*., 1996	One
FWHCA – Aquatic	Fish and wildlife habitat; habitat for locally important and threatened species, refugia in side-channels; large woody debris (LWD) and small woody debris; sediment storage and transport; water conveyance; clean water, nutrients	% bank modifications	Bank hardening <10% of shorelines	Bank hardening 10-20% of shorelines	Bank hardening >20% of shorelines	NOAA Stormwater Matrix, 2003	Two
		Bankfull channel width (CW) :depth ratio	<10	10-12	>12	NOAA Pathways and Indicators, 1996	Three
		Pool frequency	CW pool/mile 5' 184 10' 96 15' 70 20' 56 25' 47 50' 26 75' 23 100' 18 Meets pools standards above and also has opportunity for LWD recruitment	CW pool/mile 5' 184 10' 96 15' 70 20' 56 25' 47 50' 26 75' 23 100' 18 Meets pool standards but lacks opportunity for adequate LWD recruitment	CW pool/mile 5' 184 10' 96 15' 70 20' 56 25' 47 50' 26 75' 23 100' 18 Does not meet pool standards and lacks opportunity for adequate LWD recruitment	NOAA Pathways and Indicators, 1996	Three
		Temperature	<14 C	14-17 C	>17 C	EPA, 2003	Three
		Conductivity	<100 umhos/cm	100-200 umhos/cm	>200 umhos/cm	Snohomish County, 2000	Three
		Benthic Index of Biological Integrity	Index of 38-50	Index of 28-37	Index of 10-27	Karr, 1998	Three

1 Additional vegetation classes may be added if they can be delineated with high accuracy and precision.
2 TIA will also be reported on a watershed scale and sub-basin scale.

A description of each indicator and rationale for its selection is provided below. Please refer to the Snohomish County's Best Available Science document for additional information on functions and values associated with each indicator (Revised Draft Summary of Best Available Science for Critical Areas, March 2006).

Wetland area

For this monitoring program, wetlands are defined as areas that 1) are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, and that 2) in fact support such vegetation under normal circumstances.

Four wetland types will be evaluated: emergent, scrub-shrub, forested, and open water. Emergent wetlands are characterized by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) that are present for most of the growing season in most years. These wetlands are usually dominated by perennial plants (Cowardin, 1979). Scrub-shrub wetlands are defined as areas dominated by woody vegetation less than 20-feet tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions (Cowardin, 1979). Forested wetlands are characterized by woody vegetation 20-feet or greater in height (Cowardin, 1979). Areas of open water within the other wetland classifications will be classified separately if they are greater than 1-acre but less than 5-acres in area in the late winter/early spring image. Areas of open water greater than 5-acres will be classified initially as lakes, with the caveat that this definition may change in the future.

Wetland area was selected as a monitoring indicator because it is regulated directly by the CAR wetland provisions and because it is a leading indicator of change to functions and values of wetlands as well as other critical areas. Wetlands provide habitat for salmonid rearing and play a major role in groundwater and surface water hydrology, water quality, nutrient cycling, and biotic diversity. Loss of wetlands affects the entire food chain and interrupts hydrologic interactions and nutrient cycling functions.

Wetland area and associated administrative buffers will be measured using high resolution satellite imagery in combination with light detection and ranging (LIDAR), radar, digital elevation models (DEMs), National Wetland Inventory (NWI), Snohomish County wetland map products, and other field-based wetland delineations from recorded plats or critical area site plans. Remote sensing imagery classifications will be verified by field measurements. Similar methodologies have been implemented in other areas (Gergel et al., 2006; Morrissey, 2006; Sobocinski et al., 2006).

Uncertainty remains regarding level of accuracy and precision of wetland classification obtainable under local conditions using primarily remote sensing techniques, and thus the methodology will be tested and refined in the first year of the program. Forested wetlands are likely to be the most difficult to classify.

Riparian forest cover area

Areas of mature evergreen forest, medium evergreen forest, deciduous forest, and small trees and shrubs will be measured adjacent to streams, lakes and marine shorelines. These classes were established to reflect the differences in forest composition, LWD recruitment potential, size, and hydrologic maturity. The amount and maturity of forest cover within a watershed influences hydrologic processes; hydrologically mature forests are predicted to provide a similar runoff response to pre-development forest conditions (Booth et al. 2002).

The mature evergreen forest class is hydrologically mature and contributes to large woody debris (LWD), which is likely to be in excess of 2 ft in diameter (ft dbh) and 50 ft in length (Purser et al. 2002). Purser et al. (2002) overlaid USFS stand age data over Landsat imagery data and determined that trees within the mature evergreen forest class were generally 100 years or older. The large logs recruited to the stream network from this class play an important role in jam formation. Medium evergreen forest, which is predicted to be between 27 and 99 years old based on overlay analysis with USFS forest stand age data, also contributes to hydrologic function and small and mid-sized LWD recruitment (<2-ft dbh) (Purser et al. 2002). Deciduous stands are also considered to be hydrologically mature and generally provide recruitment of smaller pieces of LWD and organic material. The shrubs and small tree class includes woody vegetation that does not meet the criteria laid out for the other forest classes and that generally averages 20 feet in height or less. This class includes newly planted riparian areas.

Riparian forest cover was selected because it is directly regulated by the FWHCA regulations, directly associated with a broad range of FWHCA functions and values, and easily and precisely measured using remote sensing. Generally speaking, riparian areas influence the aquatic ecosystem by providing temperature moderation, microclimate, bank stabilization, fine or large woody material, nutrients, sediment and dissolved chemical filtration, organic and inorganic debris, and terrestrial insects. Riparian forest cover also reduces surface stormflow runoff rates and volumes and provides habitat for riparian wildlife. Mature forest is important for maintaining stream hydrology (Booth, 2000); contributing LWD to aquatic systems (Spence et al., 1996); and providing habitat for federally listed terrestrial species including Bald Eagle, Marbled Murrelet, Northern Spotted Owl, and Gray Wolf. Younger forest provides shade, bank protection, nutrient retention, and sediment reduction, but generally at a lower effectiveness than mature forest.

Riparian forest cover will be measured using high-resolution satellite imagery and LIDAR. Remote sensing imagery classifications will be trained and verified by field measurements. Depending on the information needs to support management decisions and data capabilities, the County may also measure the area of grass, landscaping, bare earth, or invasive species such as reed canary grass, Japanese knotweed, and Himalayan blackberry.

Total impervious area

Total impervious area (TIA) is the sum of all roads, parking lots, rooftops, sidewalks, and other surfaces within a given area that cannot effectively absorb or infiltrate rainfall or snow melt. Effective impervious area (EIA) is a term often used to describe the portion of impervious surface within an area from which runoff does not infiltrate within that area. Numerous research projects have shown a positive correlation between the percentage of impervious surface in a watershed (measured as both %TIA and %EIA) and environmental degradation, including hydrologic changes (Dunne and Leopold, 1978; Brown, 1988; Booth and Jackson, 1994), degraded water quality (Klein, 1979), decline in physical habitat conditions (May et al., 1997; Shaver et al., 1995; and Schueler and Galli, 1992), and decline in the abundance and diversity of stream biota (May et al., 1997; Shaver et al., 1995; Klein, 1979; Steedman, 1988; Schueler and Galli, 1992; Morley, 2000). Alberti et al. (2005) reported significant positive correlations between percent TIA within 100 meters of a stream and instream biotic integrity. These correlations have also been found at much smaller spatial scales.

TIA can be measured accurately over large areas using remote sensing techniques, but such measurements cannot always account accurately for on-site infiltration and impervious vegetated areas such as highly compacted lawns. EIA is a more accurate indicator of surface runoff and the consequent environmental effects, but it cannot be measured accurately except in the field at the site scale. Several studies have proposed relationships between EIA and TIA, including (Beyerlein (1996) [proposed the linear regression %EIA = 0.89*(%TIA) – 1.33)] and Dinacola (1989).

TIA was selected as a monitoring indicator because of its relationship to critical area functions and values as described in detail above and because it can be measured using remote sensing techniques. Also, the CAR directly regulates impervious surfaces. TIA will be measured using high-resolution satellite imagery with field verification within riparian areas and at a watershed scale. An approximation of EIA can be provided using the linear relationship between TIA and EIA.

Shoreline hardening

Shoreline hardening refers to dikes, levees, berms, vertical bulkheads and banks armored with riprap and rubble. Shoreline hardening reduces salmonid rearing capacity and productivity by reducing the quantity and complexity of slow water habitat along the channel margins (Beamer and Henderson 1998, Spence et al. 1996, Ward and Wiens 2001, and Ward et al. 1999). Channel edge habitat is critical for juvenile salmonids, particularly for Chinook salmon because they rear primarily in mainstem rivers along the riverbanks rather than in the mid-channel

(Hayman et al. 1996). Similarly, shoreline modification along lakes and marine shorelines degrades habitat for juvenile salmonids and other fish and wildlife species. For these reasons and because it is directly regulated by the CAR, it was chosen as a monitoring indicator.

Shoreline hardening along major rivers and lakes will be measured in the field using global positioning system (GPS) equipment in accordance with methods used in past Snohomish County monitoring (e.g., Haas et al., 2003). Lakes will be randomly selected by size class and sub-sampled.

Bankfull width:depth ratio

Stream channels change dimensions in response to changes in watershed or riparian conditions (e.g. clearing or paving) that alter stream flow, sediment delivery and transport, and vegetation or woody debris recruitment from riparian areas. The bankfull width:depth ratio, in which 'bankfull' refers to the bankfull discharge and depth refers to the average water depth associated with that discharge, is a sensitive indicator of trends in channel stability and disturbance to channels or watersheds (Rosgen, 1996). An increasing width:depth ratio (channel increases in width and decreases in depth) often results from watershed disturbance, which in turn causes bank erosion and a reduction in the channel's ability to transport sediment (Rosgen, 1996). Streams with high bankfull width:depth ratios also tend to have reduced shading and shallower dry-season flows, which may result in elevated water temperatures.

Bankfull width:depth ratio was chosen as a monitoring indicator because it is sensitive to changes in upstream watershed conditions and can be precisely measured. Bankfull width and depth will be measured in the field using a stadia rod, measuring table and level using field indicators and survey techniques outlined in Rosgen (1996).

Pool frequency

Pool frequency is a common measure of salmon habitat quality and complexity. Pools provide critical rearing areas for juvenile salmonids and holding areas for adult salmonids when they return to their natal streams to spawn. Pool frequency is primarily a function of LWD, sediment loading, and channel type (Montgomery et al, 1995). Low pool frequency often indicates inadequate LWD loading or excess sedimentation. Because of its importance in providing habitat for salmonids and because it is a metric that can be measured rapidly with precision (Kauffman et al, 1999), it was selected as a monitoring indicator. Pools that meet specific depth and area criteria will be tallied during field surveys.

Water temperature

Water temperature is a controlling factor in the rate of metabolic and reproductive activities for aquatic life that affects physical or chemical water indicators in the stream environment. An increase in temperature can increase metabolic activity, lower dissolved oxygen levels, and provide conditions for the growth of diseasecausing organisms and undesirable algae. Weather, streamflow, streamside vegetation, groundwater inputs, and water release from industrial activities influence water temperature. Removal of the forest canopy of streams in the Pacific Northwest has been documented to increase peak water temperatures in the summer by 3 to 8 degrees Celsius (MacDonald et al. 1991).

Performance criteria for water temperature are based on temperature regimes established for adult salmon migration (EPA, 2002). Lab studies of disease risk to migrating adult salmon indicate elevated risk above 14^{o}C and high risk above 17^{o}C (EPA 2003).

Water temperature will be measured in the field continuously throughout the summer using Hobo® water temperature probes or equivalent and reported as a 7-day moving average maximum temperature. Temperature probes will be installed in the stream using materials appropriate for the site (e.g. steel fishing leader, plastic stake). A GPS point will be recorded to facilitate probe location and retrieval.

Conductivity

Conductivity is a measure of the ability of a substance to conduct an electric current, and for water, is related to the total concentration of dissolved ions. Conductivity in natural waters is measured as the inverse of resistance in umhos/cm. Distilled water has a conductivity of about 1 umhos/cm, and melted snow can have a conductivity of 2 to 42 umhos/cm. The typical range for drinking water in the United States is 30 to 1,500 umhos/cm, and streams in the Pacific Northwest usually fall at the low end of that range (MacDonald et al. 1991).

Conductivity can be used as an indicator of contaminants in streams from urban or agricultural activities. May et al. (1997) found a strong correlation (r^2=0.83) between conductivity and the percentage of total impervious area in the Puget Sound lowland region. Conductivity in surface water can be increased by substances such as metals from road runoff, zinc from galvanized fencing and roofing, fertilizers, de-icing salts, and dust reduction compounds. Nutrients such as nitrogen and phosphorus are minor components of conductivity. Land clearing activities can increase conductivity by increasing sediment in water and thus the amount of dissolved ions. Conductivity is regarded as a sensitive indicator of change and an early warning if land development impacts are not being mitigated. Monitoring of conductivity will begin as a pilot study to test the effectiveness of new-on-the-market conductivity probes.

Benthic Index of Biological Integrity (B-IBI)

The Benthic Index of Biological Integrity (B-IBI) is a single index value derived from the relative numbers of different types of stream macroinvertebrates. Karr (1998) developed a B-IBI for Puget Sound streams in which scores range from 50 (indicating pristine conditions) to 10 (indicating highly degraded conditions).

The index provides a lumped measure of the effects of physical and chemical conditions in the stream, riparian areas, and the watershed upstream of the sample site.

Booth et al. (2002) presented a graph that plotted percent total impervious surface in Puget Sound watersheds against B-IBI scores; the data were compiled from studies by Kleindl (1995), May (1996), and Morley (2000). The data show a general decline in B-IBI scores with increased imperviousness, but with significant variability.

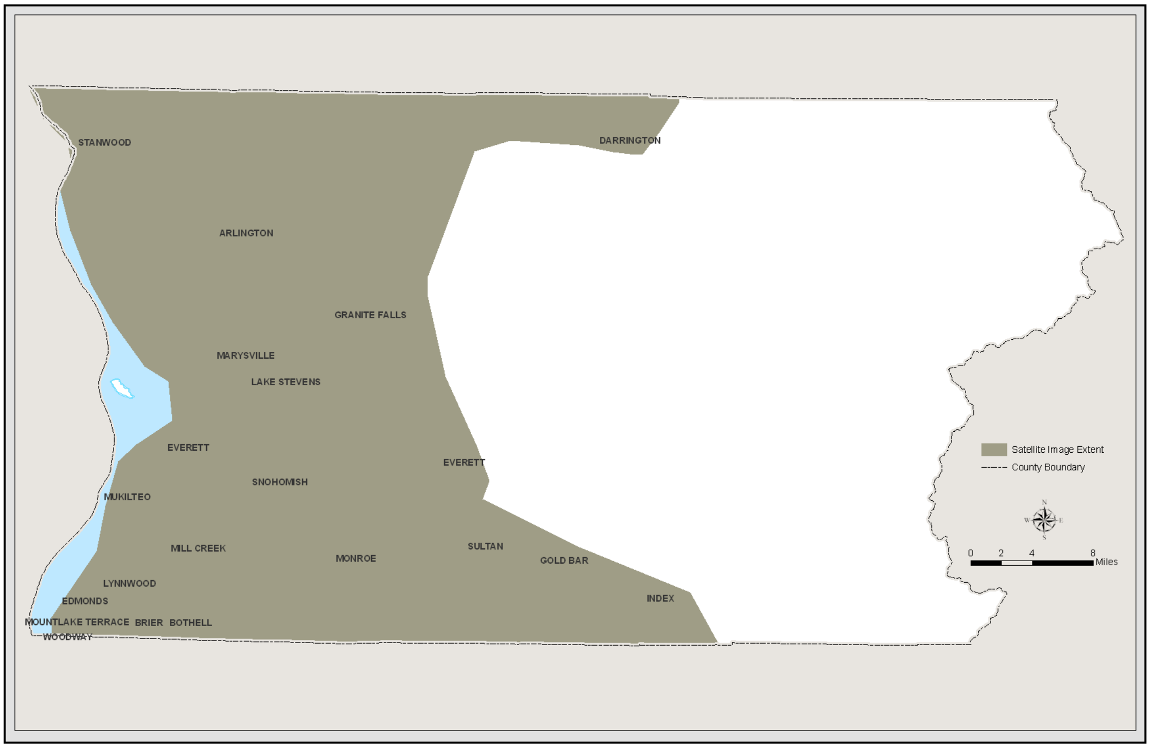
At this time it is not possible to draw strong conclusions about an individual driving factor in a watershed (such as the percentage of impervious area in riparian buffers) based solely on an individual B-IBI score. Significant changes in B-IBI scores along with changes in other watershed metrics, however, can indicate potential problems associated with land use, and thus the need for a more detailed examination of watershed conditions. For this reason and because B-IBI provides a holistic view of the health of critical areas, B-IBI was selected as an indicator for this monitoring program. B-IBI will be measured in the field using a Serber sampling net following a standard protocol.

2.5 Study Design

Critical areas will be monitored by remote sensing analysis of land cover in the entire program area, shoreline surveys of major waterbodies, and field acquisition of water quality and aquatic habitat data at selected sites associated with riparian buffer reductions. Data will be analyzed at appropriate and discernible spatial scales ranging from the river basin to the individual parcel.

<u>Component 1: Land Cover Characterization</u>

Snohomish County will conduct a survey of wetlands, riparian forest cover and impervious surfaces within buffers using remote sensing techniques with field verification. The analysis will be completed over the western half of Snohomish County and river valleys that extend into the Cascade Mountains (Map 2) using multi-spectral, high resolution satellite imagery with an infrared band and other ancillary data sources. National forests and the forest production zone, located primarily in the eastern half of the County, will be excluded because the County has a limited role in regulating these areas. The remote sensing methodology is summarized below and is described in detail in Appendix A.



Map 2 Approximate Extent of Satellite Image Analysis

Satellite imagery from two seasons, summer and late winter/early spring, will be acquired and processed biennially beginning in 2007. The summer image will be obtained in August and used to classify land cover, including evergreen and deciduous forest cover and potentially invasive species. The winter/early spring image will be obtained between January 15th and April 1st of the following winter during deciduous leaf-off. It will be used in conjunction with the summer image to assist with the classification of impervious surfaces and wetlands. High levels of cloud cover during winter months in Snohomish County may make acquisition of a full winter image challenging. If a winter image cannot be obtained, a classification methodology will be developed using the leaf-on image and ancillary data sources.

Satellite imagery data will be acquired from the Quickbird satellite in non pan-sharpened, raw format at a 2.5 meter resolution for multi-spectral bands and a 1 meter resolution for the panchromatic band. It will be classified based on differing surface reflectance values using ERDAS IMAGINE® or a comparable software package. Each land cover type forms a reflective class that possesses a unique signature. A standard combination of remote sensing methods (unsupervised classification, supervised classification, principal component analysis, and normalized difference vegetation index) will be applied to the remote sensing data to identify vegetation cover classes, impervious surfaces, and wetlands. LIDAR and other available GIS data layers including the National Wetland Inventory (NWI) wetland classification, hydric soils, and hydrography will also be considered in developing a rule-based, repeatable system for land cover classifications. This work will expand on methods developed for previous and current Snohomish County remote sensing projects such as the 2001 Classification and Analysis of Land Cover and SnoScape (2007), an interactive environmental mapping tool. Methods for imagery classification are well documented in peer-reviewed journal articles such as Gergel et al. (2006), Morrissey (2006), and Sobocinski et al. (2006).

A key task in 2008 will be to refine the remote sensing image classification methodology in order to maximize accuracy and repeatability. Remote sensing accuracy in the context of this project refers to the degree of correlation between land cover definitions determined by pixel classification and the true land cover. Based on similar studies and Snohomish County's past work with image classification, impervious surface area estimates are anticipated to have the highest accuracy relative to other land cover classes because they tend to be homogenous.

Vegetated areas have greater heterogeneity, and thus will likely have lower accuracy. Forest cover classification accuracy varies by vegetation type. A study on Vancouver Island, British Columbia reported an accuracy of 85% for old-growth, coniferous forest and 75% for deciduous forest (Gergel et al., 2006). Purser et al. (2003) reported an overall accuracy for Landsat imagery classification into 11 land cover classes, not including a separate wetland class, of 92%. Estimates of wetland area may have the lowest accuracy because wetlands vary in type and size, have mixed species composition and distribution, and are often combined with other land cover types throughout the landscape. Few studies have classified wetlands in the Pacific Northwest using remote sensing techniques, although several have been completed on the East Coast and in Florida (Morrissey 2006). These studies have been able to identify more wetlands than are mapped in the National Wetland Inventory. With all land cover types, accuracy tends to increase with larger homogenous areas of impervious surface, wetland or riparian forest.

The accuracy of the land cover classification methodology will be assessed by comparing results to known land cover classes delineated through field surveys and aerial photographs. The accuracy assessment will follow a rigorous study design involving the selection of test plots through random sampling and establishment of long-term quality control sites. Existing wetland delineations from PDS and the Tulalip Tribes will be used to verify wetland extent and classification.

Long-term quality control (QC) sites will be established throughout the monitoring program area in locations protected from significant, direct human influences such as development and timber harvest. They will allow us to assess whether or not detected changes are the result of human activities, atypical precipitation patterns or other factors. These sites need also to be accessible to field staff over the long term. Established NGPAs, public parks and other conservation areas with existing environmental data such as wetland delineations, stream surveys or critical area site plans are the most likely locations for the establishment of reference sites. The monitoring program goal is to establish multiple 50-meter x 50-meter plots for each long-term site.

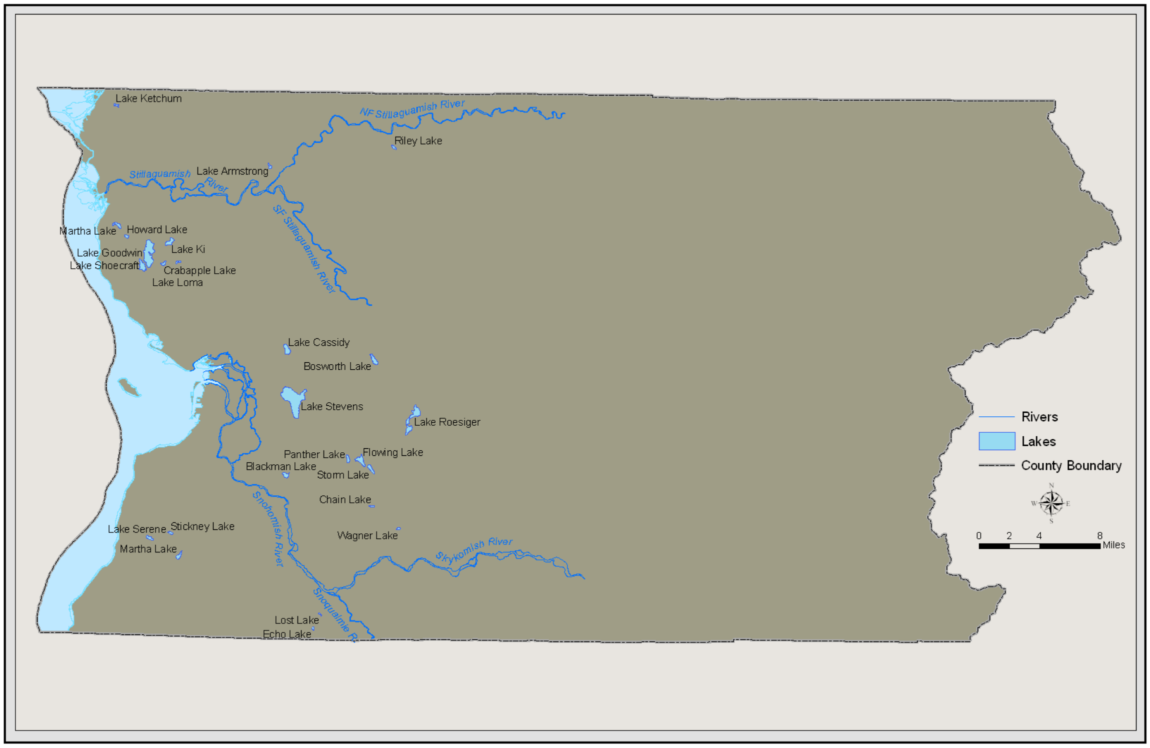
Different methods to assess accuracy will be used for different remote sensing land cover classifications. For example, accuracy assessment for broad vegetation classes and impervious surface will typically be performed by randomly selecting single pixels (or blocks of pixels) from satellite imagery and comparing them to recent ortho-rectified aerial photos. Accuracy assessment for more specific vegetation classes (e.g., invasive species) and types of wetlands may require field identification and delineation in addition to the methods described above. Data analyses will be compiled into a “confusion matrix”. A confusion matrix is an accuracy assessment approach that compares the frequency of agreement between the predicted land cover classes with actual conditions.

Component 2: Shoreline Inventory

An inventory of shoreline modifications along major waterways and lakes is the second component of the CAR monitoring plan (Map 4). The survey will be conducted along navigable portions (~130 miles of shoreline) of the Snohomish, Snoqualmie, Skykomish and Stillaguamish rivers and within the 25 lowland lakes in Snohomish County with public access (~50 miles of lake shoreline). The target sample is 50 percent of the shoreline length. A representative sample of each river reach[3] within the study population will be surveyed. Lakes will be sampled through a random sample stratified by lake size.

Rivers and lakes will be surveyed biennially beginning in 2008. The inventory will be completed primarily by boat. Survey crews will record the location and type of each modification using GPS field computers. Aerial imagery will be used to enumerate docks and estimate their extent of coverage in lakes. Ten percent of the total length of shoreline will be resurveyed by a second survey crew to evaluate the precision of the bank modification estimate.

[3] A river reach is a distinct unit delineated based on geology, valley form, river planform, and gradient.



Map 3 Lakes and Rivers Slated for Shoreline Survey

Component 3: Paired Catchment Study

The third component of the monitoring plan is designed to evaluate the cumulative effectiveness of riparian buffer provisions in protecting physical, chemical and biological conditions of the aquatic environment. It will track long-term trends in a broad range of critical area functions and values, inform regulatory updates, and contribute to Snohomish County BAS.

A “treatment” and “control” study design will be used to compare areas developing under the new CAR with reference sites that are unlikely to experience significant development. Pairs of small drainages of approximately 1-3 km^2 known as catchments were selected. “Treatment” reaches will be monitored for an ecological response from development actions. Monitoring of “control” reaches will provide for comparison and differentiation between ecological responses associated with land use actions and broader signals associated with climate patterns. Small catchments were selected because they respond rapidly to land use changes within the riparian forest and contributing drainage area.

Criteria were established for site selection. We selected “treatment” catchments that have a high probability of substantial future development that will occur under the regulatory prescriptions of the new CAR. We selected “control” catchments corresponding to “treatment” catchments with modest or no anticipated development over the next 10 years. At the time of the initial site selection, permit applications under the new CAR were limited. Additional sites will be selected in 2009 using proposed permits as a guide.

The analysis will be completed using both remote sensing and field data collection techniques. Permits and land cover changes within all study catchments will be intensively monitored. The field component of the monitoring program involves collecting data on the following proposed indicators: bankfull width:depth ratio, pool frequency, water temperature, conductivity, and Benthic Index of Biological Integrity (B-IBI). Descriptions of these indicators, rationales for their selection, and data collection methods are described in Section 2.4 above. See Appendix C for detailed site selection, data collection and analysis protocols.

3. EVALUATION

3.1 Overview

The evaluation process is focused around the central management question:

> ***If loss is occurring, what and where are program adjustments needed to protect critical area functions and values?***

In the evaluation process, monitoring data will be analyzed and compared to the baseline. If losses in functions and values are detected, statistical analyses will be completed to determine whether or not the level of change exceeds measurement precision and natural variability. If the analysis indicates statistically meaningful losses, the next step will be an analysis of actions within the area to identify the source.

This chapter describes the evaluation process, beginning with the issues of baseline and scale, followed by statistical analysis, peer review, source identification, and monitoring reporting. The source identification process will be a collaborative effort between PDS and SWM.

3.2 Baseline

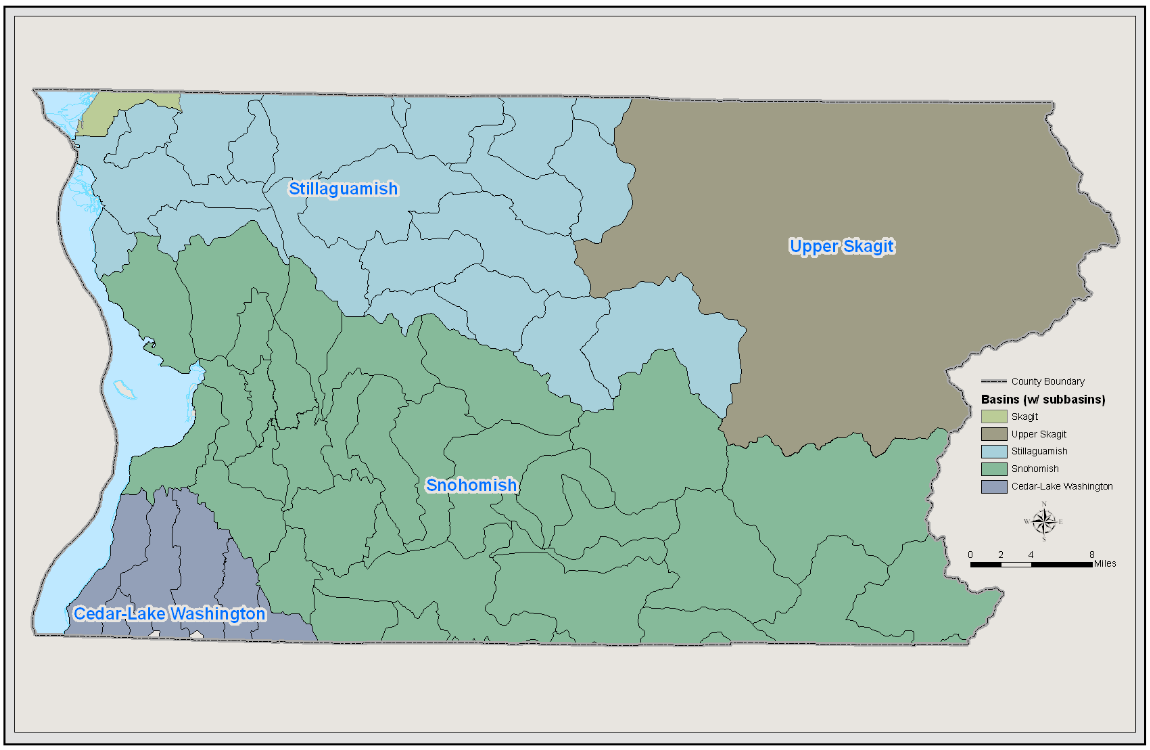
Data collection in 2007-2008 will establish a baseline of conditions for tracking gains and losses in critical area functions and values indicators. The "baseline date" is the effective date of CAR adoption, October 1, 2007. If data for specific indicators are used that substantially precede or follow this date, the County will estimate the change in conditions during the period between data collection and the baseline date. Habitat improvement projects that were underway in 2007 will be recorded as occurring after the baseline.

If water quality sampling field sites selected for this program align with sampling locations from other efforts for which several years of data exist for an indicator, it may be possible to set a baseline based on the variance observed throughout the sampling record. This would potentially allow for a quicker response to changes observed in water quality indicators than would otherwise be possible.

3.3 Scale

Monitoring data will be summarized on multiple scales. In the context of this monitoring program, the largest geographic unit is the river basin, followed in decreasing order by watershed and subbasin. The river basins considered in this program are the Stillaguamish, Snohomish, and Cedar-Lake Washington. Watersheds are intermediate units that encompass major tributaries. Each watershed is composed of subbasins. The three river basins with substantial area under Snohomish County's jurisdiction have been delineated into 6 watersheds and 57 subbasins (Map 3; Table 4).

The watershed and subbasin were selected for this program as the primary geographic scales for evaluating change because they are ecologically meaningful and at a practical scale for land use decision-making. The watershed delineation aligns closely with the delineation of independent Chinook populations (Puget Sound TRT, 2003), and thus is consistent with the salmon recovery plans. The subbasin scale provides a greater level of specificity for identifying and addressing changes in functions and values. Adaptive management triggers (section 4.2) for programmatic scale change will be tied to indicators reported on a watershed scale. Results reported at the subbasin scale will be used in the evaluation process to identify the root causes of changes in functions and values and direct conservation and mitigation actions accordingly. Other analytical scales used in the source identification process will include land use class, reach and parcel.



Map 4 Snohomish County Geography

Table 5 Snohomish County Geography

River Basins	Watersheds	Subbasins
Stillaguamish	North Fork Stillaguamish	Boulder River, Dear Creek, French-Segelson, Lower North Fork Stillaguamish, Middle North Fork Stillaguamish, Squire Creek, Stillaguamish Canyon, Upper North Fork Stillaguamish,
	South Fork Stillaguamish	Gold Basin, Jim Creek, Lower Canyon Creek, Lower South Fork Stillaguamish, Robe Valley, Upper Canyon Creek, Upper South Fork Stillaguamish,
	Lower Stillagamish	Church Creek, Harvey Armstrong Creek, Lower Pilchuck Creek, Portage Creek, Upper Pilchuck Creek
Snohomish	Skykomish	Bear Creek, Beckler River, Foss River, May Creek/Lower Wallace, Miller River, Olney Creek, Rapid River, Skykomish – Lower Mainstem, Skykomish –Upper Mainstem, Skykomish River – Lower North Fork, Skykomish River – Upper North Fork, Skykomish River – Lower South Fork, Skykomish River – South Fork, Skykomish River – Upper South Fork, Sultan River – Lower, Sultan – River Upper, Tye River, Wallace River – Upper, Woods Creek, Woods Creek – Lower, Woods Creek – West Fork
	Snohomish/Snoqualmie	Snoqualmie Mouth, Cathcart Creek, Dubuque Creek, Everett Coastal Drainages, Fobes Hill, French Creek, Lake Stevens, Little Pilchuck Creek, Marshland Drainages, Pilchuck River – Lower, Pilchuck River – Middle, Pilchuck River – Upper, Quilceda/Allen Creek, Sunnyside Drainages, Tulalip Creek, Snohomish River – estuary
Cedar-Lake Washington	South County	North Creek, Swamp Creek, Little Bear Creek

3.5 Statistical Analysis

Statistical considerations were used in the development of the sampling design and the selection of monitoring indicators. Indicators will be measured through a census survey for riparian conditions, wetlands, and impervious surface. Sites for field verification of the satellite imagery and the shoreline survey will be selected using a random sampling frame. For other indicators no fewer than 30 sampling sites will be obtained to describe a population or sub-population, the minimum required to make statistical inferences (Paulsen, 1997).

Statistical power analysis is the ability to detect a change when a change truly exists (Fore et al., 2002). This is a critical element of the program because it indicates the level at which a trend can be detected, and thus appropriate triggers for changes in management. Triggers for this program will reflect the levels of detectable change determined in replicate stream surveys completed by Snohomish County (Snohomish County Public Works SWM, 2002), field verification of remote sensing data, values reported in the literature (Larsen et al, 1999; Fore et al, 2001; Cusimono et al, 2006), and consultation with regional experts in monitoring and statistics. Statistical power for various indicators will be reevaluated through time, and trigger levels will be adjusted accordingly to maintain consistency with BAS.

3.6 Peer Review

Snohomish County consulted with experts in monitoring and statistics during the development of this plan regarding sampling design, quality control and assurance, and the establishment of thresholds based on statistically significant changes in functions and values. A consultant was hired to provide technical oversight of the imagery classification process and assessment of accuracy and precision. Further peer review from regional monitoring specialists with expertise in water quality, physical habitat, remote sensing, and statistics will occur during the establishment of the program. Monitoring reports will be independently reviewed.

3.7 Source Identification

If a statistically significant change is identified in an indicator of critical area function, the next step is to determine the root cause for the loss in function. The source of potential problems will be investigated using analyses in a GIS and information on permitted actions stored in the AMANDA database. GIS layers used in the analysis will include land use, zoning, urban growth boundaries, and parcel boundaries. PDS will extract information from the AMANDA database on permitted actions including the location and extent of buffer reductions and other alternative buffer provisions. Changes will be made to ensure that PDS biologists record the necessary information in AMANDA for every site visited.

The following questions and answers frame the source identification process:

a) Are losses of functions and values occurring not as a result of County actions, but rather actions taken outside the County's jurisdiction? (If yes, refer to appropriate jurisdiction).
b) Are losses of functions and values occurring in a specific land use or geographic area? (If yes, focus further analysis and adjustment accordingly).
c) Are losses of functions and values resulting from code violations? (If yes, increase educational outreach and enforcement).
d) Are losses of functions and values occurring despite the County's programmatic approach to managing critical areas? (If yes, modify regulations).

A hypothetical example to illustrate the source identification process is described below.

Land cover analysis indicates a loss in mature riparian forest cover in the Lower Snohomish watershed, and in particular in the Quilceda Creek subbasin. Environmental indicators such as B-IBI and stream temperature also exhibit a downward trend. SWM staff takes the first step in the source identification *process by overlaying jurisdictional boundaries, land use data and land cover data from the satellite imagery. The GIS analysis indicates that the loss is occurring in unincorporated Snohomish County within a specific portion of the based zoned for rural residential development.*

Next, PDS staff query the AMANDA database to identify permitted actions and enforcement records over the two year period between acquisition of the baseline image and the second image for the area where change in mature forest cover occurred. They randomly select a subset of permits to evaluate changes on the ground, compliance, and various treatments allowable under the code. They stratify the sample to evaluate whether or not buffers with fences retain greater functions and values than those without fences.

The adaptive management response will follow from this analysis. If for example the clearing was not an allowed activity under the CAR, the County would follow up with education and/or enforcement in addition to mitigation. This process is outlined in greater detail in Chapter 4.

3.8 Monitoring Reporting

Upon completion of the evaluation process, SWM staff will produce a monitoring report biennially summarizing the status and trends of critical area functions and values indicators. A status update will be provided annually. Results will be reported for the County's jurisdiction on multiple scales including river basin, watershed, subbasin and zoning. Landcover statistics will be reported for wetlands and the standard riparian buffer widths identified in the CAR. Furthermore, with data provided by PDS on the location and extent of buffer reductions allowed through the permitting process, SWM will describe changes occurring that are not allowable under the CAR. The report will include baseline monitoring data, summary statistics, an assessment of the accuracy and completeness of the data, a description of data collection issues identified during the reporting period, and discussion of the probable causes of any identified losses. PDS staff will summarize results of the direct effectiveness monitoring related to the evaluation of specific permits as a section in this report, or alternatively in the adaptive management report (section 4.3).

All annual status updates and the biennial monitoring reports will be presented to the County Council in writing and in oral presentations.

4. ADJUSTMENT

4.1 Overview

Adjustment is the final step in the adaptive management cycle. Using the information collected and evaluated in previous steps to inform decision-making, the County will determine and implement appropriate solutions to correct any problems identified. To provide greater certainty that desired outcomes will be achieved, the County will set threshold values of change for critical area functions and values indicators that will trigger a rapid adaptive management response to offset potential losses.

Following from the source identification process, the adaptive management response may include additional public outreach and incentives, code enforcement, mitigation, and modification of regulatory requirements. Figure 3 shows the decision tree that will be used for adaptive management. Adaptive management triggers and the decision process are discussed in section 4.2 and 4.3, respectively.

4.2 Triggers

The County will set threshold values that will trigger an adaptive management response conservatively to allow for a rapid adjustment when potential losses in functions and values are first detected. The County's adaptive management response will reflect the level of change detected and confidence that the change is meaningful. The target confidence interval is 80%. A large and/or geographically widespread, statistically significant change will result in a more substantial action including programmatic changes to minimize losses to critical area functions and values. A smaller and/or isolated change will trigger a more modest or targeted response. Mitigation measures to offset losses that may occur are associated with all thresholds.

The primary triggers for adaptive management action are tied to changes in remote sensing land cover classifications, because these results provide direct measures of wetlands and riparian conditions every two years, and thus can indicate changes in functions and values over short timeframes. Field-based monitoring will be used to assess impacts to a wider range of Wetland and FWHCA functions and values, identify longer-term environmental trends, assist in source identification, and provide additional supporting evidence for adjustment. It will support advancement of BAS and revisions to specific elements of the code related to riparian buffer protections.

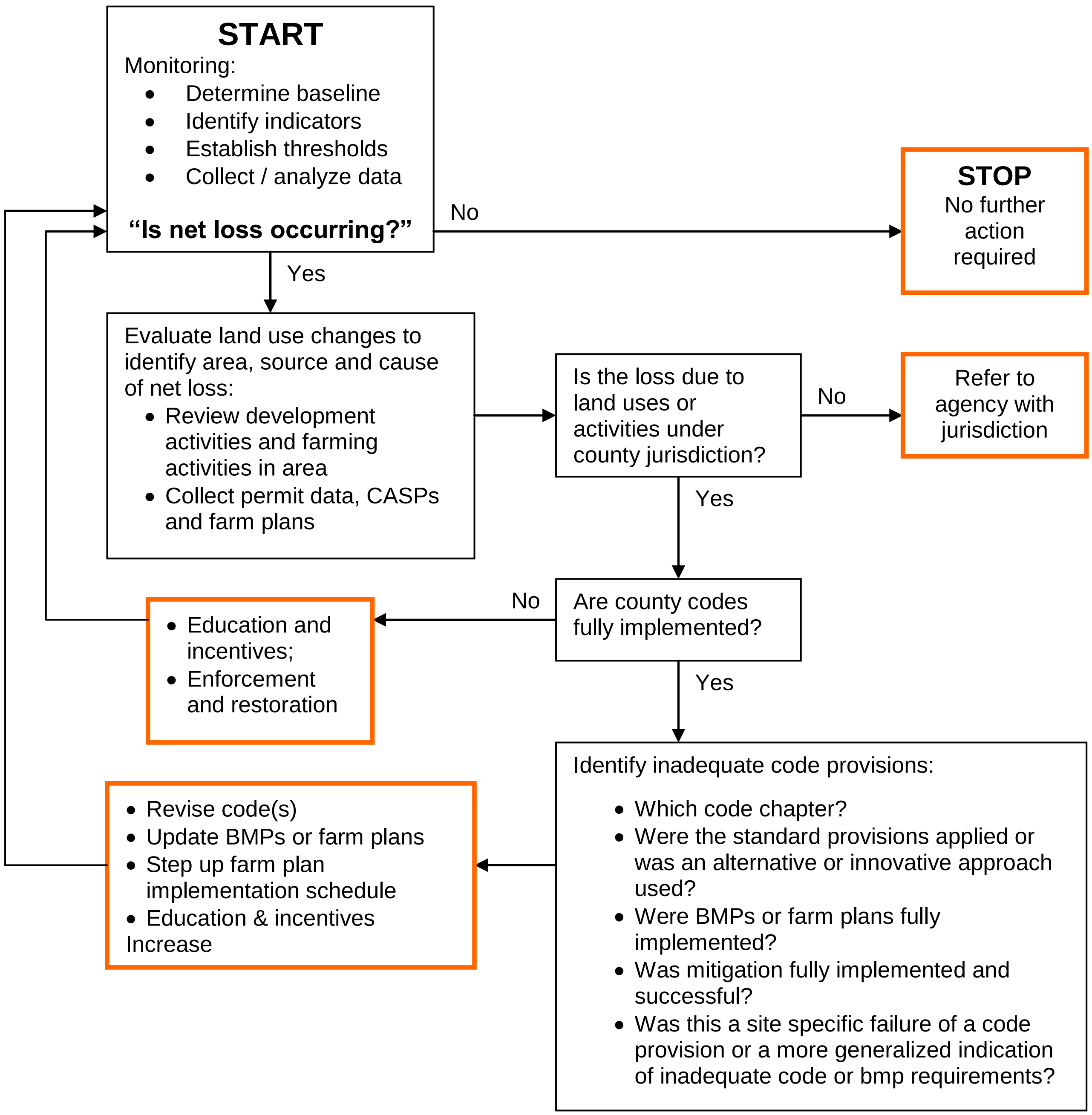


Figure 3 Adaptive Management Decision Tree

The triggers for wetland functions and values will be based directly on changes in the extent of wetlands. Indicators of riparian function may be summarized in an index of riparian functional area such as the one described below:

Riparian functional area =
(acres of mature evergreen) +
(acres of medium evergreen + deciduous forest)/2 +
(acres of small trees and shrubs)/6.

This index captures changes in mature riparian condition and the mitigation ratios included in the regulations for Wetlands and FWHCA, which assume that six acres of newly replanted forest provides a comparable level of functions and values to one acre of mature forest and three acres of non-mature forest. Some functions such as LWD recruitment will not be retained if a mature riparian forest stand is cut and replaced with small trees, even at a large mitigation ratio, and thus additional instream projects using LWD will be included in the adjustment process.

Table 5 illustrates a framework for triggering an adaptive management adjustment involving three threshold levels. Alternatively, a system could be implemented with only one level. Trigger threshold levels and the detection/adjustment timeline are estimates and will be refined in 2008 based on field verification, replicate surveys, literature review, peer review and other considerations.

Table 6 Adaptive Management Triggers[1]

Monitoring Plan Components	Indicators	Threshold 1 – triggers increase in public outreach and/or enforcement, mitigation actions	Threshold 2 – triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.	Threshold 3 – triggers programmatic adjustments including code revisions.	Estimated change detection and adjustment timeline
Component 1	Wetland area by type (open water, emergent, scrub/shrub, forested)	<5%change in any indicator across County jurisdiction within any watershed relative to baseline	5-10% change in any indicator across County jurisdiction within two or more watersheds relative to baseline	>10% change in any indicator across County jurisdiction relative to baseline	4 years
	Riparian forest quantity/quality index (including TIA)[2]	<3% in any indicator across County jurisdiction within any watershed relative to baseline	3-5% in any indicator across County jurisdiction within two or more watersheds relative to baseline	>5% in any indicator across County jurisdiction relative to baseline	2 years
Component 2	Bank modifications	<3% in any indicator across County jurisdiction within any watershed relative to baseline	3-5% in any indicator across County jurisdiction within two or more watersheds relative to baseline	>5% in any indicator across County jurisdiction relative to baseline	2 years
Component 3	Width:depth ratio Pool frequency B-IBI Temperature Conductivity	Statistically significant negative trend or difference between treatment and control sites	Statistically significant negative trend or difference between treatment and control sites in two or more indicators	Widespread statistically significant negative trend or difference between treatment and control sites in two or more indicators	4-6 years

[1] Trigger threshold levels and detection/adjustment timeline are estimates and will be refined based on replicate survey data.
[2] Riparian indicators from table 4 are combined into one metric.
[3] Water quality and habitat indicators also used to focus adaptive management actions to address concomitant effects of direct changes to critical areas

4.3 Adaptive Management Decision Process

The adaptive management decision process is designed to identify the specific corrective actions needed if threshold levels of change are reached. Generally speaking, the County will attempt to achieve restoration of functions and values first through education and voluntary means, and will take enforcement actions if these means are not effective. As appropriate, education will include the following topics: science and ecology, environmental benefits and costs of critical area functions and values, code content and requirements, and information about suitable BMPs. Incentives such as property tax incentives may also be discussed.

Particular attention will be paid to full and proper implementation of BMPs for minor development and agricultural activities. If net loss of functions and values is associated with these activities regulated by the County's regulations, adaptive management questions will include the following:

- Could a different set of BMPs be used to achieve better results?
- Can the existing BMPs be adjusted to improve their effectiveness?
- Do new BMPs need to be created to address the situation?
- Should the BMP implementation schedule be accelerated?

Site-specific or area-specific modifications of BMPs will be based on Best Available Science and, in the case of BMPs contained in the FOTG manual, developed in consultation with Conservation Districts, the NRCS, or a certified farm planner. The BMPs are adopted or revised by the County using the administrative rule making process outlined in County code.

In some cases, the County may determine that net loss of functions and values has occurred in spite of full compliance with County codes. In these cases, the County will assess the codes to determine whether revisions are appropriate. If code revisions are needed they will be processed as Type 3 legislative actions as required by County code. The County will also assess its critical area restoration efforts and increase or redirect these efforts if needed.

4.4 Adaptive Management Reporting

PDS will produce a biennial adaptive management report, based on the results of the monitoring report produced by SWM (see Section 3.8) with status updates annually. The report will contain the following information:

- Compliance assessments and source identification actions taken during the reporting period.
- Educational outreach actions as well as enforcement actions taken during the reporting period.
- Actions taken to modify BMPs on a site or area specific basis.

- Watershed monitoring priorities for the next reporting period.
- Recommendations for measures to address identified losses such as code revisions and/or increased funding for restoration efforts identified in the salmon recovery plans.

4.5 Timeline for Adaptive Management Responses

Recent decisions by State Growth Hearings Boards have stressed that monitoring and adaptive management programs need to identify and respond to problems quickly. The County anticipates that most problems related to noncompliance with codes will be identified quickly through code administration and complaint investigations. These problems will be addressed via code enforcement. In addition, the monitoring program will establish baselines for identified indicators in 2007 and 2008 and evaluate subsequent changes through annual monitoring thereafter. The adaptive management program is designed to take quick action based on monitoring results or information gained through code implementation and enforcement. Through time, actions for each year will be planned on the basis of previous year's reports.

APPENDICES

APPENDIX A Component 1: Land Cover Characterization Protocol

A.1 Protocol Overview

Remote Sensing is the science of acquiring, processing, and interpreting aerial or satellite images of the landscape. It is an efficient, cost effective tool to monitor changes in the landscape over time. Relative to surface sampling, remotely sensed satellite images have improved spatial coverage that can help study, map, and monitor the Earth's surface at local and/or regional scales. Advantages offered by remotely sensed image data compared to a ground sampling framework include:

- Synoptic/regional view,
- Cost effectiveness,
- High spatial resolution, and
- Relatively high temporal coverage on a long-term basis.

These reasons highlight the utility of remote sensing for CAR monitoring. The satellite will provide a snapshot of a broad geographic area at a specific time. It is anticipated that this approach will save money by targeting field surveys to specific objectives and reducing the amount of time spent in the field. In addition, data will be collected the same way biennially, making future acquisitions comparable and change analysis possible. The approach for classification is described below. It will be refined through further peer review by scientists from Battelle Pacific Northwest National Laboratory.

A.2 Data

High resolution Quickbird satellite imagery with visible and near infrared (IR) bands was selected to classify riparian conditions and wetlands for Snohomish County. Table A-1 summarizes characteristics of the Quickbird satellite. The two parameters that are most relevant to this project are the sensor's resolution and image bands. The resolution is 61 cm for the panchromatic band and 2.44 m for the multispectral bands. The multispectral imagery bands (blue, green, red & near IR) are critical for classifying vegetation and wetlands. The resolution and multispectral imagery bands provided by Quickbird are well suited for CAR monitoring.

Table A-1 QuickBird Satellite Characteristics

Launch Date	October 18, 2001
Launch Vehicle	Boeing Delta II
Launch Location	Vandenberg Air Force Base, California
Orbit Altitude	450 km
Orbit Inclination	97.2 degree, sun-synchronous
Speed	7.1 km/second
Equator Crossing Time	10:30 a.m.(descending node)
Orbit Time	93.5 minutes
Revisit Time	1-3.5 days depending on latitude (30^{o} off-nadir)
Swath Width	16.5 km at nadir
Metric Accuracy	23-meter horizontal (CE90%)
Digitization	11 bits
Resolution	Pan: 61 cm (nadir) to 72 cm (25^{o} off nadir) MS: 2.44 m (nadir) to 2.88 m (25^{o} off nadir)
Image Bands	Pan: 450-900 nm Blue 450-520 nm Green 520-600 nm Red: 630-690 nm Near IR: 760-900 nm

A rigorous classification is needed for the baseline dataset. Satellite imagery from two seasons, summer and (if conditions allow) winter/early spring, will be acquired and processed bi-annually beginning in 2007. The summer image will be obtained from July to September and will be used to classify land cover, including impervious surface, wetlands, and vegetative cover. The winter/early spring image, collected during deciduous leaf-off and obtained on cloud-free days between January 25th and April 1 of the following winter, will be used in conjunction with the summer image to refine the classification of impervious surfaces, wetlands and evergreen forest cover. Because of the prevailing weather patterns, the winter image will be more difficult to collect. If a winter image cannot be obtained, a classification methodology will be developed using the leaf-on image and ancillary data sources.

LIDAR (LIght Detection And Ranging) has been collected by various vendors over several years at varying levels of accuracies for the entire CAR Monitoring study area. While this piecewise approach is not ideal, the LIDAR data will be sufficient to assist with vegetation classification and stream and wetland location.

A.3 General Processing

A standard combination of remote sensing methods (unsupervised classification, principal component analysis, and normalized difference vegetation index (NDVI)) will be used to identify vegetation classes, impervious surface, and wetlands. This work will expand on previous and on-going methods developed for Snohomish County remote sensing projects, such as the classification and analysis of Snohomish County Landsat satellite imagery (Purser et al. 2003) and the SnoScape environmental mapping project (2006).The chosen methods have shown to have utility world-wide and are well documented in peer-reviewed journals (Gergel et al 2006, Morrissey 2006, Sobocinski et al 2006, etc).

A.4 Accuracy

The methods documented in the literature report varying results with respect to accuracy. This variation is primarily a result of regional landcover differences and seasonal effects. Other factors such as cloud cover and shadows may obscure the imagery, making land cover types problematic to classify. However, by obtaining multiple images in a given year, it is expected that the likelihood of cloud cover in the same location on both images will be small. Shadows from tall trees will always be a problem in satellite imagery from the Pacific Northwest, but indices such as NDVI should help minimize the effect of shadows.

The level of precision and accuracy possible in Snohomish County through imagery classification of impervious surface, forest, and wetlands is unknown at this time. Based on similar studies and Snohomish County's experience, it is expected that because impervious surfaces tend to be homogenous they will be the easiest to classify and have the highest level of accuracy. However, it should be expected that our methods will underestimate impervious surfaces because some areas will be partially obscured by tree canopy. The late winter/early spring image taken during leaf-off conditions should minimize canopy effects. A recent study (Gergel et al. 2006) reported accuracy rates of 85% for old-growth conifer stands and 75% for deciduous stands on Vancouver Island, British Columbia, respectively. Finally, wetlands are expected to have the lowest accuracy because they are heterogeneous. Few studies classifying wetlands in the Pacific Northwest have been reported in the literature, although several have been completed on the East Coast and in Florida (Morrissey 2006). These studies have all been able to identify more wetlands than are mapped in the National Wetland Inventory (NWI). This is true of previous wetland mapping efforts performed in Snohomish County, but the results vary by wetland type and size. Better results are expected with larger areas of impervious surface, wetland or riparian areas.

Theoretically, the smallest unit that can be identified would relate to the pixel resolution of the multispectral bands which is 2.5 m for the acquired imagery. However, given the amount of heterogeneity of the landscape and the goals of the project, the establishment of a larger minimum size unit is recommended to facilitate year to year comparison.

A.5 Total impervious surface

Total impervious surface area (TIA) is defined as the sum of all roads, parking lots, rooftops, sidewalks, and other surfaces within a given area that cannot effectively absorb or infiltrate rainfall or snow melt. Classification of total impervious area is necessary for the subsequent classification of wetlands, mature forest cover, small tree/shrub cover, and other cover classes. Studies using high resolution satellite imagery to classify impervious surface using typical image processing techniques are common in the literature (Abellera et al., Yuan et al 2006, Dougherty et al 2004).

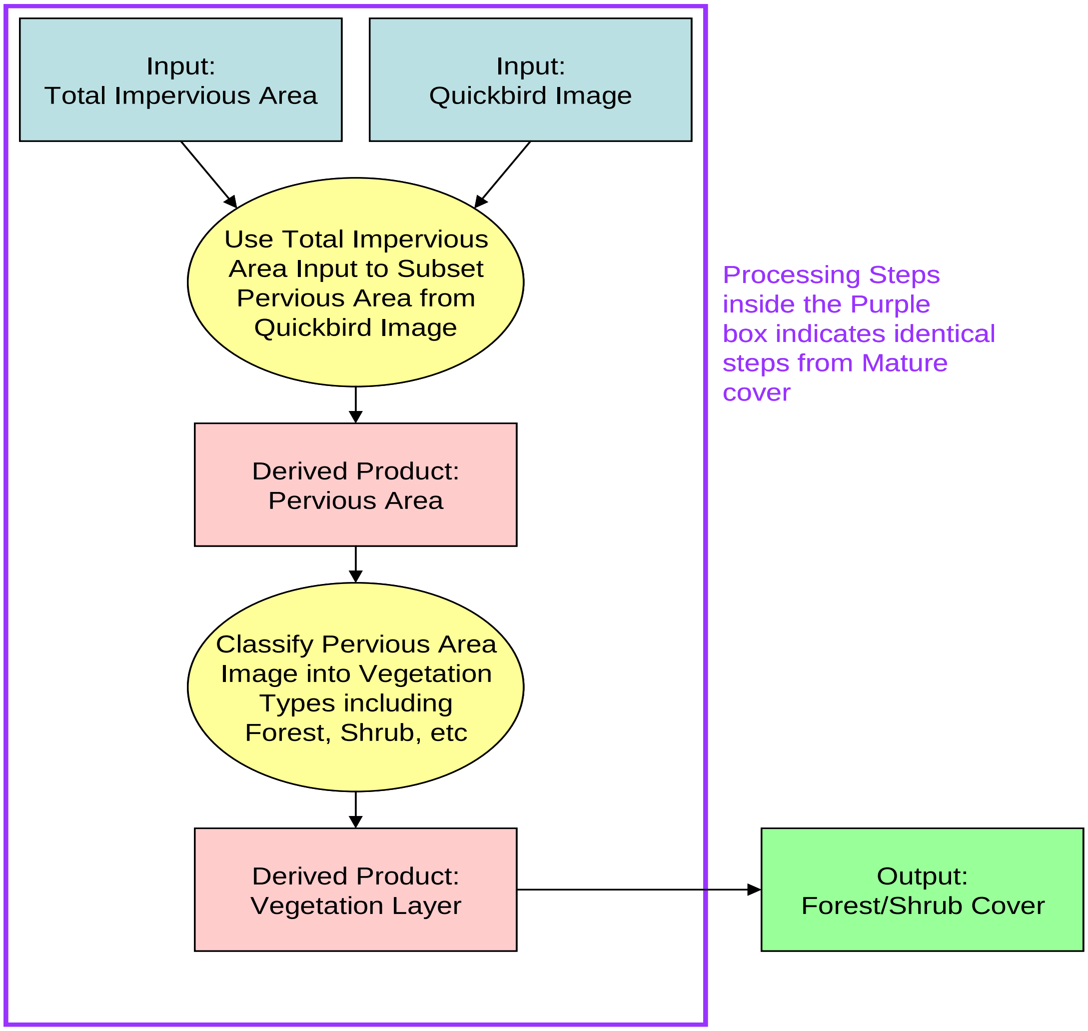
To classify total impervious surface area, an image from late winter/early spring during leaf off will be used. Ideally, this image will be cloud-free and have minimal shadows. The first step will be to minimize the effect of shadows using a Normalized Difference Vegetation Index (NDVI) model run with ERDAS Imagine. The model will use the red channel (band 3: 630-690 nm) and the near infrared channel (band 4: 760-900 nm) to create the QB NDVI dataset (Band 4 - Band3/ Band 4 + Band3).

Further processing of the NDVI output, such as principal component analysis (PCA), spectral unmixing, and supervised or unsupervised classifications, will allow the mapping of TIA. Since impervious area in commercial parcels is actively digitized by SWM staff as part of an ongoing project, the CAR total impervious area classification can be compared to arrive at an accuracy estimate for commercial parcels. Additional work may be needed to check the accuracy on residential parcels.

A.6 Forest cover

Mature forest cover includes mature evergreen forest, medium evergreen forest, and deciduous stands as defined by Purser et al. (2003). A height threshold for these classes will be set using field and remote sensing data. Using the TIA output, Quickbird imagery, LIDAR First Return Model, and LIDAR Bare Earth Model, forest cover will be classified as shown in Figure A-1. The TIA output will be used as a mask to subset only the pervious area for the Quickbird image (most likely the late summer image in which the deciduous trees have leaves).

Figure A-1 Method for Vegetation Classification



The pervious area component of the Quickbird image will then be classified into vegetation types. Elevation values of the LIDAR Bare Earth Model will be subtracted from the elevation values of the LIDAR First Return Model to give a LIDAR Difference Model that will show vegetation height. The Quickbird imagery classification and the LIDAR vegetation height data will be used to develop a vegetation class layer showing mature forest cover, young forest cover, small tree/shrub, and other vegetation types.

A.7 Wetlands

Wetlands will be classified and categorized into four different types: emergent, scrub/shrub, forested and open water. Using the vegetation layer described above, an object-based classification will be used to segment image objects. Unlike a pixel-based classification, an object-based classification will group like pixels with similar characteristics into polygon shapes. It is anticipated that these polygon shapes will better reflect the scale that CAR monitoring is targeting and also reduce the noise produced by pixel-based methods. After the image has been run through an object-based classification, the output image objects will be classified into wetland types. Additional resources available for wetland classification and mapping include LIDAR imagery, existing NWI and County wetland classification and mapping, recorded Critical Area Site Plans, recorded Wetland Mitigation Plans (including wetland banking locations), and other wetland delineation information. These data will be useful for field verification of satellite-derived wetland classification and mapping.

A.8 References

Abellera, L.V. and M.K. Stenstrom. Impervious Surface Detection from Satellite Imagery with Knowledge-based Systems and GIS. Los Angeles, UCLA.

Dougherty, M., R.L. Dymond, S.J. Goetz, C.A Jantz and N. Goulet. 2004. Evaluation of Impervious Surface Estimates in a Rapidly Urbanizing Watershed. Photogrammetic Engineering & Remote Sensing, Vol. 70, No. 11, November pp. 1275-1284.

Fen, Y and M.E. Baurer. 2006. Mapping Impervious Surface Area Using High Resolution Imagery: A Comparison of Object-based and Per Pixel Classification. ASPRS 2006 Annual Conference, Reno Nevada, May 1-5.

Gergel, S.E., Y. Stange, J.L. Morgan, N.C. Coops, C. Bater, K. Johansen, and K.R. Kirby. 2006. Prioritizing riparian conservation and restoration using high spatial resolution satellite imagery. Ecosystems.

Morrissey, L. and Rizzo, D. 2006. An Adaptive Management System using Hierarchical Artificial Neural Networks and Remote Sensing for Fluvial Hazard Mitigation, 2006VT26B, USGS.

Purser, M.D., R. Simmonds, D.D. Wilcox, and S. Brunzell. 2003. Classification and Analysis of August 2001 Land Cover: Snohomish County, WA.

Sobocinski K.L., AB Borde, L.M. Miller, R.M. Thom, and L. Tear. 2006. Columbia River Estuary Habitat Monitoring Pilot Field Study and Remote Sensing Analysis. PNWD-3475-C, Battelle-Pacific Northwest Division, Richland, WA.

APPENDIX B: Component 2: Shoreline Inventory Protocol

B.1 Shoreline Hardening and bank condition

Location and Frequency

Shorelines will be monitored around accessible lakes and along non-wadeable rivers in Snohomish County. Once the baseline dataset is established, surveys on lakes and rivers will take place every other year on alternating years during moderate to low flow conditions.

River shorelines will be surveyed continuously on the Skykomish, Snoqualmie, Snohomish, North Fork Stillaguamish, South Fork Stillaguamish, and Stillaguamish rivers throughout Snohomish County jurisdiction (non-state, non-federal, non-city and non-tribal land) where there is access and the survey can be conducted safely and efficiently from watercraft. Shoreline surveys will also be performed on lakes within Snohomish County jurisdiction with access for motorized watercraft. The 25 lakes with public access comprise the population.

Office Preparation

Field maps displaying hydrography (water courses, shorelines, or water boundary), reach breaks, river miles, boat put-in/take-out locations, and the 100-year floodplain over recent aerial imagery will be produced for each reach. These maps act as field guides and backups to GPS data collection. If previous survey points were recorded upstream or downstream of the area scheduled for survey, these data are also included on the field map to provide reference for start and/or end points and to facilitate seamless data collection.

Field Procedures

When river conditions are not suitable for motorized watercraft, surveys will be conducted from two inflatable craft, one along each bank. When use of motorized watercraft is possible, one craft will be used to survey both banks. If the channel is bifurcated, bank conditions will be assessed along the outer banks only. The exception to this is in distributary sloughs in Snohomish and Stillaguamish estuaries where all banks will be assessed. Each boat will contain two crew members, one piloting the craft and the other collecting data. Both crew members will observe banks from the boat and when necessary, as in the event of large dry bars, the data collector will go ashore and observe bank conditions on foot. Locations of change in bank condition will be recorded using Trimble GeoExplorer XH GPS data collectors.

To simplify data collection, changes in bank condition will be recorded as point features along a continuous bank line. At a change in any of the descriptive attribute fields contained in the data dictionary, a GPS location will be recorded as near the location of change as possible. The attributes given to a point characterize the bank between this point and the next downstream modification point on the same bank. On lakes, bank point attributes will describe the bank in a clockwise direction to the next point.

Banks with human-made alterations which function to limit channel and floodplain response to watershed processes will be classified as *modified*. Banks without alterations will be classified as *natural*. Modified banks will be further described by a modification type class. The classes are 1.) *revetment*, for armoring placed on a bank, 2.) *bulkhead*, including any constructed vertical wall along a bank, and 3.) *grade*, for instances when roads or railroads are immediately adjacent to the bank. Bank toe material will be categorized for each bank segment into one of 4 toe classes. Rock larger than 256 mm (10 in) placed as armor is considered *riprap*. Armor material less than 256 mm is considered *rubble* (Beamer & Henderson, 1998). Any constructed bank protection such as concrete, gabion, wood bulkheads and docks will be classed as *structural.* Earthen banks, or banks with naturally occurring (non-placed) material, such as cobbles, boulders or wood, will be classed as *earth/natural*.

Natural and modified banks will be described as *stable* or *unstable*. Banks will be deemed unstable if they show indications of breakdown, slumping, fracture or are steeper than 80^{o} from the horizontal and eroding at or above bankfull elevation (Bauer and Burton 1993). Otherwise, banks will be recorded as stable.

To assist with post processing of bank condition data, other attributes will be collected in the field. A *bank* attribute will be entered for each point. In rivers banks will be classed as *left* or *right* facing downstream. In lakes, the bank will always be classed as *left* because the survey will be performed in a clockwise direction. A confidence field will allow data collectors to rate the collected points as being *high*, *medium* or *low* quality based on their ability to occupy the exact location when recording the level of a change in bank condition. Comment fields and photographs can further communicate any necessary adjustments to the data manager.

<u>Data post processing</u>
The data manager will review field data and “snap” bank condition survey points to a digitized river and lake bank layer with ESRI® ArcGIS™. Using dynamic segmentation functions, the left and right riverbanks will be routed and assigned kilometer measure lengths. The County’s water body GIS coverage will be updated as needed. Surveyed bank condition points will be converted to linear GIS data and overlaid with reach lines in order to build a spatial relationship. This will make it possible to summarize bank condition data by river reach. Bank condition and reach segment data sets will be converted to ArcGIS® feature classes for data summarization and mapping. Data will be summarized as length of modified bank, unstable bank, and toe material by reach for rivers and for surveyed lakes.

B.2 References

Bauer, S.B. and T.A. Burton. 1993. Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management on Western Rangeland. Idaho Water Resources Research Institute, University of Idaho.

APPENDIX C: Component 3: Paired Catchment Study Protocol

C.1 Protocol Overview

The effectiveness of new land use regulations in protecting aquatic environments will be evaluated using a “treatment” and “control” study design. Paired 3rd and 4th order catchments with similar watershed characteristics were selected. “Treatment” reaches will be monitored for an ecological response from development actions. Monitoring of “control” reaches will provide for comparison and differentiation between ecological responses associated with land use actions and broader signals associated with climate patterns.

Criteria were established for site selection. We selected “treatment” catchments that have a high probability of substantial future development that will occur under the regulatory proscriptions of the new CAR. We selected “control” catchments corresponding to “treatment” catchments with modest or no anticipated development over the next 10 years. At the time of the initial site selection, permit applications under the new CAR were limited. Additional sites will be selected in 2009 using proposed permits as a guide.

Temperature, conductivity, B-IBI, width-depth ratio, and pool values will be measured in a reach at the downstream end of each catchment as ecological indicators of alterations to the stream environment resulting from changes in land use. The monitoring protocol is described below in detail. The methodology and selection of indicators will be refined through further peer review prior to the initiation of data collection.

C.2 Temperature, B-IBI, Width-Depth Ratio, and Pool Presence and Depth

<u>Location and Frequency</u>
The project team will establish a sample reach at the downstream end of each catchment. Temperature will be monitored continuously using data loggers. The use of continuously monitoring conductivity loggers will be evaluated at several sites. Benthic index of biotic integrity (B-IBI), width-depth ratio, and pool parameters will be measured once annually during August or September.

<u>Site Selection Process</u>
The catchment selection process was unbiased, but non-random. Catchments were selected based on their anticipated level of future development and other site characteristics. Third and forth order catchments were targeted because they

support perennial fish-bearing streams, yet are small enough to respond rapidly to land use changes within the riparian forest and contributing drainage area. In general, selected catchments were between 1 and 3 km^2 in size.

The “treatment” site selection process began with the review of development permits and proposals. At the time of site selection in 2008, new permit applications were limited, and thus we relied heavily on GIS analyses where urban growth boundaries, zoning, land use and property ownership where used to predict which areas will likely experience substantial development in the next 5 years. Next we selected “control” catchments with comparable drainage areas, mean elevation, landform, geology, stream characteristics and level of current development, but with minimal to no anticipated development over the next 10 years given current zoning or public ownership.

<u>Field Procedures</u>
Continuous temperature and conductivity measurements will be obtained using a Solinst Model 3001 Levelogger® probe or equivalent. It has temperature sensor accuracy of +/- 0.05^o C and conductivity sensor accuracy of +/- 0.1 mg/L. At locations where only temperature data are gathered, Optic StowAway® or HOBO® Water Temp Pro v2 temperature loggers with an accuracy of +/- 0.2 ^{o} C, will be used. Before placement in the field, the loggers will be calibrated in an ice bath and at ambient room temperature. Recorded temperatures are compared to an ASTM Certified Thermometer with +0.10C resolution. Loggers that do not meet the calibration temperatures within the specified accuracy will not be used in the field. The loggers will be programmed to record the stream temperature at two hour intervals.

Loggers will be placed in the stream in April or May and retrieved during the B-IBI survey from mid-August through September. Loggers will be positioned out of direct sun and out of view, and anchored to a stake or structure in the stream. A site photo, description, and GPS point will be collected to aid in logger retrieval. Field gear to aid in placement includes the following: Trimble GPS unit, camera, zip-ties and stakes.

B-IBI samples, width-depth ratio, and pool presence/depth will be collected between mid-August and the end of September during the low flow period. If there is a storm or other disturbance in the stream, crews will wait to sample at least three days after the disturbance. Invertebrate samples will be collected in riffles when possible and in glides when defined riffles are not available. The individual B-IBI samples will be sent to a laboratory for sorting and identification to species level.

At each site an initial channel bankfull width measurement will be made and a survey reach will be established of approximately 20 times the measured widths. Three sample locations, representative of depth, velocity and substrate within the reach, will be selected and marked as survey crews walk upstream. Surveyors will stay on the banks and disturb the stream as little as possible. If the reach is a long glide, crews will locate three representative turbulent, non-depositional locations within the glide.

B-IBI sampling will begin at the location that is farthest downstream. At each location, crews will collect one Surber® sample and combine samples from all three samples into one jar for analysis as a single sample. The net will be set firmly on the substrate so that it and the frame are sealed against the substrate. Using a small scrub brush, all large gravel and larger size particles will be thoroughly cleaned, while holding them inside the net. Cobbles will be placed outside the frame area after cleaning. Using a weed tool, crews will agitate the sediment within the frame to a depth of 10 cm for about 60 seconds, while continuing to hold the frame securely against the substrate and checking the inside perimeter of the frame for larger organisms that may not have been carried into the net. Next the net will be lifted and pulled upstream to rinse organisms into the bottom and wash fine sediment out. A spray bottle will be used to rinse any remaining organisms into the collector. Large rocks in the collector will be cleaned, inspected and removed. Any mussels, crayfish, or fish will be noted and returned to the stream.

The completed sample will be poured into a jar, using the spray bottle to gently concentrate the sample material. Samples will be preserved in 90% alcohol solution. A sampling label will be placed in the jar and a second label added on the outside of the jar upon returning to the office. The net will be rinsed thoroughly before beginning the next sample. Samples will be sent to a qualified and certified lab for processing.

Following B-IBI sampling at each representative location, crews will identify bankfull indicators (the top of deposited bedload, stain lines, the lower limit of perennial vegetation, moss or lichen, a change in slope or particle size on the stream bank, and undercut banks) and establish a cross-section at an appropriate location. Crews will extend and secure a measuring tape (in large channels) or a survey rod (in small channels) across the channel at the elevation of the bankfull indicator. Channel wetted and bankfull width and maximum wetted (water depth at thalweg) and bankfull depth (thalweg to bankfull elevation) are measured and recorded to the nearest 0.01 meter. The crew will then walk back downstream through the entire reach to identify pools and record maximum and tailout depth of each to the nearest 0.01 meter. All measurements will be entered into a data dictionary contained on a Trimble GeoXH GPS unit. At the completion of the survey, the crew will review data files for accuracy and completeness.

Data Management Procedures

Data packages from a completed set of samples will be sent to SWM by the laboratory within 30 days of the sampling date. Data reports from the analytical laboratory will be reviewed for completeness by the project manager. Potential errors and omissions will be reported to the responsible laboratory personnel.

Acceptable laboratory reports will be stored in project notebooks. Laboratory results will be entered into a database and verified. Based on the distributions and statistical characteristics of the data, various statistical and probabilistic methods may be used to compare and analyze the data.

The field data sheets will be reviewed for completeness by the field personnel before leaving a sample location. Any missing data will be added to the sampling sheet prior to leaving the sample site. The field data sampling sheets will be reviewed for completeness again by the project manager in the office.

The field sampling data will be entered into the Snohomish County database at the end of each sampling round. Project personnel will review all incoming analytical laboratory reports as they are received. The analytical reports will be reviewed for completeness by comparing the results with the analytical request submitted with the samples. The analytical laboratory reports will receive an initial scan to detect results inconsistent with ranges of past results, contaminated blanks, or other potential problems. The project manager will report any missing data, inconsistent results, or potentially contaminated samples to the analytical laboratory immediately. Missing data, anomalous results, or potentially contaminated samples will be noted on the laboratory reports for later entry into the database.

REFERENCES

Alberti, M., D. B. Booth, K. Z. Hill, R. Coburn, C. Avolio, S. Coe, and D. Spirandelli. In press. The Impact of Urban Patterns on Aquatic Ecosystems—An Empirical Analysis in Puget Lowland Sub-Basins. Landscape Ecology.

Beamer, E.M. and R.A. Henderson 1998. Juvenile Salmonid Use of Natural and Hydromodified Stream Bank Habitat in the Mainstem Skagit River, Northwest Washington. Skagit System Cooperative, La Conner, WA. 51 pp.

Beyerlein, D. 1996. Effective impervious area: the real enemy. Proceeding of the Impervious Surface Reduction Conference, City of Olympia, WA.

Best Available Science (BAS) (WAC 365-195-905). (Revised Draft Summary of Best Available Science for Critical Areas, March 2006).

Booth, D.B., Hartley, D., and Jackson, C.R. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater impacts. Journal of the American Water Resources Association 38: 835-845.

Booth, D.B. 2000. Forest Cover, Impervious Surface Area, and the Mitigation of Urbanization Impacts in King County, Washington. Prepared for King County Water and Land Resources Division.

Booth, D.B. and C.R. Jackson. June 1994. Urbanization of Aquatic Systems—Degradation Thresholds and the Limits of Mitigation. Effects of Human-Induced Changes on Hydrologic Systems. American Water Resources Association.

Brown, R.G. 1988. Effects of Urban Stormwater Runoff and Urbanization on Palustrine Wetland Vegetation. U.S. Fish and Wildlife Service. Washington D.C.

Cowardin, L.M., V. Carter, F.C. Golet, E.T. LaRoe. 1979, Classification of Wetlands and Deepwater Habitats of the United States, USFW Rep. No. FWS/OBS-79/31.

Cusimano, R., R. Plotnikoff, G. Merritt, C. Wiseman, C. Smith, and K. Krueger. July 2006 Draft. Status and Trends Monitoring for Watershed and Health and Salmon recovery Quality Assurance Monitoring Plan. Washington Department of Ecology, Olympia, WA. 93 pp.

Dinacola, R.S. 1989. Characterization and Simulation of Rainfall-Runoff Relationships for Headwater Basins in Western King and Snohomish Counties, Washington State. U.S. Geological Survey Water Resources Investigation Report 89-4052, 52pp.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York. 818 pp.

Embrey, S.S., and E.L. Inkpen. 1998. Water-Quality Assessment of the Puget Sound Basin, Washington, Nutrient Transport in Rivers, 1980-93. U.S. Geological Survey, Water-Resources Investigations Report 97-4270. Tacoma, WA. 30pp.

EPA. 1986. Quality Criteria for Water: 1986. U.S. Environmental Protection Agency, Off. Water Regulations and Standards. Washington, D.C.

EPA. 2002. Draft EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards, 2nd Public Review Draft. October 10, 2002.

EPA. 2003. Strategy for Water Quality Standards and Criteria: Setting Priorities to Strengthen the Foundation for Protecting and Restoring the Nation's Waters. US Environmental Protection Agency, Washington, D.C. September.

Fore, L. S. and C. Grafe. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). Freshwater Biology 47:10 2015.

Fore, L.S., K. Paulsen, K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams Freshwater Biology 46 (1), 109–123.

Gergel, S.E., Y. Stange, J.L. Morgan, N.C. Coops, C. Bater, K. Johansen, and K.R. Kirby. 2006. Prioritizing riparian conservation and restoration using high spatial resolution satellite imagery. Ecosystems.

Growth Management Hearings Board, WWGMHB Case No. 06-2-0012c September 14, 2006 905 24th Way SW, Suite B-2, Page 1 of 19 Olympia, WA 98502.

Haas, A.D., F.E. Leonetti, L.T. Parker, M.D. Purser, and M.D. Rustay. 2003. Stillaguamish River Bank and Physical Habitat Conditions Survey 2002 Summary Report. Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA.

Hamilton, K., and E. P. Bergersen. 1984. Methods to Estimate Aquatic Habitat Variables. Colorado Cooperative Fishery Research Unit, Colorado State University, Fort Collins, CO.

Hayman, R.A., E. Beamer, and R.E. McClure. 1996. FY 1995 Skagit River Chinook Restoration Research. Progress Report No. 1. Skagit System Cooperative, LaConner, WA.

Karr, J.R. 1998. Rivers as sentinels: Using the biology of rivers to guide landscape management. River Ecology and Management: Lessons from the Pacific Coastal Ecosystem (eds. R.J. Naiman and R.E. Bilby), pp. 502-528. Springer, NY.

Kauffman, P.R., P. Levine, E.G. Robinson, C. Seeliger, and D.V. Peck. 1999. Quantifying Physical Habitat in Wadeable Streams. EPA 620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Klein, R.D. 1979. Urbanization and Stream Quality Impairment. Water Resources Bulletin 15: 948-963.

Kleindl, W. J. 1995. A benthic index of biotic integrity for Puget Sound lowland streams, Washington, USA. Unpublished Masters Thesis, University of Washington, Seattle, Washington, USA.

LaMotte Company. 1992. The Monitor's Handbook. Chestertown, MD.

Larsen, D.P., P.R. Kaufmann, T.M. Kincaid, and N.S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences. 61.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. U.S.E.P.A. Region 10, Seattle, WA. EPA 901/9-91-001. 166 pp.

May, C.W. 1996. Assessment of Cumulative Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion: Implications for Salmonid Resource Management. Ph.D. dissertation, University of Washington, Seattle, WA, U.S.A.

May, C.W. E.B. Welch, R.R. Horner, J.R. Karr and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Water Resources Series Technical Report No. 154, University of Washington, Seattle, WA.

Montgomery, D.R., J.M. Buffington, R.D. Smith, KM Schmidt, G. Pess. 1995. Pool Spacing in Forested Channels. Water Resources Research 31, no. 4, pp. 1097-1105. 1995.

Morley, S. A. 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: restoration with a biological focus. Seattle, University of Washington, M.S. Thesis.

Morrissey, L. and D. Rizzo. 2006. An Adaptive Management System using Hierarchical Artificial Neural Networks and Remote Sensing for Fluvial Hazard Mitigation, 2006VT26B, USGS.

National Oceanic and Atmospheric Administration (NOAA). 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast.

Paulsen, S. 1997. Environmental Monitoring and Assessment Program: Integrated Quality Assurance Project Plan for Surface Waters Research

Activities. United States Environmental Protection Agency, Office of Research and Development. Corvallis, Oregon. 129 p.

Purser, M.D., R. Simmonds, D.D. Wilcox, and S. Brunzell. 2003. Classification and Analysis of August 2001 Land Cover: Snohomish County, WA. Unpublished report of Snohomish County Department of Public Works Surface Water Management Division and Department of Information.

Puget Sound Salmon Recovery Plan, 2005 Submitted by the Shared Strategy Development Committee, Shared Strategy for Puget Sound 1411 4th Avenue, Suite 1015, Seattle, WA 98101.

Puget Sound Technical Recovery Team and Shared Strategy Staff Group. 2003. Integrated Recovery planning for Listed Salmon: Technical Guidance for Watershed Groups in Puget Sound.

Reid, L., and M. Furniss. 1998. On the use of regional channel-based indicators for monitoring. USFS Technical Report. USDA Forest Service, Arcata, California.

Rosgen, D. L. 1996. Applied River Morphology. Pagosa Springs, CO.

Schueler. T. and J. Galli. 1992. Environmental Impacts of Stormwater Ponds. *In* Watershed Restoration Sources Book. Anacostia Restoration Team, Metropolitan Council of Governments. Washington D.C.

Shaver, E., J. Maxted, G. Curtis, and D. Carter. 1995. Watershed Protection Using an Integrated Approach, Stormwater NPDES Related Monitoring Needs.

Snohomish County Public Works, Surface Water Management. 2000. The State of the Waters: Water Quality in Snohomish County's Rivers, Streams and Lakes. 2000 Assessment. Everett, WA. 144 pp.

Snohomish County, Surface Water Management Division. 2002. Precision and Repeatability of Wadable Stream Habitat Survey Methods, Snohomish County Public Works Department.

Snohomish County Public Works, Surface Water Management. 2003. The State of the Lakes. Everett, WA. 65pp.

Sobocinski K.L., A.B. Borde, L.M. Miller, R.M. Thom, and L. Tear. 2006. Columbia River Estuary Habitat monitoring Pilot Field Study and Remote Sensing Analysis. PNWD-3475-C, Battelle-Pacific Northwest Division, Richland, WA.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R. P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corporation, Corvallis, OR.

Steedman, R. J. 1988. Modification and Assessment of an Index of Biotic Integrity to Quantify Stream Quality in Southern Ontario. Canadian Journal of Fisheries and Aquatic Sciences 45: 492-501.

United States Department of Agriculture. 1989. Water Quality Indicators Guide: Surface Waters. Soil Conservation Service Publication SCS-TP-161.

U. S. Geological Survey (U.S.G.S.). 1995. Nutrients in Ground Water and Surface Water of the United States - An Analysis of Data Through 1992. National Water Quality Assessment Program. Water-Resources Investigations Report 95-4031. Denver CO. 74 pp.

Ward, J.V., K. Tockner, and F.Schiemer. 1999. Biodiversity of Floodplain River Ecosystems: Ecotones and Connectivity. Regulated Rivers: Research and Management 15:125-139.

Ward, J.V. and J.A. Wiens. 2001. Ecotones of Riverine Ecosystems: Role and Typology, Spatio-Temporal Dynamics, and River Regulation. Ecohydrology & Hydrobiology 1(1-2):25-36.