Appendix A

Methodology to a Watershed Based Approach to Federal and State Clean Water Act Regulations

Methods developed by Gersib et al., 2004 and modified by:

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Water and Waste Management

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List of Acronyms and Abbreviations

303(d)	List of impaired water bodies specified in the Clean Water Act, Section 303(d)
ADT	Average daily traffic
Basin	1000 to 10000 acres
B-IBI	Benthic – Index of Biological Integrity
Catchment	32 to 320 acres
DAU	Drainage Analysis Unit
DBH	Diameter breast height
DEM	Digital Elevation Model
Ecology	Washington State Department of Ecology
EDT	Ecosystem Diagnosis and Treatment
EIA	Effective Impervious Area
EMC	Event mean concentration
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESB	Engrossed Senate Bill
FEMA	Federal Emergency Management Agency
FRAGSTATS	FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics
GeoData	Thurston County's GeoData Center
GIS	Geographical Information System
GLO	General Land Office
HSPF	Hydrological Simulation Program—Fortran
LID	Low Impact Development

LiDAR	Light Detecting and Ranging
LWD	Large Woody Debris
NEPA	National Environmental Policy Act
PAH	Polynuclear aromatic hydrocarbons
PHS	Priority Habitats and Species
SEPA	State Environmental Policy Act
SSHIAP	Salmon and Steelhead Habitat Inventory and Assessment Program
Sub-basin	100 to 1000 acres
Sub-watershed	320 to 19200 acres
TIA	Total Impervious Area
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TRPC	Thurston County Regional Planning
USDA	US Department of Agriculture
USGS	US Geological Survey
WAC	Washington Administrative Code
WADNR	Washington Department of Natural Resources
Watershed	19,200 to 320,000 acres
WDFW	Washington State Department of Fish and Wildlife
WRIA	Water Resource Inventory Area as defined in Chapter 173-500 WAC
WWHM	Western Washington Hydrologic Model
WWSMM	Western Washington Stormwater Management Manual

INTRODUCTION

This document was developed by Gersib et al. (2004), currently with the Washington State Department of Transportation. Thurston County staffs have modified the methods to better reflect the needs of local government. This report summarizes a scientific framework for watershed characterization and describes a set of methods developed at the watershed scale to assist in better land use decisions. As a conceptual framework, this document serves as the key deliverable to Puget Sound Partnership (formally Puget Sound Action Team) and Thurston County summarizing watershed characterization methods and developing key recommendations that other County departments, local jurisdictions, and other entities may use to help meet current and future environmental assessment and planning needs.

Watershed based methods will be most effective when the approach is driven by landscape need and condition rather than an individual site needs. These methods will help to refine and provide new data to meet the needs of the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Endangered Species Act (ESA), Shoreline Management Act (SMA), and Critical Area Ordinance updates. It represents a transition from a site-driven to landscape-driven approach to assessing current ecological processes of the watershed.

Despite dramatic increases in effort, legal mandates, and expenditures for environmental protection and restoration over the past 20 years, the overall condition of natural ecosystems continues to decline (Karr 1995, Montgomery et al. 1995). A growing body of work indicates that declines in ecosystem integrity are perpetuated by existing policies and traditional techniques that tend to treat local symptoms of resource degradation and fail to address the root biological and physical causes of ecosystem degradation and population decline. These policy and traditional techniques perpetuate a narrow "site" review and analysis that often results in restoration that treat symptoms of localized habitat/resource degradation rather than addressing the systemic causes of ecosystem degradation (Frissell 1996, Angermeier and Schlosser 1995, Montgomery et al. 1995, Reeves et al. 1995, Ebersole et al. 1997).

Thurston County was designated a National Pollutant Discharge Elimination (NPDES) Phase II jurisdiction in 2000 census. Thurston County submitted a NPDES Phase II permit to Ecology in March 2003. With the issuance of the NPDES Permit for Phase II communities in February 2007, Thurston County determined that a more holistic approach was needed to incorporate all the required regulations at the watershed level to promote efficiency in monitoring, analyzing, and reporting on the health of our water bodies. Current government efforts are segmented and have not proven to provide protection to Thurston County's streams and the Puget Sound.

This study process provides substantial opportunity to blend developing watershed approaches with new modeling and assessment tools to develop outcome-based approaches that Thurston County Water and Waste Management, Long Range Planning, Roads and Transportation Services, to make better land use decisions and management.

The Need for a Watershed Approach

A conventional site-specific approach to environmental protection and recovery has failed to stem the decline in water quality, base flow, fish and wildlife habitat at landscape scales. Despite the expenditure of hundreds of millions of dollars on required mitigation and voluntary recovery efforts, Puget Sound continues to decline in health.

Clearly, the scale of assessment is not the only factor in this decline, but it appears to be a key one. There is a growing awareness that the scale of assessment needs to, at least initially, match the scale of the problem (Naiman et al. 1992, Doppelt et al. 1993, Montgomery 1995, Frissell and Doppelt 1996). If water quality problems are associated with one identifiable point-source, then a site-specific scale of assessment is appropriate. However, if water quality problems are associated with many non-point sources of pollutants distributed throughout a watershed, then a watershed-scale assessment is needed to identify, understand, and prioritize management options.

Natural systems are complex. Understanding cause and effect relationships within a very complex natural system will be key to realizing measurable success in creating natural resource management plans that protect the natural resources and lend to the identification of potential environmental recovery sites. Discerning how present, past, and future land use affects physical elements of landscape pattern formation and maintenance will be an essential part of understanding cause and effect relationships and identifying core environmental problems, as well as opportunities. Navigating through this complex web of human land use impacts and associated symptoms of environmental degradation will require watershed tools that help us understand the interrelated nature of natural systems (Gersib et al 2004).

Guiding Principles

The following guiding principles serve as the fundamental building blocks on which landscape-scale assessment methods are developed. All of the guiding principles listed below have an established policy and/or technical rationale. However, it should be noted that the assessment methods were developed for the Henderson Watershed. As other watersheds within Thurston County are characterized, many of the rules and assumptions could be changed to better reflect the watershed being studied.

Major initiatives intended to aid in the recovery of salmon stocks listed as “threatened” or “endangered” under the ESA and to restore polluted water bodies in the Pacific Northwest have embraced watershed-scale planning and implementation. Further, stormwater management efforts are now beginning to explore the applicability of watershed assessment tools.

Indian Tribes of the State of Washington are guaranteed the right to protection of the fish habitat within their Usual and Accustomed Areas (Orrick Decision). Development impacts to fish habitat and all associated management plans will result in consultation with the appropriate Tribe or Tribes to ensure that no net loss of the Tribal Usual and Accustomed Area will occur.

Watershed characterization efforts seek to use landscape-scale planning and analysis to maximize environmental, social, and economic benefits of natural resource and environmentally sensitive area management plans.

Watershed characterization will help ensure that Tribal concerns regarding fish habitats are identified. Watershed characterization seeks to understand human effects on ecological processes that create and maintain the unique structure elements (habitat) that support all aquatic and terrestrial wildlife species.

Any analyses of watershed conditions need to assess the variability of watershed functions and characteristics over time and space (Euphrat and Warkentin 1994). Communities and landscapes form the ecological and evolutionary context for populations and species; preserving integrity at a landscape-scale is critical to species persistence (Angermeier and Schlosser 1995). Watershed characterization seeks to better understand the effect of human land use on ecological processes at different spatial and temporal scales.

Establishment of Technical Team

Understanding the cumulative effects of land use impacts on ecological processes at landscape scales requires expertise in hydrology, hydrogeology, ecology, biology, and many other scientific disciplines (Reid 1993). This dictates the formation of a technical team that works together to develop an interdisciplinary understanding of watershed processes. To meet this need, an interdisciplinary technical team should be formed consisting of a hydrologist, hydrogeologist, ecologist, biologist, and water quality specialist. Essential technical support from a GIS analyst and GIS technician is also required. The technical team will be responsible for conducting the watershed characterization, with regular input from all stakeholders during the process. It is Thurston County's goal to work jointly with all regulatory agencies to ensure a successful application of a watershed based approach to clean water efforts.

Local Watershed Coordination between Government Agencies

The Cities of Olympia, Lacey, and Tumwater, as well as the Squaxin, Nisqually, and Chehalis tribes, share natural resource management responsibilities within Thurston County. Successful management at the landscape scale will require the coordination of responsible local and tribal governments. While the methods described are to be developed for Thurston County, our goal is to provide the data to all stakeholders to be considered in their management decisions, where appropriate.

Local watershed planning efforts are considered to be a fundamental mechanism for natural resource and environmentally sensitive area management. Watershed councils and planning groups bring stakeholders together to develop plans that consider all local interests and concerns. For this reason, local planning initiatives are assumed to be most effective at understanding and addressing the needs and priorities of local residents and the natural resources on which they depend. Local watershed planning groups often acquire and compile local or regional data sets that can be of substantial value to watershed characterization efforts.

Thurston County was an active participant in Watershed Resource Inventory Areas (WRIA) planning efforts under Engrossed Substitute House Bill (ESHB) 2515, as well as ongoing Salmon Recovery Efforts under ESHB 2496. Incorporating the results of local watershed planning efforts at the earliest stages of environmental planning creates additional opportunities for the collection of locally developed data that are needed for watershed characterization. Watershed characterization assists local governments in achieving watershed management goals and objectives.

General Framework for Watershed Characterization

1. Define appropriate spatial scales to be used in watershed characterization;
2. Compile land use/land cover information for pre-development and current conditions and estimate the type and extent of future growth/development;
3. Develop an understanding of the ecological processes within drainages occurring in the area, identify key drivers for those processes, and begin to understand how past and present land use has altered processes and disturbance regimes;
4. Assess landscape sensitivity to process alteration and identify areas most sensitive and most resistant to development;
5. Characterize the general condition of ecological processes within the largest acceptable landscape scale;
6. Identify landscape areas having specific levels of degradation to targeted ecological processes under current conditions;
7. Assess the probability that processes within target landscape areas will be maintained over the long-term using the future build-out scenario; and
8. This framework employs and adapts the five-step strategy outlined by Beechie and Bolton (1999). A complete, detailed scientific framework for watershed characterization is presented in this document.

See Figure 1 which outlines the process of conducting a watershed characterization.

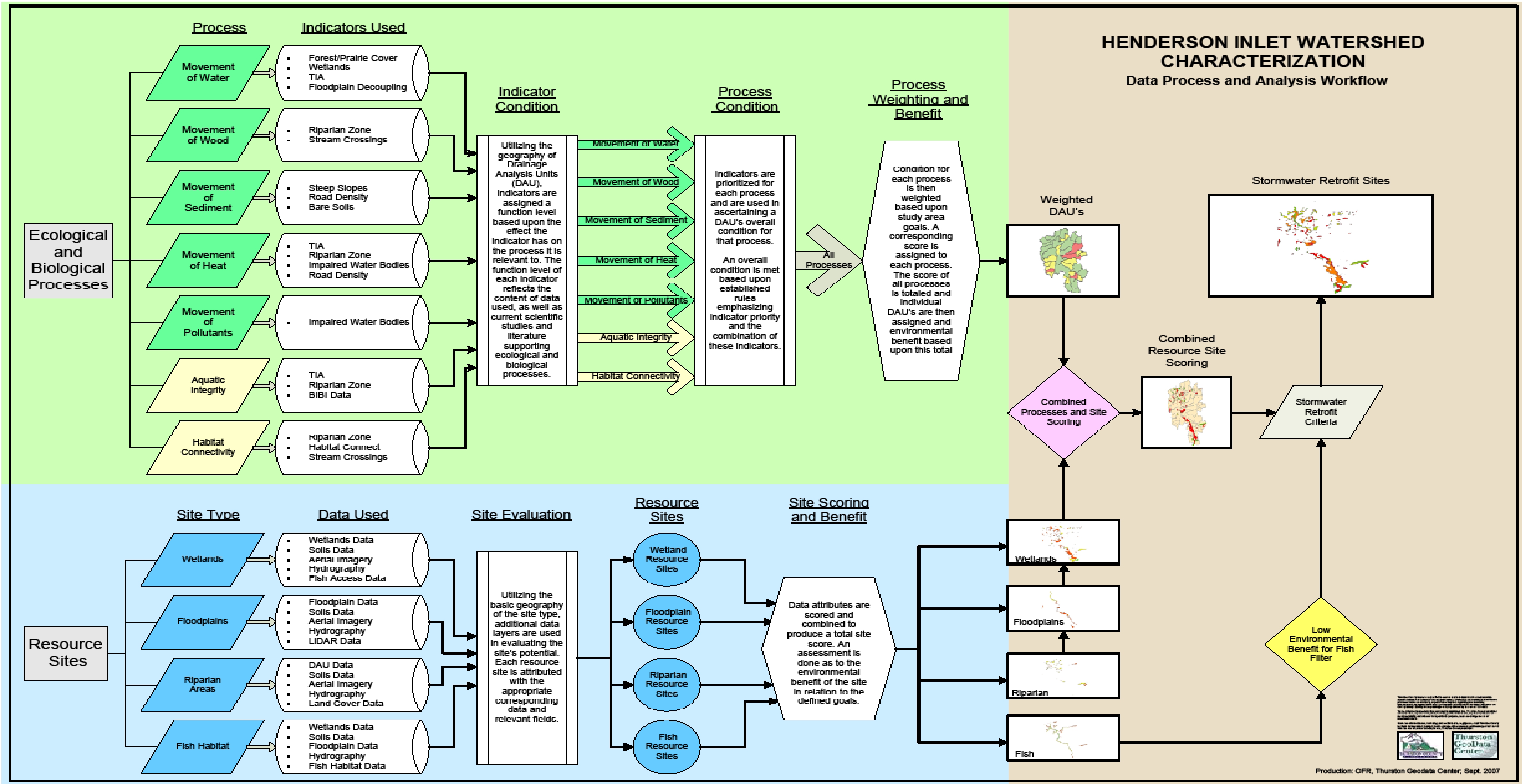


Figure 1. Data Process and Analysis Workflow

PART I. LANDSCAPE CHARACTERIZATION

The Approach

This first step seeks to characterize the effects of human land use on ecological and biological processes within the basin area. The ecological and biological processes focused on in this work include:

Physical processes:

- Delivery and routing of water
- Delivery and routing of sediment
- Delivery and routing of nutrients/toxicants/bacteria
- Delivery and routing of large wood
- Delivery and routing of heat

Biological processes:

- Aquatic integrity
- Upland habitat connectivity

The alteration of these core ecological processes (or pathways) by human land uses result in a change in physical structure or biological elements that will, in turn, result in a change in how a site functions. Many ecological processes operate over large spatial and temporal scales. To address core problems that often exist miles from the site where functions are degraded, it is imperative that protection efforts focus on reversing the effects of human land use on ecological processes.

The watershed characterization approach seeks to better understand the relationship between land use change and the resulting change in ecological processes. This approach also seeks to understand the relationship between a change in ecological processes and the resulting change in site functions.

Step 1. Establish Spatial Scales of Analysis

Purpose

Omernik (1995) has developed a hierarchically based tool to stratify the landscape into more homogeneous units. Ecology (R. Gersib, personal communication, as cited in Gersib et al., 2004) has used the fourth level eco-regions developed by Omernik to assist in characterizing wetland resources in the Nooksack River Basin in northwestern Washington State. These tools are used in creation of some spatial layers. Step 1 primarily establishes the necessary spatial data layers for watershed characterization: assessment and analysis. It also establishes the necessary spatial data layers for the assessment and analysis of shoreline regions within the characterized watershed.

Step 1A.   Establish Study Area

Definition

The study area is the sum of all the sub-watersheds that fall within the watershed to be characterized.

Purpose

To create a spatial layer that will represent the boundaries of the study area.

Methods

1. The study area is established through a GIS process of displaying the drainage areas data layer and dissolving all interior polygons.

Data Needs

Sub-watersheds data layer.

Product

A GIS data layer of the study area.

Step 1B. Establish Drainage Analysis Units Areas

Definition

The study area is divided into manageable units for characterization. Drainage analysis units (DAU)s are developed based on the needs of the study. Table 1 provides guidance on the minimize size of the DAU. Locally developed boundaries for drainage areas/basins should be used when available. For this study, we utilized two DAU scales; 0.1 square mile and 0.25 square mile. These scales were used because the focus of this study was stormwater retrofits using natural resource sites (wetlands, riparian, and floodplain restoration).

Purpose

The DAU scale has potential for assessing direct impacts and cumulative impacts of existing and future land uses. This scale was established using the Center for Watershed Protection guidance, and the need to assess and address storm water impacts on an individual stream basis. Second, the DAU scale is the fundamental spatial scale for characterizing the condition of larger spatial scales.

Methods

1. Acquire Digital Elevation Model (DEM) data of the study area.
2. Establish scale for assessment and planning needs. Use Table 1 as guidance.
3. Use the automated DEM analysis to develop drainage boundaries.

Table 1: Description of the Various Watershed Management Units

Watershed Management Unit	Typical Area (square miles)	Influence of Impervious Cover	Sample Management Measures
Catchment (Drainage Analysis Unit (DAU))	0.05 to 0.5 32 to 320 acres	very strong	stormwater management and site design
Sub-watershed	0.5 to 30 320 to 19200 acres	strong	stream classification and management
Watershed	30 to 100 19200 to 320000	moderate	watershed-based zoning
Sub-basin	100 to 1,000	weak	basin planning
Basin	1,000 to 10,000	very weak	basin planning

Zielinski, Center for Watershed Protection, 2002

Data Needs

1. DEM data
2. Topographic data

Product

1. A GIS data layer of DAUs within the study area.

Step 1C. Establish Watershed Areas.

Definition

Watershed is the catchment area of a stream or streams comprising 20 to 50 square miles and equivalent to a Washington Department of Natural Resources (WADNR) Watershed Administrative Unit ("WAU") or US Geological Survey 5th field Hydrologic Unit Code ("HUC"). The Center for Watershed Protection Institute (Zielinski 2002 has defined a watershed to be 30 to 100 square miles (see Table 1). This methods document utilizes the definitions in Table 1.

Purpose

Establish a spatial scale for analysis of potential restoration and preservation sites. The goal is to analyze the appropriate scale to address the needs of the watershed characterization.

Methods

1. Identify and acquire available spatial data from local, state, tribal, and federal sources.

   Use Table 1 as a guideline to the scale(s) to be analyzed.

Data Needs

1. Available local, state, tribal, and federal spatial data.

Product

2. The GIS data layer of the spatial scales to be analyzed.

Step 1D. Establish Lithotopo Units

Definition

Lithotopo Unit is that part of the study area having a common 4^{th} level eco-region and surficial geology as the project area. Lithotopo units were not used in this study.

Purpose

Compared to surface water catchment based spatial scales, lithotopo units are geology/ topography based means of stratifying the landscape. Because of this difference, it is assumed that lithotopo units have potential to increase success in the in-kind replacement of functions needed to compensate for past development of the landscape.

The Environmental Protection Agency (EPA) has completed a 4th level eco-region data layer for much of the United States. Montgomery (1999) uses the term lithotopo units to define finer-scale areas with similar topography and geology, within which similar suites of geomorphic processes influence gross habitat characteristics and dynamics. Further, unpublished data on watershed-scale wetland restoration assessment and planning in the Nooksack Basin, Washington (R. Gersib personal communication, as cited in Gersib et al., 2004) indicate that the stratification of 4th level eco-regions by surficial geology appears to substantially reduce variability in wetland size, hydrogeomorphic class, and functions provided. Lithotopo unit area was chosen as an experimental spatial scale that will be evaluated throughout watershed characterization methods development.

Methods

1. Acquire Levels III and IV eco-regions data layer from the EPA Spatial Data Library System.
2. Clip ecoregions data layer to the boundary of the study area.
3. Subdivide the study area level IV eco-regions.
4. Overlay the Level IV ecoregions and geology onto the project sub-watershed.
5. Refine the 1:250,000 Level IV eco-region boundaries based on 1:100,000 geology units.
6. Use surficial geology units to further subdivide Level IV ecoregions.
7. Each polygon represents a lithotopo unit. Name each mapping unit and create that lithotopo data layer.

Data Needs

1. EPA 4th level ecoregion GIS data layer
2. Surficial geology

Product

3. A GIS data layer of the lithotopo units within the study area.

Step 2. Establish Temporal Scales of Analysis

Cumulative impact assessment and an assessment of water quality loading rates under a build-out scenario require multiple temporal scales. Pre-development and current land use conditions are needed to assess cumulative impacts. Current and future build-out conditions are needed to understand potential future cumulative impacts in a build-out scenario and assess the potential for the watershed to maintain its essential ecosystem processes and functions over time, including those unique to the shoreline regions of the watershed.

Step 2A. Create a Pre-Development Data Layer

Purpose

A pre-development land use data layer is the reference point for assessing the current and future state of natural resources. In turn, an assessment of landscape condition requires an understanding of the extent of change in ecological processes from a pre-development to present and future land use conditions.

Methods

1. Acquire available data on the pre-development land cover condition of the study area.
2. Access General Land Office (GLO) data from the Washington State Department of Natural Resources website and compile land cover vegetation information GLO vegetation data include tree/shrub species and tree/shrub diameter breast height (DBH) for each section corner, and each half- and quarter-mile section line. For small areas, all vegetation data should be compiled and entered in a spreadsheet. For larger areas, a sample of vegetation data by geologic unit can be compiled.
3. Develop a database that groups diameter at breast height (DBH) size into 1-12 inch, 13-24 inch, 24-36 inch, and greater than 36 inch.
4. Compile available historic maps of stream systems and when available add to the pre-development land cover data layer.
5. For predevelopment grassland areas, follow the same process using grassland communities.

Data Needs

Available pre-development land cover data for the watershed.

Product

A narrative characterization or GIS data layer of pre-development land cover.

Step 2B. Select a Current Land Use/Land Cover Data layer

Purpose

Current land use/land cover data are used in three ways. First, this data set is used with the pre-development data layer to gain perspective on the extent of change in land cover. Second, this data layer is used to calculate key landscape attributes used to characterize the extent of alteration in the five ecological processes.

Methods

1. Contact local, state, federal, and tribal sources of land use/land cover data to determine available data options for the study area.
2. Select the most current land use/land cover data set. Thurston County used 2005 SPOT imagery.

Data Needs

1. Current land use/land cover data.

Product

1. A GIS data layer of current land use/land cover.

Step 2C. Create a Future Build-Out Land Use Data layer

Purpose

Future build-out data will be used to assess the natural resource sites ability to maintain long-term success if restored. We did not evaluate the sites under future land-use at this time because Thurston County is currently updating their zoning.

Methods

1. Compile comprehensive plans from local jurisdictions in the study area. Use plans developed under the Growth Management Act to determine future land-use.

Data Needs

1. Current land cover.
2. GIS data layers for all local comprehensive plans.

Product

1. A GIS data layer of future build-out land use.

Step 2D. Estimate Total Impervious Area for Existing and Future Build-Out Conditions

Purpose

Total Impervious Area (TIA) is used in watershed characterization to describe the degree of hydrologic alteration within drainage basins. It is defined as the percentage of land within an area that is impervious to water, and includes rooftops, paved surfaces, and compacted earth. TIA is derived from land use/land cover data, and is a key indicator of ecological condition.

Methods

1. Estimate TIA within each drainage basin for existing conditions. Currently, Thurston County has 10 meter satellite data that will be used to determine TIA. TIA values for land cover categories can then be assigned based on relationships described by Booth and Jackson (1997), Azous and Horner (1997), and Booth et al. (2001), a shown in Table 2.
2. Estimate TIA for future build-out land use.TIA can then be estimated using literature-derived values for common land use classes, as shown in Table 3.

Table 2. Total Impervious Area values for land cover categories.

Land Cover Class	% TIA	Source
Forested (deciduous, coniferous, mixed)	3	Booth et al. (2001)
Grass, pasture, bare earth, recent clear cuts, scrub/shrub, herbaceous	5	Booth et al. (2001)
Mixed urban/low density (assumed to be equivalent to suburban)	35	Booth and Jackson (1997)
Urban/high density (assumed to include commercial, industrial, office space, high density residential)	75	Midpoint of range from Azous and Horner (1997)

Although open water is often treated as impervious in hydrologic modeling, we assign it a TIA value of 0 to reflect our use of TIA as a surrogate for developed area.

Table 3. Total Impervious Area estimates for common land use classes.

Land Use	% TIA	Source
Agricultural	5	Azous and Horner (1997)
Commercial, light industrial, downtown	75	Midpoint of range from Azous and Horner (1997)
Forestry, forested open space	3	Booth et al. (2001)
Industrial	80	Azous and Horner (1997)
Mining	80	Azous and Horner (1997) value for industrial
Schools, parks, golf courses, non-forested open space	5	Booth et al. (2001) value for grasses and shrubs
Residential High (>10 dwelling unit/acre)	60	Booth and Jackson (1997)
Residential Medium (1 to 10 dwelling units /acre)	35	Booth and Jackson (1997)
Residential Low (<1 dwelling unit /acre)	10	Booth and Jackson (1997)

Table 4. Total Impervious Area estimates for common land use classes.

Land Cover Type	% Impervious	Source
Agriculture	0	Karr 1998
Forest	5	Karr 1998
Grasslands	5	Karr 1998
Transitional	10	Karr 1998
Dirt Road	15	Karr 1998

Light Intensity Residential	30	Karr 1998
High Intensity Residential	44	Karr 1998
Commercial/Industrial	80	Karr 1998
Transportation	50	Karr 1998

Data Needs

1. Existing land use/land cover.
2. Future land use/land cover

Products

1. TIA within each DAU for existing conditions
2. TIA within each DAU for future build-out conditions

PART II. CHARACTERIZE CONDITION OF ECOLOGICAL AND BIOLOGICAL PROCESSES IN STUDY AREA

Purpose

Methods that characterize the condition of important ecological and biological processes produce results that can be used to:

- Help understand the landscape-scale condition of and constraints on aquatic and terrestrial resources and fish and wildlife habitats
- Establish a landscape context for assessing restoration options and alternatives
- Help identify where landscape-scale indicators of natural resource degradation exist at multiple scales, further providing context for understanding project impacts and restoration opportunities
- Help understand core problems that influence a site's capability to provide and maintain functions
- Establish the condition of habitat connectivity within stream basins.

Methods

1. Use appropriate landscape scale information in the analysis to determine the condition ("properly functioning," "at risk," or "not properly functioning") of ecological processes (such as delivery and routing of water, sediment, pollutants, large wood, and heat) and biological processes (aquatic integrity and upland habitat connectivity).
2. Characterize the condition of selected landscape attributes for each key ecological and biological process. Characterization work should occur at the DAU scale, unless justification exists and is documented.
3. The following text is derived from the Table 7 that details the landscape attributes and conditions appropriate for the analysis.

Delivery of Water

- Calculate percent TIA for each drainage basin. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.
- Calculate percent forest land cover for each drainage basin. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.
- Determine the condition and extent of wetlands within each drainage basin. Calculate percent of wetlands hydrologically altered (drained or filled) within drainage basins where wetlands represent five percent of more of the drainage basin. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.

- Calculate percent change in drainage network for each drainage basin. The hydrologist on the technical team evaluates available data to determine the best attributes for assessing this landscape indicator. Examples of land uses that increase the drainage network include wetland drainage, floodplain drainage ditches, storm drains, and roadside ditches assign a condition of “properly functioning,” “at risk,” or “not properly functioning” for this landscape indicator using criteria provided in Table 7.

Routing of Water

- Calculate percent channel length straightened for each drainage basin. Overlay hydrography datasets onto the drainage basin coverage and visually identify stream reaches that have potentially been straightened. Highlight potentially straightened stream reaches, overlay land use/land cover, and identify potentially straightened stream reaches with native vegetation and those with altered vegetation. Stream reaches with native vegetation should be assumed to have a natural stream configuration and were eliminated from further consideration. Stream reaches with agricultural, high density residential, or commercial/industrial land uses should be assumed to have an artificially straightened stream reach. Use aerial photography to support decision-making when uncertainty exists. Use GIS tools to calculate the percentage of stream channel that has been straightened. Assign a condition of “properly functioning,” “at risk,” or “not properly functioning” for this landscape indicator using criteria provided in Table 7.
- Calculate percent of floodplain decoupled from the river channel for each drainage basin. Acquire available data on the location and extent of floodplain dikes and levees. Develop a GIS dataset that identifies that part of the floodplain that lies behind dikes and levees and has reduced opportunity to store and desynchronize flood flows and sediment. Use GIS tools to calculate the percentage of floodplain area decoupled. Assign a condition of “properly functioning,” “at risk,” or “not properly functioning” for this landscape indicator using criteria provided in Table 7.

Delivery of Sediment

- Calculate percent bare soil areas for each drainage basin. A primary source of fine sediment in the Puget Lowland is assumed to be un-vegetated or disturbed soil areas. Evaluate available land use/land cover datasets and identify land uses that are considered to have bare or disturbed soils. In general, all agricultural areas, including fallow, or-chards / vineyards, pasture, row crops, and small grain crops are assumed to meet these criteria. Use GIS tools to calculate the percentage of bare soil areas within each drainage basin. Assign a condition of “properly functioning,” “at risk,” or “not properly functioning” for this landscape indicator using criteria provided in Table 7.

- Calculate road density (road miles per square mile) for each drainage basin. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.
- Refer to previously calculated results for percent channel length straightened and percent floodplain decoupled from a stream.
- Where less than five percent of the drainage basin consists of slopes greater than 30 percent, calculate the percent of unstable slopes in non-forest land cover. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.

Delivery and Routing of Nutrients and Toxicants

- Determine the number of 303(d) listed water bodies for each drainage basin. Due to the limited ambient monitoring data, this landscape indicator should be used with caution. This information is excellent at indicating what drainage basins are "not properly functioning." However, most streams do not have ambient monitoring data and we can't assume that streams without data are "properly functioning." If 303(d) data is limited for the study area, it should not be used as an indicator of condition for this ecological process. When adequate information is available, assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7. If the sub-watershed or watershed is 303(d) listed, then the default condition is "at risk" because the regulatory requirement to restore the water body to meet water quality criteria.

Delivery of Large Wood

- Determine the percent of 67 meter riparian zone in mature forest for each drainage basin. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.

Routing of Large Wood

- Determine the average number of stream crossings per kilometer of stream for each analysis unit. Assign a condition of "properly functioning," "at risk," or "not properly functioning" for this landscape indicator using criteria provided in Table 7.

Delivery and Routing of Heat

- Refer to previously calculated results for 303(d) listed water bodies, percent of 67 meter riparian zone in mature canopy, road density, and percent TIA.

Aquatic Integrity

- Plot and evaluate available Benthic - Index of Biological Integrity (B-IBI) scores within the study area.

- Use previously calculated condition results of percent riparian area in forest land cover by drainage basin.
- Use previously calculated condition results of percent total impervious area by drainage basin.

Snyder et al. (2003) synthesized results of existing studies relating to the influence of upland and riparian land use patterns on stream biotic integrity. This paper notes that in studies where scale influences were tested, whole catchment land use patterns were found to be better predictors of stream biological integrity in some studies, while others suggest riparian land use patterns were more influential. This information was used to support the use of both percent riparian area in forest land cover and percent total impervious area as landscape attributes for aquatic integrity.

Booth and others (2001) suggest that biological measures provide better information about environmental quality than chemical or physical measures because biological measures are one step closer to the factors that constitute environmental quality for living things. As a result of this work, B-IBI data were compiled and used when available, with best professional judgment, to modify the final condition rank of each drainage basin for aquatic integrity. Table 5 shows criteria for assigning aquatic integrity condition rank to drainage basins.

Table 5. Criteria for Assigning Aquatic Integrity Condition Rank to Drainage Basins.

Attribute	Attribute Priority	Condition Rank
Benthic – Index of Biological Integrity	Primary	Scores of: 10-22 – Not Properly Functioning 24-40 – At Risk 42-50 – Properly Functioning
Percent Riparian Area in Forest	Secondary	As noted in Table 7
Percent Total Impervious Area	Secondary	As noted in Table 7

Habitat Connectivity

- Clip the satellite derived land cover data to the stream catchment boundaries
- In raster format, create a layer of forest, non-forest and water classifications from the satellite imagery, labeled per stream catchment. Forest and water are defined in Hill et al. (2003), and all other classifications will be referred to as non-forested. Grain size should be appropriate for the precision of the imagery and the size of the study area.
- Under an 8-neighbor rule, to encompass the most area per patch and include riparian systems, run FRAGSTATS with the metrics found in Table 6:

Table 6. FRAGSTATS-calculated landscape metrics used for this project.

Metric	Name	Description
AREA	Area	Area of each patch (ha)
CA	Class Area	Total class area within a landscape (ha)
TA	Total Area	Total landscape area (ha)
PLAND	Percent of Landscape	Percentage of landscape in class (%)
GYRATE_AM	Area-weighted Mean Radius of Gyration	The area-weighted mean radius of gyration, correlation length, the average distance traversed from a random starting point in a random direction with in a landscape, its traversability.
COHESION	Patch Cohesion Index	Physical connectedness of patches in a class, approaches 0 as class becomes less aggregated (comparative value)

- Use FRAGSTATS to calculate the total forested area per stream catchment. This creates an approximation of habitat condition and forested area within the study area and individual stream catchments.
- Rank the stream catchments by PLAND value, weighted by GYRATE_AM, and compare it to the COHESION index.

Properly functioning -- Catchments with a COHESION index > 90% and a PLAND > 41%

At risk -- Catchments with greater than 90 % COHESION but a PLAND of < 41 %

Not properly functioning -- All other catchments, below 90 % COHESION are catchments with a large GYRATE_AM score that are near either border of the "at risk" category should be assessed individually, and reassigned if appropriate. This creates a baseline rating of habitat connectivity for each DAU.

Table 7. Matrix of Landscape-scale Pathways and Indicators.

Ecological Process	Landscape Indicator	Effect	Properly Functioning	At Risk	Not Properly Functioning
Delivery of Water to a Stream System	1) Percent change in Drainage Network [i]	Reduces Delivery Time; Habitat Degradation	Zero or minimal increases (<5%) in drainage network density due to development	Moderate increases (5% to 20%) in drainage network density due to development	Substantial increase (>20%) in drainage network density due to development
	2) Percent TIA [ii]	Reduces Delivery Time; Increases Amount of Water Delivered; Habitat Degradation	5% or less TIA	>5% and <30% total imperious area	≥30% TIA
	3) Percent Forest Land Cover and/or prairie cover[iii]	Reduces Delivery Time; Increases Amount of Water Delivered; Habitat Degradation	>65% of area in hydrologically mature forested land cover and non-forested areas scattered through-out	50% to 65% of area in hydrologically mature forested land cover with some larger areas of non-forest land cover	<50% in hydrologically mature forested land cover with large continuous areas of non-forest land cover
	4) Condition and Extent of Wetland Resources [iv]	Loss of assimilative capacity	>95% of all historic connecting wetland capacity present and unaltered	70-95% of historic connecting wetland capacity present and unaltered	<70% of historic connecting wetland capacity pre-sent and unaltered
Routing of Water Through a Stream System	5) Percent of Channel Length Straightened	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) of natural drainage network straightened	Moderate increases (5% to 20%) in natural drainage network straightening	Substantial increase (>20%) in drainage network straightening
	6) Percent of Flood-plain Decoupled from Stream [v]	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) in decoupled flood-plain	Moderate increases (5% to 20%) in decoupled flood-plain	Substantial increase (>20%) in decoupled flood-plain
Delivery of Sediment to a Stream System	7) Percent of Bare Soil Areas in Non-forest Areas	Increased Fine Sediment Inputs; Habitat Degradation	<5% of area in land uses having bare soils s	5-15% of area in land uses having bare soils	>15% of area in land uses having bare soils
	8) Road Density [vi]	Increased Fine and Coarse Sediment Inputs; Habitat Degradation	Road densities < 2 miles/square mile	Road densities of 2-3 miles/square mile	Road densities > 3 miles/square mile
	9) Unstable Slopes	Increased Inputs of Fine and Course Sediment	≥5% of DAU in > 30 percent slope and <10 percent of high slope area in non-forest land cover	≥5% of DAU in > 30 percent slope and ≥10%< 25% of high slope area in non-forest land cover	≥5% of DAU in > 30 percent slope and ≥25% of high slope area in non-forest land cover
Routing of Sediment Through a Stream System	10) Percent of Channel Length Straightened	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) of natural drainage network straightened	Moderate increases (5% to 20%) in natural drainage network straightening	Substantial increase (>20%) in drainage network straightening
	11) Percent of Flood-plain Decoupled from Stream [vii]	Reduced Routing Time; Reduced Access to Habitat	Zero or minimal increases (<5%) in decoupled flood-plain	Moderate increases (5% to 20%) in decoupled flood-plain	Substantial increase (>20%) in decoupled flood-plain

Ecological Process	Landscape Indicator	Effect	Properly Functioning	At Risk	Not Properly Functioning
Delivery and Routing of Nutrients, Toxicant, and Bacteria to a Stream System	12) Extent of 303(d) Listed Water Bodies for Nutrients, Toxicants, and Bacteria [viii]	Documented Water Quality Problem	Area meets water quality standards for all parameters. No excess nutrients or toxicity.	Water quality in the area has one parameter that exceeds water quality criteria by 10 per-cent or greater	More than one parameter exceeds water quality criteria by 10 percent or greater. Sub-lethal and lethal effects from toxics.
	13) Condition and Extent of Wetlands [ix]	Loss of assimilative capacity	Historic wetland area >5% and <25% of wetlands have been drained or hydrologically altered	Historic wetland area >5% and 25% to 40% of wetlands have been drained or hydrologically altered	Historic wetland area >5% and >40% of wetlands have been drained or hydrologically altered
Delivery of Large Wood to a Stream System	14) Percent of 67 meter Riparian Zone in Mature Condition [x]	Source of Large Wood to the Stream System; Habitat Degradation	85% of overall riparian zone in forest or wetland cover	50-85% of overall riparian zone in forest or wetland cover	<50% of overall riparian zone in forest or wetland cover
Routing of Large Wood Through a Stream System	15) Stream Crossings/Kilometer [xi]	Blocks Routing of Large Wood and Facilitates Removal from System; Habitat Degradation	< 2 – 20 meter stream crossings per kilometer of stream	2 to 4 – 20 meter stream crossings per kilometer of stream	> 4 – 20 meter stream crossings per kilometer of stream
Delivery and Routing of Heat to a Stream System	16) Extent of 303(d) Listed Water Bodies for Temperature [xii]	Identifies Problem Areas but Does Not Address Causes; Habitat Degradation	Area meets water quality standards for temperature	One parameter that exceeds temperature criteria 10 percent or more of the time	More than one parameter exceed temperature criteria 10 percent or more of the time
	17) Percent of 67 meter Riparian Zone with Mature Canopy [xiii]	Increase in Solar Energy to Stream; Habitat Degradation	85 percent or more of channel with riparian canopy intact and no large continuous stretches of open canopy	50 to 85 percent of riparian canopy intact but having some continuous stretches of open canopy	Riparian canopy fragmented, > 50 percent and contains large continuous stretches with no canopy
	18) Road Density [xiv]	Reduced Stream ; Habitat Degradation Depth	Road densities < 2 miles/square mile	Road densities of 2-3 miles/square mile	Road densities > miles/square mile
	19) Percent TIA [xv]	Change in Groundwater Recharge/Discharge; Habitat Degradation	5% or less TIA	>5% and <30% TIA	30 percent or more TIA
Biological Integrity	20) Benthic – Index of Biological Integrity	Overall Habitat Condition	Benthic – Index of Biological Integrity score ≥42	Benthic – Index of Biological Integrity score of 24 to 40	Benthic – Index of Biological Integrity score < 24
	21) Percent of 67 meter Riparian Zone in Mature Condition [xvi]	Buffers Effects of Upland Disturbance	85% of overall riparian zone in forest or wetland cover	50-85 % of overall riparian zone in forest or wetland cover	<50% of overall riparian zone in forest or wetland cover
Upland Habitat Connectivity	22) Level of Habitat Connectivity	Risk of Habitat Isolation	Use methods described elsewhere using Fragstats	Use methods described elsewhere using Fragstats	Use methods described elsewhere using Fragstats

* These Indicators require additional work at time of publication, and exact numbers are not available – if needed, contact authors for more information

Table 8. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for the Delivery and Routing of Water

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Water	Primary	% TIA	When % TIA is PF and % forest/prairie cover are PF, and wetlands are not an indicator, the final rank is PF	PF
	Secondary	% Forest cover/Prairie cover	When % TIA is PF and % forest/prairie cover are AR or NPF, and wetlands are not an indicator, the final rank is AR	AR
	Tertiary	Condition/extent of wetlands when used as a landscape indicator	When % TIA is AR and % forest/prairie cover is PF, and wetlands are not an indicator, the final rank is AR	AR
	Tertiary	% Floodplain decoupled from the channel	When % TIA is NPF and % forest/prairie cover is AR or NPF, and wetlands are not an indicator, the final rank is NPF	NPF
	Secondary (with complete infrastructure data)	% Change in the drainage network	When % TIA is PF, % forest/prairie cover is PF, and wetlands are PF, the final rank is PF	PF
			When % TIA is PF, % forest/prairie cover is PF, and wetlands are AR or NPF, the final rank is AR	AR
			When % TIA is AR, % forest/prairie cover is AR or NPF, wetlands are AR or NPF, and a large lake/wetland system existing in the drainage basin, the final rank is AR	AR
			When % TIA is NPF, % forest/prairie cover is AR or NPF, wetlands are AR or NPF, the final rank is NPF	NPF
			When % TIA is PF, % forest/prairie cover is AR or NPF, and wetlands are AR or NPF, the final rank is AR	AR
			When % TIA is AR, % forest/prairie cover is AR or NPF, wetlands are AR or NPF, the final rank is NPF	NPF
			When % TIA is AR, % forest/prairie cover is AR or NPF, wetlands are PF, the final rank is AR	AR
			When % TIA is AR and % forest/prairie cover is AR, and wetlands are not an indicator, the final rank is AR	AR

Table 9. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for the Delivery and Routing of Sediment

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Sediment	Primary	% Bare soil	When road density and bare soils are PF and unstable slopes are either PF or not evaluated, the final rank is PF	PF
	Secondary	Unstable slopes	When two indicators are PF and one is AR, the final rank is AR	AR
	Secondary	Road density	When two indicators are PF and one is NPF, the final rank is AR	AR
			When road density is NPF, bare soils are either PF or AR, and unstable slopes is not an indicator, the final rank is AR	AR
			When any combination of indicators has a different condition rank (i.e., PF, AR, and NPF), the final rank is AR	AR

Table 10. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for the Delivery and Routing of Wood

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Wood	Primary	% of 67 m riparian zone in mature condition	When % riparian is PF, and stream crossings are PF, the final rank is PF	PF
	Secondary	Stream crossings/kilometer	When % riparian is PF, and stream crossings are AR, the final rank is AR	AR
			When % riparian is AR, and stream crossings are PF or AR, the final rank is AR	AR
			When % riparian is AR, and stream crossings are NPF, the final rank is NPF	NPF
			When % riparian is NPF, and stream crossings are either PF, AR or NPF, the final rank is NPF	NPF
			When % riparian is PF, and stream crossings are not an indicator, the final rank is PF	PF
			When % riparian is AR, and stream crossings are not an indicator, the final rank is AR	AR
			No riparian indicators	N/A

Table 11. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for the Delivery and Routing of Pollutants, Nutrients, and Bacteria

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Pollutants, Nutrients, and Bacteria	Primary	CWA 303(d) list for toxicants (sub-lethal and lethal to fish)	If the stream is listed, then regardless of rank, the final rank will be AR because of the legal requirement to meet WQ standards	AR
	Secondary	CWA 303(d) list for bacteria	No Riparian Zone	N/A
	Secondary	CWA 303(d) list for nutrients		

Table 12. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for the Delivery and Routing of Heat

Process	**Indicator Priority**	**Landscape Indicator**	**Condition**	**Final Rank**
Heat	Primary	CWA 303(d) list for temperature	If the stream is listed, then regardless of rank, the final rank will be AR because of the legal requirement to meet WQ standards	AR
	Primary	% 67 meter riparian mature canopy	When % riparian is PF, road density is PF, %TIA is PF, the final rank is PF	PF
	Secondary	Road density	When % riparian is PF, and either road density or %TIA is AR or NPF, the final rank is AR	AR
	Secondary	%TIA	When % riparian is AR, and both road density and %TIA is either PF or AR, the final rank is AR	AR
			When % riparian is AR, and one of the two secondary indicators is NPF, with the other being PF or AR, the final rank is AR	AR
			When % riparian is AR, and both road density and %TIA is NPF, the final rank is NPF	NPF
			When % riparian is NPF, road density is PF or AR, %TIA is PF or AR, the final rank is AR	AR
			When % riparian is NPF, and either road density or %TIA is AR or NPF, the final rank is NPF	NPF
			When % riparian is NPF, and both road density and %TIA is NPF, the final rank is NPF	NPF
			No Riparian Zone	N/A

Table 13. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for Aquatic Integrity

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Aquatic Integrity	Primary	B-IBI	When B-IBI score is PF, and both % riparian and %TIA are PF, the final rank is PF	PF
	Secondary	% 67 meter riparian forest cover	When B-IBI score is PF, and either or both % riparian and %TIA are AR, the final rank is AR	AR
	Secondary	%TIA (value either above 30 or below 30)	When B-IBI score is AR, and either or both % riparian and %TIA are PF or AR, the final rank is AR	AR
			When B-IBI score is AR, and % riparian is NPF and %TIA is either PF or AR, the final rank is AR	AR
			When B-IBI score is NPF, and either or both % riparian and %TIA are AR, the final rank is NPF	NPF
			When %TIA is NPF, % riparian is AR of NPF, and B-IBI is AR or NPF, the final rank is NPF	NPF
			No Riparian Zone	N/A
			No BIBI Data	N/A

Table 14. Rule Examples and Rule Assumptions Used to Establish an Overall Condition Rank for Habitat Connectivity

Process	Indicator Priority	Landscape Indicator	Condition	Final Rank
Habitat Connectivity	Primary	FRAGSTATS Metrics	When metrics, % riparian and road crossings are PF, the final rank is PF	PF
	Secondary	% 67 meter riparian forest cover	When metrics are PF, and % riparian is PF, and road crossings are AR, the final rank is PF	PF
	Tertiary	Road crossings	When metrics are PF, with no riparian zone, and road crossings are PF, the final rank is PF	PF
			When metrics are PF, and % riparian is AR, and road crossings are PF or AR, the final rank is AR	AR
			When metrics are PF, and % riparian is NPF, and road crossings are PF or AR, the final rank is AR	AR
			When metrics, % riparian and road crossings are AR, the final rank is AR	AR
			When metrics are AR, with no riparian zone, and road crossings are PF or AR, the final rank is AR	AR
			When metrics are AR, and both riparian zone and road crossings are PF, the final rank is AR	AR
			When metrics are AR, and riparian zone is AR, and road crossings are PF or AR, the final rank is AR	AR
			When metrics are AR, and % riparian is NPF, and road crossings are PF, the final rank is AR	AR
			When metrics are AR, and % riparian is NPF, and road crossings are AR or NPF, the final rank is NPF	NPF
			When metrics, % riparian and road crossings are NPF, the final rank is NPF	NPF
			When metrics are NPF, and riparian zone is AR or NPF, and road crossings are PF, AR or NPF, the final rank is NPF	NPF
			When metrics are NPF, with no riparian zone, and road crossings arePF, AR or NPF, the final rank is NPF	NPF

PART III. CHARACTERIZE NATURAL RESOURCES IN STUDY AREA

Purpose

This step develops an understanding of the natural resources within the study area. The purpose is to determine natural resource sites that can be preserved or restored in the watershed that will provide the greatest ecological benefit.

Methods

The following natural resources will be evaluated: wetlands, floodplains, and riparian corridors. The results will then be assessed in context of each DAU condition.

Step 1. Determine Location, Extent, and Condition of Wetland Resources.

Purpose

Identifying the location, extent, and condition of wetlands provides valuable insight into a landscape's capacity to store surface water, sediment, and nutrients/toxicants/bacteria. This information is used to help characterize the condition of ecological processes within drainage basins in the study area. The location and extent of existing, degraded, and destroyed wetlands serve as the pool of preservation sites and potential restoration sites for development impacts to wetlands.

> ***NOTE****: A clear distinction must be made between a wetland inventory and an inventory of potential wetland restoration sites. Wetland inventories attempt to identify the location and extent of existing wetland resources. An inventory of potential wetland restoration sites identifies the location, extent and condition of existing wetland areas and additional historical wetlands, now upland due to human alteration that can be reestablished through restoration actions.*

Methods

1. Identify and compile available data sets of the location, extent, and condition of historic and existing wetlands within the study area.
2. Evaluate effectiveness of the data at identifying potential wetland restoration sites. When existing data are adequate to use for characterizing ecological processes and identifying potential wetland restoration sites, no additional data assessment is required.

When existing data are inadequate, continue to Number 3.

3. When existing wetland data do not meet needs, use available data sets and aerial photo interpretation to develop a list of potential wetland restoration sites.
4. Existing polygons from available wetland inventories are used to establish the location and extent of all known wetlands. All available wetland inventories are overlaid in a priority order based on assumed accuracy using ArcMap. When wetlands are identified on more

than one wetland inventory, the polygon of the site in the inventory with the highest assumed accuracy is used to identify the location and extent of the potential wetland. Within Washington State, potential data sets include National Wetland Inventory, WADNR hydrography coverage (codes 111 and 421), Washington State Department of Fish and Wildlife (WDFW) Priority Habitats and Species (PHS) data, and local wetland inventories. Create an ArcMap data layer of existing wetlands. This data layer will function as the starting point for a potential wetland restoration data set. Wetland attributes within each wetland inventory should be evaluated for applicability to this work. Relevant attributes from each wetland data set should be imported into the new data layer table to support photo interpretation.

5. Acquire soils data and identify wetland hydric soils within the study area (hydric soils with no upland soil inclusions and hydric soils with upland soil inclusions). Clip hydric soils to the study area boundary and establish a hydric soils data layer. This data layer provides an indication of the predevelopment location and extent of wetlands in the study area.
6. To the existing wetland data layer table, add new attribute fields to the data table to allow the photo interpreter to record additional data compiled during photo interpretation. Suggested attributes to be photo interpreted and recorded in the data table include:

- **Potwet -** This attribute represents the photo interpreter's opinion of the site's potential to be either an existing wetland or a historical wetland area that has restoration potential. This attribute is used to distinguish between wetland and potential wetland areas and upland and historic wetland areas having no restoration potential.

  Y - site is an existing wetland or has restoration potential

  N - site is not and existing wetland and has no restoration potential due to site or surrounding human land use/alteration.

- **Rest_Pot** – This attribute represents the photo interpreter's opinion of a wetland or upland site's need and ability to be restored to a natural wetland condition. This attribute is used to distinguish between potential wetland sites that have potential to be used as a restoration site and wetlands that have minimal restoration site potential.

  0 – no/minimal potential for restoration; this can include both high quality wetlands and degraded or destroyed wetlands with substantial development that precludes reasonable options to restore the wetland

  1 – wetland has some level of restoration potential based on signatures from aerial photos indicating some level of hydrologic and/or vegetative alteration

  2 –the wetland site has adequate restoration potential to serve as a viable restoration option

- **Mit_pot** – This attribute represents the photo interpreter's opinion of a wetland site's potential. This attribute is based soling on the signatures observed during photo interpretation. Considerations used to determine restoration potential include the size of the potential restoration site, the extent of hydrologic and vegetative alteration, indications of many separate landowners, and major infrastructure development, such as high power transmission lines or major water conveyances.

0 – site may have restoration potential but limited potential to serve as a high natural resource restoration site do to one or more site attributes observed during photo interpretation

1 – site has restoration potential and potential for serving as a development restoration site

- **Wclass** – This attribute represents the photo interpreter's opinion of the hydrogeomorphic wetland classification (Table 15) under existing site conditions. This attribute, paired with Pclass, can be used to describe the level of hydrologic alteration and gain understanding into potential functions that the wetland can provide under existing (Wclass) and restored (Pclass) conditions.

Table 15. Hydrogeomorphic wetland types used to classify wetlands

Hydrogeomorphic Code	Hydrogeomorphic Type	General Description
RI	Riverine Impounding	Topographic depressions on a valley bottom
RF	Riverine Flow-through	Wetland systems associated with rivers and streams where water tends to flow through rather than pond
DC	Depressional Closed	Topographic depressions outside of valley bottoms having no surface water connection to a stream
DF	Depressional Flow-through	Topographic depressions outside of valley bottoms having a surface water connection to a stream
LF	Lacustrine Fringe	Wetlands occurring at the margins of deepwater lakes
LC	Lacustrine Open Water Lake	A lake system >20 acres in area and >2 meters deep
SL	Slope Wetland	Wetlands occurring on a slope where water tends to sheet flow through
UN	Unknown	Unable to determine hydrogeomorphic type from photos
NW	Non-wetland	Site is upland area
MM	Man made	Stormwater ponds and other artificial impoundments
ES	Estuary	Direct connection to marine waters

- **Pclass -** This attribute represents the photo interpreter's opinion of the potential hydrogeomorphic wetland classification of the site once restored. Hydrogeomorphic codes used to determine Wclass, above, were also used in determining Pclass. This at-tribute, paired with Pclass, can be used to describe the level of hydrologic alteration and gain understanding into potential functions that the wetland can provide under existing (Wclass) and restored (Pclass) conditions.

- **Hydro_alt -** This attribute represents the photo interpreter's opinion of the extent of human induced hydrologic alteration for the site based on photo interpretation and available locally developed information.

  0 – no/minimal hydrologic alteration

  1 – some hydrologic alteration evident but portions of the site appear to be providing reasonable levels of wetland functions

  2 – extensive hydrologic alteration is evident from surface drains and ditches, filling or is presumed to exist because of human land uses

- **Vg_alt** - This attribute represents the photo interpreter's opinion of the extent of human induced vegetative alteration for the site based on photo interpretation and avail-able locally developed information.

  0 – no/minimal vegetative alteration

  1 – some vegetative alteration/clearing is evident from aerial photos and/or LiDAR

  2 – extensive vegetative alteration/clearing is evident from aerial photos and/or LiDAR

- **SLU -** This attribute represents the photo interpreter's evaluation of the general type of land use that surrounds the potential wetland site. Suggested land use codes are presented in Table 16.

Table 16. Land use types recorded during wetland photo interpretation.

Land Use Code	Land Use Type
res	Residential
par	Park/Open Space
for	Forest
com	Commercial/Business
ind	Industrial
agr	Agriculture

- **Prsrv -** This attribute identifies high quality, high value existing wetlands that, in the photo interpreter's opinion, warrant consideration for preservation status, based on photo interpretation and location in the watershed. Sites identified in this attribute are either high quality sites located in a forested area with minimal risk of degradation from human development or high quality sites that have some human alteration but appear to be of such high value, even if degraded, that they warrant preservation and restoration status.

  In addition to high quality wetlands, sites located at headwaters of streams and in the upper watershed that provide storage and attenuation of stormwater should also be identified for preservation.

  0 – site doesn't warrant preservation

  1 – site warrants consideration as a preservation site

- **Notes** – this attribute field is provided to allow the photo interpreter to add observations of the site not captured in the other attributes.

7. Overlay the existing wetland and hydric soil data layers onto orthophotos as a base map. The orthophoto will facilitate rapid site orientation between your computer screen displaying ArcMap and aerial photos on a flat work surface. The existing wetland and hydric soils data layers provide logical areas that identify the most probable location of

current and historic wetlands. The existing wetland data layer is then renamed and used as a starting point when identifying potential wetland restoration sites.

8. Each section of land within the study area is photo interpreted using the most current high quality stereo-paired aerial photos. We recommend a wetland biologist with experience photo interpreting wetlands and a standard stereoscope with 1:12,000 color or black and white stereo-paired aerial photos.

9. Use aerial photo transects to systematically photo interpret each section of land within the study area. Using ArcMap and the potential wetland restoration and hydric soil polygons as a starting point, compare the location and extent of wetland and hydric soil polygons

10. When the photo interpreter estimates that the location and extent of the potential wetland restoration site is substantially different (greater than 25 percent error) than that of the existing wetland polygon, the polygon is modified in ArcMap to more accurately reflect location and extent of the potential wetland restoration site, as represented on aerial photos.

11. Once all polygons within a section are evaluated and data collected and recorded in the data table, the photo interpreter should scan other parts of the section to identify wetland signatures that don't coincide with a wetland or hydric soil polygon. When additional wetland signatures are identified, a new polygon is added to the potential wetland restoration data layer and recorded.

12. Use data associated with existing wetland inventories and local and regional reports when available to support determinations made during photo interpretation.

If the purpose of the characterization is to provide information on a specific development action, the following fields should be included in the characterization. Attributes to be added to the potential wetland restoration site dataset relating uniquely to wetland sites within or adjacent to the study area include:

- **Site_avoid** – This attribute represents the wetland scientist's opinion using best professional judgment of the site-specific resource value of the wetland. A value of High, Medium or Low is then assigned to the wetland for the purpose of avoidance and minimization. When Ecology wetland categories are not available, the reviewer should develop criteria and include in the final report of the study area.

  H – High Avoidance; wetland is an Ecology Category I or Category II (Ecology, 1993) and warrants the highest consideration for avoidance and minimization.

  M – Moderate Avoidance; wetland is an Ecology Category III or IV (Ecology, 1993) and warrants medium consideration for avoidance and minimization.

  L – Low Avoidance; wetland is an Ecology Category III or IV (Ecology, 1993) and warrants low consideration for avoidance and minimization.

- **Land_avoid** – This attribute represents the wetland scientist's opinion using best professional judgment of the landscape-scale resource value of the wetland in relation to the landscape and other natural resources surrounding it. A value of High, Medium or Low is then assigned to the wetland for the purpose of avoidance and minimization.

H – High Avoidance; wetland warrants the highest consideration for avoidance and minimization based on its relationship to the natural resources around it.

M – Moderate Avoidance; wetland warrants medium consideration for avoidance and minimization based on its relationship to the natural resources around it.

L – Low Avoidance; wetland warrants low consideration for avoidance and minimization based on its relationship to the natural resources around it

- **Fin_avoid** – This attribute represents the wetland scientist's opinion using best professional judgment of the overall resource value of the wetland based on averaging the site-scale and landscape-scale avoidance and minimization rank. A value of High, Medium or Low is then assigned to the wetland for the purpose of avoidance and minimization.

  H – High Overall Avoidance; wetland warrants the highest consideration for avoidance and minimization based on averaging its site-scale and landscape-scale ranks.

  M – Moderate Overall Avoidance; The wetland warrants medium consideration for avoidance and minimization based on averaging its site-scale and landscape-scale ranks.

  L - Low – Low Overall Avoidance; wetland warrants low consideration for avoidance and minimization based on averaging its site-scale and landscape-scale ranks.

- **Ecol_cat** – This attribute represents the wetland scientist's opinion using the Washington State Wetlands Rating System (Ecology, 1993) and best professional judgment to categorize each wetland. A value of High, Medium or Low is then assigned to the wetland for the purpose of avoidance and minimization.

  H – High Value; wetland is an Ecology Category I or Category II (Ecology, 1993) and is a high quality or rare wetland and warrants the highest consideration for avoidance and minimization.

  M – Moderate Value; wetland is an Ecology Category III or IV (Ecology, 1993) and provides functions and values not provided in a Category I or II wetland. These wetlands warrant medium consideration for avoidance and minimization.

  L - Low Value; wetland is an Ecology Category III or IV (Ecology, 1993) and may be small or isolated wetlands, with Category IV having the least diverse vegetation. These wetlands warrant low consideration for avoidance and minimization.

During potential restoration site prioritization, the following attributes were used to prioritize potential wetland restoration sites:

- **Rare_types** – This attribute identifies wetland fens and bogs considered to be rare, unique, and/or irreplaceable. Potential fens and bogs are identified using the soils data layer. We assume that potential wetland sites having hydric soils with > 25 % organic matter have the greatest potential of identifying peat bogs or fens.

  0 – potential wetland sites having <33 % of the polygon area in a hydric soil series having >25 % organic matter

1 – potential wetland sites having > 33 % of the polygon area in a hydric soil series having > 25 % organic matter

- **Rechrg_pot** – This attribute identifies wetland sites having the greatest potential to recharge groundwater aquifers. Hydrologic code attributes within the soils data layer are used to identify soil types having moderate to high percolation.

  0 – potential wetland sites with 50 percent or less of the polygon intersecting soil mapping units with a Hydrologic Code of A or B

  1 – potential sites with > 50 % of the wetland polygon intersecting soil mapping units with a Hydrologic Code of A or B

- **Sw_connect** – This attribute identifies potential wetland sites having a surface water connection as defined by wetland hydrogeomorphic classification. For this attribute, surface water connection is defined as surface water movement from the wetland to a stream or lake for all or part of the year.

  0 – potential wetland sites with a potential wetland classification (Pclass) of Depressional Closed (DC)

  1- wetland sites with a potential wetland classification (Pclass) of Depressional Flow-through (DF), Riverine Flow-through (RF), Riverine Impounded (RI), Lacustrine Fringe (LF), Lacustrine Open Water Lake (LC), or Slope (SL) wetlands.

- **Sw_flood** – This attribute identifies wetland sites having a direct connection to a perennial stream or lake. This attribute is assessed by identifying the intersection of a wetland site and a stream or lake identified on the 1:24,000 hydrography data layer.

  0 – no direct intersection exists between the wetland site and a stream or lake

  1 – a direct intersection exists between the wetland site and a stream or lake

- **Fish_acces** – This attribute identifies wetland sites having a direct connection to a perennial stream or lake and one or more species of fish have potential to access the wetland.

  0 – no direct intersection exists between the wetland site and a stream or lake or a direct intersection exists but fish do not have access to that portion of the stream or lake

  1 – a direct intersection exists between the wetland site and a fish bearing stream or lake

- **Adjpub** – This attribute identifies wetland sites located on or adjacent to public lands. Publicly owned lands include all parcels that have permanent protections or easements, and include, but not limited to: land trust properties; parks; reserves; schools; and green belts. To account for all potentially properties, query parcels that pay no real estate tax. Using the best available public ownership data, a determination of adjacency was made.

  0 – the potential wetland site does not occur on or adjacent to publicly-owned land

  1 – the potential wetland site occurs on or adjacent to publicly-owned land

- **Local_prio** – This attribute identifies potential wetland restoration sites that have also been identified as being a priority restoration project in one or more locally developed natural resource plans. Available watershed plans and recovery projects were compared with the potential wetland restoration site dataset for matches.

  0 – the potential wetland site does not occur on a local watershed plan or is not prioritized in some manner for restoration

  1 – the potential wetland sites does occur on a local watershed plan or is on a prioritized wetland restoration list

Data Needs

1. All available wetland coverages and data sets that provide wetland information.
2. Soil survey data
3. Digital orthophotos
4. 1:12,000 color or black and white stereo paired aerial photos of the study area
5. 1:24,000 hydrography or better
6. Fish access data
7. Public landownership data
8. Local natural resource planning documents

Products

1. A GIS data file of potential wetland restoration sites within the study area with data needed to identify, assess, and prioritize potential preservation and restoration sites.

2. Photo interpreted data for each potential wetland restoration site that can be used to assess the extent of wetland alteration at both the site- and landscape-scales.

Step 2. Determine Location, Extent, and Condition of Floodplain Resources.

Purpose

Identifying the location, extent, and condition of floodplain resources provides valuable insight into a landscape's capacity to store surface water, sediment, large wood, and nutrients, toxicants, and bacteria. The proportion of functioning versus non-functioning floodplains provides additional insight into potential restoration sites.

Methods

1. Identify the location and extent of riparian and floodplain areas using available coverages and data.
2. Evaluate historic (Holocene) floodplain conditions. Holocene floodplain is delineated using topographic data combined with GIS coverage of alluvial soil deposits.
3. Establish condition of current floodplains within the study area. Using the Federal Emergency Management Agency (FEMA) floodplain coverage and orthophotos, identify the proportion of floodplain that is decoupled from the stream (area behind dikes or levees

or affected by a road crossing), confined (channel locked in place by dredging, rip-rap etc), and free-flowing (channel is free to migrate across floodplain).

4. Evaluate floodplain restoration potential using the following methodology focused on the potential for storage restoration, stemming from analysis of floodplain decoupling. Floodplain storage areas become decoupled due to development activities that involve the construction of dikes, revetments, and filled terraces and dredging of the river channel. In order to identify these landscape changes LiDAR (Light Detecting And Ranging) data is assembled for the watershed. From those data, produce two GIS coverages. The first is a shaded relief topographic layer, which allows for rapid and accurate identification of changes in elevation, especially involving linear features (such as dikes, roads, etc.). The second GIS coverage is a 2-foot contour topographic coverage used to quantify the extent of vertical relief for the decoupling features being analyzed. Lay these coverages over the orthophoto coverage to generate a base map for geospatial analysis of floodplain decoupling. Additional coverages for FEMA floodplains, wetlands, and riparian zones are used to help identify coupled and decoupled floodplain features.
5. Each decoupled feature is then tied to the adjacent topographic features and/or the valley wall floodplain margin. From this a storage polygon is developed for each feature, depicting the spatial extent of the lost storage areas.
6. Each decoupled polygon is then analyzed for potential for restoration. To accomplish this several additional field attributes are identified and evaluated. These include land use, channel migration potential, development surrounding the site, and soils data.
7. Orthophotos are used to identify land uses for decoupled floodplain polygons. Each polygon is sorted into categories including residential, industrial/commercial, agriculture and open space. Because of the expense involved in acquiring developed land and removing the structures, only lands in agriculture and open space are identified as having restoration potential.
8. The polygons are then evaluated to determine the extent of surrounding development (to ascertain the relative fragmentation of polygons with floodplain restoration potential). Those polygons that have less development surrounding them are deemed to have higher potential restoration value. This determines the relative level of fragmentation for each polygon and its potential to reconnect adjacent undeveloped floodplain polygons.
9. Analysis of the floodplain reveals some polygons that had been removed from the jurisdictional floodplain, probably through Letters of Map Revision ("LOMR"), etc. that are adjacent to floodplain polygons with restoration potential. Those that share attributes with the adjacent floodplain polygons are identified and categorized as non-FEMA floodplain polygons in proximity to potential restoration sites. Land use for these is examined and those that were undeveloped were deemed to have restoration potential, however they were categorized as "non-jurisdictional" polygons.
10. Next, the polygons are evaluated to determine the potential for restoration of channel migration or channel complexity. This is done by identifying remaining vestiges of channel geomorphology, most notably mender bends and confluences. Polygons adjacent to these remainder geomorphic features receive a higher value in terms of restoration potential. This

is done to identify the most likely locations for restoration activities to be augmented by remaining aspects of riverine geomorphic processes.

11. The coverage showing type A and B soils is then applied to each decoupled floodplain polygon to determine the potential for restoring riparian, wetland, aquifer recharge and nutrient exchange functions for the polygon, based on the extent to which the coverages overlap.

    - L - < 25 % of the polygon.
    - M - 25 – 50 % overlap of polygon
    - H - 50 % overlap of polygon

Attributes used include:

- **Decoupled** – This attribute represents the photo interpreter's opinion if the site has been decoupled from the active floodplain

  Y – site has been decoupled.

  N – site has not been decoupled

- **Mend_fdpln** – This attribute represents the photo interpreter's opinion if the site can mend isolated patches of floodplain

  Y – site can mend floodplain

  N – site can't mend floodplain

- **Chinmig_pot** – This attribute is a measure of the polygon's ability to migrate across the floodplain

  Y – the site could migrate

  N – the site could not migrate

- **Confined** – This attribute represents the photo interpreter's opinion if the site has been confined from the active floodplain

  Y – site has been confined

  N – site is not confined

- **Notes** – This attribute provides more detail on a polygon's site information beyond what was given in the other attributes.

Data Needs

1. Current orthophoto GIS coverage
2. LiDAR or other accurate topographic data
3. GIS riparian coverage
4. GIS wetland coverage
5. GIS type A and B soils coverage
6. GIS coverage of dikes, levees, and riprap

7. GIS FEMA floodplain coverage
8. Hydrography
9. Background information on flood control activities most notably channel dredging, levee construction and flow control structures
10. Current land use/land cover

Products

1. Information on the floodplain systems.

Step 3. Determine Location, Extent, and Condition of Riparian Resources

Purpose

Identifying the extent, location, and condition of riparian resources provides valuable insight into a landscape's capacity to store and transport surface water, sediment, large wood, nutrients, toxicants, and bacteria (Hyatt et al. 2004, Morley and Karr 2002, Sweeney et al. 2004). This information is used to help characterize the condition of ecological processes, or aquatic integrity, within in the study area. The location and extent of existing deforested riparian areas also serves as a pool of potential restoration sites for past impacts to riparian areas.

Methods

1. Clip the hydrography layer to the study area boundary.
2. Identify the extent of riparian areas using available GIS data layers. Apply a 33-meter and a 67-meter buffer to a 1:24,000 scale hydrography layer within the study area, creating a riparian buffer layer around all rivers and streams. The buffer is based on established minimum shade requirements and site potential tree height (SPTH) for large woody debris recruitment, respectively.
3. Using available riparian coverage, current land cover and digital orthophotos, create polygons around all non-forested areas within the riparian buffer.
4. Add attributes to this new layer of non-forested riparian areas according to existing land cover data.

Attributes used include:

- **Potrip** – This attribute represents the photo interpreter's opinion of the site's potential to be used as a riparian restoration site.

  Y – site has restoration potential.

  N – site has no restoration potential due to site or surrounding human land use.

- **Landuse** – This attribute represents the photo interpreter's opinion of the site's current land use. Suggested land use codes are:

  Res - Residential

  Com - Commercial

Ind - Industrial

Open - Parks, agriculture, open space

- **Add_forest** – This attribute is a measure of the polygon's proximity to forest patches, whether the polygon would add forest to the existing forest if it were chosen as a restoration site and restored.

  Y – the site would add forest to the existing forest

  N – the site would not add forest to the existing forest

- **Mend_forest** – This attribute is a measure of the polygon's ability to link two disjunct forest patches, if it was chosen for riparian restoration.

  Y – the site would link two forest patches

  N – the would not link two forest patches

- **CTS** – This attribute represents the range of forest cover within the polygon, how much of the area is Cleared To Stream on a scale of 1 to 3, based on the 33-meter and 67-meter buffer distance from the stream.

  1 - corresponds to partial clearing,

  2 - some trees,

  3 - no trees.

- **Notes** – This attribute provides more detail on a polygon's site information beyond what was given in the other attributes.

After the entire study area has been evaluated for non-forested riparian areas, merge the DAU layer with the non-forested riparian area layer. There should now be an attribute for each polygon stating its DAU designation.

The remaining area in the riparian buffer is the forested area per DAU. Create a new layer of forested polygons within the riparian buffer.

Add the following attributes to each layer, calculating the area of each polygon.

- Area – square feet of each polygon
- Acres – acreage of each polygon

The forested and non-forested layers tables can now be exported to a spreadsheet and the data compiled for the study area, the individual stream catchments, and the individual drainage basins to determine the condition of the riparian area.

Select only the non-forested polygons with restoration potential and create a new layer. Additional attributes to help with characterization of the potential riparian restoration sites may be included. Suggestions for useful attributes include:

- CDsoils – Overlay the soils layer and assess how much of the potential restoration area per polygon contains C or D soil types. If a large percentage of the polygon contains C or D soils, the site will provide more benefit from restoration than a site with A or B soils.

1 - > 50 percent C or D soils

0 - < 50 percent C or D soils

- **Adjpub** – This attribute shows an indication of a polygon's adjacency to publicly owned lands, which can have educational or social benefits. Publicly owned lands include all parcels that have permanent protections or easements, and include, but not limited to: land trust properties; parks; reserves; schools; and green belts. To account for all potentially properties, query parcels that pay no real estate tax. Overlay available property ownership layers and compare the polygon's location with publicly owned lands.

  1 - Public ownership on or adjacent to the potential restoration site

  0 – No public ownership on or adjacent to the potential restoration site.

- **Local_prio** – This attribute gives special consideration to polygons that are within areas designated by local jurisdictions as priority sites for restoration.

  1 - Local priority site

  0 – Not a local priority site

Potential riparian restoration polygons that intersect potential wetland or floodplain areas should be clipped to the border of the wetland or floodplain and their area and acreage recalculated.

A copy of the layer should be made and the potential riparian restoration polygons less than three acres in area removed from the new layer, creating a layer of potential riparian restoration sites greater than three acres in size.

Data Needs

1. Hydrography layer.
2. Available riparian coverages, current land cover, digital orthophotos, stereo-paired if available.
3. Study area, Stream Catchments, and drainage basin boundary layers.
4. Soil survey layer, C and D soils.
5. Land ownership layer or maps of publicly owned lands.
6. Local priority sites.
7. Wetland and floodplain potential restoration sites (when available).

Products

1. An approximation of riparian condition and forested riparian area within the study area, DAUs and sub-watersheds.
2. A GIS data file of potential riparian restoration sites within the study area, DAUs and sub-watersheds.

Step 4. Determine Location, Extent, and Condition of Fish Habitat Resources

Purpose

This landscape method has been developed to prioritize potential wetland, floodplain, and riparian restoration sites for maximizing habitat benefits for salmonid fish species. The results will then be used in the identification of stormwater retrofits sites. Sites with high fish habitat value will be avoided.

Introduction

Natural resource mitigation efforts have often focused on a projects ability to provide functions at the site scale. These functions are assessed by evaluating key physical features, such as pool riffle ratios and channel complexity in streams or open water to emergent plant ratios and snags per acre in wetlands. However, there is growing evidence that significant stressors within individual watersheds play an important role in how a site will function and must be identified and evaluated before natural resource improvements 'are initiated (Booth et al. 2001). Further, not all watersheds are created equal (Booth 1991) when human land use intensity increases. Because of the diverse physical and biological influences on watershed processes and conditions, aspects of the regional and local geology must be understood for stream restoration or rehabilitation to be successful (Booth et al. 2003). Likewise, stormwater treatment and control infrastructure has typically been an engineered system to store and convey surface stormwater. Watershed characterization is a tool to evaluate using the natural landscape to mitigate stormwater treatment and runoff, vs. the traditional engineered attempts to mimic the natural runoff characteristics of a drainage area.

Geology, climate, and gross reach morphology are ultimate controls over the landscape processes and are independent of land-use management over the long-term (centuries to millennia), act over large areas (> 1 km2), and shape the range of possible processes and habitat conditions in a watershed (Naiman et al. 1992; Beechie and Bolton 1999).

Proximate controls are affected by land management over the short term (i.e., years to decades), act over smaller areas, and determine habitat conditions expressed at any point in time (Naiman et al. 1992, as cited in Beechie et al. 2003).

Given the enormous area over which anadromous salmonid species complete their freshwater life-history stages, it is not surprising that landscape processes have a profound influence on populations (Feist et al. 2003). A landscape's regional topography, climate, geological substrate, soil, vegetation types, and biogeography define, in large part, the biota of the region (Booth et al. 2001).

We apply this understanding through the development of the following criteria used to prioritize potential wetland, floodplain, and riparian restoration sites. Our purpose is to prioritize potential natural resource restoration sites based on each site's opportunity to maximize habitat benefits to salmonid fish species

Methods

Criteria used to rank natural resource restoration sites for potential to provide important habitat for salmonid fish species is presented in Table 17. Rationale for each criterion follows.

The priority ranking process follows the five steps outlined in Table 17. Potential floodplain, wetland, and riparian restoration site datasets, detailed in this methods document, were used as the starting point for this ranking process.

Table 17. Fish Habitat Ranking Criteria

Ranking Step	Criteria	Rating	Rationale
Step 1. Identify key habitat areas for salmonids at a landscape scale	Number of salmonid species spawning in a Drainage Analysis Unit (DAU) under past or present conditions Note: Spawning and rearing areas were determined through the Washington Lakes and Rivers Information System (WLRIS) that includes the Salmon and Steelhead Inventory (SaSi) database. Because WLRIS contains historic data on spawning and rearing, the DAU mayor may not currently maintain the number of spawning or rearing salmonid species identified in WLRIS.	High -three or more salmonid species spawning or rearing in a DAU. Moderate -one or two salmonid species spawning or rearing in a DAU. USE TYPE 2 = known spawning and 3 = known juvenile rearing Low -no salmonid species are known to spawn or rear in the DAU	Habitat occupied by multiple salmonid species is assumed to have higher environmental benefit than areas with fewer species. Known spawning areas are key habitat areas that provide one or more critical life stages for salmonid species. Studies in the Pacific Northwest (PNW) have documented that native trout remain close to their spawning areas (Moore and Gregory 1988,as cited in Montgomery et al., 1999), implying that distribution of juvenile fish closely reflects the species spawning distribution (Montgomery et al.,1999).
Step 2. Identify landscape areas where restoration actions have the greatest potential for measurable environmental benefits	Ecological process condition rank	High, Moderate, or Low -based on the number of ecological processes in an "At Risk" condition Only sites having a High or Moderate ecological process condition rank are considered in prioritizing sites.	A high ecological process condition rank indicates that a majority of ecological processes evaluated within the DAU, both physical and biological, are in an "At Risk" condition. A core premise of watershed characterization is that targeting restoration actions within DAUs having ecological processes in an "At Risk" condition provides the greatest opportunity for maximizing environmental benefits.
Step 3. Identify DAUs having high groundwater recharge potential and resulting strong summer baseflows	Percent of DAU in advance and recessional outwash areas As determined by the United States Geological Service and Washington State department of Natural Resources geological mapping	High ->30% advance and recessional outwash in the DAU Moderate -<30% advance and recessional outwash in the DAU	Outwash geology provide essential phreatic and hyporheic functions that salmonid species rely on to provide spawning habitat and maintenance of summer baseflow (Booth et al. 2003)

Step 4. Identify sites having important habitat characteristics for salmonids	Riparian areas -stream gradient and channel confinement Floodplains -surrounding development and potential to restore channel migration Wetlands -fish access and potential for open water during high flow events (100 year)	High -riparian restoration sites having 0-2% stream gradient unconfined channel and <1% moderately confined channel High -floodplain restoration sites with DevSur = 0-1 and ChanMigPot = y High -wetland restoration sites with fish access and potential for open water (Fish_acces = 1 and DF, Rl and RF) Moderate -All sites not ranking High	<2% unconfined channels are key habitat to five species of salmonid species Floodplains (0-1%) are key habitat to four salmonid species Open water ponds are key habitat for three salmonid species (Beechie et al. 2003; Pess et al. 2002)
Step 5. Rank sites by size	Site area	Larger site prioritized over smaller	Final rank to separate sites with identical habitat criteria.

Riparian: 1V = GCDESC <1% unconfined, 2V = GCDESC 1-2% unconfined, 1M = GCDESC <1% moderately confined

Floodplain: DevSur = development surrounding the site

O = no development on any side

1 = one side is developed

ChanMigPot = channel migration potential is based on photo interpretation of remnant geomorphic features such as meander bends, confluences, etc.

Wetland: Fish_acces –This attribute identifies wetland sites having a direct connection to a perennial stream or lake and one or more species of fish have potential to access the wetland.

O = no direct intersection exists between the wetland site and a stream or lake or a direct intersection exists but fish do not have access to that portion of the stream or lake

1 = a direct intersection exists between the wetland site and a fish bearing stream or lake

DF = Depressional flow through wetland

Rl = Riverine impounding wetland

RF = Riverine flow through

Step 1. Identify key habitat areas for salmonids at a landscape scale.

The first criterion is based on the number of salmonid species known to historically spawn or rear in, or is currently spawning or rearing in the DAU. We rated potential restoration sites High if the Drainage Analysis Unit (DAU) contained three or more known spawning species, Moderate for one or two species, and Low for no species. Spawning and rearing distribution data was acquired through the use of Washington Lake and Rivers Information System (WLRIS) that contains existing Salmon and Steelhead Inventory (SaSi) data compiled by the Washington State Department of Fish and Wildlife (WDFW). Information contained in the database on spawning and rearing areas contain historic and current information on salmonid species and bull trout. It should be noted that the current number of spawning species mayor may not be currently present. However, we assume that DAUs, capable of supporting multiple salmonid species in the past have important physical attributes at landscape scales capable of supporting diverse aquatic habitats if restored.

The first proposed criterion is based on the premise that fish presence and distribution is dependent upon the physical attributes of the watershed that are formed and maintained by the ecological processes and the underlying geology. Increasing survival during freshwater residency may have the greatest likelihood of reversing population declines (Kareiva, et al. 2000, as cited in Feist, et al., 2003), addressing habitat locations possessing the physical attributes associated with high salmon abundance is a logical first step (Feist, et al. 2003). The goal is to identify where there are known spawning and rearing areas, and then use that information to identify other potential sites (Feist, et al. 2003). Thus, the first step of method development is to determine where aquatic habitat historically supported, or currently supports spawning and rearing in the study area.

High salmon spawning begins with the adult spawner homing to their natal habitats. Population structure begins at spawning for all species, however, species mobility during subsequent life phases and the organization of habitats may also influence the spatial structure of the population (Martin, et al. 2004). The criteria for identifying core areas are focused on spawning because spawning is the geographic starting point for structuring populations and we have the most knowledge of this life stage (Martin, et al. 2004).

Spawning reaches were chosen as key areas based on studies in the Pacific Northwest have documented that native trout tend to remain close to their spawning areas (e.g., June 1981; Moore and Gregory 1988), implying that distribution of juvenile fish closely reflects the species spawning distribution (Montgomery, et al. 1999).

King County, with multiple partners completed a watershed assessment, including a Viable Salmon Population model to determine potential high usage areas by chinook that they labeled Core areas and Satellite areas. King County has also recently published a framework document for identifying critical habitat for salmon (Martin et al. 2004) based on known chinook spawning areas. While our method took into account the King County et al. methods, our key habitat areas focused on catchments that have the potential to support multiple salmonid species, and thus diversity, compared to focusing on one species over another.

Our approach more closely resembles methods developed by Dr. Chris May, Battelle (May and Peterson 2003) in the development of two refugia studies for Kitsap and Jefferson counties, and methods in the Ecosystem Recovery Planning for Listed Salmon: An Integrated Assessment Approach for Salmon Habitat (2003) published by the U.S. Department of Commerce National Oceanic And Atmospheric Administration National Marine Fisheries Service, in that restoring specific salmon populations is sub-ordinate to the goal of restoring the ecosystem that supports multiple salmon species.

Step 2. Identify landscape areas where restoration actions have the greatest potential for measurable environmental benefits

One of the tasks in this watershed characterization was to determine the appropriate scale to identify potential fisheries habitat resource restoration sites. Habitat areas should be classified at a relatively coarse level of resolution (e.g., estuary, main stem, overwintering habitats), because the information available for evaluating which habitats limit salmon recovery is very sparse and the certainty of answers is very low (Beechie et al. 2003). Our approach uses the condition of ecological processes at the DAU scale as a foundational component when ranking candidate sites for salmonid fish habitat potential. Key ecological processes characterized including physical processes; movement of water, wood, and sediment, and biological processes; aquatic integrity and habitat connectivity

The second criterion is based on the ecological process rank completed for the five ecological processes. Each of the five ecological processes was determined to be "Properly Functioning", "At Risk", or "Not Properly Functioning" condition. An ecological process rank of High or Moderate was assigned each DAU based on the number of ecological processes in an "At Risk" condition. We believe this approach is consistent with Beechie et al. (2003) where they note that an ecosystem approach includes analysis of landscape and habitat features to help set recovery goals, and analysis of disrupted ecosystem processes to identify watershed and aquatic restoration actions (Beechie et al. 2003). The goal of watershed characterization is to contribute to recovery planning by providing environmental benefit by offsetting impacts in areas where ecological processes can be enhanced or restored to facilitate recovery efforts of all salmonid and trout species (Federally or State listed and not listed).

Step 3. Identify DAUs having high groundwater recharge potential and resulting strong summer base flows

Note: This criteria requires an new evaluation for every watershed characterization because of the varied geology in Thurston County.

The third step involves the amount of advance and recessional outwash geology that were present in each DAU studied. A histogram of the varying amounts of each type of geology and AB soils were analyzed. Within a study in the 1-405 / SR-520 study area, there was an obvious break at 30%, and thus it was determined that DAUs with greater than 30% of the geology types would be classified as high, while less than 30% would be classified moderate.

At the landscape scale, available literature suggests that geology plays a large role in determining the suitability of a stream system to be used by salmonid species. Because of the diverse physical and biological influences on watershed processes and conditions, aspects of the regional and local geology must be understood for stream restoration or rehabilitation to be successful (Booth et al. 2003).

Glacial deposits have a wide range of physical properties. From the perspective of hydrologic processes and stream-channel response, two of these properties, permeability and consolidations are particularly important (Booth et al. 2003). Outwash deposits (both recessional and advance) compose the majority of permeable sediments found across the Puget Lowland. In contrast, consolidation is associated not with depositional environment, but with stratigraphic position (Booth et al. 2003).

Subsurface geology becomes critical where natural erosion or human disturbance has thinned, compacted, or stripped the surficial soil. Precipitation typically would result in a subsurface flow regime if the surficial soil layers were present, however when soils are removed or compacted, the runoff becomes Horton overland flow. This can lead to changes in peak discharges, sediment delivery, and water chemistry (Booth et al. 2003).

Conversely, where deep permeable deposits, such as glacial outwash are present, erosion of the surficial soils is unlikely to impose significant hydrologic changes. But if urban development covers these areas of once permeable substrate with pavement, tremendous relative increases in discharges can result (Booth, et al. 2003). In the Pacific Northwest, the fundamental hydrologic effect of urban development is the loss of water storage in the soil column (Booth 2000).

In addition to geology contributing to maintaining base flow, outwash and alluvial geology has been investigated as areas that salmon cue into to spawn. Geist and Dauble (1998) proposed that geomorphic features promotes groundwater-surface water interactions within hyporheic habitats and may play a role in spawning site selection by fall chinook in the Colombia River. Upwelling in spawning areas contained more oxygen and was composed of a higher proportion of river water than upwelling in non-spawning areas. These upwelling characteristics could provide cues that adult fall Chinook salmon used to locate preferred spawning habitats.

Berman and Quinn (1991) determined that spring chinook was found to cue in to pools and banks receiving cool water inputs. The majority of the fish were associated with islands (67%) and pools and rock outcroppings (33%) along the bank (Berman and Quinn, 1991). Although energy benefits may be derived from inhabiting thermal refugia areas, costs may also be incurred. Refuge areas supplied by groundwater or subsurface seeps may have low dissolved oxygen concentrations (Bilby 1984, as cited in Berman and Quinn). It is possible that smaller fish with decreased oxygen requirements relative to large fish could maintain themselves in a thermal refuge supplied with oxygen poor groundwater for a longer period of time. Thus, smaller fish may be able to inhabit a broader range of refuge areas.

Geist (2000) evaluated the relationship between hyporheic discharge and fall salmon spawning site selection in the Hanford Reach, an alluvial floodplain section of the Columbia River. Hyporheic discharge includes a mix of phreatic ground water and river water that discharges from the hyporheic zone into the river channel (e.g., Verier et al., 1992; Harvey and Bencala 1993; Brunke and Gonser 1997, as cited in Geist (2000). Phreatic ground water is beneath land areas and contains a significant component of dissolved solutes derived from a long residence time in the subsurface (Freeze and Cherry 1979, as cited in Geist 2000). Fall Chinook salmon spawning locations were highly correlated with hyporheic discharge that was composed of mostly river water and not phreatic ground water (Geist 2000)

Geomorphic bed features (i.e., islands, gravel bars, riffles) of alluvial rivers are able to create hydraulic gradients sufficient to direct surface water into the bed (Standford et al. 1996; Brunke and Gonser 1997, as cited in Geist 2000). The more permeable the alluvium, the more the physicochemical characteristics of the hyporheic waters will resemble surface water rather then ground water (Geist 2000).

Leman, 1993 determined the hydraulic features of a river channel and its form result in differential hydrostatic pressures in the subsurface flow whereby, in certain sites, positive pressure causes an upwelling through the substrate. It is such sites that are selected by the salmon for spawning.

Step 4. Identify sites having important habitat characteristics for salmonids

At the reach scale we ranked key habitat types that are critical habitats for one or more life stages of salmon as listed in Beechie et al. (2003). Beechie et al. (2003) defined reach-level habitat types for anadromous salmonid species in the Skagit River as either "key" or "secondary" based on literature and local studies. The following three key habitat types were rated high for providing essential habitat for multiple salmonid species; riparian <1-2% unconfined pool-riffle and forced pool riffle provide key habitat for five species, floodplains, where the floodplain had the potential to be restored to some function, can provide key habitat to four species, and open water wetlands that currently provide access to fish or had the potential to provide access to fish if restored, provide habitat for three species.

We used information cited in Beechie et al. (2003), and extrapolated their approach to streams in our study area. We assume that the distinction between large and small rivers is arbitrary since the geometry and hydraulic aspects of rivers are often similar in small shallow streams and large deep rivers (Stalnaker et al. 1989, as cited in Geist and Dauble 1998).

Step 5. Rank sites by size

Lastly, when all the criteria was applied to the current list of natural resource sites, and multiple sites met all the criteria, larger sites were prioritized over smaller sites. The result is a list of riparian, floodplain, and wetland sites that have the potential to directly or indirectly provide benefit to salmonid species.

PART IV. IDENTIFY AND ASSESS POTENTIAL SITES

Drainage Analysis Units in the study area were evaluated based on their potential to maintain natural processes, thus to promote habitat that can support aquatic species. Following a watershed characterization of the five ecological and two biological processes, DAUs were identified as “not properly functioning”, “at risk,” and “properly functioning” for each of the five ecological processes based on rules and assumptions developed in Tables 8-14.

1. Compile available results on the current condition of the five core ecological processes and two biological processes.

Data Needs

1. Characterization results for all available ecological and biological processes.

Products

1. A map that details the current state of the five ecological processes in each DAU within the study area.

2. A narrative report summarizing the current state of aquatic habitat in the study area.

Step 1. Identify Drainage Analysis Units Having “At Risk” Ecological Processes

Purpose

This step seeks to identify DAUs within the study area having ecological and biological processes that are considered “at risk” under current and future land use conditions. To maximize environmental benefit, there is growing evidence (Booth et al. 2001, Booth et al. In Press update) that mitigation efforts should target areas where ecological processes have been altered at a low to moderate level, rather than targeting “the worst first” or a random selection of mitigation sites. Further, DAUs in the “at risk” category for multiple key ecological and biological processes are assumed to provide the greatest potential to maximize environmental benefits when restored.

Methods

All results from the characterization of ecological and biological processes should be used in the creation of an ecological process score and rank. The following processes will be used in characterizing landscape condition:

- Delivery and Routing of Water
- Delivery of Sediment
- Delivery of Pollutants

- Delivery and Routing of Large Wood
- Delivery and Routing of Heat
- Aquatic Integrity
- Habitat Connectivity

1. Using the condition rank assigned to the DAU in which a potential mitigation site occurs, identify which ecological and biological processes are considered “At Risk”. Use the local planning theme identified earlier to identify a single ecological or biological process as the local recovery priority. Then weight ecological and biological processes based on the following criteria:

In the Henderson Inlet characterization, the following weighting criteria were used.

Table 18. Weighted criteria to rank DAUs.

Ecological / Biological Process in “At Risk” Condition	Score Weight	Total Score
Movement of Water	1 X 3	3
Local Theme – Movement of Pollutants	1 X 2	2
Movement of Large Wood	1 X 1	1
Movement of Heat	1 X 1	1
Movement of Sediment	1 X 1	1
Aquatic Integrity	1 X 1	1
Upland Habitat Connectivity	1 X 1	1
Maximum score for a DAU when all processes are “at risk”		**10**

Note: based on potential to contribute ecological and biological benefits at landscape scales when five ecological and biological processes were characterized.

To calculate the ecological/biological process score follow these rules:

Score one point for each ecological/biological process that is in an “At Risk” condition,
If water is “At Risk” add two additional points; and
If the local theme is “At Risk” add one additional point
Final process score is the sum of scores from 1-7, above.

All DAUs are assigned an ecological process score. This score is then used to develop an ecological process rank using technical team best professional judgment. Under this scenario, a final process rank was established using the conversion shown in Table 19.

Table 19. Convert Ecological Process Score to Ecological Process Rank

Ecological/Biological Process Score	Ecological/Biological Process Rank
7, 8, 9, 10 points	High
3, 4, 5, or 6 points	Moderate
0, 1, or 2 points	Low

Following the ranking of each DAU, all potential sites are given an environmental benefit ranking score to be evaluated within each DAU. Calculate an environmental benefit score and rank for each potential wetland, floodplain, and riparian restoration site using Table 20, Table 21, and Table 22, respectively. The environmental benefit score is used to establish environmental benefit ranks of high, moderate, and low.

Table 20. Potential Wetland Restoration Site Environmental Benefits Ranking Criteria

Scoring Criteria	Points	Rationale
Site has restoration potential and:		
1) Site has extensive hydrologic alteration (Hydro_alt = 2) (If criteria for #1 are met, skip #2)	3	Loss of hydrology can mean the total conversion of the site from wetland to upland. Sites with extensive hydrologic alteration have the greatest potential to restore many of the recognized wetland functions. Restoring hydrologic alteration results in added flood storage desynchronization and flow control, as well as other functions specific to the site.
2) Site has some hydrologic alteration (Hydro_alt = 1)	2	Sites with some hydrologic alteration still function as a wetland, at some level. Mitigation credits are gained for only the functions restored, not maintained. Restoring natural hydrology results in an increase in flood storage /flow control function.
3) Site has extensive vegetation alteration (Veg_alt = 2) (If criteria for #3 are met, skip #4)	2	Sites with extensive forest clearing have potential to restore some flood storage/flow control, water quality, temperature maintenance, and organic export functions.
4) Site has experienced some vegetation alteration (Veg_alt = 1)	1	Sites with some forest clearing have potential to re-store that portion of the flood storage / flow control, water quality, temperature maintenance, and organic export functions affected by forest clearing.

5) More than 50 percent of site has Hydric Code A or B soils	1	Site has increased potential for provide groundwater recharge function.
6) Site is has surface hydrology connection to river/stream Sw_connect = y	1, 2, or 3	Improves site's ability to provide impacted functions and priorities from City Comprehensive Plans. One point if site has surface water connection, 2 points for regular surface water flooding, and 1 additional point if the site's stream reach supports fish species.
7) > More than 33 percent of site on Orcas peat, Seattle muck, Shalcar muck, or Tukwila muck	1	Site has bog or fen characteristics that make it a unique wetland type.
Ranking Criteria:	**Maximum Score**	
Environmental Benefit Criteria	13	

Table 21. Potential Riparian Restoration Site Environmental Benefits Ranking Criteria

Scoring Criteria	Points	Rationale
Site has restoration potential <u>and</u>:		
1) Site reconnects two large forest patches (If criteria for #1 are met, skip #2) Mend_forest = y	2	Maximizes potential to reduce habitat fragmentation/increase connectivity.
2) Site adds to an existing forest patch Add_forest = y	1	Has potential to reduce habitat fragmentation/increase connectivity.
3) Site has 67 meter buffer cleared to stream (If criteria for #3 are met, skip #4, 5, and 6) CTS = 3	3	Reforestation of 67 meter buffer has potential to provide maximum temperature attenuation, water quality treatment, fish habitat value, and wood recruitment.
4) More than 50 percent of site has Hydrologic Code C or D soils	1	The recharge potential of outwash soils precludes substantial increase in flow control if the site is reforested. Riparian reforestation on till or bedrock areas are assumed to provide greater flow control potential.
Ranking Criteria:	**Maximum Score**	
Environmental Benefit Criteria	7	

Table 22. Potential Floodplain Restoration Site Environmental Benefits Ranking Criteria

Scoring Criteria	Points	Rationale
1) Site is decoupled from floodplain Decoupled = y	3	Sites having lost connectivity to the floodplain provide maximum potential for the recovery of floodplain functions.
2) Site has riparian restoration potential Rip_pot = y	1	Sites that can restore riparian areas have potential to provide flow control and improve floodplain function.
3) Site hydrologically reconnects two large floodplain patches (If criterion for #3 are met, skip #4) Mend_fdpln = y	2	Reestablishes floodplain hydrologic connectivity.
4) Site adds to an existing floodplain patch Confined = n	1	Adds to floodplain hydrologic connectivity.
5) Site has wetland restoration potential Potwet = y and Hydro_alt = 1 or 2	1	Sites that can also restore wetland areas have potential to improve floodplain function.
6) Channel migration potential Chnmig_pot = y	2	Sites with channel migration potential have greater potential to restore and maintain diverse floodplain functions.
Ranking Criteria:	**Maximum Score**	
Environmental Benefit Criteria	10	

Table 23. Potential Fish Habitat Environmental Benefits Ranking Criteria

Scoring Criteria	Points	Rationale
Site has restoration potential <u>and</u>:		
1) Number of species spawning or rearing in the DAU 3 or more species = 2 1-2 species = 1 Zero species = 0 USE-TYPE = 2 or 3 in Washington Lakes and Rivers Information System (WLRIS) database	2	Habitat occupied by multiple salmonid species is assumed to have higher environmental benefit than areas with fewer species. Known spawning areas are key habitat areas that provide one or more critical life stages for salmonid species. Studies in the Pacific Northwest (PNW) have documented that native trout remain close to their spawning areas (Moore and Gregory 1988), implying that distribution of juvenile fish closely reflects the species spawning distribution (Montgomery et al. 1999).
2) DAUs that have high groundwater recharge potential	1	Outwash geology provide essential phreatic and hyporheic functions that salmonid species rely on to provide spawning habitat and maintenance of summer baseflow (Booth et al. 2003)

>30% advance and recessional outwash = 1 <30% advance and recessional outwash = 0		
3) Identify sites having important habitat characteristics for salmonids Riparian reaches having 0-2% stream gradient unconfined channel and <1% moderately confined channel Gradient = 0-2% = 1 Gradient >2% = 0 Confin = unconfined or moderate = 1 Confin = confined = 0	2	<2% unconfined channels are key habitat to five species of salmonid species
Floodplain sites with ChanMigPot = y = 1 ChanMigPot = n = 0	1	Floodplains (0-1%) are key habitat to four salmonid species
Wetland restoration sites with fish access and potential for open water (Fish_acces = 1 and DF, Rl and RF) = 1 All other sites = 0	1	Wetlands - fish access and potential for Open water ponds are key habitat for three salmonid species (Beechie et al. 2003; Pess et al. 2002)
4) Rank sites by size		Final rank to separate sites with identical habitat value
Ranking Criteria:	**Maximum Score**	
Environmental Benefit Criteria	7	

Table 24. Potential Stormwater Retrofit Site Environmental Benefits Ranking Criteria

Scoring Criteria	Points	Rationale
1) More than 50 percent of site on SCS Hydro A or B soils >50% A or B soils = y	1	Infiltration contributes to stream base flow and hyporheic exchange.
2) More than 50 percent "Qgos, Qgo, Qga, Qa" surficial geology	2	Infiltration contributes to stream base flow and hyporheic exchange.
3) Site has the ability to divert stormwater from existing stormwater infrastructure Stormwater infrastructure within 300 feet of site	1	Breaking conveyance where possible will improve water quality and recharge groundwater supplies
4) Site avoids habitat with high potential to support anadromous fish. Fish habitat environmental benefit ranking No connect = 3 L = 2	2	Stormwater conveys many chemical constituents that are harmful to fish and high volumes can cause erosion to the streambanks, thus the goal is to avoid high quality fish habitat.

M = 1		
5) Stormwater retrofit area is on or adjacent to public lands	1	Site has increased potential for cost savings.
Ranking Criteria:	**Maximum Score**	
Environmental Benefit Criteria - #1 - #5	7	

Sites having an environmental benefit rank of low are removed from further consideration. Starting with the sites having an ecological process rank of high, subdivide these sites into two groups. Group one has an ecological process rank of high and an environmental benefit rank of high. All sites in group one rank above sites in group two, which have an ecological process rank of high and an environmental benefit rank of moderate. This same sorting process is done again for sites with an ecological process rank of moderate, and then again for sites with an ecological process rank of low.

3. Within sites occurring having a common ecological process rank and a like environmental benefit rank, sort each common group by resource in this order: floodplains, wetlands, riparian, stormwater retrofit.

4. Within each common group established in Step #3, order by each sites rank score for contributing to wildlife mobility. Ranks sites scoring 3 above sites having a score of 2, and so on.

5. Within each common group established in Step #4, order all local priority sites ahead of non-local priorities.

6. Within each common group established in Step #5, order all sites on or adjacent to public lands ahead of those not adjacent to public lands.

7. Within each category established in Step #6, order by size, largest area first. Delete sites less than 3.0 acres in size.

Stormwater Priority Ranking Criteria

All Steps for natural resource ranking except #2

Priority ranking criteria for stormwater flow control uses the identical 7-step process described above with one major exception. That exception relates to Step #2 and the use of a proximity score to help meet regulatory stormwater requirements. Step #2 below replaces that step in the natural resource mitigation criteria with specific stormwater criteria to prioritize stormwater flow control sites.

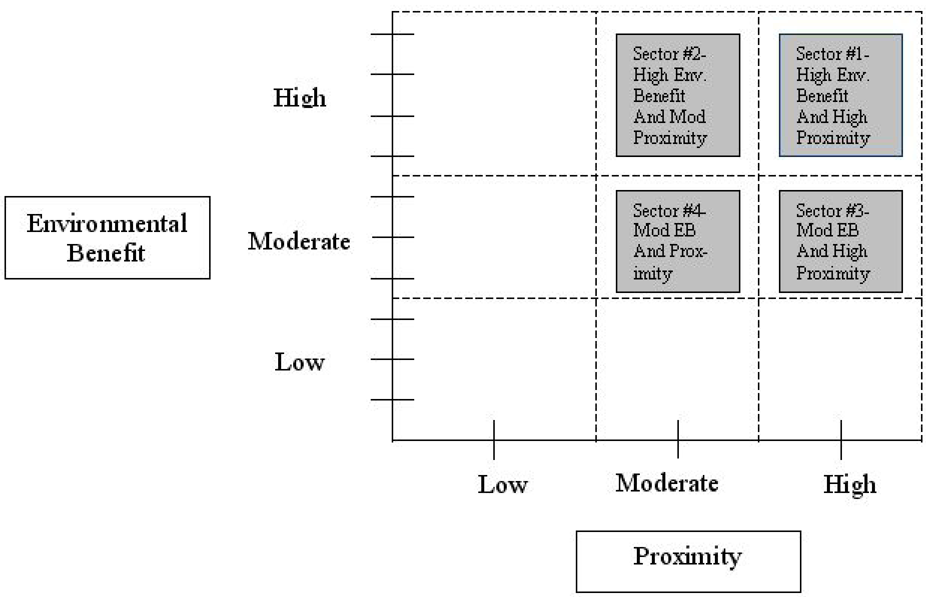
Step #2 for Stormwater Retrofit Site Ranking

Chart potential sites by proximity and environmental benefit rank and establish a sector score for each site, as shown in Figure 2. Then order potential mitigation sites within each process rank, by sector rank.

Establish a priority rank for each site based on the site's upslope distance from the project area (Tables 20 to 23). Establish a sector score for each site using proximity rank and environmental benefit rank and ordering according to Figure 2.

Starting with the sites having an ecological process rank of high, subdivide these sites into four groups based on sector score. All sites with a high ecological process rank and a sector score of 1 are ranked above those with a sector score of 2, and so on. Repeat this same sorting process with sites having an ecological process rank of moderate and then with sites having an ecological process rank of low.

Figure 2. Sector Score for Stormwater Mitigation Sites



Note: Based on Potential Environmental Benefits and Site Proximity to Development Area.

Within each category established in Step #5, order all sites on or adjacent to public lands ahead of those sites that are not on or adjacent.

Step 2. Identify Drainage Analysis Units Having the Greatest Potential to Maintain Function in the Long-term

Purpose

This step identifies DAUs that have the greatest potential to maintain and potentially improve target ecological processes over the long-term. Too often, mitigation sites are selected for their ability to provide needed functions under existing conditions at the site. If substantial growth or development is planned for the surrounding landscape, some functions may not be maintained, leading to environmental degradation. By considering both current and anticipated future land use pressure on each potential mitigation site, managers have the greatest potential to select sites providing functions capable of being maintained in the future. NOTE: This is a future task following the outcome of any future zoning changes.

Methods

1. Identify "at risk" DAUs for target ecological processes developed. .

2. Develop a table that compares current and future land use/land cover.

3. Assess the effects of change in land use intensity on ecological processes through the threshold criteria established in the matrix of landscape pathways and indicators. One important effect of a change in land cover relates to percent TIA used in the characterization of the delivery of water. Identify DAUs in which percent TIA changes from a "properly functioning" condition under current conditions to "at risk" under future build-out conditions and DAUs that change for an "at risk" condition under current conditions to "not properly functioning" under future build-out conditions. Determine the effect of this change on the overall rank condition for the delivery of water. Identify the DAUs in which a change in the condition rank for percent TIA results in a change in the delivery of water from "properly functioning" to "at risk." Under this situation, consider all potential mitigation sites within these DAUs as "at risk" and revise the ecological condition rank accordingly. Likewise, identify the DAUs in which a change is indicated in the condition rank from an "at risk" condition under current conditions to "not properly functioning" under future build-out condition. Under this situation, consider all potential mitigation sites within these DAUs as "not properly functioning" and revise the ecological condition rank accordingly.

Data Needs

1. Data on the condition of target ecological processes within DAUs under both current and future land use conditions.
2. Current and future land use/land cover layers.

Products

1. A GIS coverage of DAUs in the "at risk" condition for ecological and biological processes under both current and future land use conditions.
2. Revised potential floodplain, wetland, and riparian restoration site databases with the condition rank of all ecological and biological processes assigned to the DAU in which the site resides.

REFERENCES

Angermeier, P. L. and I. Schlosser. 1995. Conserving aquatic biodiversity: beyond species and populations. In: Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation. Nielsen, J. L. (ed.) American Fisheries Society Symposium 17:402-414

Azous, Amanda L. and R.R. Horner. 1997. Wetlands and Urbanization; Implications for the Future. Washington Department of Ecology, King County Land and Water Resources Division, and the Univ. of Washington, Seattle.

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries 24(4):6-24.

Beechie, T.J., E.A. Steel, P. Roni, and E. Quimby (editors). 2003. Ecosystem recovery planning for listed salmon: an integrated assessment approach for salmon habitat. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-58, 183 p.

Berman, C.H., and T.P. Quinn. 1991. Behavioral thermoregulation and homing by spring chinook salmon, Oncorhynchus tshawytscha (Walbaum), in the Yakima River. Journal of Fish Biology 39:301-312.

Booth, D.B., 2000. Forest Cover, Impervious Surface area, and Mitigation of Urbanizing Impacts in King County, Washington.

Booth, D.B. Urbanization and the Natural drainage system – Impacts, Solutions, and Prognoses. 1991. The Northwest Environmental Journal, 7:93-118. University of Washington, Seattle, Washington 98195

Booth and Jackson. 1997. "Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and Limits of Migration," *Journal of the American Water Resources Association*, Vol. 33, No. 5, pp. 1077-1089.

Booth, D. B., J. R. Karr, S. Schauman, C. P. Konrad, S. A. Morley, M. G. Larson, P. C. Henshaw, E. J. Nelson, and S. J. Burges. 2001. Urban stream rehabilitation in the Pacific Northwest. Final Report of EPA Grant Number R82-5284-010. University of Washington.

Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. In Press. Reviving Urban Streams: Land Use, Hydrology, Biology, and Human Behavior. Journal of the American Water Resources Association.

Booth, D.B., R.A. Haugerud, and K.G. Troost, 2003. Geology, Watersheds, and Puget Lowland Rivers: chapter in D. Montgomery, S. Bolton, and D.B. Booth, eds., Restoration of Puget Sound Rivers: University of Washington Press.

Brinson, M. M. 1993. A Hydrogeomorphic Classification for Wetlands. Wetlands Research Program Technical Report WRP-DE-4. U.S. Army Corps of Engineers, Springfield, VA.

Center for Watershed Protection. 1997. National Pollutant Removal Performance Database for Stormwater Best Management Practices. For the Chesapeake Research Consortium.

Dinicola, R. S. 2001. Validation of a Numerical Modeling Method for Simulating Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey Water Supply Paper 2495.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. Entering the watershed, a new approach to save America's river ecosystems. The Pacific Rivers Council. Island Press. 462 pp.

Ebersole, J. L., W. Liss, and C. Frissell. 1997. Restoration of stream habitats in the Western United States: restoration as re-expression of habitat capacity. Environmental Management 21(1):1-14

Euphrat, F. D. and B. P. Warkentin. 1994. A watershed assessment primer. US Environmental Protection Agency 910/B-94/005. EPA Region X, Seattle, WA.

Feist, B.E., E.A. Steel, G.R. Pess, and R.E. Bilby. 2003. The influence of scale on salmon habitat restoration priorities. Animal Conservation. The Zoological Society of London, United Kingdom. 6:271-282.

Frissell, C. A. 1996. A new strategy for watershed restoration and recovery of Pacific salmon in the Pacific Northwest. In: Watershed and Salmon Habitat Restoration Projects: Guidelines for Managers of State Trust Lands. Dominguez, L. (ed.). Washington Department of Natural Resources. Olympia, WA 90 pp.

Frissell, C. and B. Doppelt. 1996. A new strategy for watershed protection, restoration and recovery of wild native fish in the Pacific Northwest. In: Healing the Watershed, a guide to the restoration of watersheds and native fish in the West. Pacific Rivers Council, Inc. 212 pp.

Geist, D.R., and D.D. Dauble. 1998. Redd site selection and spawning habitat use by fall chinook salmon: the importance of geomorphic features in large rivers. Environmental Management 22:655-669.

Geist, D.R., 2000. Hyporheic discharge of river water into fall Chinook salmon (Oncorhynchus tshawytscha) spawning areas in the Hanford Reach, Columbia River. Can. J. Fish. Aquatic Sci. 57: 1647-1656 (2000).

Gersib, R. 2001. Characterizing wetland restoration potential at a river basin scale, Nooksack River Basin, Washington State. Draft Report. Washington State Department of Ecology.

Gersib, R., L. Wildrick, C. Freeland, S. Grigsby, K. Bauersfeld, S. Butkus, R. Coots, and J. Franklin. 1999. Process-based river basin characterization: a case study Snohomish Basin, Washington. Washington State Department of Ecology. Olympia, WA.

Gersib, Richard. 1997. Restoring Wetlands at a River Basin Scale - A Guide for Washington's Puget Sound. Operational Draft. Washington State Department of Ecology.

Hill, K., E. Botsford, and D. B. Booth. 2003. A rapid land cover classification method for use in urban watershed analysis. University of Washington Department of Civil and Environ-mental Engineering, Water Resources Series Technical Report No. 173. http://depts.washington.edu/cwws/Research/Reports/landcover03.pdf

Hyatt, T. L., T. Z. Waldo and T. J. Beechie. 2004. A watershed scale assessment of riparian forests, with implications for restoration. Restoration Ecology 12:175-183.

Karr, J. R. 1995. Clean water is not enough. Illahee 11(1-2):51-59.

Karr, J. R. and D. R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 5: 55-68.

Martin, D., L. Benda, and D. Shreffler. 2004. Core Areas: Habitats that Functionally Control the Spatial Structure of Salmon Populations. King County, Department of Natural Resources and Parks, Water and Land Resources Division, Science Section. Project No. T01426T.

Leman, V.N. 1993. Spawning sites of chum salmon, Oncorhynchus keta: Microhydrological regime and viability of progeny of redds (Kamchatka River Basin). Journal of Ichthyology 33:101-117.

May, C. and G. Peterson, 2003. East Jefferson County Salmonid Refugia Report

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html

Montgomery, D. R. 1995. Input- and out-oriented approaches to implementing ecosystem management. Environmental Management 19(2):183-188.

Montgomery, D. R., G. Grant, and K. Sullivan. 1995. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin 31(3):369-386.

Montgomery, D. R., Pess, G., Beamer, E. M., and Quinn, T. P., 1998. Channel type and salmonid spawning distributions and abundance, Canadian Journal of Fisheries and Aquatic Sciences, v. 56, p. 377-387, 1999.

Montgomery, D.R. 1999. Process Domains and the River Continuum. Journal of the American Water Resources Association. Vol. 35, No. 2, 397-410.

Naiman, F. J., T. Beechie, L. Benda, D. Berg, P. Bisson, L. MacDonald, M. O'Connor, P. Olson, and E. Steel. 1992. Fundamental elements of ecological healthy watersheds in the Pacific Northwest coastal ecosystems. In: Naiman (ed.) Watershed Management, Springer-Verlag, p. 127-188.

National Marine Fisheries Service [NOAA-Fisheries]. 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. Environmental and Technical Services Division, Habitat Conservation Branch. 28 pp.

National Research Council. 1992. Restoration of aquatic ecosystems. National Academy Press, Washington, D. C.

National Research Council. 1999. New strategies for America's watersheds. National Academy Press. Washington, D. C.

NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region.

Omernik, J. M. 1995. Ecoregions: a spatial framework for environmental management. In: W. S. Davis and T. P. Simon (eds.) Biological Assessment and Criteria, Tools for Water Re-source planning and Decision Making. Lewis Publishers.

Pess, G.R., D.R. Montgomery, E.A. Steel, R.E. Bilby, B.E. Fiest, and H.M. Greenberg. 2002. Landscape Characteristics, land use, and coho salmon (Oncorhynchus kisutch) abundance, Snohomish River, Wash., U.S.A. Can. J. Fish. Aquat. Sci. 59:613-623

Reeves, G. H., L. Benda, K. Burnett, P. Bisson, and J. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. In: Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation. Nielsen, J. L. (ed.). American Fisheries Society Symposium 17:334-349.

Reid, L. M. 1993. Research and cumulative watershed effects. USDA Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-141. 118 pp.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22:1-20.

Snyder, C.D., J.A. Young, R. Villella, and D.P. Lemarie. 2003. Influences of upland and riparian land use patterns on stream biotic integrity. Landscape Ecology 18:647-664.

Stelle, Jr. W. 1996. National Marine Fisheries Service letter dated September 4, 1996. Subject: Implementation of "Matrix of Pathways and Indicators" for evaluating the effects of human activities on anadromous salmonid habitat.

Strecker, E., B. Wu, and M. Iannelli. 1997. Analysis of Oregon Urban Runoff Water Quality Data Collected from 1990 to 1996. Prepared for The Oregon Association of Clean Water Agencies by Woodward-Clyde Consultants.

Sweeney, B. W., T. L. Bott, J. K. Jackson, L. A. Kaplan, J. D. Newbold, L. J. Standley, W. C. Hession, and R. J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the national*

Academy of Sciences of the Unites States of America (PNAS) 101(39): 14132-14137. Available at: http://www.pnas.org/cgi/doi/10.1073/pnas.0405895101

US Fish and Wildlife Service. 1998. A framework to assist in making endangered species act determinations of effects for individual or grouped actions at the bull trout subpopulation at a watershed scale.

Vaccaro, J.J., A.J. Hansen, Jr., and M.A. Jones, 1998. Hydrogeologic Framework of the Puget Sound Aquifer System, Washington and British Columbia. US Geological Survey Professional Paper 1424-D.

Washington State Department of Ecology. 1993. Washington State Wetlands Rating System, Western Washington (second edition). Washington State Department of Ecology. Publication #93-74.

Washington State Department of Ecology. 2003. Environmental Information Management System, On-line searchable database.

Washington State Department of Fish and Wildlife. 1991. Washington Department of Wildlife. *Management Recommendations for Washington's Priority Habitats and Species*. Wildlife Management, Fish Management, and Habitat Management Divisions. Olympia, Washington.

Washington State Department of Fish and Wildlife. 2001. *Priority Habitats and Species Database*. July 18, 2001. 2 pg + maps.

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[i] Narrative criteria for indicator condition taken from US Fish and Wildlife Service (1998), numeric criteria added by authors

[ii] Revised 8/04 based on Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. In Press. Reviving Urban Streams: Land Use, Hydrology, Biology, and Human Behavior. Journal of the American Water Resources Association. Further rationale presented in Appendix XX

[iii] NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region

[iv] NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region

[v] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998), numeric criteria added by authors

[vi] Narrative and numeric criteria for indicator condition taken from NOAA-Fisheries (1996)

[vii] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998), numeric criteria added by authors

[viii] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998)

[ix] NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[x] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[xi] NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[xii] Based on common criteria established by NOAA-Fisheries (1996) and the U.S. Fish and Wildlife Service (1998) for chemical contamination/nutrients

[xiii] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[xiv] Narrative and numeric criteria for indicator condition taken from Stelle (1996)

[xv] Revised 8/04 to better reflect findings in Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. In Press. Reviving Urban Streams: Land Use, Hydrology, Biology, and Human Behavior. Journal of the American Water Resources Association

[xvi] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region