WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Mt. Baker-Snoqualmie National Forest, Upper White Watershed Sediment and Temperature TMDL for Aquatic Habitat

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Submittal Report

June 2003
Publication No. 03-10-032

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Prepared by:

Gary Ketcheson, USFS
Peter Leinenbach, EPA
Joanne Schuett-Hames, Ecology
Tony Whiley, Ecology
Cindy James, Ecology

June 2003
Publication No. 03-10-032

For additional copies of this document contact:

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Acknowledgements

We wish to thank:

Technical workgroup members: David Adams (Tahoma Audubon), John Coulthard (Pierce Conservation District), Roy Huberd (Pierce County), Tom Kantz (Pierce County), Russ Ladley (Puyallup Fisheries), Don Nauer (WDFW), Tyler Patterson (USFS), and David Renstrom (Pierce County).

Lorraine Edmond (EPA) for a much appreciated liaison role between Ecology and EPA for this TMDL, and for assistance determining how to take conceptual approaches and apply them within a TMDL context.

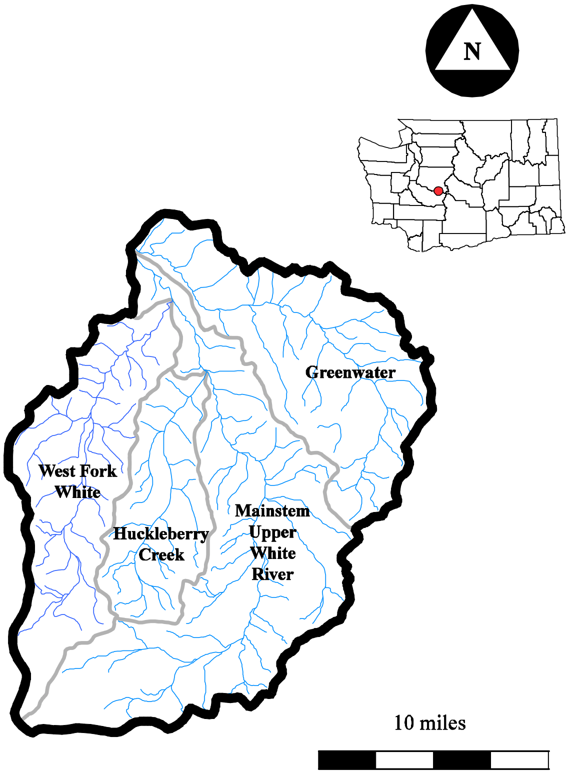
Ron McBride for consultation and draft and final document production, Ann Kahler for formatting assistance, Jeanna Ridner and Nancy Lowe for administrative assistance, Roberta Woods for document review, and Greg Pelletier for technical consultation (all Ecology).

The Puyallup Watershed Council for assistance with public meeting notification, and for hosting the initial public meeting.

Geoff Poole (EPA), Dick Gersib (formerly Ecology), and Chris Peredney (Ecology) for early contributions to the TMDL.

Executive Summary

The Upper White River watershed is an area of primarily forested, mountainous terrain within the Puyallup Basin (WRIA 10). Its headwaters flow from the north side of Mount Rainier bringing glacial characteristics to the mainstem White River and the West Fork White River. In contrast, two major tributaries within this TMDL area, the Greenwater River and Huckleberry Creek, are non-glacial. The study area for the TMDL is shown below.



This watershed is a rich and diverse area for aquatic species. However, past management practices have affected riparian zone function, amounts of sediment delivered to streams, and amounts of water delivered during peak discharge events to the Greenwater River. These watershed process changes have caused stream temperature, sediment, and habitat impairments to streams within the Upper White watershed. The importance of rectifying these impairments is highlighted by the presence and needs of two ESA listed species, White River spring chinook and bull trout, as well as for native steelhead which have recently undergone a severe population decline.

Temperature, sediment and habitat impairments have been identified broadly across this watershed. Consequently, the TMDL assessment work focused on obtaining a better understanding of changes to watershed processes related to sediment production and to heat energy that is delivered to streams. Based on the studies, sediment loads from management activities, and effective shade loads have been developed to guide management and restoration activities within the watershed. The table below indicates the implementation approach for achieving the load allocations based on land ownership. In particular, USFS lands comprise 86% of the managed lands (including private residential areas) within the watershed. As a result, following approval of this TMDL by EPA, a next step will be the development of a detailed water quality restoration plan by the USFS. Appendix A contains additional implementation information.

Land ownership and application of sediment and temperature load allocations.

Ownership	Implementation
USFS	Water Quality Restoration Plan within One Year
Mount Rainier National Park	Existing Measures
Private Forest Lands	Forest and Fish Agreement
Private Residences	Voluntary Measures

I. Introduction

1.1 TMDL Overview – The Clean Water Act and Total Maximum Daily Load Studies

The federal Clean Water Act (CWA) requires each state to establish water quality standards to protect, restore, and preserve water quality. These standards have been set to protect designated uses such as drinking water supplies or cold water habitat critical to the survival of certain organisms. Criteria, usually numeric, are used as a gage to achieve those uses. When a lake, river, or stream fails to meet water quality standards after application of technology-based pollution controls, Section 303(d) of the CWA requires that states include it on a list of impaired water bodies and prepare an analysis called a total maximum daily load (TMDL). The United States Environmental Protection Agency (EPA) has established regulations (40 CFR 130) and developed guidance for establishing water clean up plans (EPA 1991).

A water cleanup plan (TMDL) includes a quantitative assessment of the extent of the water quality problem(s), identifying pollutant sources and, ultimately leads to the implementation of corrective measures so that the water body will eventually attain designated water quality standards.

Through the TMDL process, a loading capacity (the maximum amount of a given pollutant that can be discharged to a water body and still meet water quality standards), is determined. That load capacity is allocated among the various sources responsible for the pollution problem. If the pollutant originates from a discrete source (point source) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If the pollutant originates from a diffuse source (nonpoint source) such as sediment from a forest road, that source's share is called a load allocation.

The TMDL analysis must also consider seasonal variations in pollutant concentrations and include a margin of safety that takes into account uncertainty about the causes of the water quality problem or a water body's specific loading capacity.

This TMDL is being prepared in accordance with the requirements of a number of laws, regulations, and guidance documents. For example: federal law, Section 303(d) of the Clean Water Act (CWA); 40 CFR Parts 130-131; Guidance for Water Quality-based Decisions: The TMDL Process, EPA document 440/91-001, April 1991; and, Memorandum of Agreement between The USEPA and Washington State DOE regarding The Implementation of Section 303(d) of the Federal CWA, October 1997.

1.2 Statement of Problem (scope of the TMDL study: Temperature and Sediment)

This TMDL covers the Upper White River watershed. For the purposes of this TMDL we identify the beginning of this watershed as the confluence of the Greenwater River with the White River. It includes the major tributary subwatersheds of the Greenwater River, West Fork White and Huckleberry Creek.

This TMDL study specifically addresses chronically elevated water temperatures observed in the lower and mid-reaches of the Greenwater River. Water temperature has been observed to exceed the state water quality standard at several monitoring locations on the Greenwater River (river mile 2.2, 8.5, and 11.0), which led to its inclusion on Washington's 1996 and 1998 303(d) lists (water body identification number WA-10-1046). The state temperature standard that applies to the Greenwater River, a Class AA water, is 16 C (60.8 F).

In addition, recent water quality monitoring covering temperature, sediment, and habitat within the Upper White River watershed indicates that the introduction of elevated levels of sediments to specific reaches within the Upper White River watershed has resulted in physical impairments to aquatic habitat and increased vulnerability to heating. State standards that apply to the Upper White River watershed include narrative standards for beneficial use of wildlife habitat, and for protection from deleterious substances. Based on this, the TMDL study included sediment within its scope. The TMDL addresses the watershed processes responsible for temperature and sediment impairments throughout the Upper White watershed. As such, this TMDL will also provide for the restoration of aquatic habitat forming processes, and therefore habitat impairments as well.

1.3 TMDL Goals and Objectives

The TMDL goal is: "To protect and restore stream habitat forming processes; and by doing this, to support the health of biological communities."

This goal will be achieved through the following objectives:

1. By identifying and assessing the core processes operating in the watershed that maintain and restore native biological communities and general aquatic health;

2. By developing an implementation plan for watershed protection and restoration, and;

3. By developing an effectiveness monitoring strategy.

This report fulfills objective #1. The included Summary Implementation Strategy (SIS, Appendix A) will be used as guidance for fulfilling objectives #2 and #3. As described in the SIS, the USFS will develop a detailed implementation plan ("Water Quality Restoration Plan") for Forest Service lands within one year of EPA approval for this

TMDL. Private lands, (these comprise 8% of the watershed) are covered by the TMDL load allocation as well. Protection and restoration measures for these lands are through state Forest Practice Regulation (WAC 222) for forest management, and are voluntary for private residences. Further description is included in the SIS.

1.4 National Forest System Lands Management Framework

Forest plans are required by the National Forest Management Act (NFMA) for each National Forest. These plans establish land allocations, goals and objectives, and standards and guidelines used by land managers, other government agencies, private organizations, and individuals. Figure 1.1 shows the land ownership categories and the land allocations for USFS lands within the Upper White River watershed.

The 1990 Mt. Baker-Snoqualmie National Forest Land and Resource Management Plan (MBS Forest Plan), as amended by the 1994 NW Forest Plan ROD, provides management direction for this National Forest. The Forest Plan allocates approximately 72% of Forest Service land within the Upper White River watershed to Late-Successional Reserve (LSR). When combined with the wilderness designation, 89% of the Upper White River is managed for LSR habitat. In addition, all streams are covered by the Riparian Reserves component of the Aquatic Conservation Strategy (ACS). Existing levels of protection afforded by these designations have been incorporated into the TMDL technical assessment, and the SIS. Details on Forest Service land management allocations are provided below.

1.4.1 Management Allocations

Late –Successional Reserves

The management objective for LSR is to protect and enhance conditions of late-forest ecosystems, which serve as habitat for late-successional and old-growth species. Limited forest stand management is permitted, subject to review by the Regional Ecosystem Office.

Management Area 8E Greenwater Special Area

The Huckleberry Land Exchange (USDA Forest Service 2001) created a new land allocation for elk habitat. Up to 2340 acres within the Greenwater River that the Forest Service acquired in the land exchange would be evaluated to provide elk forage. Management would include the creation/maintenance of openings, the majority of which would be 15 acres or less in size. Approximately 1600 to 1700 acres within the inventoried elk winter range, plus 640 acres in elk summer range would be managed in

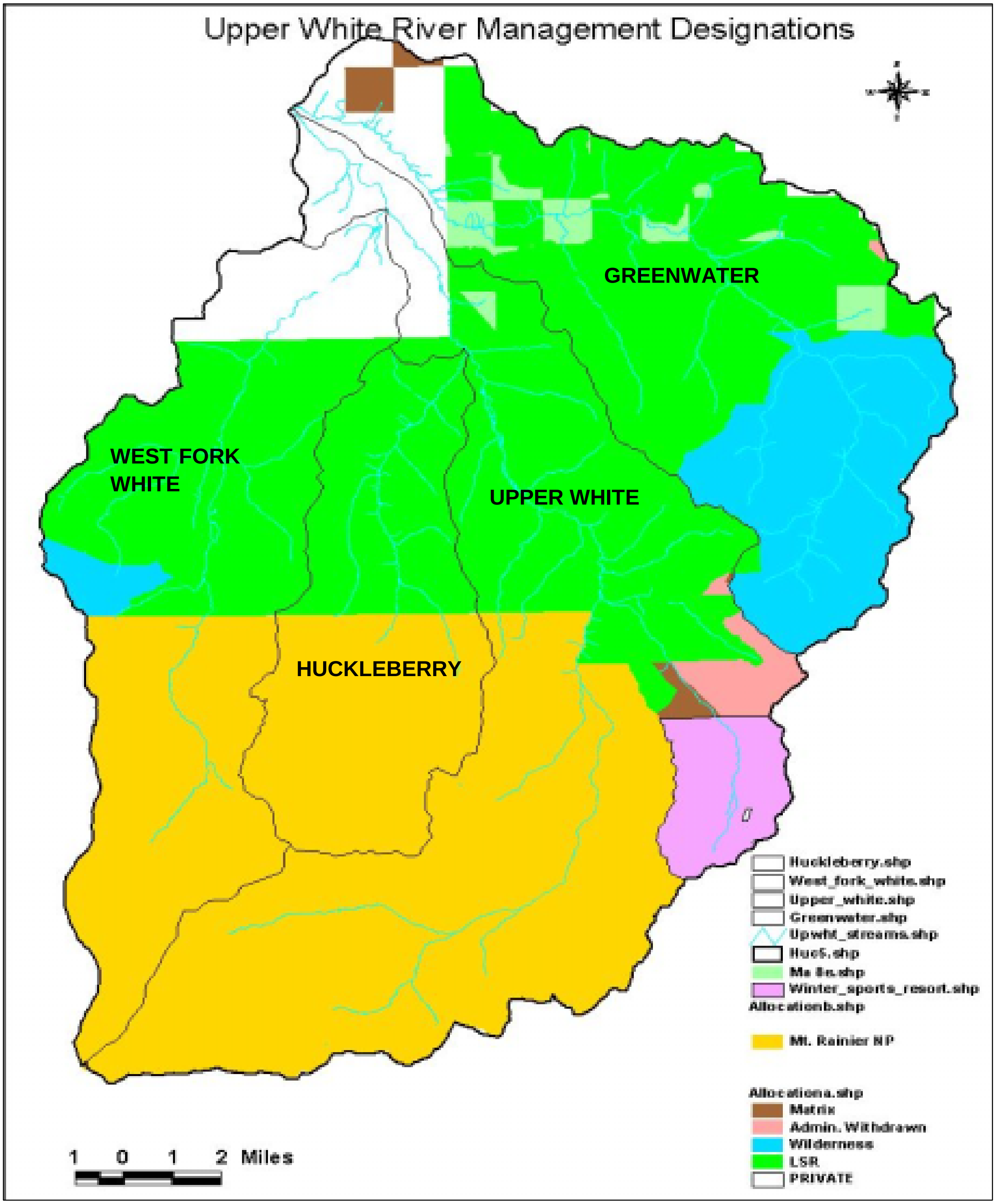


Figure 1.1. Land ownership and USFS land allocations within the Upper White River watershed.

this way. The goal is a no net loss of forage habitat while being consistent with all other laws and regulations.

Forage openings will avoid suitable nesting habitat for the northern spotted owl and marbled murrelet, unstable slopes, and Riparian Reserves. The Final Supplemental EIS estimates that up to 400 to 500 acres in elk winter range and 100 to 130 acres in summer range can be maintained as forage openings. Areas of Management Area 8E outside of the forage openings will be managed as late-successional forest. Site–specific environmental analyses are required prior to creation of any forage openings. These analyses will evaluate compliance with the Forest Plan standards and guidelines for Riparian Reserves, CWA and ESA.

Riparian Reserves

The NW Forest Plan ROD established Riparian Reserves for streams, wetlands, ponds, lakes, and unstable or potentially unstable areas on NFS lands. Riparian Reserves overlay all other management areas, and the Riparian Reserve standards and guidelines apply wherever Riparian Reserves occur (including designated Wilderness and Late Successional Reserves).

Riparian Reserves include those portions of a watershed directly coupled to streams and rivers, that is, the portions of a watershed required for maintaining hydrologic, geomorphic, and ecologic processes that directly affect standing and flowing waterbodies such as lakes and ponds, wetlands, streams, stream processes, and fish habitats. Riparian Reserves include areas designated in current plans and draft plan preferred alternatives as riparian management areas or streamside management zones and primary source areas for wood and sediment such as unstable and potentially unstable areas in headwater areas and along streams. Riparian Reserves occur at the margins of standing and flowing water, intermittent stream channels and ephemeral ponds and wetlands. Riparian Reserves generally parallel the stream network but also include other areas necessary for maintaining hydrologic, geomorphic, and ecologic processes. Specifically, the following definitions are used to define areas under Riparian Reserve Protection in the Upper White River watershed:

- Fish bearing streams - Riparian reserves consist of the stream and area on either side of the stream extending from the edges of the active stream channel to the top of the inner gorge or the outer edges of the 100-year floodplain, or to the outer edges of riparian vegetation or to a distance equal to the height of two site-potential trees or 300' slope distance (600 feet total, including both sides of the stream channel), whichever is greatest. Locations of fish-bearing

and non-fish-bearing streams in the Upper White River watershed are shown to the right.

- Permanently flowing nonfish-bearing streams - Riparian reserves consist of the stream and the area on either side of the stream extending from the edges of the active stream channel to the top of the inner gorge or to the outer edges of the 100-year floodplain, or to the outer edges of riparian vegetation, or a distance equal to the height of one site-potential tree, or 150' slope distance (300 feet total, including both sides of the stream channel), whichever is greatest.

- Seasonally flowing or intermittent streams, wetlands less than 1 acre and unstable or potentially unstable areas - Extent of unstable and potentially unstable areas (including earthflows), stream channel and extend to the top of the inner gorge, stream channel or wetland and the area from the edges of the stream channel or wetland to the outer edges of riparian vegetation, and extension from the edges of the stream channel to a distance equal to the height of one site-potential tree, or 100 feet slope distance, whichever is greatest.

- Wetlands greater than 1 acre - Consist of the wetland and the area to the outer edges of the riparian vegetation, or to the extent of seasonally saturated soil, or the extent of unstable or potentially unstable areas, or to a distance equal to the height of one site-potential tree, or 150 feet slope distance from the edge of the wetland greater than 1 acre.

- Lakes and Ponds - Consist of the body of water and the area to the outer edges of the riparian vegetation, or to the extent of seasonally saturated soil, or to the extent of unstable or potentially unstable areas, or to a distance equal to the height of two site-potential trees, or 300 feet slope distance, whichever is greatest.

In 1996, the USFS published the Watershed Analysis for the Greenwater and Upper White River subbasin (Mt. Baker-Snoqualmie National Forest 2000). This analysis enables watershed planning that achieves Aquatic Conservation Strategy objectives of the Forest Plan. The Watershed Analysis provides the basis for monitoring and restoration programs for this watershed. It is an assumption that the application of current Riparian Reserves restoration and protection programs will facilitate the development of "system potential land cover" conditions (see Section 4 of this report) within Riparian Reserves.

Management Area 3C Winter Sports Resorts

The Crystal Mountain Resort operates at the head of Silver Creek. This land allocation provides for a diversity of winter and summer recreation activities within the resort permitted area.

Administratively Withdrawn

These are areas the MBS Forest Plan withdrew from general timber management and include mountain goat habitat (MA 15), semi-primitive non-motorized (MA 1B), and scenic viewshed (MA 2A and 2B) designations. Timber harvest in scenic viewsheds must meet the view retention requirements specified in the Plan. Timber harvest is not scheduled in the other designations except for health and safety and resource protection.

Matrix

Lands not reserved for specific purposes by the Northwest Forest Plan. This designation allows timber management subject to restrictions that apply through other Forest Plan standards and guidelines.

1.5 Private Forest Management Framework

Private and state timberlands are governed through WAC 222, implementing regulations (RCW 76.09) and additional provisions contained in the forest and fish Report (www.wa.gov/dnr/htdocs/fp/fpb/forests&fish.html).

The goals of the forestry module of the Forests and Fish Report are fourfold:

- Provide compliance with the Endangered Species Act for aquatic and riparian-dependent species on non-federal forest lands
- Restore and maintain riparian habitat on non-federal forest lands to support a harvestable supply of fish
- Meet the requirements of the Clean Water Act for water quality on non-federal forest lands
- Keep the timber industry economically viable in the State of Washington.

To achieve the overall objectives of the Forests and Fish initiative, significant changes to rules regarding sediment delivery to channels from roads, and to riparian forest management policy are prescribed.

Under the new rules, road management must provide for better control of road-related sediments, provide better streambank stability protection, and meet current Best Management Practices. DNR is responsible for oversight on these activities.

The goal of riparian management and conservation as recommended in the Forests and Fish Report is to achieve restoration of high levels of riparian function and maintenance of these levels once achieved. For west-side forests such as the Upper White River watershed, the Forests and Fish Report specifies riparian silvicultural treatments and conservation measures that are designed to result in "desired future conditions." Desired future conditions are the stand conditions of a mature riparian forest, agreed to be 140 years of age, and the attainment of resource objectives. These desired future conditions are a reference point on the pathway to restoration of riparian functions, not an endpoint of riparian stand development.

The riparian functions addressed by the recommendations in the Forests and Fish Report include bank stability, the recruitment of woody debris, leaf litter fall, nutrients, sediment filtering, shade, and other riparian features that are important to both riparian forest and aquatic system conditions. The diversity of riparian forests across the landscapes is addressed by tailoring riparian prescriptions to the site productivity and tree community at specific sites.

Shade and sediment load allocations are included in this TMDL for private and state forest lands in the Upper White River watershed in accordance with the section of Forests and Fish entitled “TMDLs produced prior to 2009 in mixed use watersheds”. Also consistent with the Forests and Fish agreement, implementation of the load allocations established in this TMDL for private and state forestlands will be accomplished via implementation of the revised forest practice regulations. The effectiveness of the Forests and Fish rules is being measured through monitoring and adaptive management.

2. Background

2.1 Description of Study Area

The Upper White Watershed TMDL area is located in Western Washington on the Mt. Baker-Snoqualmie National Forest about 35 miles southeast of Tacoma. The area covers four subwatersheds: the Upper White River, West Fork White River, Greenwater River, and Huckleberry Creek. The headwaters of the West Fork White and the mainstem White River are situated along the northeastern side of Mount Rainier. At 14410 feet, Mount Rainier has a dominating influence on the regional geology and hydrology. The town of Greenwater is located at the most downstream boundary of the study area at elevation 1800. The Greenwater River and its tributary Meadow Creek form the jurisdictional boundary between Pierce and King Counties. (Pierce County is located to the south of the Greenwater.) The majority of the study area lies within Pierce County (263 square miles) with only 28 square miles lying within King County.

Major land uses in the watershed are forest management and recreation. The USFS, National Park Service, and Hancock Company are the primary landowners. Of the 309 mi^2 38 percent is within Mt. Rainier National Park and 54 percent is within the Mt. Baker-Snoqualmie National Forest, and eight percent is privately owned. The only concentrations of commercial and residential development within the study area are the town of Greenwater, located at the confluence of the Greenwater River and the White River, and Crystal Mountain resort located in the headwaters of Silver Creek. The only major roadway through the study area is State Highway 410. This highway traverses the study area for approximately 23 miles running parallel to the mainstem White River.

2.1.1 Physical Characteristics

The study area covers four subwatersheds: the Greenwater, the mainstem White River, West Fork White River, and Huckleberry Creek. Table 2.1 provides an overview of some physical characteristics relevant to this TMDL for these subwatersheds. Headwaters of the West Fork White and the mainstem White River are situated along the northeastern side of Mount Rainier.

Table 2.1. Physical characteristics of the major drainages within the study area.

	White R.	**Greenwater**	**Huckleberry**	**W. F. White**
Area (mi^2)	112	76	38	66
Annual Avg. Air Temp. (C)	4.0	5.1	4.2	4.6
August Max. Temp. (C)	18.4	20.0	18.3	18.5
Annual Precip. (in)	72.4	87.4	78.2	84.8
Elev. s(ft)				
Avg.	4812	3947	4638	4451
Min.	1668	1667	2073	1835
Max.	14207	6687	7305	14309
Rain on Snow (% of watershed in zone 1500 to 2500 ft elev.)	8.4	16.0	4.3	11.5
Mean Annual Discharge (cfs)	863	211		

2.1.2 Hydrology

Precipitation

Annual precipitation levels vary across the study area from approximately 130 inches at the top of Mount Rainier to 60 inches at the town of Greenwater (Figure 2.1). The overall annual average precipitation for the study area is 80 inches with the majority of the annual precipitation falling as snow from November to February above approximately 3000 feet.

Mount Rainier, due to its height (peak elevation of 14,410 feet) and profile, has a major influence on storm patterns and precipitation levels throughout the study area. Mount Rainier creates a "rain shadow" to the east and north of the mountain, an area that includes the study area, because the prevailing winter storms off the Pacific Ocean come from the southwest. For this reason the southwestern side of Mount Rainier receives significantly higher precipitation levels than the northeastern side.

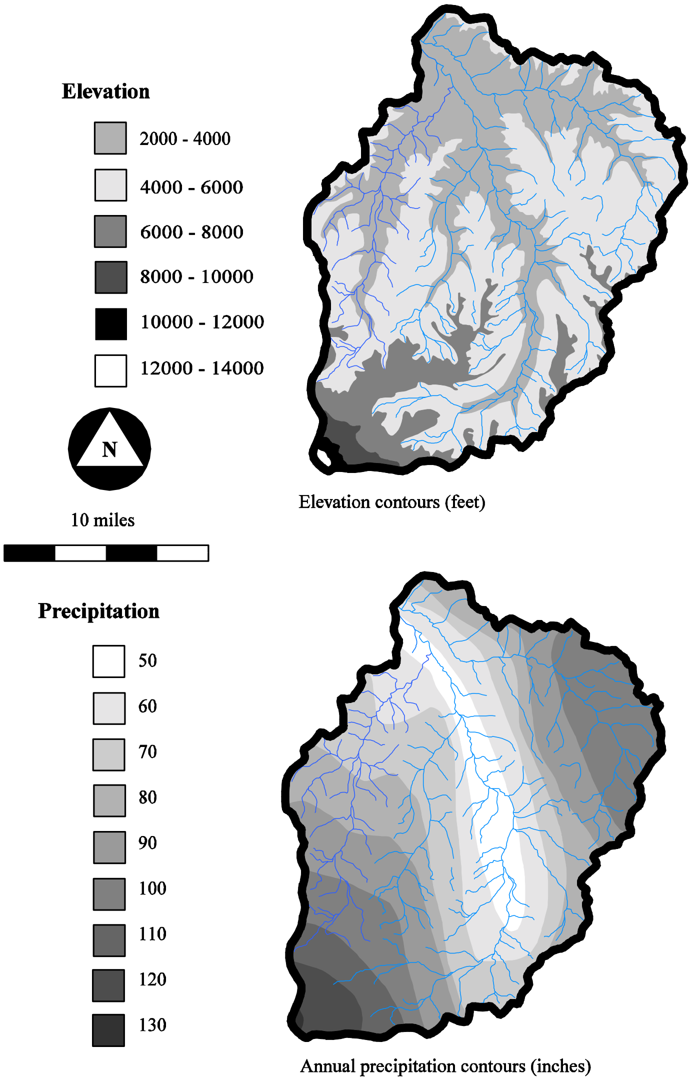


Figure 2.1. Elevation and precipitation characteristics of the Upper White River watershed.

Because of its height and proximity to the Pacific Ocean, Mount Rainier receives amounts of precipitation that are among the highest annual levels in the contiguous United States with over 56 feet of snow falling annually at the tree line elevation (Paradise Ranger Station, elevation 5400 ft).

Flow

Two distinct flow patterns are observed in streams within the study area. Both the West Fork White and the mainstem White River originate from glaciers on Mount Rainier resulting in sustained summer flows due to melting ice. The Greenwater River and Huckleberry Creek, which originate at springs, and have no glacial influence, have very low flows in summer after precipitation and snowmelt effects have subsided.

Historically, there were three USGS gauging stations within the study area (Table 2.2). Currently, only one is still active (station 12097500 Greenwater River @ Greenwater, Washington). However, the flow records of the two discontinued stations illustrate seasonal influence of glacial melt on flow volumes. During the months of August through October, when the lowest flows are observed, the White River has a discharge, adjusted for drainage area, of 2.4 cubic feet per second per mile squared (cfs/mi^2) while the Greenwater has a discharge of 0.8 cfs.

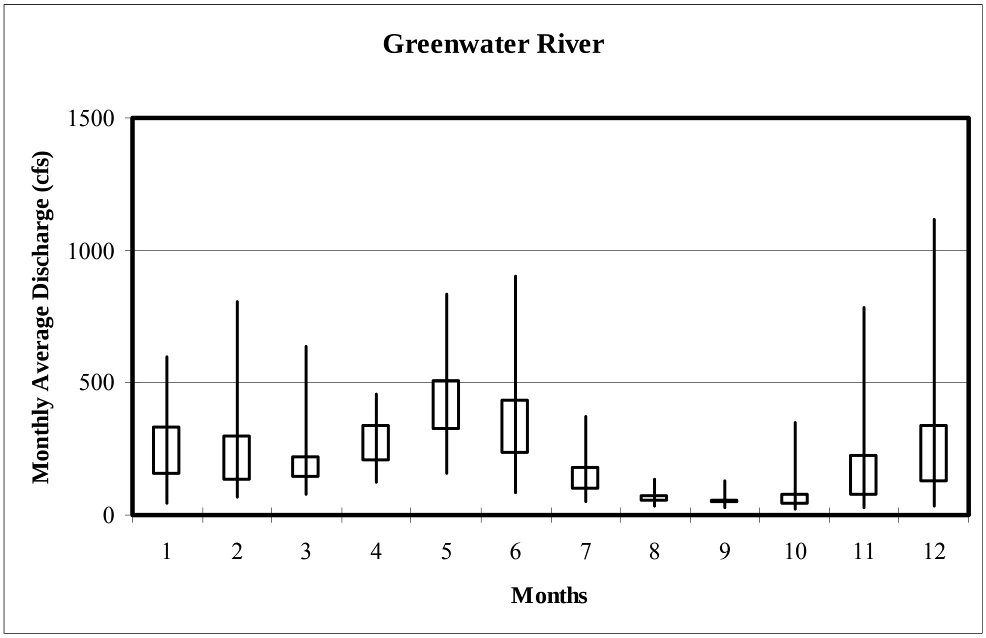
Table 2.2. USGS gauging stations.

Station Name	Station Number	Period of Record	Drainage Area (mi^2)	Annual Mean Discharge (cfs)
Greenwater River @Greenwater, WA	12097500	1911-12, 1929-77, 1980-Present (60 year record)	74	211
White River @ Greenwater	12097000	1911-12, 1929-75 (48 year record)	217	863
White River near Greenwater	12096600	1964-1970 (7 year record)	16	121

Figure 2.2 displays box plots of average monthly flows for the period of record for the USGS Greenwater and White River at Greenwater stations. At the Greenwater station the monthly average flows follow a similar though less distinct pattern to the White River station. Average discharge levels at both stations tend to peak in the late spring (May-June) due to snowmelt. For the White River the influence of glacial melt on summer period flows can be observed. An additional discharge characteristic that both rivers share is rain-on-snow events.

Rain-on-Snow Events

During winter months, the lower elevation Huckleberry Creek and the Greenwater River drainages are affected by rain-on-snow events when winter storms bring warm wind and heavy rains resulting in rapid snow melt at the lower elevations. Warm winter storms from the Pacific Ocean can occur in western Washington following periods of cold weather when snow accumulates at low elevations. The warm air mass, combined with the typically heavy rainfall associated with these storms, causes the rapid melting of snow located at lower elevations (500 to 3500 feet). These “rain-on-snow” events can generate floods quickly if there are large amounts of rainfall over 3 to 4 days and rapid melting of low elevation snow. Rain-on-snow events affect the low to middle elevation portions of the study area and can, under extreme conditions, result in major flooding events. The



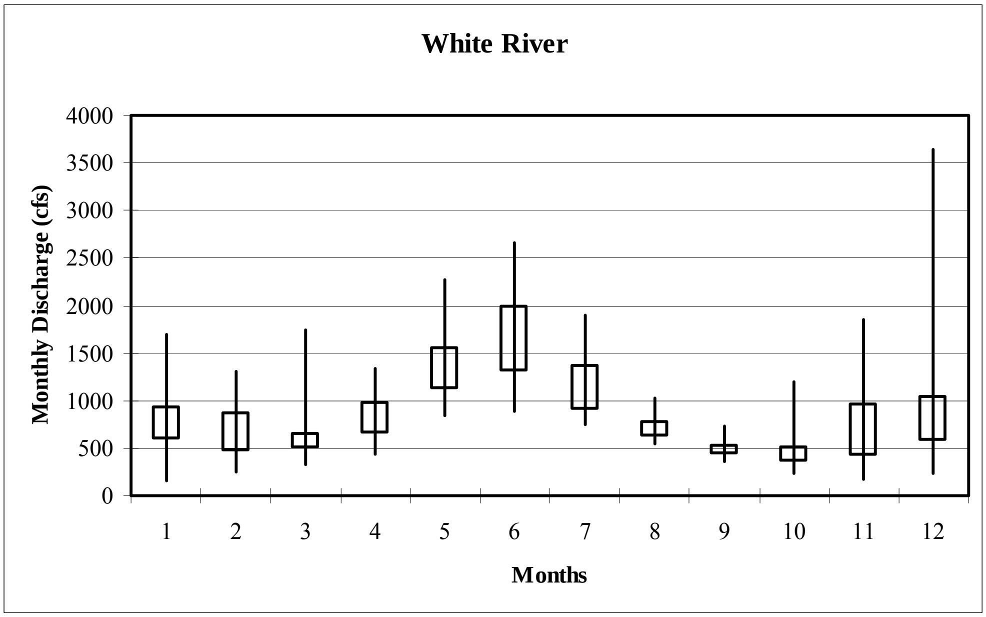


Figure 2.2. Average monthly flows at the USGS Greenwater (top) and White River (bottom) stations.

percent of the drainage area represented by the rain-on-snow zone with the Greenwater, Huckleberry, and the West Fork White are 17%, 5%, and 11%. Of the entire 309 square mile study area, 11% or 33 square miles lies within elevations susceptible to rain-on-snow events. Rain-on-snow storms produce high peak flows and floods primarily from November through January. Spring snowmelt can also produce flooding, however, this is much less common than the winter storm generated floods.

Peak Discharge

Peak discharge information is available for the Greenwater River gauging station and the station on the White River @ Greenwater. From the 58 year record for the Greenwater River, the highest recorded discharge level is 10,500 cubic feet per second (cfs). (The median annual peak flow is 1325 cfs.) Based on the flow record, approximately 60% of the annual peak flows occur during December and January, likely the result of rain-on-snow events.

The historic White River gage, located just above the confluence with the Greenwater, has a 48 year record. During that period, the highest peak discharge was 18,100 cfs and the median peak was 4580 cfs. In a pattern similar to that seen at the Greenwater station, peak flows at the White River gage tend to occur during the period November to January, representing 63% of the total peak discharge record. Differences apparent for the White River record, in comparison to the Greenwater, are the higher representation of peak flows in the spring months associated with snowmelt. For instance, 25% of the peak flows occurred during the months of May and June. In comparison, only 12% of the peak flows occurred at the Greenwater station during May and June.

2.1.3 Fish and Wildlife Resources

This information has largely been excerpted from Mt. Baker-Snoqualmie National Forest (2000). Readers are referred to this source for additional fish and wildlife information.

Fish

The Greenwater River and Upper White River support several species of salmonids, including chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), rainbow trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), potentially Dolly Varden (*S. malma*) although to date only bull trout have been confirmed, and non-indigenous eastern brook trout (*S. fontinalis*). Various species of sculpin (*Cottus spp.*) also occur.

Fish species found in lakes may be primarily or entirely the result of stocking. Species known to be stocked included rainbow trout (local, Goldendale, McCloud, and Mount Whitney stocks), coastal cutthroat trout (local stock), westslope cutthroat trout (Twin Lake stock), Yellowstone cutthroat trout (Henry Lake stock), eastern brook trout, and artic grayling (*Thymallus arcticus*).

The Puget Sound Energy Buckley Diversion Dam, at river mile (RM) 24.3, and the Mud Mountain Dam, at RM 29.6, block natural upstream fish migration to the analysis area. The Army Corps of Engineers operates a trap and haul facility at the diversion dam to assist returning fish attempting to pass upstream of the dams. The fish are transported upstream of the Mud Mountain Dam impoundment where they are released back into the White River at RM 33.9.

The White River Chinook salmon are an independent population within the Puget Sound evolutionary significant unit (ESU). This chinook ESU is listed as threatened under the Endangered Species Act (ESA) by the National Marine Fisheries Service. Coho salmon and steelhead trout were considered to be "healthy" in the 1992 Salmon and Steelhead Stock Inventory, (Washington Department of Fisheries et al. 1993) but recent escapement data may indicate the beginning of a downward trend for both species within the analysis area. The bull trout and/or Dolly Varden population within the analysis area are part of the distinct population segment listed as threatened under the ESA by the U.S. Fish and Wildlife Service. There has been no effort made to date to assess the status of other resident fish species known to be present within the analysis area.

The chinook, coho, and pink salmon are considered to be important management indicator species for assessing environmental health by the Mt. Baker-Snoqualmie National Forest (USDA Forest Service 1990). The chinook and coho salmon, coastal cutthroat and bull trout are considered to be sensitive species by the USDA-Forest Service, Region 6 Regional Forester. Coho salmon is a candidate for future federal ESA listing by NOAA Fisheries within the Puget Sound Evolutionary Significant Unit.

Wildlife

The analysis area is home to approximately 288 species of mammals, birds, reptiles, and amphibians as well as a number of mollusk species. All species are expected to use riparian habitat for at least part of their life cycle, but there are 60 wildlife species primarily associated with, or dependent on, riparian communities for survival. Species with large home ranges that use the area include deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), cougar (*Felis concolor*), and black bear (*Ursus americanus*). Species that require old-growth habitat include northern spotted owl, marbled murrelet, goshawk, marten (*Martes americana)* and fisher (*M. pennanti*). Amphibian species observed during surveys in lakes and associated riparian areas, within the analysis area, include northwestern salamander (*Ambystoma gracile*), long-toed salamander (*Ambystoma macrodactylum*), roughskin newt (*Taricha granulosa*), Pacific giant salamander (*Dicamptodon tenebrosus*), tailed frog (*Ascaphus truei*), western toad (*Bufo boreas*), and cascade frog (*Rana cascadae*) (USDA Forest Service 1995, Fritzell and Hoffman 2000).

Of the total number of wildlife species, 43 are of heightened management concern. These species include those that are listed or candidates for listing under the Endangered Species Act, Forest Service Sensitive species, ROD survey and manage species (USDA Forest Service and USDI BLM 1994), Management Indicator Species (USDA Forest Service 1990), and other Forest Service species of special interest.

TMDL Indicator Species

In later sections of this background information, chinook, bull trout and tailed frogs are incorporated as indicator species for this TMDL. Because of this, additional background information for these species is provided.

White River Spring Chinook are the sole remaining spring chinook stock in the Puyallup River watershed, as well the only remaining native spring chinook stock in south Puget Sound. White River spring chinook salmon are known to occur within the analysis area in the mainstem White River up to and within Silver Springs (WRIA 10.0233A) at approximately RM 61. Chinook are also present in the Greenwater River to approximately RM 9, in the West Fork White River to approximately RM 8, and in Huckleberry Creek to approximately RM 2. Chinook are presumed to have occupied more habitat historically.

Spring chinook typically arrive at the Buckley trap from May through early August and their population peaks in late June or early July. Summer/ fall chinook runs arrive from August through October and peak in late August or early September (Salo and Jagielo 1983).

The majority of chinook that spawn within the analysis area are of the “spring” variety. Spawning occurs within the upper mainstem White River, the Greenwater River, the West Fork White River, and Huckleberry Creek from early September through mid-October (WDFW et al. 1996). Based on observations in Schuett-Hames and Adams (2003) fry emerge from redds in late February and early March. Typically Puget Sound chinook salmon are ocean-type because the juveniles typically migrate to sea within weeks after emerging from the spawning gravels and do not rear in streams. Spring chinook juveniles are usually regarded as stream type, i.e. remaining in fresh water for up to a year after emergence. However, most White River Spring Chinook (80%) exibit somewhat ocean-type behavior and migrate to marine waters as sub-yearlings. In addition, the marine exodus is extended from mid-February to the end of October.

White River chinook juveniles have been known to migrate to the Puget Sound estuary both as yearlings and sub-yearlings (Dunston 1955: In WDFW et al. 1996). Most spring chinook return to the White River as three or four-year-old adults, but some return as two, five, or six-year-olds (WDFW et al. 1996).

White River chinook salmon counts at the Buckley trap from 1940 to 1999 indicate a significant reduction in population size during that time period, from a high of 5,431 fish in 1942 to a low of six fish in 1986. Since the late 1970’s, White River spring chinook are supplemented through hatchery programs at the Hupp Springs Hatchery, the White River Hatchery, and saltwater netpens near Manchester and Squaxin Island. Recent returns of chinook show improvement.

Native char (bull trout and/or Dolly Varden) occur in the mainstem White River to RM 68, and the Greenwater River to RM 12 (MRNP 2000, WDFW 1997, USDA Forest Service 1990 and 1991). Native char are also known to occur in the West Fork White River to RM 7 and Huckleberry Creek, but nothing is currently known about their distribution in Huckleberry Creek (USDA Forest Service 1980, WDFW 1997).

Three distinct ecotypes of native char most likely exist within the analysis area: resident, fluvial, and anadromous. Resident forms are those that spend their entire life in headwater tributaries, quite often above migration barriers. Fluvial forms are those that migrate from large rivers to smaller tributary streams to spawn, and anadromous forms are those that migrate from the marine environment back to native freshwater streams to spawn annually.

One stock of native char is known to exist within the analysis area. The White River native char are distinct based on geographical distribution, and are maintained by wild production. Spawn timing and location are not determined for this stock, and its status is currently unknown.

Trap counts of native char from 1991 to 1999 indicate low numbers of fish migrate to the Upper White River (5 to 40 fish per year). These data are collected inconsistently at intervals ranging from once a month to three times per month (WDFW 1997). Also, these data do not adequately represent all three life forms likely present above and below the trap and haul facility, particularly resident native char. Since 1994, the White River has been closed to fishing for native char, but there may be some mortality from incidental hook and release while targeting other fisheries (WDFW 1997). Anthropogenic factors affecting other salmonids in these rivers are assumed to have also impacted native char.

Tailed frog larvae live in clear, cold swift flowing streams from sea level up to 6,000 feet in elevation. All sightings of this species within the analysis area were in the headwaters of the drainages. Trends for this species within the analysis area are uncertain.

2.2 Watershed Processes and Forest Management

Watershed processes are responsible for the formation and maintenance of channel habitat. These processes are defined as follows by the Joint Natural Resources Council (2001): "Habitat-forming processes are the physical agents of landscape pattern formation and maintenance; i.e., the natural rates of delivery of water, sediment, heat, organic materials, nutrients, and other dissolved materials."

There is a large body of research regarding forest management-caused changes to these watershed processes. Spence et al. (1996) and Naiman and Bilby (1998) provide summaries of the research. A short overview of forest management caused changes to hydrology, sediment production, and heat delivery to streams is provided here.

Tree removal can increase the amount of water that infiltrates into the soil, and reaches streams. However, soil compaction may lessen infiltration, and increase the opportunity for surface runoff (reviewed by Spence et al. 1996). Larger peak flows and flow volumes were found in west coast streams after watersheds underwent logging. For example, stream flow increased year round in a clearcut Oregon forest with increases up to 200% greater than pre-logging predicted flows occurring in the fall (Rothacher 1971). Harr et al. (1975) found peak flow increased when roads and other compacted areas occupied 12% of an Oregon watershed; further increase occurred when 72% of the drainage was logged. Both studies reported runoff from major winter flood events was not affected by logging as these events occurred after soils were saturated, minimizing variations in runoff from forested and cut areas.

Roads create impermeable surfaces, intercept subsurface water from road cuts (increasing the drainage network), and concentrate runoff in the road drainage system (ditches and culverts). This can, but may not, result in faster delivery of runoff to streams, creating higher peak flows than would occur without management activities.

Management activities can additionally influence the size of rain-on-snow peak flows by altering snow accumulation and melt in clearcuts and altering the interception and delivery of water to streams by roads (Coffin and Harr 1992, Jones and Grant 1996). Clearcuts create openings where snow collects at greater depths due to no interception, and melts faster due to exposure to warm winds during storm events.

Soil mass movement is the dominant erosion process in steep mountainous areas of the western states and the general effect of logging, road building and fire is to disrupt the delicate balance of forces on these slopes resulting in initiation and acceleration of erosion processes (Swanston 1971). A study of steep, forested watersheds in western Oregon showed that sediment production increased 109 times over natural levels in a watershed with 6% roads as compared to 3.3 times over natural levels in a clearcut watershed without roads (Fredriksen 1970). The largest sediment sources were landslides and the scouring action of mudflows moving down the stream channel following landslides. A study in the lower Klamath basin, California showed that the number of landslides increased geometrically as the percentage of the basin logged increased (Leopold 1981). On one tributary, landslide frequency increased from 1 to 30 per mi^2 after 77% of the basin was harvested. In an Oregon forest, 72% of the landslides originated from roads while landslides from clearcuts occurred at almost 10 times natural rates (Dyrness 1967 IN: Reid 1981). A study of debris torrent initiation sites in two western Oregon watersheds indicated that roads triggered torrents at 40-167 times natural rates; in comparison, clearcuts initiated torrents at 5-10 times natural rates (Swanson et al. 1976). Over 80% of all debris torrent triggering mechanisms were landslides.

Reid (1981), in a study of road related sediment production in the Clearwater basin in the Olympic Peninsula of western Washington, found the presence of logging roads increased sediment production by a factor of 3.4 – 4.9 over natural rates. The higher rates occurred in steeper, more unstable areas. Road induced landslides were the dominant source of total sediment production. Over 70% of sediment from road related mass movements came from a few large landslides which triggered debris torrents. Although sediment production from debris torrent scouring was relatively low compared to that produced from landslides, torrents were exceedingly important because they were effective in delivering sediment from the triggering landslide to the stream channel.

Road construction disrupts slope stability by altering drainage, slope loading and by undercutting (Swanston 1974a). Alteration of slope drainage includes interception and concentration of surface and subsurface flow by ditching, bench cutting and massive road fills. This causes soil saturation, increased pore-water pressure and increased soil weight in road prisms, side cast materials and upslope soils, leading to failure. Poor drainage and plugged culverts magnify these problems and cause further erosion. Slope loading from the weight of massive road fills and sidecast material increases gravitational stress on oversteepened slopes below the road, while road cuts remove support for slopes above the road. Fiksdal and Brunengo (1981) state the failure of road fill and sidecast material is extremely common. These materials are often oversteepened, poorly compacted, and poorly drained. They are prone to failure where they cover wet areas or cross headwater streams, triggering a large proportion of debris torrents.

Swanston (1974b) observed numerous landslides in SE Alaska on clearcut slopes that exceeded the angle of repose. These were shallow soil failures triggered by high pore-water pressure above impermeable bedrock during heavy precipitation. Tree roots were found to be important stabilizers of the soil, anchoring the thin soil mantle to bedrock and connecting laterally across unstable areas. After logging, the roots decayed within 3-5 years, corresponding with the observed lag time between logging and widespread debris avalanching.

Different types of channels respond differently to changes in sediment supply and discharge, with some being more likely to adjust their channel characteristics than others. An overview of reach level potential for changes in channel morphology is provided in Table 2.3. Pool-riffle and plane-bed reaches are typically used for salmonid spawning and rearing. These reach types are classed as response reaches (Montgomery and Buffington 1998) and are generally likely to exhibit changes in channel depth, scour depth and slope, as well as possibly in channel width, roughness and sediment storage.

Table 2.3. Interpreted reach-level channel response potential to moderate changes in sediment supply and discharge (+ likely to change; p = possible to change; - = unlikely to change). Excerpted from Montgomery and Buffington (1998).

	Reach level morphology	Width	Depth	Roughness	Scour depth	Grain size	Slope	Sediment storage
Response	dune-ripple	+	+	+	+	-	+	+
	pool-riffle	+	+	+	+	+	+	+
	plane-bed	p	+	p	+	-	+	p
Transport	step-pool	-	p	p	p	p	p	p
	cascade	-	-	p	-	p	-	-
	bedrock	-	-	-	-	-	-	-
Source	colluvial	p	p	-	p	p	-	+

Stream temperature is affected by changes in riparian condition, channel width and stream depth, making it an integrator of watershed processes. Channels may become wider and shallower in response to changes in hydrology and sediment production. Wide, shallow channels in turn expose more surface area to solar radiation and allow greater temperature exchange with the air, which can increase stream temperature. (Sullivan et al. 1990). Harvest of trees in the riparian zone (or other disturbance such as locating roads by streams also allows more direct solar energy to be delivered to the water. Loss of riparian forest cover can additionally affect soil temperature, and thus increase heat transfer from the stream bank to the water column.

2.3 Management History and Watershed Conditions

The Upper White watershed has had extensive forest management and recreational use. The Upper White and Greenwater Watershed Analysis (Mt. Baker-Snoqualmie National Forest 2000) provides information on these uses and identified changes to watershed conditions. Vegetation disturbance was used as an indicator for whether rain-on-snow effects might be occurring, changes to stream flow from roads could be occurring, and if mass-wasting hazards might be elevated due to reduction of forest coverage. Currently, high disturbance levels (greater than 20%) were found in much of the lower Greenwater and West Fork White Rivers, and in lower Huckleberry Creek. Disturbance levels are low (less than 10%) in all of the upper subwatersheds that lie within wilderness or Mt. Rainier National park. Moderate levels of disturbance (between 10% and 20%) were found to exist in much of the remainder of the subwatersheds.

The watershed analysis also found that stream gage records for the Greenwater suggest a change in peak discharges is occurring and that the magnitude of a given return frequency flood has increased. Based on vegetation disturbance levels, lower portions of the West Fork White River, Huckleberry Creek, and the Upper White River are likely experiencing some effect on hydrology as well. Vegetation disturbance is less than it was during the 1970's and 1980's, and, as the vegetation continues to mature, the peak flow effect is expected to decrease.

A landslide inventory of the Greenwater subwatershed documented 193 landslides (Mt. Baker-Snoqualmie National Forest 2000). Two tributary watersheds (NWSE Creek and Pyramid Creek) accounted for 46% of the failures. Overall, the majority of landslides (69%) occurred within clearcuts and/or roadfills. Ninety-two percent of the failures were estimated to deliver sediment to a stream channel. The highest delivery of sediment volume (45%) is believed to have occurred between 1956 and 1984, caused by timber harvesting and road building. The majority (70%) of inventoried landslides occurred within areas that were identified as having a moderate risk for mass-wasting activity. Twenty-one percent occurred within areas identified as having a high risk for slope failures.

2.4 Stream, Habitat and Temperature Conditions

The Washington Conservation Commission and Pierce County have summarized habitat conditions and priority needs for the purpose of salmon recovery in the Puyallup Basin. These salmon recovery reports include the study area and provide useful background. The first is a limiting factors report prepared by Washington Conservation Commission (1999). Second, is the Pierce County Ecosystem Diagnosis and Treatment (EDT) report (Mobrand Biometrics, Inc., 2001). The USFS, Puyallup Tribe, Muckleshoot Tribe, Weyerhaeuser Corporation, Tahoma Audubon, State Fish and Wildlife, USGS and Ecology have collected various types of habitat data for Upper White watershed streams. This section reviews relevant information from the two salmon recovery documents and then additionally summarizes information from several habitat and temperature studies.

<u>Salmon Recovery Reports</u>

The limiting factors report includes the following "key findings and data gaps" of relevance to this TMDL:

- Data on temperature, spawning gravels, large woody debris and holding pools indicates the chinook beneficial uses are currently poorly supported.
- Additional data on presence and distribution of anadromous salmonids and native char needs to be collected.
- Freshwater life history data needs to be collected, including spawning run timing of all species of naturally produced salmonids.
- A sediment budget for the White River needs to be prepared.
- Development of baseline data on habitat utilization by salmonid species in the sub-basin needs to be addressed for effective management of the watershed.

The EDT analysis uses a combination of existing data and observations by biologists familiar with the aquatic systems to develop ratings for life history components, by stream reach. Table 2.4 provides a summary of the identified changes in watershed factors (e.g. sediment load, channel stability, temperature, etc.) that cause loss of productivity, life history diversity and abundance to chinook, in the TMDL area. Those factors defined as showing “high impact” (i.e. a high negative impact on species survival) are discussed below. In addition, moderate impact concerns (those with a moderately negative impact on species survival) are summarized in the table.

For the White River between the Greenwater River and Huckleberry Creek, channel stability and habitat quantity (lower section only) show high impact. The two reaches between Huckleberry Creek and Silver Springs have no high impact factors. Between Silver Springs and Klickitat Creek, food is rated as a high impact concern.

The Greenwater River is broken into 14 reaches between its confluence with the White River, and RM 12.2, the anadromous barrier below Greenwater Lakes. Of these, 11 reaches are rated as having high impact to survival from sediment load; eight for high impacts from changes in channel stability; six for high impacts to habitat diversity; five

Table 2.4. Summary of change in watershed factors causing loss of productivity, diversity and abundance to White River chinook. Data summarized from Mobrand Biometrics Inc. (2001) for TMDL streams. The highest impact level for categories that have at least one life-stage rating of moderate (M), high (H) or extreme (E) level of impact to salmonid survival is shown. River miles may not be exact.

River/Reach Description	Channel Stability	Competition with Hatchery Fish	Flow	Food	Habitat Diversity	Harassment/ Poaching	Pathogens	Predation	Sediment Load	Temperature	Key Habitat Quantity
White River											
Greenwater R to WF White R	H	M	M	M	M	-	M	M	-	M	H
WF to Huckleberry	H	-	-	-	-	-	-	-	-	-	-
Huck. to Silver Cr.	-	-	-	M	-	-	-	-	-	-	-
Silver to Silver Sp. Cr.	-	-	-	-	-	-	-	-	-	-	-
Silver Sp. to Klickitat Cr.	-	-	-	H	-	-	-	-	-	-	-
Greenwater River											
Mouth to RB Trib0123 @RM0.4	M	-	M	-	M	-	-	-	H	M	M
Trib0123 to RB Trib0124@RM0.9	M	-	M	-	M	-	-	-	H	M	M
Trib0124 to RM 1.5	M	-	M	-	M	-	-	-	H	M	M
RM 1.5 to RB Trib0125-RM2.9	M	-	M	M	M	M	-	-	H	M	M
Trib0125 to Midnight Cr.	M	-	M	M	M	M	-	-	H	H	M
Midnight to Foss Cr.	H	-	M	M	H	M	-	-	H	M	H
Foss to 28 Mi Cr.	H	-	H	M	H	M	-	-	H	M	H
28 Mi to Slide Cr.	H	-	M	-	M	M	-	-	H	M	H
Slide to RM7.5	H	-	M	-	H	M	-	-	H	-	M
RM7.5 to RM9.5	H	-	M	M	H	-	-	-	-	H	M
RM9.5 to Whistler-RM9.8	H	-	M	M	-	-	-	-	-	H	M
Whistler to Pyramid - RM10.5	H	-	H	M	H	M	-	-	H	-	H
Pyramid to George Cr.-RM11.2	H	-	H	M	H	H	-	-	H	-	H
George to barrier below lakes-RM12.2	-	-	-	M	-	M	-	-	-	-	-
West Fork White River											
Mouth to RBTrib0187-RM1.9	H	M	H	M	H	M	M	M	-	-	M
Trib0187 to RBTrib0189-RM2.3	**E**	M	H	M	H	M	M	-	-	-	M
Trib0189 to LBTrib0194-RM4.2	**E**	M	H	M	H	M	M	M	-	-	M
Trib0194 to Pinochle Cr.-RM5.7	**E**	M	H	M	H	M	M	M	-	-	M
Pinochle to Wrong Cr.-RM5.8	H	-	M	-	H	M	-	-	-	-	M
Wrong to Trib0214-RM9.5	**E**	M	H	M	H	-	M	-	-	-	-
West Fork White River Tributaries											
Trib0187- RM0.0-0.3	H	M	M	M	H	-	-	M	-	-	-
Huckleberry Creek											
RM0.0-First Bridge-RM0.3	H	-	M	-	M	-	-	-	-	-	H
Bridge to LBTrib0254-RM1.2	**H**	-	M	M	H	M	-	-	-	-	H
Trib0254 to LBTrib0256-RM2.3	**H**	-	M	M	H	M	-	M	-	-	H
Trib0256 to RBTrib0257-RM2.7	**H**	-	M	-	H	M	-	-	-	-	H
Trib0257 to Eleanor Cr.-RM3.2	**H**	-	M	-	H	M	-	-	-	-	H
Eleanor to 2500' above Lost Cr.-RM6.2	**E**	-	H	M	H	M	-	M	-	-	H

from loss of key habitat quantity; one from harassment/poaching; three from flow; and, three from temperature.

The West Fork White River is broken into six reaches between its confluence with the White River and Trib 0214 at RM 9.5. All reaches are rated high for loss of habitat diversity, five for flow, and all are rated either high (two reaches) or extreme (four reaches) for channel stability. West Fork Trib 0187 is rated high impact for stability and habitat diversity.

Huckleberry Creek is the final area addressed by the EDT analysis, within the TMDL study area. Of five reaches which stretch between RM 0.0 and Eleanor Creek at RM 3.2, all are rated to have high impact from changes to channel stability, and from changes to key habitat quantity. Habitat diversity impact is high in four reaches.

Temperature and Habitat Studies

Studies and reports done for watershed analyses and for TMDL related purposes provide further information on stream habitat, including temperature. Summaries of some of this information are presented below.

Weyerhaeuser (1996) included the lower 2.5 river miles of the Greenwater, and an adjacent section of the White River in a state watershed analysis. An inventory of large woody debris for this analysis found the following locations lacked adequate large woody debris: lower segments of Greenwater tributaries 10.0123, 10.0124 (Christoff Creek), and 10.0125 (Brush Creek), the Greenwater River between Christoff and Brush Creeks, and the lower segment of 10.0185, a tributary to the White River.

Sediment samples collected with a McNeil sampler in 1995 in the Greenwater River (RM 0.0-0.6), had a mean fine sediment level (<0.85 mm) of 14.2 percent (Keown and Summers 1998). This level of fines is rated as fair for salmon embryo survival by Washington Forest Practices Board (1997), and indicates impact to salmonid survival is occurring. Gravel samples in 1995 for Huckleberry Creek (RM 0.0-1.0) were rated good, with a fine sediment level of 9.58 percent <0.85 mm. However, only four of 13 spawning gravel locations inventoried as part of the study design were able to successfully be cored during sampling indicating a general lack of spawning gravel in the segment (Keown and Summers 1998).

Stream temperature has been collected by Ecology, the Puyallup Tribe, the Muckleshoot Tribe, and the USFS. This data is reported in Schuett-Hames et al. (2003), and a summary chart is provided in Table 4.2 within the temperature analysis section of this report. These data show a range of temperature regimes for individual streams, and segments. The coldest streams were

Silver Springs and Klickitat Creek, upper watershed tributaries to the White River. These tributaries were sampled in 2001 to gain data on currently known bull trout spawning areas. The maximum water temperature recorded in Klickitat Creek between 15 July and

15 August was 8.4 C. The maximum temperature in Silver Springs during the same period was 7.6 C. Spawning gravel water temperatures taken at a depth of 10 cm closely mirrored the surface water temperatures.

Several other streams or stream locations were cool with no exceedences of the 16 C standard. These were: Greenwater River at river mile 11.7, Greenwater tributaries Slide, Burns, and Forest Lake Creek, and Huckleberry Creek, and the West Fork White at RM 7.1. Among the warmest streams and locations were the Greenwater River at river miles 0.45, 1.2, and 1.5, and Greenwater tributaries Brush and Whistler Creeks. These all had recorded exceedences of the state water quality temperature standard of 16 C on greater than 50% of days between the focus survey period of 15 July to 15 August. These locations also all had maximum daily temperatures over or close to 19 C during this time. Shade, riparian conditions and channel width/depth ratio were factors evaluated as being related to temperature exceedences in the Greenwater at river mile 1.2 for 1996 (Schuett-Hames et al. 2003). Other streams or locations that exceeded the temperature standard were: Greenwater River at river miles 0.05, 5.3, 5.5, 5.8, 8.5; Greenwater tributaries Straight and Pyramid Creeks, and the West Fork White River at river mile 4.25. Additional information and analysis of the temperature data is provided in Section 4 of this report.

Monitoring of redds, channel scour, and channel surface elevations during chinook incubation in the Greenwater River has been ongoing since the fall of 1996. Data from 1996 to 2001 are reported in Schuett-Hames and Adams (2003). Scour monitor and peak incubation discharge data show a strong negative correlation between increasing annual peak discharge and increasing depth of scour. Bed scour monitor data indicates that 50% of monitors scoured to the top of egg pocket depth for 2 of 4 years. Historically the study found that pre-1970 (n=41 years), discharges predicted to have scoured ≥50% of monitor sites in spawning habitat to ≥15 cm occurred at a 5.9-year frequency. Currently (1970 to 2000, n=16 years) these discharges are expected to occur nearly twice as often.

2.5 Biological Indicator Species and Linkages to Watershed Processes

The goal of the TMDL is to protect and restore stream habitat forming processes and by doing this, to support the health of aquatic communities. For the Upper White watershed TMDL area native White River spring chinook, bull trout, and tailed-frogs are indicator species chosen to link watershed process restoration with habitat recovery and aquatic beneficial use support. Chinook salmon provide focus to aquatic protection and restoration needs of mainstem and larger tributary reaches. Bull trout use the spectrum of mainstem reaches through small tributaries to meet life history needs and are among the most sensitive of Washington's salmonid species to water temperature. They require cool water for most life history stages and are less competitive with other species when summer average temperatures exceed 7.9 C (Hicks 2000). As a further example of their sensitivity to warming temperatures, predictions of global warming increases of 4 to 5 C are expected to allow replacement of bull trout by steelhead in the Methow Basin of eastern Washington (Brown 1993, citing Williams and Mullan 1992). Tailed-frogs have stream-dwelling tadpoles that depending on the stream, take between 1 to 4 years to metamorphose. Hicks (2000) in a summary of the temperature needs of this species reports that 1 to 2 year olds prefer water temperatures around 5-8 C, but 4 year olds prefer waters of 12 to 16 C. A recent analysis (Hayes et al. 2002) indicates tailed-frogs are a good choice for an amphibian biodiversity indicator.

The beneficial use goals for these species are:

- Chinook and bull trout: “To assist with restoring and maintaining robust populations of chinook and bull trout by meeting their migration, rearing and spawning needs within the Upper White River watershed.”
- Tailed frog: “To restore or maintain healthy populations of tailed frog larvae throughout their probable use zone within the Upper White River watershed.”

Tables 2.5, and 2.6 show linkages between watershed processes and the indicator species. Measurable parameters that tell us how well stream habitat is supporting the indicator species and achieving these goals have been developed. The parameters for chinook were developed for this purpose by the Upper White River Chinook TMDL Framework Team (1998). The bull trout and tailed-frog parameters were developed based on literature (bull trout: Brown 1993, Cavender 1978, Fraley and Shepard 1989, Hicks 2000, Rieman and McIntyre 1993; tailed-frog: Hicks 2000, Leonard et al. 1993, Bury and Corn 1991). These parameters are useful as a basis for understanding the existing condition of beneficial use support. They will also be part of the TMDL and WQMP monitoring plan.

Table 2.5. Chinook habitat parameters and linkages to core natural watershed processes. (See text and Appendix A of: Upper White River Chinook TMDL Framework Team 1998, for more information.)

River*	Parameter	Methods	Measures	Affected Uses	Input Variables ←Linkage →	Core Natural Watershed Processes
All Chinook Use Rivers	Large woody debris (LWD) key pieces.	Use State Watershed Analysis.	Target: State Watershed Analysis index for good condition. Interim Target: Watershed Analysis index for fair.	Chinook spawning, rearing, and holding.	Wood	Hydrology, Vegetation, Mass wasting & Erosion.
	Holding pools.	Use State Watershed Analysis adapted with USFWS Habitat Suitability Index.	Target: State Watershed Analysis diagnostics with USFWS Habitat Suitability Index (HSI) Rating of A. Interim Target: HSI Rating of B.	Chinook holding (before and during spawning).	Sediment Flow Wood	Hydrology, Large woody debris & Vegetation, Mass wasting & Erosion.
	Channel width/ depth ratio.	Field measurements. Forest Service stream surveys.	No target: Informal target may be developed. For use in support and interpretation of other indicators.		Flow Sediment	Mass wasting & Erosion Hydrology Vegetation.
	Temperature.	Thermographs and stream temperature reach assessments.	State water quality criteria.	Chinook holding, spawning, incubation, rearing.	Shade/ heat energy Sediment Flow	Large woody debris & Vegetation Hydrology, Mass wasting & Erosion.
Non-Glacial Chinook Use Rivers	Redd survival from scour and channel change.	TFW scour method adapted with redd elevations.	Target: To be based on Schuett-Hames and Adams 2003.	Chinook egg and alevin incubation.	Flow Sediment Wood	Hydrology, Large woody debris & Vegetation, Mass wasting & Erosion.
Glacial Chinook Use Rivers	Riparian vegetation outside of channel migration zone.	Evaluate riparian zone outside of channel migration zone.	Target: State Watershed Analysis Riparian High. Interim Target: Moderate.	Chinook holding, spawning, incubation and rearing.	LWD recruitment Overhead cover Channel stability	Hydrology, Large woody debris & Vegetation, Mass wasting & Erosion.
	Active channel/ Channel migration zone aerial photo review.	Trend analysis of channel and vegetation patterns.	No target: For use in support and interpretation of other indicators.		Flow Sediment Wood	Hydrology, Large woody debris & Vegetation, Mass wasting & Erosion.

* Glacial rivers are: West Fork White and the mainstem White. All other rivers are non-glacial.

Table 2.6. Bull trout and tailed frog tadpole habitat parameters and linkages to core natural watershed processes.

River and Species	Parameter	Methods	Measures	Affected Uses	Input Variables ←Linkage →	Core Natural Watershed Processes
All Bull Trout Use Rivers	Water temperature.	Thermographs and stream temperature reach assessments.	State water quality criteria.	Spawning, incubation, juvenile rearing, thermal migration needs	Shade/heat energy, Sediment, Flow	Large woody debris & Vegetation, Hydrology, Mass wasting & Erosion.
	Substrate composition (% fines).	TFW McNeil samples.	To be determined.	Incubation (STE), rearing	Fine sediment in spawning gravels and rearing areas, Channel stability	Mass wasting & Erosion, Hydrology, Vegetation.
	Habitat complexity (Pools >3' deep, LWD, Undercut banks, Overhanging vegetation, substrate cover, off-channel habitat)	Forest Service stream surveys.	To be determined.	Spawning, incubation, rearing, forage, migration	Wood, Sediment, Flow, Overhanging vegetation, Channel stability	Vegetation, Mass wasting & Erosion, Hydrology
	Riparian condition.	Forest Service stream surveys & aerial interpretation.	To be determined.	Spawning, incubation, juvenile rearing, migration, Forage	LWD recruitment, Overhanging cover, Channel stability	Vegetation (also, Hydrology, Mass wasting & Erosion)
	Scour	TFW scour methodology.	To be determined.	Incubation (STE), Rearing(?)	Flow, Sediment, Wood	Hydrology, Mass wasting, Vegetation
All Tailed Frog Tadpole Use Streams	Water temperature.	Thermographs and stream temperature reach assessments.	State water quality criteria.	Egg laying, embryo development, tadpole rearing	Shade/heat energy, Sediment, Flow	Large woody debris & Vegetation, Hydrology, Mass wasting & Erosion
	Sediment.	Embeddedness.	To be determined.	Egg laying, embryo development, tadpole rearing	Fine sediment	Mass wasting & Erosion, Hydrology, Vegetation

2.6 Applicable Water Quality Criteria

This TMDL analysis addresses the impairment of characteristic uses of surface waters within the upper White River drainage area caused by both elevated water temperatures and sediment loading. The Washington Administrative Code (WAC) that addresses water quality and, specifically, the protection of characteristic uses is Chapter 173-201A Section 30. Section 30-1(b) defines characteristic uses to include the following:

(i) Water supply (domestic, industrial, agricultural).
(ii) Stock watering.
(iii) Fish and shellfish – Salmonid migration, rearing, spawning, and harvesting. Other fish migration, rearing, spawning, and harvesting. Clam and mussel rearing, spawning and harvesting. Crayfish rearing, spawning, and harvesting.
(iv) Wildlife habitat.
(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).
(vi) Commerce and navigation.

Specific to Section 30, within the study area, impairment to characteristic uses from elevated water temperatures and sediment loads includes impairment of salmonid migration, rearing and spawning, and wildlife habitat. Elevated water temperatures and sediment loading impair habitat conditions required for the healthy propagation of salmonids and other aquatic dependent species.

Section 30-1(c) defines the water quality criteria that apply to Class AA waters, a designation for all surface waters within the study area. The water temperature criteria for Class AA waters include:

- Water temperatures are not to exceed 16 degrees Celsius due to human activities.
- When natural conditions exceed 16 degrees Celsius then no temperature increases, resulting from human activities will be allowed which raise the receiving water temperature by greater than 0.3 degrees Celsius.
- Incremental temperature increases, resulting from nonpoint source activities, shall not exceed 2.8 degrees Celsius (and must remain below 16 degrees Celsius).
- Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=23/(T+5). “t” is the maximum permissible temperature increase measured at a mixing zone boundary. T is the background temperature as measured at a point or points unaffected by the point source discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

As per Section 30-1(c), the temperature target for this TMDL is 16 C. However, the temperature load allocation is based on recovery of a riparian shade condition that produces the “system potential effective shade”, and thus restoration of the naturally attainable temperature regime. In many streams this may be cooler than 16 C. For example, Schuett-Hames et al. provide documentation for 14 streams (or segments of streams) within the TMDL area that do not exceed the temperature standard of 16 C. In addition, state water quality standards for temperature are under revision. As part of this revision, the temperature standards for the TMDL area will likely be changed. These newer standards are expected to include cooler water temperatures for bull trout. Because it is not yet known what the new standards criteria will be, and when final adoption and EPA approval will be, this TMDL uses the current standard of 16 C. However, it is anticipated that monitoring of temperatures, including bull trout waters will be an important part of the TMDL monitoring plan. Adaptive management will also be employed to assure that updated standards are reviewed with the temperature data, and that watershed restoration is effective for maintaining or restoring cool temperatures to bull trout waters.

Sediment standards applicable to this TMDL are narrative standards (those that do not have numeric targets established in the water quality regulations. They are comprised of two pieces.

- The characteristic use, wildlife habitat is a use to be protected and is construed to include protection from harmful sediment.
- WAC 173-201A-030(1)(vii) includes protection from sediment levels that would be construed to be deleterious. This standard is as follows: "Toxic, radioactive, or deleterious material concentrations shall be those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent up those waters, or adversely affect public health, as determined by the department (see WAC 173-201A-040 and 173-201A-050).

An additional component of WAC 173-201A, relevant to this analysis is Section 70 the anti-degradation provision. WAC 173-201A-070 states:

(1) Existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurious to existing beneficial uses shall be allowed.
(2) Whenever the natural conditions of said are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.
(3) Water quality shall be maintained and protected in waters designated as outstanding resource waters in WAC 173-201A-080 (see below).
(4) Whenever waters are of a higher quality than the criteria assigned for said waters, the existing water quality shall be protected and pollution of said waters which will reduce the existing quality shall not be allowed, except in those instances where:
    (a) It is clear, after satisfactory public participation and inter-governmental coordination, that overriding considerations of the public interest will be served.
    (b) All wastes and other materials and substances discharged into said waters shall be provided with all known, available, and reasonable methods of prevention, control, and treatment by new and existing point sources

before discharge. All activities which result in the pollution of waters from nonpoint sources shall be provided with all known, available, and reasonable best management practices.

(c) When the lowering of water quality in high water quality waters is authorized, the lower water quality shall still be high enough quality to fully support all existing beneficial uses.

(5) Short-term modification of water quality may be permitted as conditioned by WAC 173-201A-110.

2.7 Water Quality and Resource Impairments

Within the study area, three stream segments, all on the Greenwater River, appear on both the 1996 and 1998 303(d) lists (WBID number WA-10-1046) due to having water temperatures that exceed the state standard (Table 2.7, Figure 2.3). The TMDL addresses these segments.

Table 2.7. Upper White River TMDL CWA Section 303(d) listings.

Waterbody	WRIA	1996 WBID	1998 WBID	Parameter	River Mile	Location	1996	1998
Greenwater River	10	WA-10-1046	IT88EW	Temperature	2.2	T19N R9E Sec11	X	X
Greenwater River	10	WA-10-1046	IT88EW	Temperature	8.5	T19N R10E Sec23	X	X
Greenwater River	10	WA-10-1046	IT88EW	Temperature	11.0	T19N R11E Sec31	X	X

Chronically elevated water temperatures for the Greenwater River have been confirmed through more recent temperature monitoring. In addition, temperature, sediment and habitat impairments have been identified more widely within the Upper White watershed (Table 2.8, Figure 2.4, Table 2.9, Figure 2.5). These impairments are not on the 303(d) list but are covered by this TMDL. As a result of the broad spatial scope of impairments this TMDL was developed to cover the entire Upper White watershed.

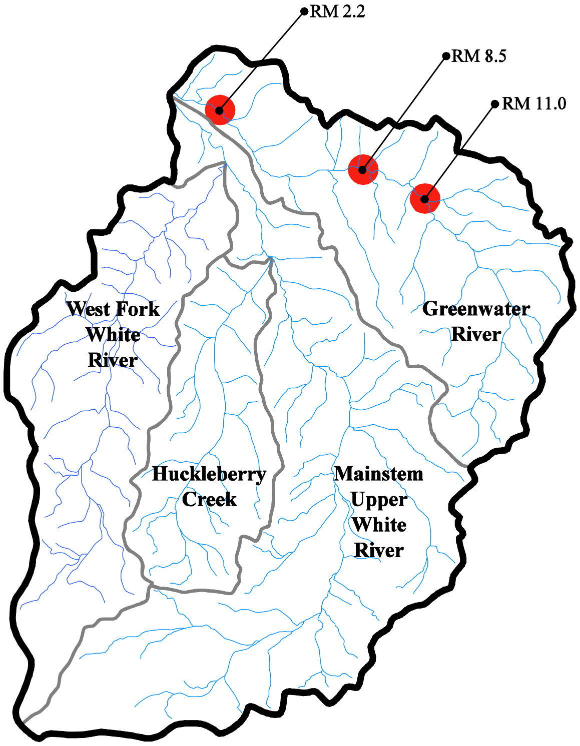


Figure 2.3. Clean Water Act Section 303(d) listings within the Upper White watershed.

Table 2.8. Upper White River impaired but not-listed temperature, spawning gravel fine sediment, and coarse sediment segments that are addressed by the TMDL. Stream codes are from Williams et al. (1975). See Appendix B for supporting information.

Waterbody	River Mile	Location	Parameter
Greenwater River (10.0122)	0.5,1.2,1.5, 5.3, 5.5	T19N R9E Sec4,10,11,19,20	Temperature
Unnamed (Brush, 10.0125)	0.2	T19N R9E Sec11	Temperature
Straight Creek (10.0132)	0.3	T19N R10E Sec22	Temperature
Whistler Creek (10.0136)	0.4	T19N R10E Sec24	Temperature
Pyramid Creek (10.0143)	0.4	T19N R10E Sec25	Temperature
West Fork White (10.0086)	4.3	T18N R9E Sec4	Temperature
Greenwater River (10.0122)	0.0 - 0.6	T19N R9E Sec3,4,10	Spawning gravel fine sediment
Greenwater River (10.0122)	0.0, 8.0	T19N R9E Sec4, R10E Sec21	Coarse sediment
Unnamed (Brush, 10.0125)	0.0	T19N R9E Sec11	Coarse sediment
Twenty-eight Mile Creek (10.0129)	0.0	T19N R10E Sec21	Coarse sediment
Slide Creek (10.0130)	0.0	T19N R10E Sec21	Coarse sediment
Pyramid Creek (10.0143)	0.0	T19N R10E Sec25	Coarse sediment
West Fork White (10.0086)	0.0	T19N R9E Sec23	Coarse sediment
Eleanor Creek (10.0258)	0.0	T18N R9E Sec14	Coarse sediment
Lightning Creek (10.0252)	0.0	T18N R9E Sec6	Coarse sediment
Minnehaha Creek (10.0300)	0.0	T18N R9E Sec5	Coarse sediment

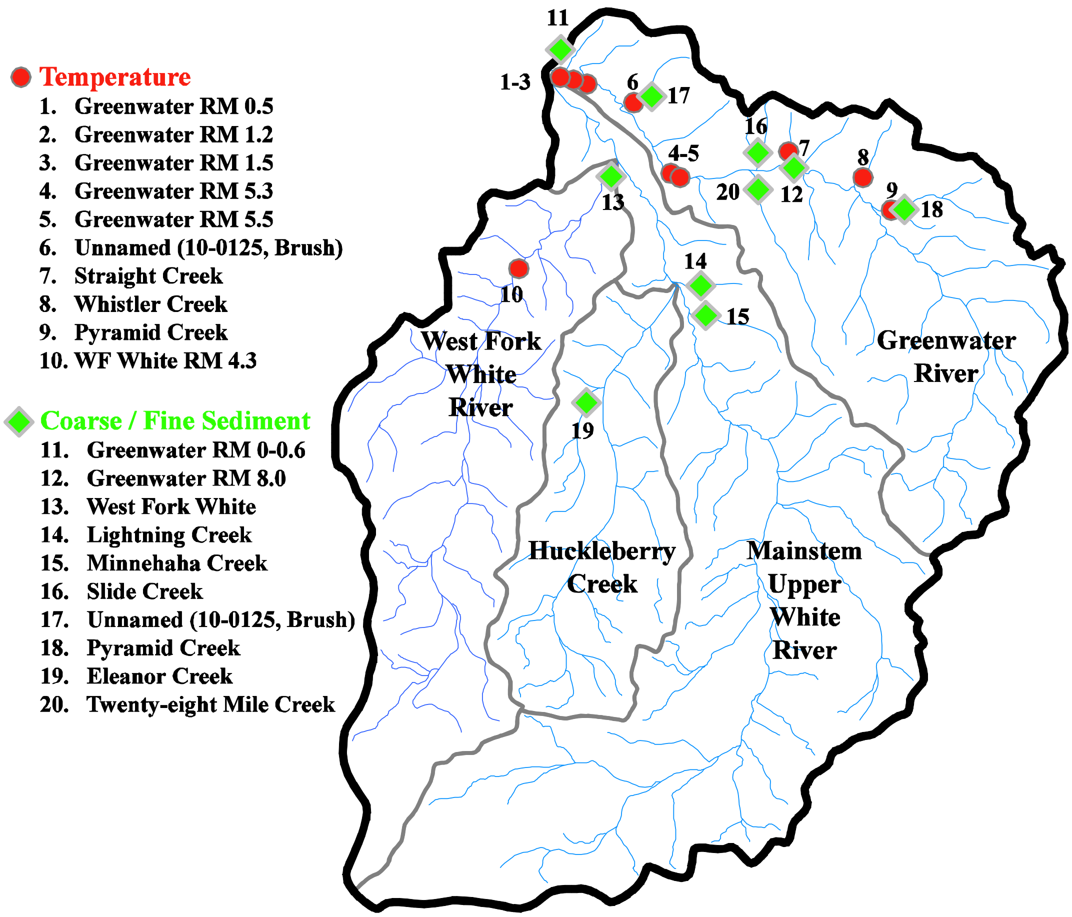


Figure 2.4. Locations of impaired but not-listed temperature, fine sediment, and coarse sediment segments within the TMDL area.

Table 2.9. Upper White River impaired but not-listed habitat segments that are addressed by the TMDL. Stream codes are from Williams et al. (1975). See Appendix B for supporting information.

Waterbody	River Mile	Location	Parameter
Greenwater River (10.0122)	0.0	T19N R9E Sec3	Floodplain connec., bank stability, LWD, pools, side-chan., fine sediment, riparian
Greenwater River (10.0122)	1.5 - 2.4	T19N R9E Sec11	Bed scour
Unnamed Creek (Brush, 10.0125)	0.0	T19N R9E Sec11	Floodplain connec., bank stability, LWD, pools, side-chan., fine sediment, riparian
Midnight Creek (10.0126)	0.0	T19N R9E Sec13	LWD, pools, riparian
Foss Creek (10.0128)	0.0	T19N R10E Sec19	Bank stability, LWD, pools, fine sediment, riparian
Twenty-eight Mile Creek (10.0129)	0.0	T19N R10E Sec21	Bank stability, LWD, pools, side-channels, riparian
Slide Creek (10.0130)	0.0	T19N R10E Sec21	Floodplain connectivity, LWD, pools, riparian
Straight Creek (10.0132)	0.0	T19N R10E Sec22	LWD, pools, riparian
Forest Lake Creek (10.0134)	0.0	T19N R10E Sec22	LWD, pools, fine sediment, riparian
Whistler Creek (10.0136)	0.0	T19N R10E Sec24	Bank stability, LWD, pools, riparian
Pyramid Creek (10.0143)	0.0	T19N R10E Sec25	Bank stability, LWD, pools, fine sediment, riparian
George Creek (10.0150)	0.0	T19N R10E Sec25	Riparian
WF White River (10.0086)	0.0	T19N R9E Sec23	Floodplain connec., bank stability, LWD, pools, side-chan., riparian
Unnamed Creek (10.0187)	0.0	T19N R9E Sec26	LWD, pools
Cripple Creek (10.0204A)	0.0	T18N R9E Sec18	LWD, pools, fine sediment, riparian
Pinochle Creek (10.0198)	0.0	T18N R9E Sec17	Bank stability, LWD, pools, side-channels, riparian
Viola Creek (10.0199)	0.0	T18N R9E Sec18	Bank stability, LWD, side-channels, riparian
Wrong Creek (10.0205)	0.0	T18N R9E Sec17	LWD, pools, riparian
Lightning Creek (10.0252)	0.0	T18N R9E Sec6	Bank stability, LWD, pools, fine sediment, riparian
Huckleberry Creek (10.0253)	0.0	T18N R10E Sec6	Floodplain connec., bank stability, LWD, pools, side-chan., riparian
Eleanor Creek (10.0258)	0.0	T18N R9E Sec23	LWD, fine sediment, riparian
Minnehaha Creek (10.0300)	0.0	T18N R10E Sec5	Bank stability
Silver Creek (10.0313)	0.0	T18N R10E Sec34	Bank stability, LWD, fine sediment
Goat Creek (10.0314)	0.0	T18N R10E Sec34	LWD
Silver Springs Creek (10.0322A)	0.0	T17N R10E Sec11	LWD, pools

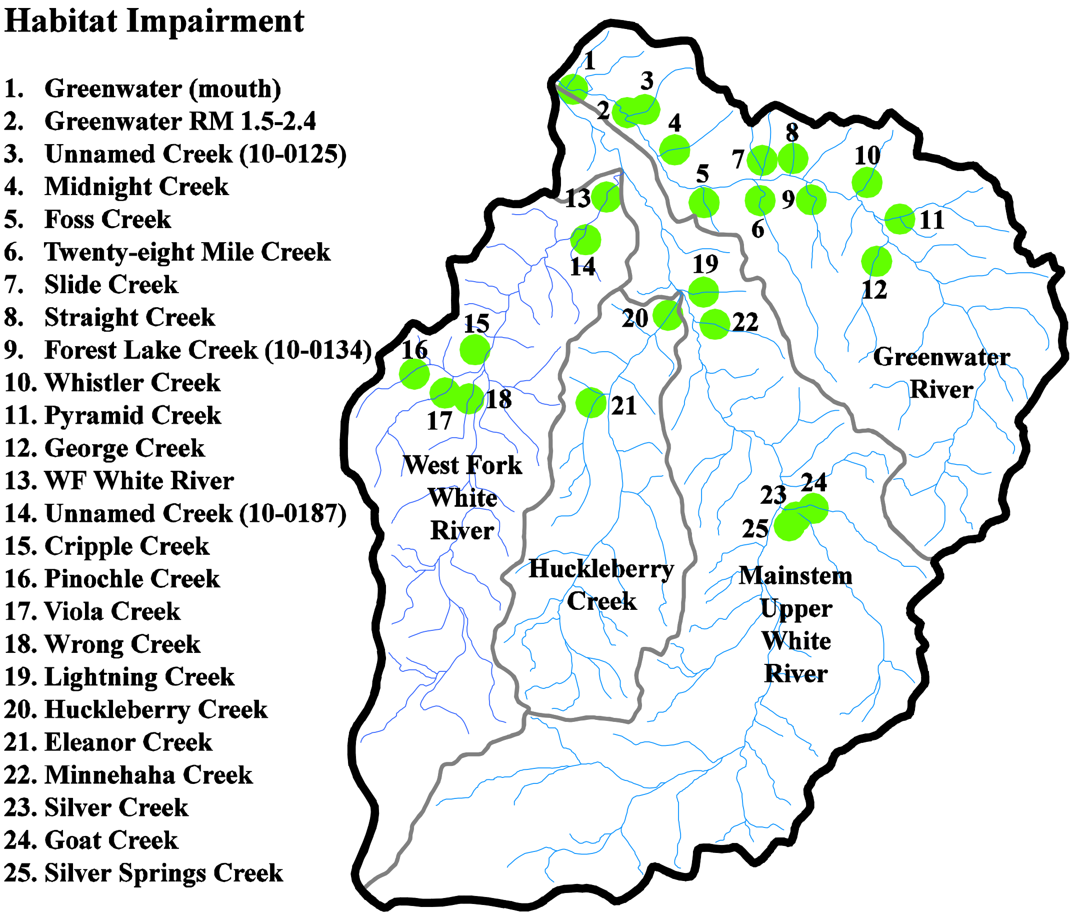


Figure 2.5. Locations of impaired but not-listed habitat segments within the TMDL area.

3. Sediment TMDL

3.1 Basis for Sediment Assessment

The 303(d) listing within the Upper White River watershed is for temperature in the Greenwater River subwatershed. So why is a detailed discussion of sediment included in this TMDL? One of the purposes of this TMDL is to identify and assess the core processes operating in the watershed that maintain and restore native biological communities and general aquatic health. Sediment can have a dramatic influence on aquatic health through direct effects on aquatic biota and through indirect effects on habitat through channel morphology.

Channel morphology in the assessment area varies dramatically, and much of it is the result of valley and channel types. The small order streams are typically steep and well confined. Once these channels enter the lower gradient, main valleys they become unconfined and meander and migrate across the broad valleys. In the broad valleys the distinctions between the glacial (White and West Fork White) and non-glacial (Greenwater and Huckleberry) streams become apparent. The glacial streams, with the naturally high sediment load, tend to be braided while the non-glacial streams are single thread.

This simplified, textbook description of the channel morphology is complicated by the effect of management activities on the flow and sediment regimes. The Greenwater River shows signs of braiding but has no glacial influence. Channel avulsion has been dramatic in the Greenwater and West Fork Huckleberry Creeks as well as the main White River.

While temperature data provide the basis for the 303(d) listing in the Greenwater subwatershed, there is ample evidence that sediment is also impairing water quality as well as contributing to the temperature impairment. The working hypothesis for this TMDL is that changes in the sediment regime have altered channel morphology in the Upper White River watershed and contribute to the elevation of stream temperature.

3.2 Seasonal Variation and Critical Conditions

It’s long been known that landslides and mudflows occur during major climatic events. In the western Cascade Mountains, these climatic events are known as rain-on-snow events that occur one or more times most winters. The disposition of the sediment generated during these storms has not been well understood, however some models have emerged in recent years (Benda and Dunne 1997). Not only do the events that generate the erosion vary dramatically over time, but the movement of the sediment within a watershed is also highly variable.

3.2.1 The Nature of Erosion and Sediment Transport

Sediment movement in the streams of the Upper White River watershed varies dramatically both spatially and temporally. The Greenwater River and Huckleberry Creek are not influenced by active glaciers and therefore do not have the high suspended sediment loads during the summer that are characteristic of the White and West Fork White Rivers.

Sediment transport is directly proportional to the availability of eroded material and the stream power to move it. Stream power is lowest during low discharge conditions and erosion (with the exception of creep erosion) is only active during runoff events (storms). Therefore, the minimum in sediment transport is in the late summer for Huckleberry Creek and the Greenwater River, and during early spring or fall for the West Fork and White Rivers. High glacier melt rates during the heat of the summer elevate fine sediment transport in the West Fork and White Rivers (Figure 3.1).

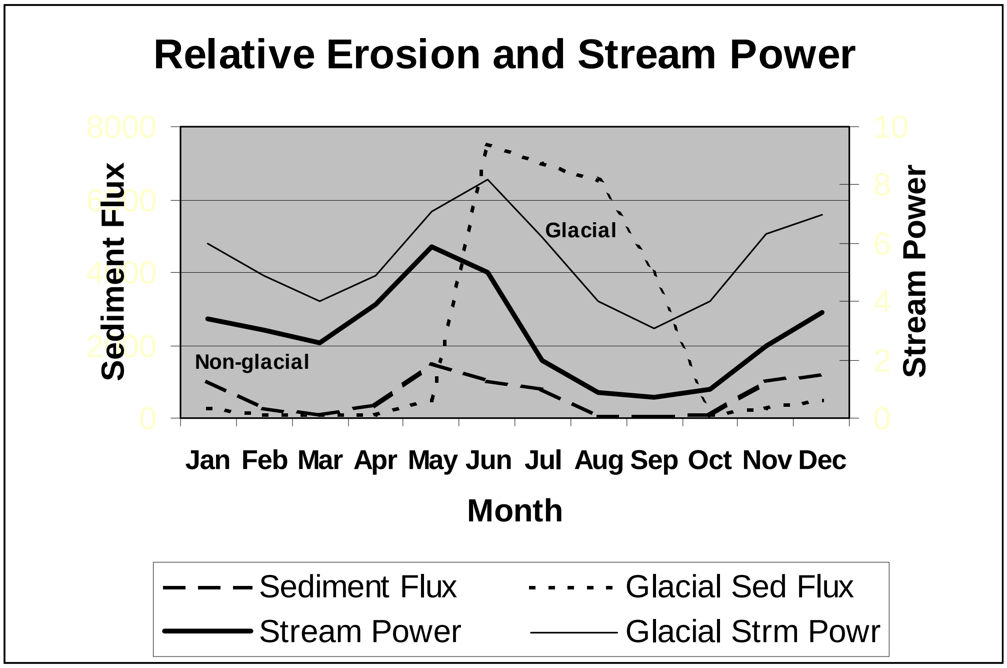


Figure 3.1. Schematic of relative erosion and stream power for glacial and non-glacial subwatersheds in the Upper White River watershed. (Values are for illustration only, based on monthly stream flow from USGS gauging stations and temporal sediment estimates from Nisqually Glacier (Metcalf 1979)).

Sediment transport in non-glacial streams is high with major fall and winter storms that activate hill slope erosion processes and increase channel erosion through high stream flow (stream power). Spring snowmelt varies by weather pattern but is usually associated with the peak sediment transport. In glacial systems fall and winter sediment transport is similar to non-glacial streams and is in relation to storms. However, Metcalf (1979) measured nearly 99 percent of the suspended sediment flux from the Nisqually Glacier between June and September.

3.2.2 Critical Conditions

This TMDL describes sediment in terms of long-term average annual loads. While this masks the true nature of erosion and sediment transport, to attempt to describe the pollutant in any more definitive terms would rely on statistics and probabilities. The loads would then be described as a “probable” event, which would not add to the certainty of the result.

The critical conditions for beneficial uses impacts may be separated in time from the critical climatic conditions that generate the sediment. A noted above, the critical climatic conditions are periods of heavy rain and/or snow when soils are saturated. These events are generally times when sediment transport potential is high in the channels (high discharge) but certain anadromous fish species may not be present in the channels during these events. Therefore the impacts are not in the transport of the sediment immediately after erosion, but are manifested later where the sediment is deposited. The sediment may bury existing salmon eggs in the gravels or impair the quality of spawning gravel for future use. There are several mechanisms by which sediment can impact fish, many of which are separated in time from the actual erosion event, although direct impacts do occur.

Anadromous fish stocks that occur in the assessment area of the White River watershed have a wide temporal distribution for spawning and incubation. For example, chinook spawn in the Upper White River watershed from late August to mid-October; coho from late August to January; and steelhead from early March to mid-June. Incubation occurs until late February through March for chinook, February through April for coho, and June through August for steelhead.

Since one life-stage or another of one or more species is present much of the year, picking a critical condition for sediment impacts is not practical. Much more important is understanding the mechanisms and nature of the impacts so that treatments will “stormproof” the erosion sites and create resiliency in the habitats to protect beneficial uses.

3.3 Developing the Sediment Budget

In order to understand the role of management on the sediment regime of the Upper White River, a sediment budget was developed. The sediment budget incorporates material derived from glaciers, hillslope processes of creep and rapid mass wasting (debris avalanches), road surface and mass erosion, and channel migration. This is only a partial sediment budget because erosion sources from riparian impacts created by dispersed recreation (recreation outside of developed recreation sites), special uses such as summer home and group camp developments, wildfire, and State Highway 410 are not included. Stream bank erosion from channel migration is based on measurements for four channel reaches in the West Fork White River and Greenwater River only. No sediment routing or sediment transport assessment was completed. The sediment budget only reflects sediment available to channels in the watershed. For the purpose of this assessment, “management-related” sediment is that attributable to timber harvest and road construction. Where roads are discussed as a specific sediment source, management relates to timber harvest only.

3.3.1 Glaciers

Sediment derived from glaciers on Mt. Rainier was estimated from suspended sediment and streamflow measurements taken in the White River below Emmons Glacier in 1958 and 1959 (Fahnestock 1963). Mills (1975) developed a relationship between the area of glaciers and proglacial environments and the sediment measured by Fahnestock. The erosion rate derived by Mills and used in this sediment budget is 33,000 tons of suspended sediment per square mile of glacial ice and proglacial debris per year. Westbrook (1987) assumed bedload sediment adds an additional ten percent of the suspended sediment. This erosion rate may be conservative since the retreat rate of glaciers on Mt. Rainier increased in the 1980s.

Westbrook noted that bedload transport in the river was limited to the winter and spring high runoff periods while the majority of the suspended load was transported during the summer months when the glaciers are actively melting.

The results of this analysis show glacial sediment for Huckleberry Creek. Although there is no active glacier within the Huckleberry Creek subwatershed, there is a significant amount of “periglacial” terrain that is included as a sediment source.

3.3.2 Erosion from Soil Creep

Stream bank erosion was estimated using the procedures developed by the Washington State Department of Natural Resources for watershed analyses conducted for Forest Practices. Coefficients and assumptions used in the watershed analysis for the Clearwater and Middle White Rivers (Weyerhaeuser 1996) were used for the Upper White sediment budget.

Creep was assumed to be effective only on streams with gradients greater than two percent. These are the streams that occupy the narrow valleys with steep side slopes. Lower gradient streams typically occupy the broad floodplain valleys where creep process are not significant for bringing soil material to the channel banks.

Different creep rates are used based on hillslope steepness. In the Upper White 20 percent of all streams were assumed to be associated with hillslopes of less than 30 percent. As for the Clearwater/Middle White River watershed analysis, the creep rate for slopes less than 30 percent gradient is 1 mm/year, and for slopes greater than 30 percent, 2 mm/year. Effective stream bank depth for soil creep effects was assumed to vary some by stream gradient, a surrogate for hill slope:

Stream Gradient (%)	Effective soil depth (feet)
3-4	3
5-10	2.5
11-20	2
20+	2

Creep erosion is then calculated by multiplying the channel length times the effective soil depth times the creep rate.

3.3.3 Stream Bank Erosion

Streams naturally erode stream bank material, either that delivered through soil creep as discussed above or floodplain material that is eroded as the channel migrates across the floodplain. For streams less than two percent gradient, it is assumed that the floodplain bank erosion is the dominant process of background bank erosion.

Stream channel investigations in the Clearwater and Middle White Rivers (Weyerhaeuser 1996) estimated that 50% of the stream banks were actively eroding. This same estimate is applied to the Upper White low gradient streams. Stream class was used to vary stream bank height; soil groups were developed based on their susceptibility to erosion to assign erosion rates; and riparian structure class (vegetation condition) was used to modify erosion rates.

Stream Class	Stream Bank Height (ft)
1 and 2	5.9
3	3.3
4	2.0

Stream classes are defined in the Mt. Baker-Snoqualmie National Forest Resource Management Plan (Mt. Baker-Snoqualmie National Forest 1990).
Class 1: perennial or intermittent fish-bearing streams or domestic water sources. These streams are used by large numbers of fish for spawning, rearing, and/or migration.
Class 2: perennial or intermittent fish bearing streams. These streams are used by moderate, though significant numbers of fish for spawning, rearing, and/or migration.
Class 3: all other perennial streams
Class 4: all other intermittent streams

Soil Group/Erosion Potential	Erosion Rate (ft/yr)
A – Low	0.002
B – Moderate	0.033
C – Moderate to High	0.050
D – High	0.066

Riparian Structure Class	Erosion Factor
Small, non-Forest	2.0
Sapling	1.5
Immature	1.0
Mature/Old	0.8

Soil susceptibility to erosion is described for soil map units in the Mt. Baker-Snoqualmie National Forest Soil Resource Inventory (SRI) (Snyder and Wade, 1972). Riparian structure classes are derived from vegetation information contained in the forest vegetation GIS layer. This layer is based on the Timber Resource Inventory (TRI) database for the Mt. Baker-Snoqualmie National Forest and the assessment is included in the Upper White and Greenwater Watershed Analysis (Mt. Baker-Snoqualmie National Forest 2000).

3.3.4 Road Surface Erosion

Computation of road surface erosion is patterned after the Middle White and Clearwater Watershed Analysis. All roads are assumed to be insloped with a ditch and greater than two years old. Road area is based on widths using cut slopes of 1:1 and fill slopes of 30 percent gradient.

Road Maintenance Level	Lanes/ shoulder width	Side slope (%)	Total Road Width (ft)
3, 4, 5	2 – 12 feet/ 2 foot	30	50
1, 2	1 – 14 feet/ 2 foot	60	42

Road Maintenance Levels are defined in the Mt. Baker-Snoqualmie National Forest Resource Management Plan (Mt. Baker-Snoqualmie National Forest 1990). One of five levels is assigned to each road based on the maintenance required to provide the desired type of access.
Level 1: Closed roads that are kept in a storage condition until the next project access need.
Level 2: Roads open for high clearance vehicles.
Level 3: Low speed, single lane roads with turnouts and spot surfacing open and maintained for travel by a prudent driver in a standard passenger car.
Level 4: Double or single lane roads with aggregate or paved surfaces that provide a moderate degree of user comfort and convenience at moderate travel speeds.
Level 5: Double lane roads generally with paved surfaces, but may be aggregate, that provide a high degree of user comfort and convenience.

Soil groups were used to modify the basic erosion rates based on surface erosion potential (SEP). This is an indicator of soil particle detachability. The same soil groups were used to establish the ground cover density for cut and fill slopes. The less erosive the surface soil, the better the revegetation success.

Soil Group/SEP	Road Erosion Rate (tons/ac/year)	Ground Cover Factor
A / low	10	0.18
B / moderate	30	0.53
C / moderate to high	30	0.63
D / severe	60	0.77

The operational maintenance level describes traffic volume and type of use. Only Road 70 (Greenwater Road) is considered to have active log haul; Plum Creek Timber Company hauls logs from the east side of the Cascades through Naches Pass. All other use is by recreationists and for administrative uses. Road 70 log haul is heavy use, operating for six months. The remainder of the year is non-use due to snow. All other Level 3-5 Roads are considered to have moderate traffic for six months; Level 2 roads with light traffic for six months, and Level 1 Roads with no traffic as per Washington State watershed analysis TFW manual (WFPB 1993).
Road surfacing factors were applied based on TFW.

3.3.5 Mass Wasting

Erosion from mass wasting was estimated from aerial photo based inventories of landslides. Photograph years from 1979, 1983-1984, and 1991, or 1996 were used. Kari Paulsen completed a comprehensive inventory of the Greenwater River (Mt. Baker-Snoqulamie National Forest 2000). Cox (2001) inventoried the remainder of the Upper White River watershed in 2001. Consistency of methods was stressed, however, some differences exist due to different interpretations by the observers. Landslides were mapped on photo overlays, then digitized into a GIS. Areas and length of slide tracks were estimated using ARCVIEW tools. Slide depth in the Greenwater was based on SRI soil depths and estimated by the observer for the Upper White.

Landslides scars were assumed to erode during major storm events. Landslides were categorized as chronic or not (except for the Greenwater inventory). Chronic landslides appeared active in subsequent photos. Chronic landslides were assumed to erode at 0.1 foot for each major winter storm. Major storm is defined as those that rank in the top ten for precipitation amount for the period of record (1940 – 1996) at the Mud Mountain Dam weather station. The Middle White Clearwater watershed analysis used an erosion rate on landslide scars of 5 mm/year. Non-chronic landslides were assumed to erode at 0.1 ft for the first storm after occurrence and 0.04 ft for the second storm. These slides are assumed stable thereafter.

3.3.6 Unit Consistency

Erosion estimates for glaciers and from the TFW methodologies are in tons per year. Photo interpreted mass erosion was estimated in cubic meters. All values are converted to metric tons per year for consistency. An average particle density of 2.65 Mg/m3 (megagram/cubic meter)(Brady and Weil 1999) is used to convert the volume measures.

3.3.7 Bedload/Suspended

Total sediment from inventoried landslides was partitioned into bedload and suspended load based on soil descriptions in the SRI (Snyder and Wade 1972). Bedload from glaciers was estimated as described above (ten percent of the glacial erosion). Actual soil locations for the Greenwater landslide inventory were not available so an average estimate was made based on the expected soil at the origination of the landslides. Long debris avalanche tracks crossed more than one soil type but only the soil at the origination point was used for this estimate.

3.3.8 Landslide Characteristics

A total of 447 landslides were recorded in the two landslide inventories (Table 3.1). Forty four percent of the landslides occurred in the Greenwater River alone. The Greenwater and Upper White River subwatersheds account for 73 percent of the landslides. Nearly 60 percent of the landslides were related to management activities, roads and clearcuts, with the vast majority originating from roads.

Table 3.1. Distribution of landslide occurrences by land condition at the failure source.

Number of Landslides by Source								
Subwatershed	Naturally Unvegetated	Mature Forest	Stream Channel	Clearcut	Road Fill	Road Cut	Road	Total
Greenwater	11	45	0	64	71	4		195
Upper White	62	30	1	8	3	0	27	131
West Fork	6	15	1	5	23	1	39	90
Huckleberry	0	11	0	1	6	0	13	31
Total	79	101	2	78	103	5	79	447
% of Total	18	23	0.4	17	23	1	18	

Certain soils tend to have the majority of the landslide origins (Table 3.2). Soil information is not listed for the Greenwater River, however, the landform characteristics and soils are similar to the other subwatersheds. The Upper White and Greenwater watershed analysis (Mt. Baker-Snoqualmie National Forest 2000) discussed the relationship of landslide occurrence to the modeled mass wasting hazard. This looked at the natural hazard for mass wasting as well as the risk associated with management activities. The mass wasting risk model uses soil characteristics and slope conditions. The relationship between the modeled risk and failure occurrence is strong (Table 3.3). It would be expected that the relationships of landslides to soil units and management activities described below holds for the Greenwater River.

Twenty-one percent of the landslides outside of the Greenwater River occur on soil units 6 and 7. These two soils dominate the failure sites for landslides categorized as naturally unvegetated or mature forest in Table 3.1 above. Unit 6 is characterized by steep rock outcrop and talus on high elevation ridgetops and cirque topography. Unit 7 consists of rock outcrop, talus slopes, and avalanche tracks. These landforms are where natural debris and snow avalanches erode the hillslope troughs, and are characteristic of the

Table 3.2. Distribution of landslide occurrence by SRI map unit.

	Number of Landslides				
SRI Map Unit No.	Greenwater	Upper White	West Fork	Huckleberry	Total
5		0	3	0	3
6		59	0	0	59
7		20	8	7	35
8		1	0	0	1
12		6	2	0	8
13		0	1	0	1
23		0	1	0	1
31		0	1	0	1
33		0	8	4	12
313		0	1	0	1
330		0	1	0	1
335		0	4	3	7
41		6	8	10	24
413		4	2	1	7
42		2	13	0	15
420		0	25	0	25
423		0	4	0	4
428		1	3	0	4
43		10	1	2	12
435		0	1	0	1
438		2	0	0	2
44		0	0	2	2
440		0	0	2	2
448		4	0	0	4
452		0	1	0	1
46		0	1	0	1
47		0	1	0	1
48		16	0	0	16

Table 3.3. Relationship of inventoried landslides to natural landscape conditions and management activities in the Greenwater River (Mt. Baker-Snoqualmie National Forest 2000).

	Percent of Greenwater Landslides		
	Low Risk	Mod. Risk	High Risk
Natural Landscape Characteristics	9	70	21
Management Influenced Characteristics	8	33	59

Upper Greenwater and Upper White River subwatershed areas. Except for Crystal Mountain Ski Resort in Silver Creek, these landforms are typically undisturbed.

The most common soils for the majority of the remaining landslides are Units 41, 42, 420, 43, and 48. Soil Units 41 and 42 occur on steep side slopes within the dominant rain-on-snow zone. Map unit 420 is a complex of 70 percent Unit 42 and 30 percent Unit 30, which contains rock outcrop and talus slopes. Unit 43 occurs on steep upper side slopes. Unit 48 occurs as very deep unstable soils on dissected mid slopes and toe slopes. All these soils are identified as high hazard for erosion when exposed in harvest units and road cuts and fills. Most are associated with the dominant timber resource zone and are relatively productive. The landslides on these soils are mostly related to management activities.

3.4 Partial Sediment Budget for the Upper White River

Glacial sediment dominates the White and West Fork White Rivers and Huckleberry Creek (Figure 3.2). The order of magnitude greater erosion from glaciers and recently exposed glacial terrain overshadows all other sources of sediment. Stream bank and creep erosion calculated using TWF methodologies are minimal. Background mass erosion (natural sources, mostly from avalanche chutes on the steep, glacial trough terrain) is most significant in the Upper White River subwatershed. Mass wasting related to management (timber harvest units and roads) is greatest in the Greenwater and West Fork White Rivers.

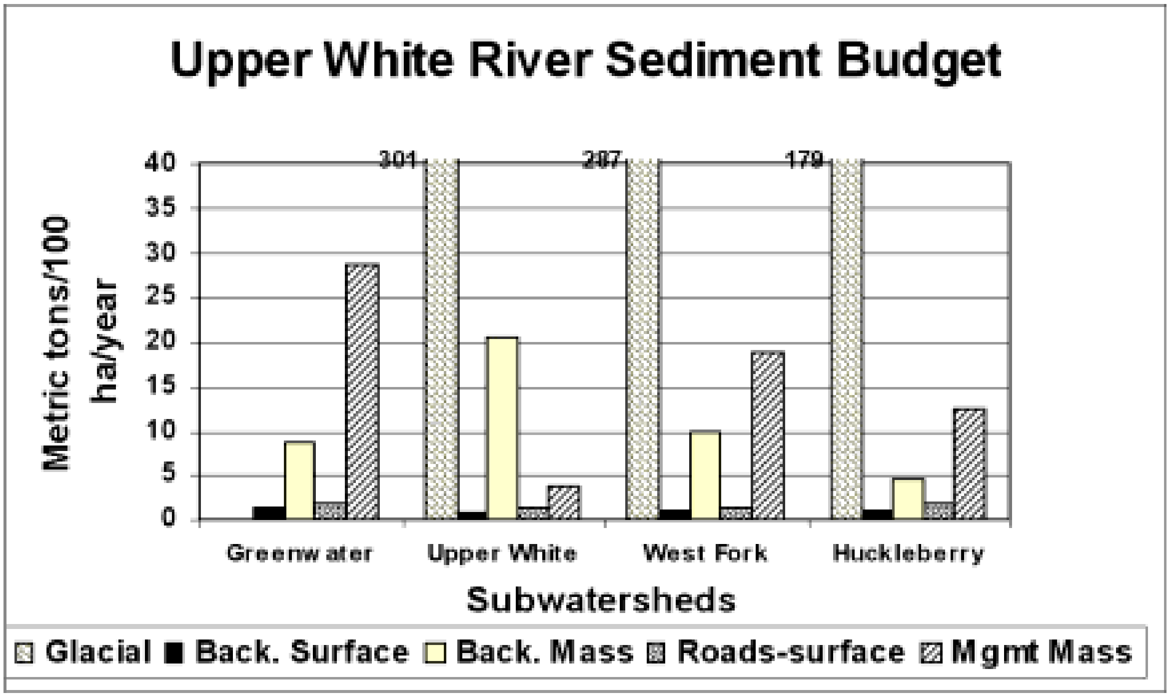


Figure 3.2. Sediment budget for Upper White River watershed displayed by subwatershed (metric tons/100 ha/ year).

3.4.1 Road Sediment Versus All Other Sources

In order to discriminate between the harvest- and road-related sediment, all road sediment was separated from other management sediment (Figure 3.3). This shows that, with the exception of the Greenwater River, mass wasting that originates in harvest units is a greater source of sediment than are those related to roads. This is contrary to most of the literature that compares road and in-unit sediment, and may be the result of estimation of slide depth and appropriate source when both a harvest unit and road are associated with the failure.

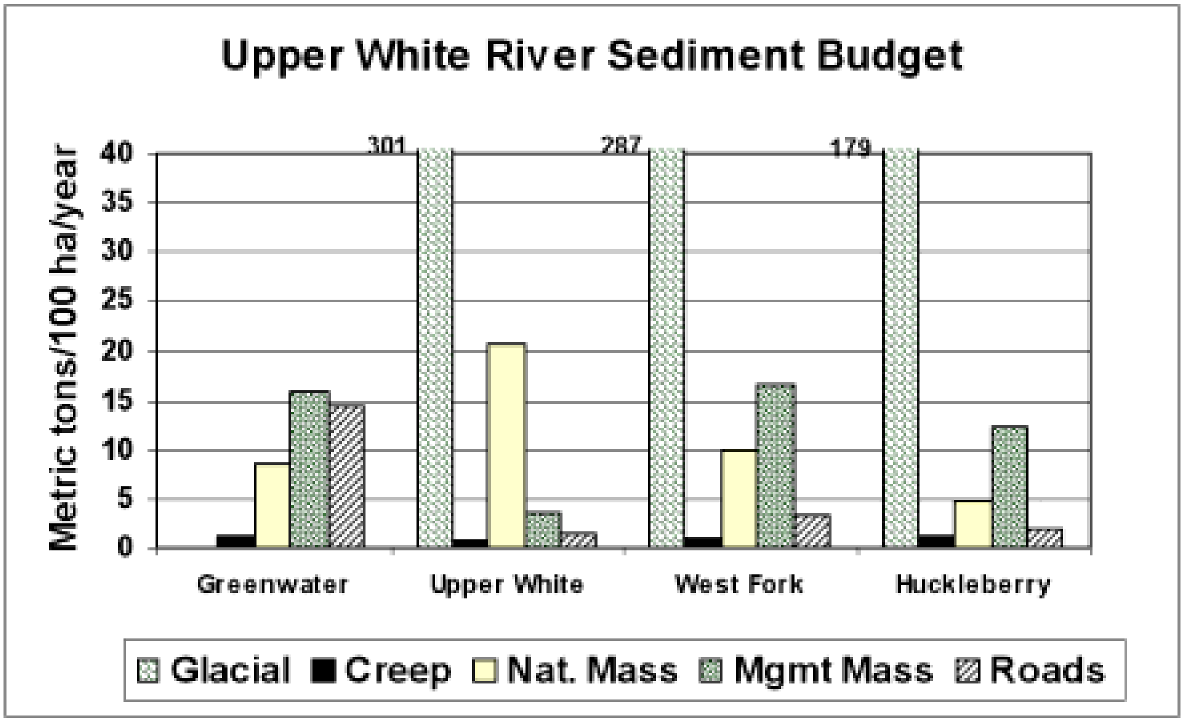


Figure 3.3. Sediment budget for Upper White River watershed displayed by subwatershed (metric tons/100 ha/year) with roads separated from other management related mass wasting.

3.4.2 Suspended Load Versus Bedload

Sediment transport in rivers occurs as two distinct types; suspended load and bedload. Suspended load is the finer particles that move in the water column in faster water and settle out in very slow water. Bedload consists of larger particles that move along the bed of the stream and are deposited in as gravel bars or within faster water areas such as riffles. While both forms of sediment transport occur naturally, changes in regime can impact aquatic resources. Too much suspended sediment in pools and spawning gravels can reduce habitat quality and smoother incubating fish eggs. Too much bedload movement, or scour, can physically damage or too deeply bury fish eggs or injure small fish that hide in the spaces between gravel particles.

Since natural sediment, high in suspended load, dominates the sediment budget for these rivers, an additional assessment was conducted to determine if the type of sediment (bedload vs. suspended load) is different between natural sources and management related sources. No data were available to discern the proportions of bedload from suspended load from all sources, so estimates were made as described above.

For both natural and management sediment sources, bedload sediment makes a small proportion of the total sediment (Figure 3.4). The data indicate the proportions between natural and management-related sediment do change some by subwatershed. The change is most pronounced in the West Fork White River where the proportion of bedload sediment changes from 10 percent for natural sources to 34 percent for management sources (Table 3.4). This indicates a clear shift to more bedload sediment in the West Fork White River, resulting from management activities. The proportion of bedload sediment appears to double between natural and management sources in Huckleberry Creek.

In the Greenwater River, the proportion of bedload sediment is much greater from natural sources because there is no fine glacial flour. The proportion of bedload sediment is not significantly different between natural and management sources. However, the amount of bedload from management sources in the Greenwater River is more than double that from natural sources (Figure 3.4).

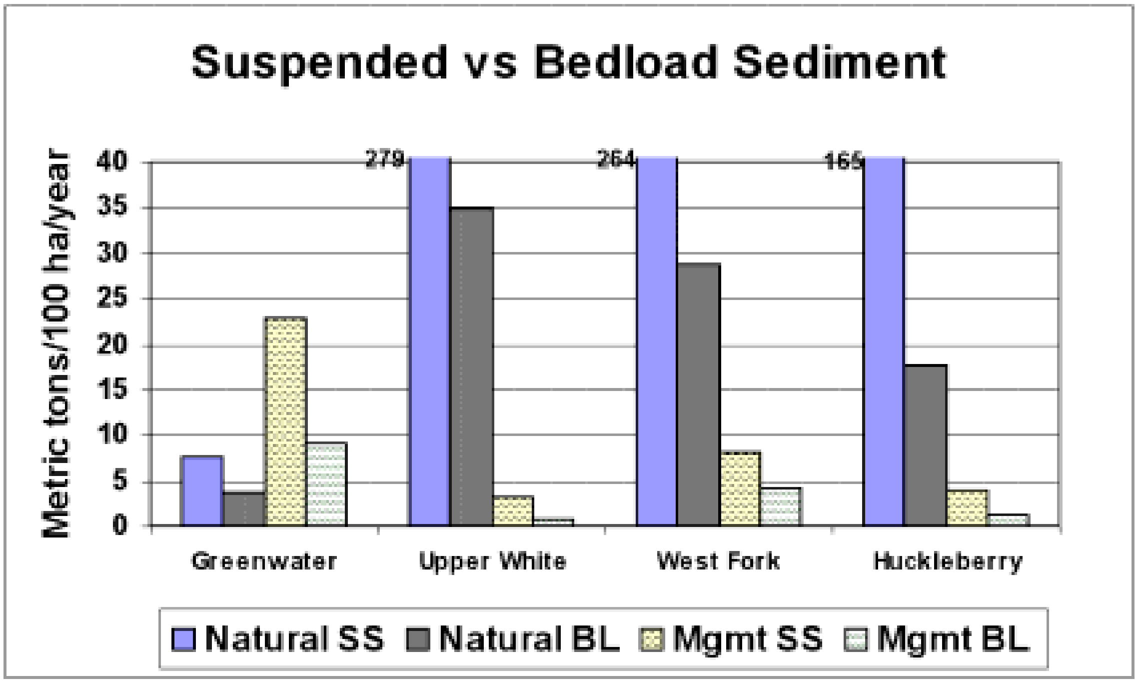


Figure 3.4. Comparison of suspended sediment and bedload sediment in the Upper White River subwatersheds (metric tons/100 ha/year).

Table 3.4. Comparison of the proportion of total sediment that is suspended sediment between natural sources and management sources for Upper White River subwatersheds.

Subwatersheds	Bedload Sediment as a Percent of Total Sediment	
	Natural Sources	Management Sources
Greenwater	32	28
Upper White	11	17
West Fork White	10	34
Huckleberry	10	22

3.5 Synthesis of Sediment

The hypothesis presented in the beginning of the sediment section states that changes in the sediment regime have altered channel morphology in the Upper White River watershed and contributed to the elevation of stream temperature. The sediment budget presented here, suggests that this is the case, at least in the Greenwater River. In the Greenwater River, management activities have increased total sediment by 400 percent and bedload sediment by 250 percent (Table 3.5). These high percentages relative to the other subwatersheds, reflect the absence of glacial sediment in the Greenwater River. Much of the management-related sediment is from roads. This large increase in sediment is likely a major factor in the morphology changes measured by Schuett-Hames and Adams (2003) and Laurie (2002).

At the subwatershed scale, naturally derived sediment from glaciers and natural debris chutes dominates the sediment load in all but the Greenwater River. The apparent increase in sediment from management is relatively small for the Upper White and West Fork White Rivers and Huckleberry Creek (Table 3.5). However, there appears to be a shift to a higher percentage of bedload sediment in the West Fork White River and Huckleberry Creek attributable to management activities. Harvest units generate the highest volume of sediment, after the glaciers, in the West Fork White River and Huckleberry Creek.

The relationship between increases in sediment and the channel morphology of the subwatersheds in the Upper White River is influenced by a number of complicating factors. Channels respond not only to sediment load, but also to flow and changes in channel structure influenced by large woody debris.

Major channel avulsions have occurred in both the West Fork White and Greenwater Rivers. These abrupt changes appear to be related to floods that followed riparian timber harvest. The floodplains and channel migration corridors were logged and roaded.

Table 3.5. Total sediment (metric tons/year) and percent increase from management-related sediment in the Upper White River watershed.

Subwatershed	Natural Sediment	Management-Related Sediment	Total Sediment	Apparent Increase from Management – **Total** Sediment (Percent)	Apparent Increase from Management– **Bedload** Only (Percent)
Greenwater	11,825	48,407	60,232	409	250
Upper White	552,558	9,125	561,683	1.7	2
W. F. White	309,489	22,912	332,401	7.4	14
Huckleberry	110,570	8,664	119,234	7.8	14

Subsequent floods found little floodplain complexity or roughness and channel changes took advantage of the lower resistance. The effects of these channel shifts last for many years and can translate downstream with detrimental effects to riparian areas, as in the Greenwater River where late successional floodplain forests are being undermined by stream bank erosion.

An assessment of channel area was conducted on four short reaches of the West Fork White River using aerial photographs (Figure 3.5). The upstream reach is just inside Mt. Rainier National Park; the lower reach is approximately 2 miles downstream of the Forest Boundary. This assessment shows a general increase in channel area for these four reaches since 1956. The reach above the Road 74 bridge is the reach with two dramatic channel avulsions in the 1980s. Proper controls for the national park reach on the 1991 photos could not be obtained so that critical point is missing.

The changes in channel area have not been converted to sediment volumes and included in the sediment analysis for a number of reasons. First, the depth dimension would be highly variable and difficult to determine. This is a significant variable in determining the volume. Second, the selected reaches are relatively short and do not represent the entire stream system. They could be considered representative of similar channel types, but management activities on the site have a great influence on the channel erosion. Third, there would be some overlap with the stream bank erosion already included in the sediment budget.

There are four other factors that are likely contributing to the channel conditions in these subwatersheds: flow, dispersed recreation use, large woody debris, and glacial retreat.

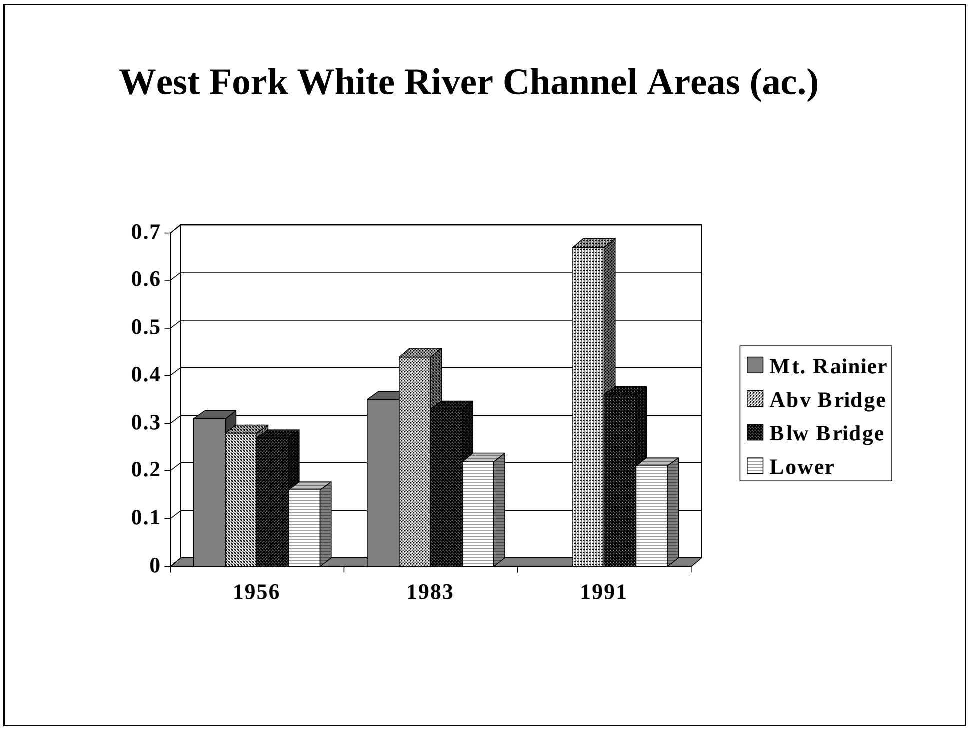


Figure 3.5. Stream channel areas in the West Fork White River, taken on four reaches from three aerial photograph flights. Approximate locations: Lower – RM 2; below Rd 74 bridge – RM 6; above Rd 74 bridge – RM 8; Mt. Rainier National Park – 13.

Peak flow analysis of the Greenwater River stream gage has shown an increase in the magnitude of peak flows between the pre-1970 and post-1970 portions of the record (Mt. Baker-Snoqualmie National Forest 2000)(Figure 3.6). The Greenwater River has been harvested much more intensively than the other subwatersheds, but some effects on flow would be expected in the West Fork and Upper White in particular. For the West Fork and Upper White River subwatersheds, affected by glaciers, glacial retreat on Mt. Rainier increased during the 1980s and continues (National Park Service 2003). This results in more sediment and more meltwater delivered to the river systems.

Dispersed recreation use has intensified along the lower portions of these subwatersheds, with the most use being in the Greenwater River. The effects of this use are soil compaction and loss of vegetation cover, trampled stream banks, loss of woody debris through firewood use, and sanitation. The degree to which this contributes to increased erosion and loss of bank stability is not known. The Forest is proposing to inventory and quantify the effects of streamside dispersed recreation on riparian and stream habitats. There is a tremendous opportunity to work with the public to increase understanding of, and sensitivity to, the effects of this use on the channel and water quality and engage the public on ways to protect the resources.

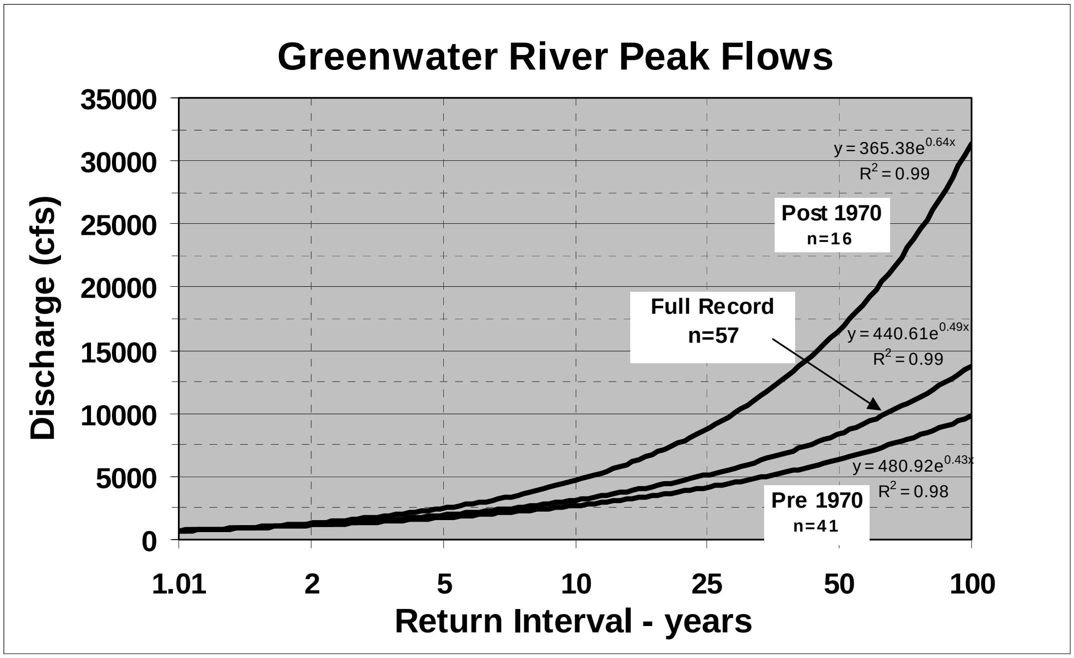


Figure 3.6 Peak flow return interval shift using Greenwater at Greenwater USGS stream gage records. The year 1970 is used to distinguish the period when timber harvest and road building increased dramatically in the Greenwater subwatershed.

Large wood was removed from all of these streams in the late 1970s (Mt. Baker-Snoqualmie National Forest 2000). Loss of this wood decreased channel complexity and reduced the channels' capacity to store sediment. Sediment movement through the channels likely increased. The additional sediment load accumulated downstream, causing additional channel widening in the lower reaches.

The increased **retreat rate** of the glaciers on Mt. Rainier in the 1980s increased the total water yield and can increase the sediment delivered to the river system below. Ground recently exposed by retreat of ice is highly susceptible to erosion and stream bank erosion rates are high.

Increases in peak flows can result in more stream bank erosion and channel widening. Additional sediment derived from glacial melt and retreat and denuded stream banks and bank erosion can increase channel instability and migration. The combination of these factors has contributed to the unstable conditions in these channels. To better isolate the problem areas individual drainage areas have been assessed through this analysis.

There is no single causative factor for the erosion and sediment loadings in these subwatersheds. Yet the above discussion demonstrates there are particular sources for major portions of the total sediment that can be identified for treatment. Elimination of anthropogenic sediment sources will assist to return the streams in the Upper White River watershed to a more stable condition. However, the other factors listed above must also be addressed in a restoration plan.

3.5.1 Vegetation Disturbance

One measure of watershed condition and susceptibility to rain-on-snow effects used in the Upper White and Greenwater Watershed Analysis is vegetation disturbance (Mt. Baker-Snoqualmie National Forest 2000). Vegetation disturbance is a measure of the amount of the watershed where vegetation has been altered by harvest, roads and fire. It is a measure of hydrologic maturity. Disturbance varies through time, as shown in the plot for the West Fork White River (Figure 3.7).

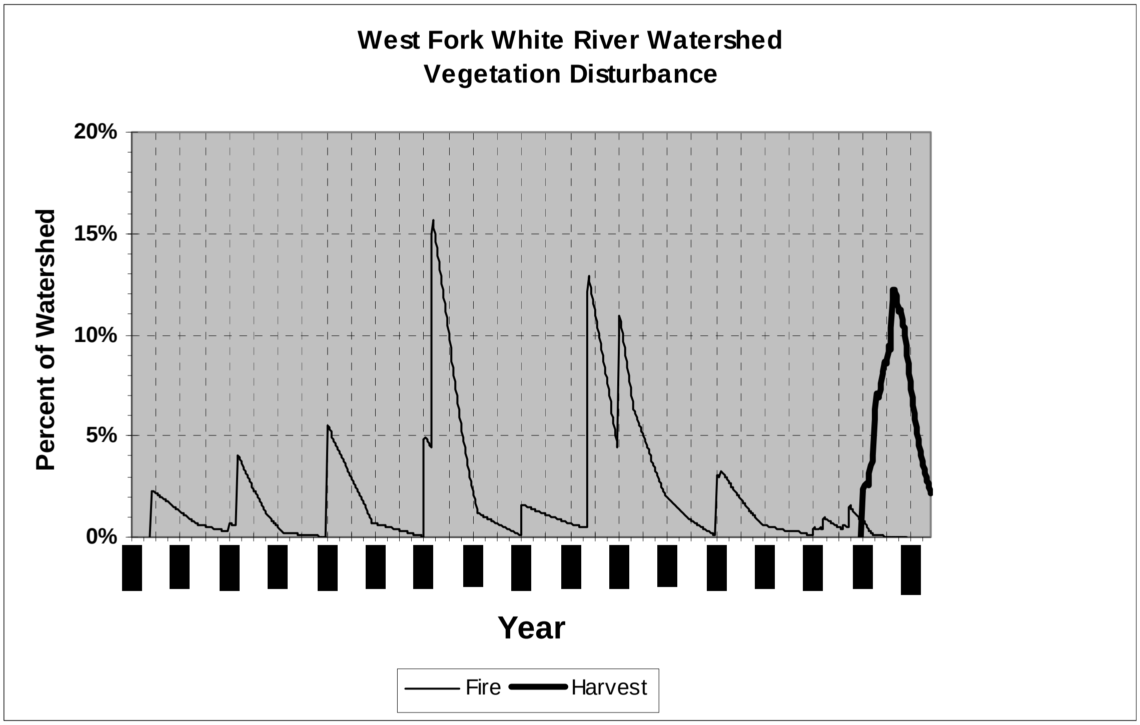


Figure 3.7. Vegetation disturbance for the West Fork White River, Mt. Baker-Snoqualmie National Forest. Data source: Forest fire history and TRI vegetation database on GIS.

Data used in the graph is limited to National Forest System lands. National Park management creates minor (considered insignificant) openings in the vegetation canopy. Private land harvest data outside the National Forest boundary were not available for this analysis. If included, private land timber harvest would increase the vegetation disturbance in the West Fork White and Greenwater Rivers. If all private land were currently harvested, the disturbance level would increase to 20 percent in the West Fork and Greenwater subwatersheds. This is not the case, but is used to illustrate the worst-case situation. The Mt. Baker-Snoqualmie National Forest uses a disturbance level of 15 to 20 percent (Mt. Baker-Snoqualmie National Forest 2000) as a threshold for concern for cumulative watershed effects, particularly for rain-on-snow effects.

The vegetation disturbance level on National Forest System lands in the West Fork White River in the 1980s was nearly as high as it ever had been from past fires. Historic fires in the Upper White River affected large areas of the subwatersheds, but most likely left a mosaic of burned and unburned forest. Riparian areas probably burned lightly or not at all. Recovery of the forest canopy was relatively rapid.

Timber harvest, which started slowly in the 1950s and accelerated in the 1970s, also affected large areas. These effects persist over a longer time period, and also bring other disturbances to the subwatersheds. These disturbances, from roads and streamside harvest, as well as the removal of important large wood from stream channels, alter the way the hill slopes and stream channels recover.

Figure 3.8 shows the vegetation disturbance level for the individual drainage areas of the Upper White River watershed in the year 2000. This clearly shows the low disturbance in the wilderness headwaters of the subwatersheds and the higher disturbance levels in the downstream areas where they are intensively managed. Drainage areas that have a high percentage of private land were given a high disturbance level because, while not quantified, much of the area has been harvested.

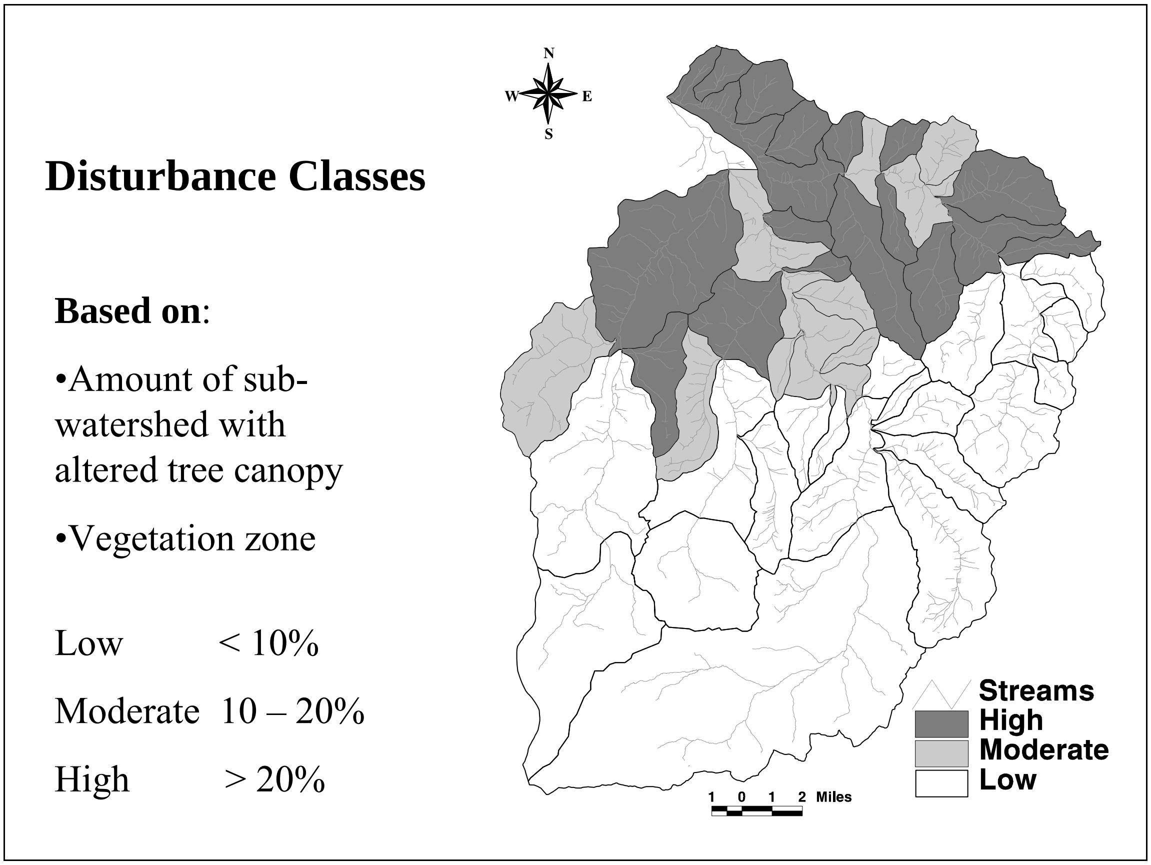


Figure 3.8. Vegetation disturbance levels in the Upper White River watershed using fire history and TRI vegetation databases. Mt. Baker-Snoqualmie National Forest GIS.

Since the Upper White River is predominantly wilderness or to be managed for late-successional forest, the vegetation disturbance level will decrease over time. As indicated in Figure 3.7, this decrease will be relatively rapid, but taper to a low level that is caused by more permanent disturbance due to roads.

Vegetation disturbance is used as an indicator of overall watershed conditions. Figure 3.9 shows that a relationship exists between vegetation disturbance and the average annual sediment production when assessed at the drainage area scale.

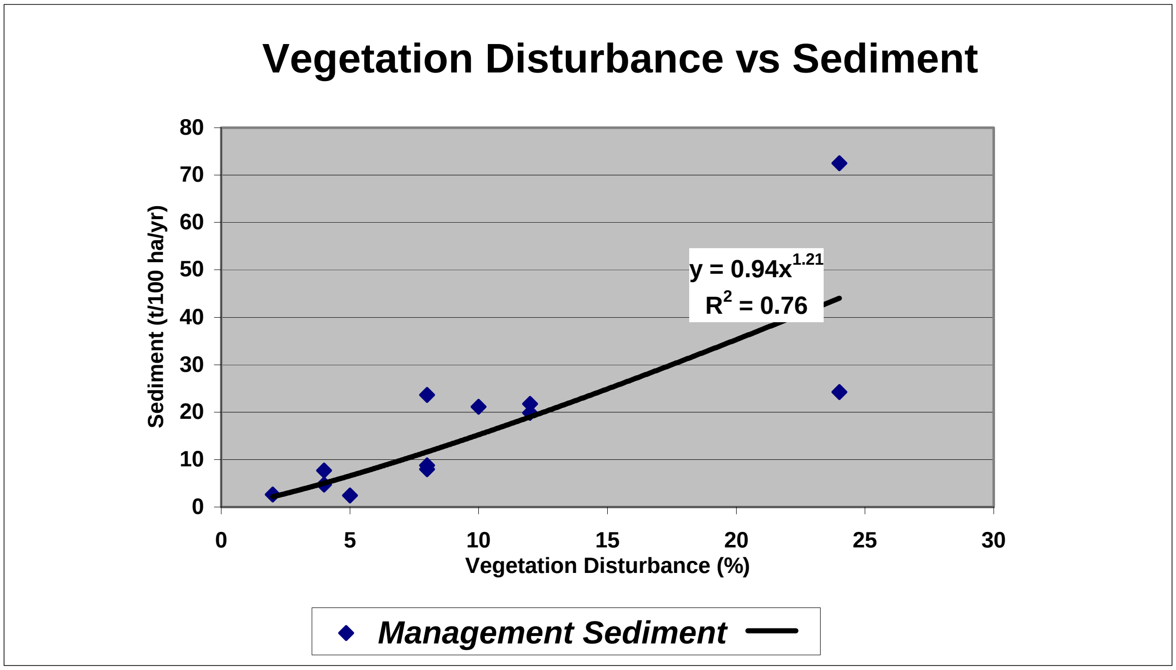


Figure 3.9. Relationship between vegetation disturbance levels and management-related sediment production, Upper White River watershed. Mt. Baker-Snoqualmie National Forest. Data source: Sediment budget; three aerial photo periods for each of four subwatersheds.

3.5.2 Finer Scale Information

Additional information that will be utilized for the water quality restoration plan includes more site-specific erosion information generated during development of the sediment budget. The sediment information was computed on a finer spatial scale. For example, the distribution of sediment for smaller drainage areas in the Greenwater River (Figure 3.10) shows specific areas within the Greenwater River where the majority of sediment is generated. Areas with high management-related sediment will be targeted for treatment. Appendix B contains this information for the other subwatersheds as well.

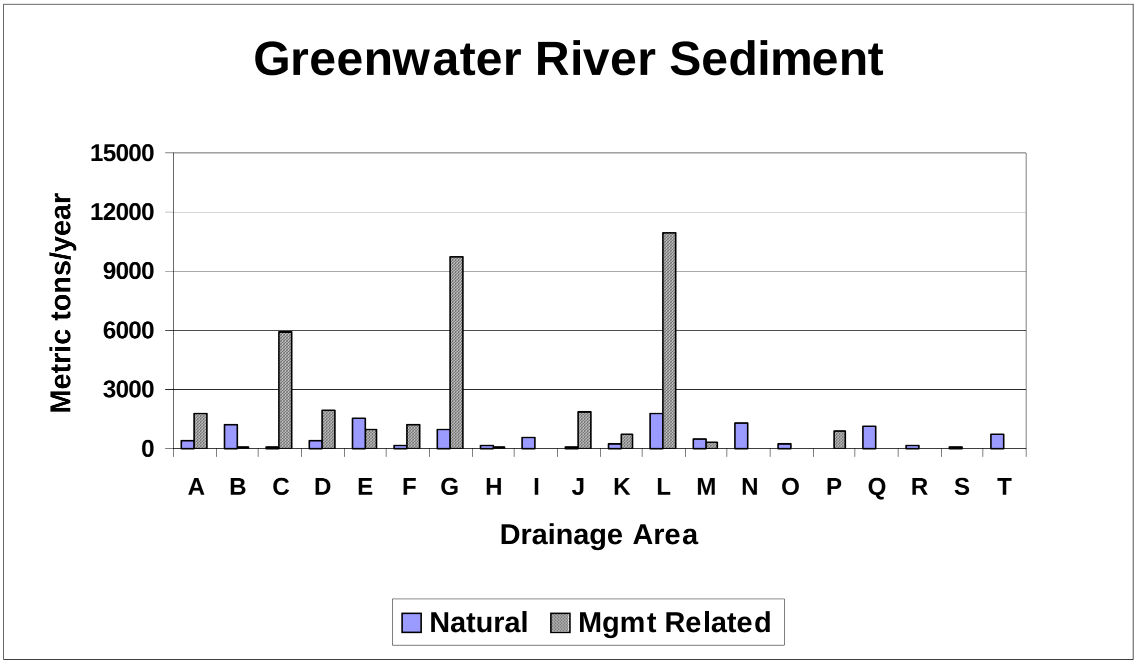


Figure 3.10. Natural and management related erosion by drainage area in the Greenwater River.

3.6 Sediment and Channel Linkage

The capacity of these streams to assimilate increases in sediment is unknown. Stream systems have an inherent ability to transport sediment based on the geology, landform, and climate. These factors control how much water (energy) is available for transport and the quantities of sediment that are delivered. Sediment delivery to stream channels is episodic. Pulses of sediment move through a stream system, causing changes to channel morphology in differing locations at any one time. When system-wide channel morphology changes occur, there is concern that the capacity of the system to maintain a dynamic equilibrium has been exceeded.

Based on this sediment assessment, the watershed analysis (Mt. Baker-Snoqualmie National Forest 2000) and other studies in the Upper White River (Laurie 2002, Schuett-Hames and Adams 2003), there is strong evidence that the Greenwater and West Fork White Rivers are out of equilibrium. These conditions are due to a number of factors: increased sediment loads, loss of stable riparian communities, removal of large woody debris from channels, and increases in flow from vegetation manipulation, roads, and glacial retreat.

As stated in the beginning of this TMDL, one goal was to identify and assess the core processes operating in the watershed that maintain and restore native biological communities and general aquatic health. The accompanying hypothesis was that changes in the sediment regime have altered channel morphology in the Upper White River watershed and contribute to the elevation of stream temperature. With a good picture of where the sediment sources are we can now look at the channel responses. Using geomorphic relationships among channel parameters (Rosgen 1996) we compare the existing channel widths measured during stream surveys to expected channel widths obtained from *regional curves*[1] built by Laurie (2002). This analysis determined that many of the channels in the Upper White River watershed are wider than would be expected from the regional curves. The three channels illustrated below demonstrate a channel near expected channel width (Huckleberry Creek), one considerably wider than predicted (Viola Creek), and how bankfull channel width may vary longitudinally (Greenwater River).

Figure 3.11a illustrates the changes in channel width of the Greenwater River. For the headwaters within the Norse Peak wilderness, river miles (RM) 14-18, the channel width matches that expected from the regional curve. From approximately RM 7.5 to 10, the channel is confined in a narrow gorge and the channel widths are narrower than predicted by drainage area. RM 6 to 7 is the location of a channel avulsion that occurred in 1990 (Laurie 2002) and the current channel is in a gully. This gully is widening to accommodate the river, but measured widths are still narrower than predicted. Once the channel is out of the gully, the channel abruptly widens to about 20 feet greater than predicted by the regional curve. This change is due in part to the high sediment load and peak flow changes. The mouth of the Greenwater River is channelized by a rip rapped dike and is narrower that the natural channel would be.

Of the channels with stream survey data available, only Huckleberry Creek and portions of the Greenwater River have channel widths in the range of that predicted by regional curves. Those with channel widths wider than predicted are: Eleanor, Twenty-eight Mile, Viola, Pinochle, Jim, Mule, Maggie, Pyramid, and Lost Creeks.

The implications of this are that the cumulative effects of sediment, flow, and riparian conditions have resulted in wider stream channels. Streamside vegetation is more effective for shading stream channels and maintaining stream temperature when channel widths are narrow. The wider the channel, the taller the vegetation must be to shade the channel. As the channels in the Upper White River have widened, the effective shade of riparian vegetation, whatever the condition of the riparian areas, has diminished. If the channel processes are restored and channel widths narrow, riparian vegetation will be more effective at shading the channels and stream temperatures will lower.

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[1] A regional curve is a bankfull hydraulic geometry relationship developed for a particular hydro-physiographic region. Regional curves describe the relationship between drainage area and channel cross-sectional area, discharge, and mean depth and width, all at bankfull stage.

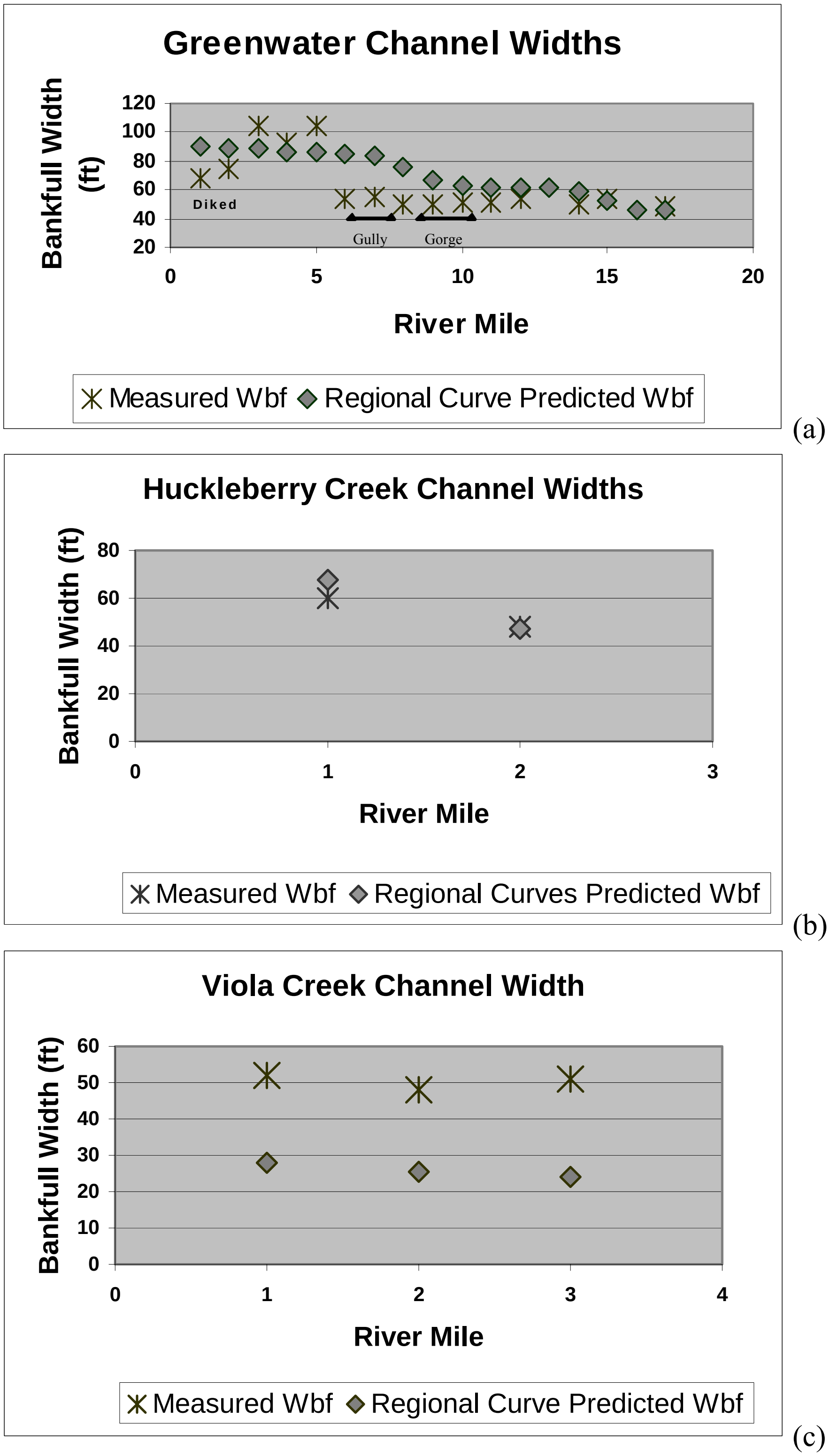


Figure 3.11. Examples of measured channel widths versus bankfull widths predicted from regional curves. Measured channel widths from Forest Service stream surveys. Regional curve developed by Laurie (2002).

3.7 Crystal Mountain Ski Area Development

Master Planning at the Crystal Mountain Resort began several years ago and is nearing a final EIS. This sediment analysis and TMDL development have progressed on a near parallel timeline and the ski area assessments and findings have been incorporated into this sediment assessment.

A watershed condition report (Jones and Stokes 1997) looked at erosion and sediment within the Master Permit Area and Silver Creek. Several debris and snow avalanche tracks were identified. A number of these have been inactive since the development of the current forest cover. Others continue to move sediment downslope to the valley floor and in a few cases to Silver Creek. The debris fans influence the channel location and increase bank erosion by Silver Creek. The watershed condition report concluded that the major source of sediment from ski area management is from winter sanding of Crystal Mountain Blvd and that in general the slope processes are in a period of stability or recovery. The landscape erosion processes were more active after the last large fire in 1890 that burned an estimated 60 percent of Silver Creek.

The predicted annual sediment from road sanding was added as a separate line item in the TMDL sediment budget for the drainage areas affected by the sanding. This sediment is included in the Upper White River subwatershed sediment budget. Studies are underway at Crystal Mountain to greatly reduce or eliminate sand to maintain Crystal Mountain Boulevard for winter travel.

Effects of Crystal Mountain Resort development on stream flow have been assessed (Mt. Baker-Snoqualmie National Forest 2001 Appendix L). Some clearing of vegetation for ski runs and resort facilities has, and will, occur. This development is higher in elevation than the peak rain-on-snow zone. Water use within the resort results in the diversion of streamflow. The streamflow assessment predicts a two percent increase in monthly flows in May due to melt of machine-made snow, and a six percent decrease in base flows in December due to snowmaking. No changes in one-day maximum discharge are indicated for the Master Plan area. A storm management plan has also been developed for the area.

The Draft Environmental Impact Statement (DEIS) for Crystal Mountain (Mt. Baker-Snoqualmie National Forest 2001) evaluated each Aquatic Conservation Strategy Objective (ACSO) for the development plan. ACSO 5 refers to maintaining and restoring the sediment regime. The DEIS concludes that the current conditions are outside the desired future conditions for sediment because of road sanding and a small amount of rill and gully erosion on the slopes. The effects of the master plan development alternatives were assessed at three scales: the site, Silver Creek, and the Upper White River subwatershed. Silver Creek is a 7400-acre tributary to the White River. The Upper White River for the purposes of the Crystal Mountain master planning was the White River upstream of the Greenwater River and excluding the West Fork White River and Huckleberry Creek.

At the site scale, all alternatives would continue to impact on-site conditions although there would be a mix of new and continued sediment sources (roads and road sanding) and restoration or elimination of other sediment sources (paved parking lots or parking garage requiring less parking lot development, reduction of road length in riparian reserves, and restoration of gullies). At the Silver Creek scale, effects on the sediment regime would not be significant since only three percent of the soils and only one percent of the Riparian Reserves would be affected. At the Upper White River subwatershed scale the effects on sediment regime are even smaller; less than 0.1 percent of soils and Riparian Reserves are affected.

Master Planning at the Crystal Mountain Resort includes restoration, road management, and monitoring (Mt. Baker-Snoqualmie National Forest 2001). Restoration of the predominant erosion sites (Appendix C), stabilization of Silver Creek channel processes (Appendix I), improved road management (Appendix E), especially sanding of Crystal Mountain Boulevard, and monitoring of the effectiveness of mitigation measures (Appendix D) are all part of the Master Use Permit. (*Appendices refer to those in the Draft Environmental Impact Statement.*)

The monitoring plan will include: project monitoring to determine if project implementation follows what is approved in the master use permit and that all measures to reduce or mitigate environmental impacts are in place; and effectiveness monitoring to see if the desired conditions are being achieved. In addition, watershed scale monitoring is in place to determine the effectiveness of management measures to maintain desired watershed conditions within the permit area, Silver Creek and Upper White River. The annual monitoring report, submitted to the Mt. Baker-Snoqualmie National Forest, will identify if changes in management are warranted to meet objectives of the Forest and achieve and/or maintain desired conditions.

Management of the Upper White River subwatershed will not likely include additional significant development. Approximately ninety percent of the Upper White River is either National Park Service or National Forest System lands. Approximately ten percent of the National Forest System lands would be managed other than Late Successional Reserve (LSR) or wilderness. Late Successional Reserves are managed to provide habitat for late-successional and old growth forest dependent species.

The Crystal Mountain master planning area makes up most of the non-LSR acreage in the Upper White River subwatershed. The master use permit area comprises approximately 65 percent of Silver Creek, seven percent of the Upper White River subwatershed, and five percent of this TMDL assessment area.

3.8 Sediment Loading Capacity and Targets

The loading capacity of these streams is unknown. The above assessment shows the highly variable nature of erosion. Stream systems have an inherent ability to transport sediment based on the geology, landform, and climate. These factors control how much water (energy) is available, and the quantities of sediment that are delivered for transport.

Sediment delivery to stream channels is episodic, therefore describing sediment loads in terms of average annual amounts is somewhat limiting. Pulses of sediment move through a stream system, causing changes to channel morphology in differing locations at any one time. When system-wide channel morphology changes occur, there is concern that the capacity of the system to maintain a dynamic equilibrium has been exceeded.

Based on this sediment assessment, the watershed analysis (Mt. Baker-Snoqualmie National Forest 2000) and other studies in the Upper White River (Laurie 2002) (Schuett-Hames and Adams 2003), there is strong evidence that the Greenwater and West Fork White Rivers are out of equilibrium. These conditions are due to a number of factors: increased sediment loads, loss of stable riparian communities, removal of large woody debris from channels, and increases in flow from vegetation manipulation, roads, and glacial retreat.

As stated in the beginning of this TMDL, one objective was to identify and assess the core processes operating in the watershed that maintain and restore native biological communities and general aquatic health. This assessment has shown there are significant sources of management-related sediment that are likely contributing to channel conditions that are not desirable. A target of no anthropogenic sediment would allow the streams to respond to a sediment regime similar to that under which these channels formed. Under that regime, the channels would be expected to stabilize and narrow.

As stated above, sediment reduction alone will not restore these channels. Peak flows are still higher than in the past and the amount of large woody debris is less than optimum. Peak flow increases due to rain-on-snow effects are predominantly dependent on the return of hydrologic maturity, as measured by vegetation disturbance. Secondarily, peak flows may be affected by the road system. Return to hydrologic maturity and fixing all the road effects will not occur over night. Therefore a phased approach to reaching the target of no anthropogenic sediment is proposed below. The allocation of sediment per decade is based on the natural growth of the forest (using the relationship between vegetation disturbance and sediment in Figure 3.9) and the expectations for Forest Service road stabilization agreed to under a Memorandum of Agreement between the Forest Service Region 6 and Washington Department of Ecology (USDA Forest Service and Washington Department of Ecology 2000).

The following assumptions are used to determine the targets:

- Open roads can be treated to eliminate up to 80 percent of the erosion using surfacing and revegetation techniques (USDA Forest Service 1981). Decommissioned roads produce no sediment. Forest roads under the MOA will be fully stabilized in 15 years (from 2000), or the second decade.
- Vegetation re-growth will return hillslope erosion rates to background once hydrologic maturity is reached.
- The relationship between vegetation disturbance and sediment is used to predict management-related sediment (other than roads) to be achievable by decade.

This approach, using ranges of sediment loading, recognizes the difficulty in determining the sediment load capacity of a channel that will restore or maintain channel morphology and protect beneficial uses. It also recognizes that erosion and sediment transport through a watershed are episodic and a change in sediment yield is difficult to measure. A target of no anthropogenic sediment is the goal, but there is acknowledgement that the existing infrastructure in the watershed will be subject to low levels of erosion and that large storm events will periodically generate sediment above background. Monitoring is critical to determining if channel processes are reacting to sediment reduction in a manner that protects beneficial uses.

Beneficial use protection is likely to occur at sediment loads greater than natural background but the actual level is unknown. Human infrastructure will remain in the watershed to produce a minimal management-related sediment load. This load is expected to be within the range where stream processes will recover. The target for this TMDL in the third decade is the range of zero to ten percent above natural background to account for the sediment from existing infrastructure, since controls will not be 100 percent effective. Table 3.6 shows the average annual background and the average annual management sediment yields, the third decade total expected sediment yield, and the target for percent reduction in management caused sediment yield for the next three decades. In practice, attainment of the TMDL target will be considered successful when monitoring shows processes and conditions that support beneficial uses are being achieved.

Table 3.6. Upper White River sediment targets for each subwatershed.

	Average Annual Sediment Amount in Metric Tons per Year			**Percent Reduction in Management Sediment by Decade**		
Subwatershed	**Background**	**Background Plus 10%***	**Management Related**	**1 (2003 - 2012)**	**2 (2013 - 2022)**	**3 (2023 - 2032)**
Greenwater	11800	13000	36400	69	87	88
Upper White	552300	607500	8700	81	91	92
West Fork White	309500	340400	20600	88	95	96
Huckleberry	110600	121600	8500	87	95	96
Target Reduction in Anthropogenic Sediment (%)				**60-100**	**80-100**	**90-100**
* This is the third decade, metric tons per year target for sediment production.						

3.9 Sediment Load Allocations

The subwatershed sediment targets in this TMDL are the sediment load allocations. The allocations by subwatershed do involve several land ownerships. Coordination among landowners will be required to meet the targets. The implementation strategies by which these TMDL targets will be achieved on the various ownerships are describe in Appendix A, the Summary Implementation Strategy.

U.S. EPA regulations indicate that load allocations are "best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR 130.2(g)]. Sediment budgets are by nature gross estimates of volume and, when done using aerial photographs covering long and non-uniform time periods, are not specific enough to justify estimates other than long-term annual averages. Sediment impacts to beneficial uses may occur over long time periods after the initial erosion event. Measurement of recovery must also be done over long time periods to account for the episodic nature of erosion.

3.10 Margin of Safety

The Clean Water Act requires a Margin of Safety to account for uncertainty in the science or data available for the assessment and also for uncertainty in the effectiveness of pollutant controls.

3.10.1 Limitations of the Science and Data

This sediment assessment utilized aerial photo interpretation and the extrapolation of a limited number of studies quantifying erosion from glaciers and other natural sources. There are a number of sources of uncertainty in this approach. In addition, the use of average annual sediment as a measure helps simplify complex temporal scale issues, but masks the detail. The Water Quality Restoration Plan will address many of those details.

Not all sediment sources could be quantified in this assessment, however the predominant sources are included.

Determining the capacity of a stream to assimilate increases in flow and sediment is a very complex analysis, well beyond the methodology employed for this TMDL. In the case of the Upper White River watershed, two sediment/flow regimes must be evaluated: non-glacial and glacial. Sediment in glacial streams is derived primarily from the meltwater and erosion of periglacial materials. This source so dominates these watersheds that determining the effects of management-related sources is difficult. Therefore a conservative approach is taken by setting controls that address the management-related sediment with the goal of eliminating sediment from those sources.

The sediment targets derived through this assessment are based on environmentally conservative assumptions made during the assessment:

- If a landslide scar was unvegetated in consecutive photo flights, it was considered as a chronic source.
- No hillslope or channel sediment routing was used, so all sources that connected to a channel were considered to completely deliver sediment.
- Targets are based on the assumption that road sediment controls prevent up to 80 percent of erosion and that all existing roads will be open. A number of miles of roads will be decommissioned, resulting in even less sediment.
- It is assumed that recovery of stream channel widths depends on the elimination of management-related sediment, when in fact channels have some level of assimilative capacity within a state of dynamic equilibrium.

3.10.2 Uncertainty of Controls

The effect of forest management on erosion has been well studied for the last 30 years. While the success of control measures for these sediment sources has not been well studied, a number of measures have been utilized and monitored over the last 20 years. Experience of the Mt. Baker-Snoqualmie National Forest has shown a number of road treatments to be highly effective in reducing road failure. These techniques, which include road decommissioning and stabilization, will be used on the road systems in the Upper White River watershed with a high degree of certainty.

3.10.3 Other Factors Affecting Certainty

Channel morphology responds to both sediment and flow. This sediment assessment evaluates the effects of sediment and targets sediment reduction as part of the overall TMDL. This is based on the premise that sediment increases from management have caused channel widening. However, this is only part of the story, as noted above in the synthesis of sediment discussion. Changes in peak flows due to forest management also contribute to channel instability and morphological changes.

The Mt. Baker-Snoqualmie Forest Plan allocates most of the Upper White River watershed to Late Successional Reserves and wilderness. In addition, the Riparian Reserves allocation applies to all streams. These land allocations mean that most areas of young forest will grow to late successional forests. The vegetation disturbance model shows that all but a few drainage areas in the lower Greenwater and West Fork White River will have low levels of vegetation disturbance by year 2015. This vegetation condition is expected to reduce the damaging rain-on-snow runoff to more natural levels. Mature Riparian Reserves will restore stream bank stability provided by root systems of large conifer trees. Eventually the forest will generate higher levels of large woody debris to restore floodplain and stream channel function. This will combine with sediment reduction treatments to restore dynamic equilibrium to the stream systems.

One large project is proposed in the Greenwater to actively restore channel morphology through channel realignment and restoration of the floodplain. While the channel realignment is a risky venture, several projects in western Washington and Oregon show promise for restoring large wood to stream systems. These projects will contribute to the natural channel function.

4. Temperature TMDL

4.1 Introduction

The Upper White River watershed is within WRIA #10. The Greenwater River is a tributary of the White River within the Upper White River watershed. Several segments of the Greenwater River were identified as water quality limited due to temperature. Accordingly, these segments are included in the Washington 1998 303(d) List as waters quality limited for temperature (Table 2.7), and additional waters within the Upper White River watershed have also been determined to be impaired but not-listed (Table 2.8).

4.2 Pollutants

The Upper White River watershed Temperature TMDL is developed for heat loading (i.e., incoming solar loading). Heat is considered a pollutant under Section 5092(6) of the Clean Water Act. Heat generated by solar radiation reaching the stream provides energy to raise water temperatures. Riparian vegetation, stream morphology, hydrology, climate, and geographic location all influence the amount and timing of heat loading to rivers and streams within the Upper White River watershed (see Appendix C). While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities. The primary human activities that contribute to degraded thermal water quality conditions in the Upper White River watershed are associated with forestry, roads, recreation and rural residential related riparian disturbance. A typical example of an area with human impact on the riparian zone along the Greenwater River is illustrated in Figure 4.1.

Specifically, the elevated summertime stream temperatures attributed to anthropogenic nonpoint sources result from the items listed below:

Near stream vegetation disturbance removal reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface (shade is commonly expressed as measured as percent effective shade or open sky percentage). Riparian vegetation also plays an important role in shaping the channel morphology, resisting erosive high flows and maintaining floodplain roughness.

Channel modifications and widening (increased width to depth ratios) increase the stream surface area exposed to energy processes, namely solar radiation. In addition, channel (i.e., bankfull width) widening decreases potential shading effectiveness of shade-producing near-stream vegetation.

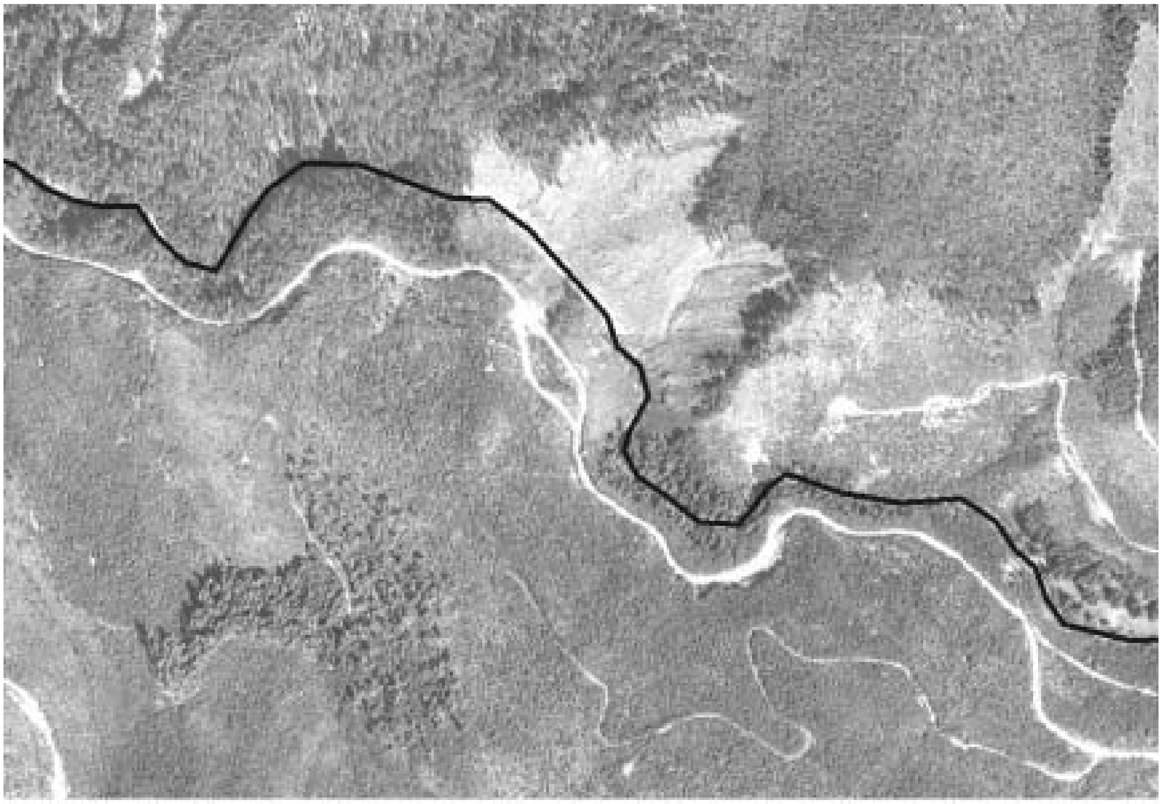


Figure 4.1. Example image of riparian areas along the Greenwater River.

Finally, it was reported in the Upper White and Greenwater Watershed Analysis that:

> *"Riparian conditions along the lower reaches of the Upper White, West Fork White, and Greenwater Rivers and Huckleberry Creek are significantly impacted by land management activities (Timber harvest, Forest road and State highway construction, and recreational activities). The impacts have compromised the shade cover, LWD [Large Woody Debris] recruitment and bank stability functions of these riparian areas. The NW [Northwest] Forest Plan designated broad Riparian Reserves to prevent further impacts to aquatic resources. As the vegetation in these areas matures, shade conditions will improve, LWD availability will increase, and unstable banks will have a greater chance to heal. Shade will recover relatively quickly (50-100 years); LWD recruitment will be slower (100-250 years) and bank stability may be long term depending on how rapidly watershed processes and other stream channel morphology elements recover."*
>
> *(Mt. Baker-Snoqualmie National Forest 2000)*

Natural sources and stream temperature conditions that may impact riparian vegetation and result in elevated stream temperature include drought, fires, insect damage to riparian vegetation, diseased riparian vegetation and windthrow and blowdown in riparian areas. The processes by which natural conditions affect stream temperatures include increased stream surface exposure to solar radiation and decreased summertime flows.

4.3 Stream Temperature Source Assessment

4.3.1 Measured Stream Temperature within the Watershed

Continuous water temperature data was collected in the Upper White River watershed by Federal and State agencies, and the Puyallup and Muckleshoot Tribes over the past decade. Sampling locations are illustrated in Figure 4.2. Table 4.2 presents calculated temperature statistics developed from this data. It should be noted that several sites throughout the Upper White River watershed had measured temperatures in exceedance of the water quality standard for Class “AA” streams (WAC 173-201A-030). However, only three segments along the Greenwater River were listed for temperature on the 1998 303 (d) List.

Figure 4.2. Temperature sampling locations

As can be seen in this Figure, most temperature sampling sites were located along the mainstem of the Clearwater and the Greenwater rivers. Accordingly, subsequent Temperature Source Assessment analysis will focus on these areas. It should be noted that Clearwater River tributary is outside of the domain of the TMDL. This analysis is

Table 4.1. Calculated temperature statistics - Upper White River watershed

Site	Agency	Dates	Highest Daily Max Temperature (*C)	Max 7-Day Av of Daily Max (*C)	21-Day Av of Daily Av (*C)
Clearwater (RM 0.4)	Ecology	7/4 - 9/4/96	16.4	16.1	13.1
Clearwater (RM 0.5)	Puyallup Fish.	7/16 - 9/30/95	16.5	15.3	13.0
Clearwater (RM 1.2)	Muckleshoot	7/18 -9/5/92	17.6	17.0	14.0
Clearwater (RM 2.1)	Ecology	7/4 - 9/4/96	18.1	17.6	14.2
Clearwater (RM 2.3)	Puyallup Fish.	7/7 - 9/30/95	17.4	16.5	14.0
Clearwater (RM 2.7)	Ecology	7/4 - 9/4/96	18.3	17.9	14.2
Clearwater (RM 3.15)	Puyallup Fish.	7/16 - 10/22/99	16.4	15.9	12.7
Clearwater (RM 3.8)	Puyallup Fish.	7/6 - 9/30/95	18.0	17.0	13.7
Clearwater (RM 3.85)	Puyallup Fish.	7/4 - 9/20/01	16.8	16.5	13.4
Clearwater (RM 4.3)	Ecology	7/4 - 9/11/96	18.8	18.1	13.7
Clearwater (RM 4.9)	Ecology	7/4 - 9/11/96	17.5	16.8	12.9
Clearwater (RM 5.7)	Puyallup Fish.	7/16 - 9/30/95	15.1	13.9	11.7
Mineral (RM 0.1)	Ecology	7/4 - 9/21/96	12.7	12.5	12.1
Byron (RM 0.1)	Ecology	7/14 - 9/4/96	13.8	13.3	10.9
Lyle (RM 0.1)	Muckleshoot	8/10 - 10/27/95	13.0	12.3	11.3
Lyle (RM 0.1)	Ecology	7/4 - 9/11/96	16.7	16.0	13.3
Milky (RM <0.1)	Ecology	7/4 - 9/11/96	22.1	21.0	14.8
White (RM 38.1)	Puyallup Fish.	7/4 - 9/26/01	16.6	15.6	12.9
Camp (RM 0.1)	Ecology	7/17 - 9/2/96	16.1	15.6	13.4
Slippery (RM 0.1)	Ecology	7/11 - 9/2/96	13.3	12.9	11.5
Greenwater (RM 0.05)	Puyallup Fish.	7/16 - 9/5/99	17.5	16.9	13.3
Greenwater (RM 0.45)	Puyallup Fish.	7/4 - 9/26/01	19.5	18.9	14.5
Greenwater (RM 1.2)	Ecology	7/12 - 9/13/95	19.0	17.9	14.0
Greenwater (RM 1.2)	Ecology	7/11 - 9/2/96	19.6	19.2	14.6
Greenwater (RM 1.5)	Ecology	7/10 - 10/6/99	17.3	16.9	13.6
Greenwater (RM 1.5)	Ecology	7/13 - 10/1/01	18.8	18.3	14.3
Greenwater (RM 5.3)	Ecology	7/12 - 9/13/95	17.3	16.1	13.2
Greenwater (RM 5.5)	Ecology	7/10 - 10/4/99	15.6	15.1	12.4
Greenwater (RM 5.5)	Ecology	7/13 - 10/4/01	16.5	16.1	12.9
Greenwater (RM 5.8)	Ecology	7/12 - 9/13/95	17.3	16.0	13.1
Greenwater (RM 8.5)	Muckleshoot	8/11 - 9/21/89	16.8	15.1	11.9
Greenwater (RM 8.5)	Muckleshoot	5/24 - 9/30 /90	17.3	16.6	13.4
Greenwater (RM 11)	Muckleshoot	8/11 - 9/21/89	17.3	15.6	12.5
Greenwater (RM 11.7)	USFS	6/22 - 9/28/95	14.2	13.5	12.3
Brush (RM 0.2)	Ecology	7/11 - 9/2/96	19.8	19.5	15.7
Burns (RM 0.3)	USFS	6/22 - 9/28/95	14.8	13.2	11.1
Forest Lake Ck (RM 0.8)	USFS	6/22 - 9/28/95	12.3	11.7	8.8
Pyramid (RM 0.4)	USFS	6/22 - 9/28/95	16.7	15.8	12.4
Slide (RM 0.1)	USFS	6/22 - 9/28/95	12.3	11.7	10.5
Straight (RM 0.3)	USFS	6/22 - 9/28/95	17.7	16.5	13.0
Whistler (RM 0.4)	USFS	6/22 - 9/28/95	19.9	18.9	12.0
WF White (RM 4.25)	USFS	7/19 - 9/28/01	16.5	16.0	9.8
WF White (RM 7.1)	USFS	7/19 - 9/28/01	15.1	14.6	8.9
Huckleberry (RM 0)	USFS	7/19 - 9/28/01	13.7	13.5	10.5
Huckleberry (RM 0.2)	Puyallup Fish.	7/4 - 9/27/01	13.7	13.5	10.5
Huckleberry (RM 0.9)	Ecology	7/10 - 9/16/95	13.3	12.5	9.9
Huckleberry (RM 5.6)	Puyallup Fish.	7/16 - 8/16/99	9.1	8.8	7.4
Huckleberry (RM 5.7)	Ecology	7/11 - 8/18/95	10.3	9.7	7.9
Klickitat Ck (RM 0.5)	Ecology	7/13 - 10/4/01	8.4	8.2	7.3
Klickitat Ck (RM 0.5)	Ecology	7/13 - 10/4/01	8.2	8.1	7.3
Silver Springs (RM 0.3)	Ecology	7/13 - 10/4/01	8.3	8.1	7.5
Silver Springs (RM 0.3)	Ecology	7/13 - 10/4/01	8.2	8.0	7.5

intended to show the general temperature trends, and to support the evaluation of temperature pollutant loading within the watershed.

Water temperature profiles for the Greenwater and Clearwater Rivers are illustrated in Figure 4.3. The longitudinal temperature profile shows that mainstem temperatures progressively increase in a downstream direction in the Greenwater River. However, mainstem temperatures in the Clearwater River are greatest within the higher elevation reaches and slowly decrease in temperature downstream of this location.

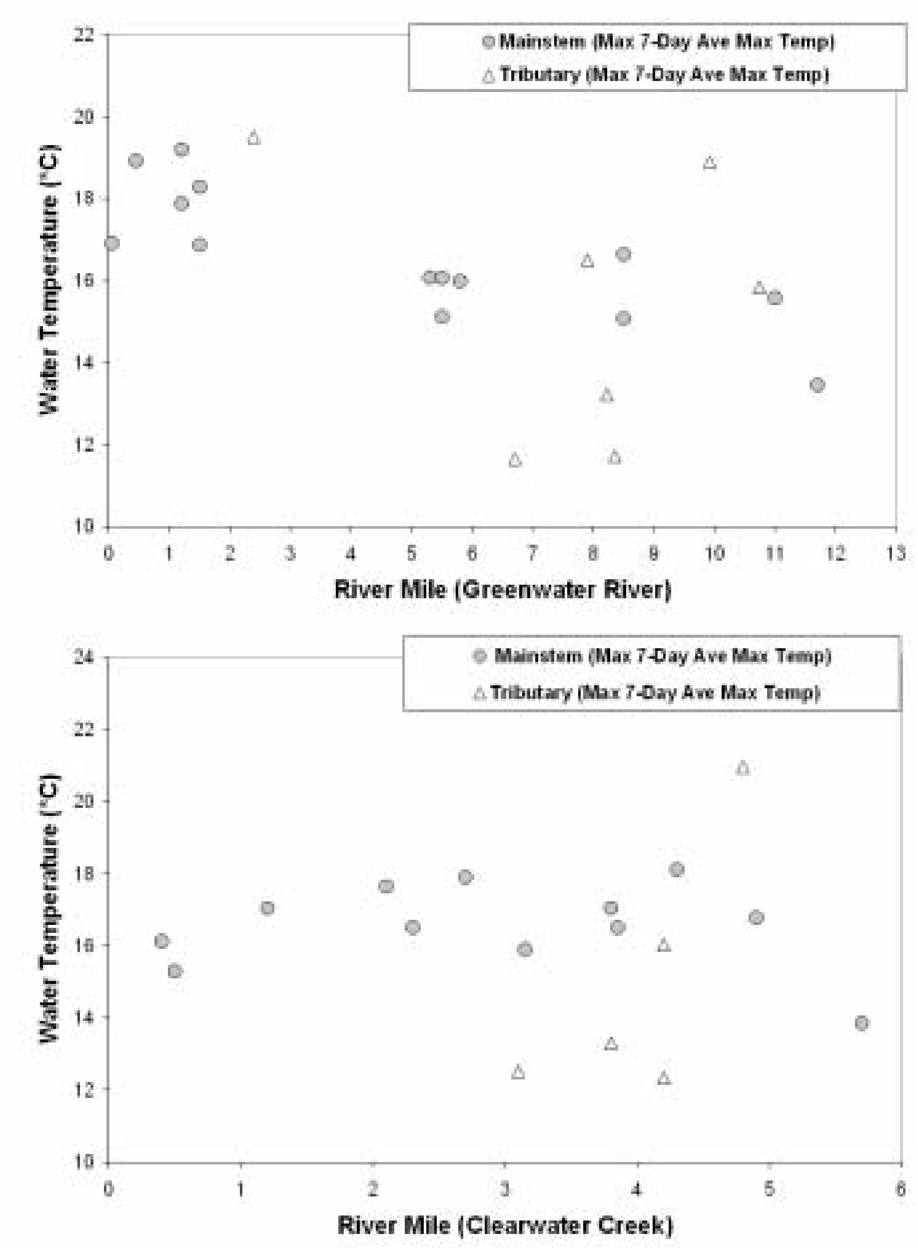


Figure 4.3. Calculated water temperature statistics – maximum 7-day average of daily maximum temperatures for the Clearwater and Greenwater rivers.

Seasonal Variation – CWA §303(d)(1)

Figure 4.4 shows daily maximum temperatures along the Clearwater and Greenwater rivers during the summer of 1995. In the Clearwater River, the highest temperatures are observed near the headwaters (RM 3.8) throughout most of the season, and temperatures decrease downstream of this location. In contrast, as would be expected, water temperatures progressively increased in a downstream direction in the Greenwater River during 1995.

Because temperatures tend to rise and fall throughout these rivers at the same time, it can be assumed that these changes are caused by universal factors (solar load, atmospheric load, etc). However, it must be noted that areas with increasing temperature conditions (i.e., RM 5.7 to RM 3.8 in the Clearwater River) are much more responsive to temperature changes during periods of temperature rising (e.g., temperatures rise at a much greater rate then other areas of the river). In addition, it is important to note once again that this upper reach of the Clearwater River experiences high levels of riparian disturbance. The effects of this disturbance on the river temperature are transferred downstream.

Daily maximum water temperatures in several tributary streams discharging into the Greenwater and Clearwater Rivers are illustrated in Figure 4.5. (The river miles presented in this image indicate the location along the respective mainstem where the tributary discharges into the mainstem.) This image indicates that several tributaries experience high temperatures and large temperature swings. These tributaries are draining into the mainstem rivers and therefore add an energy load to these mainstem systems.

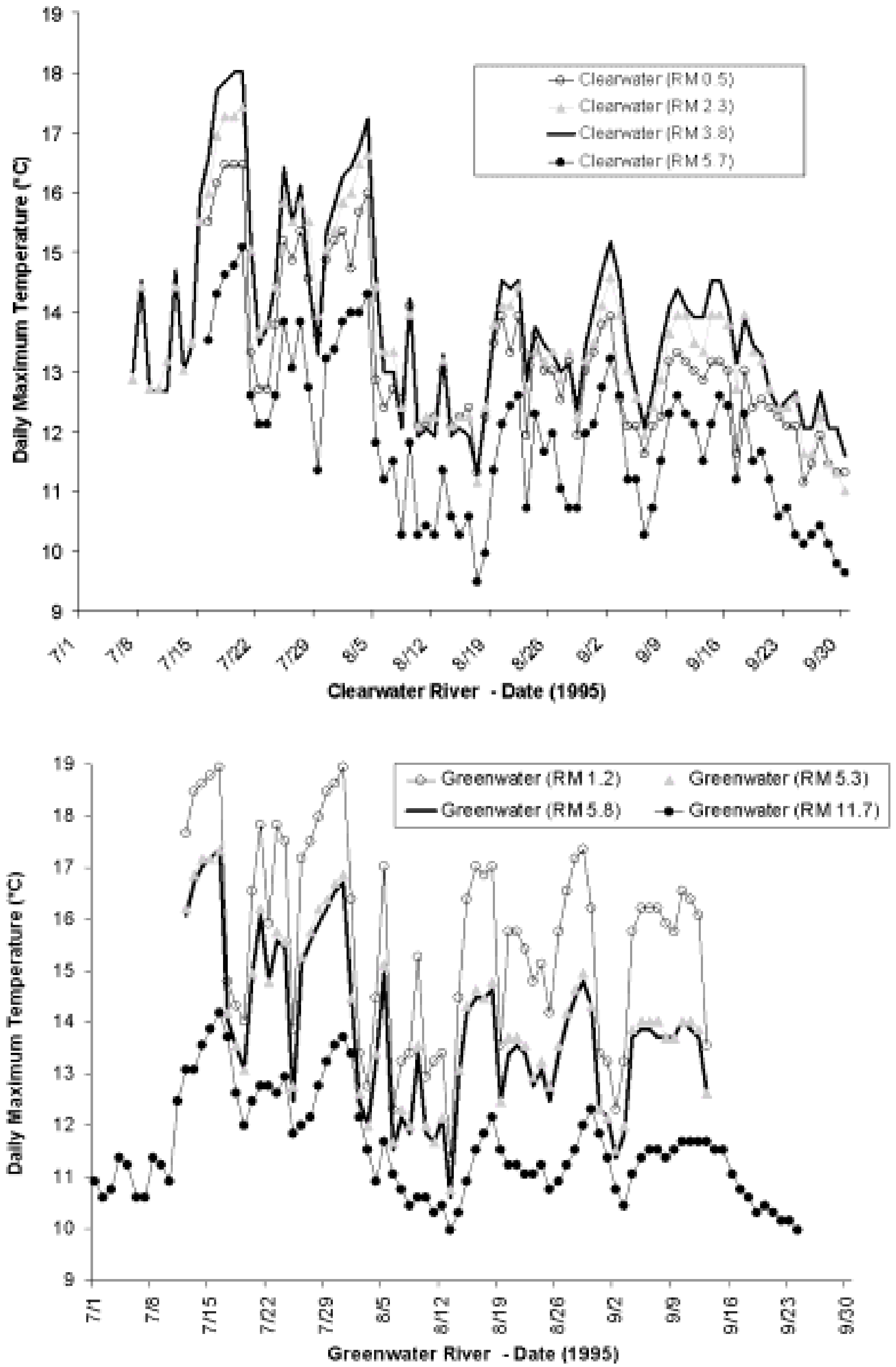


Figure 4.4. Clearwater and Greenwater rivers – daily maximum temperatures in 1995.

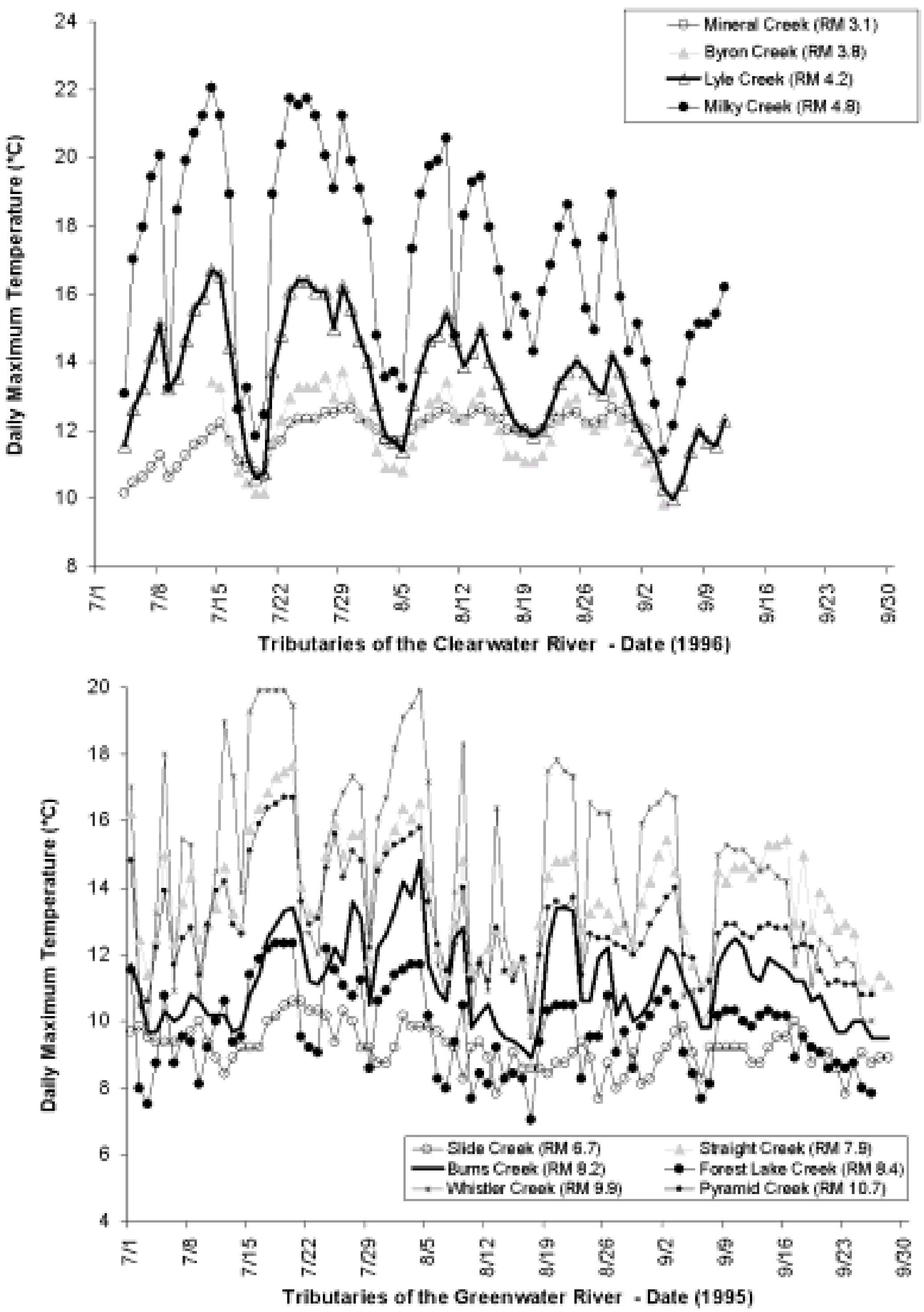


Figure 4.5. Tributaries of the Clearwater and Greenwater rivers – daily maximum temperatures in 1996 and 1995, respectively.

4.3.2 Current Effective Shade and Temperature Conditions

Overview – Current Effective Shade Calculations

Effective shade was calculated using a modified version of the HeatSource model (ODEQ 2000), developed by Washington Department of Ecology. Riparian vegetation size and density was sampled from the GIS coverages at 100-foot intervals along the Greenwater River using the Tools extension for Arcview that was developed by ODEQ (ODEQ 2001). Specifically, the vegetation grid was sampled orthogonal to the stream riparian zone from each bank of the stream at each 100' stream transect location. Other model input data that were estimated at each transect location includes stream aspect, and topographic shade angles to the west, south and east. Stream widths were estimated from USFS data (Figure 3.11).

Analytical Framework

Data collected during this TMDL effort has allowed the development of a heat energy loading simulation methodology that is both spatially continuous and which spans full-day lengths (quasi-dynamic steady-state diel simulations). The GIS and modeling analysis was conducted using two specialized software tools:

- ODEQ's Tools extension for Arcview (ODEQ 2001) was used to sample and process GIS data for input to a modified version of the HeatSource model (Washington Department of Ecology 2002),
- The HeatSource model was used to estimate effective shade and energy loading (ly/day) along the mainstem Greenwater River.

All input data for the HeatSource model are longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments. Model input data were derived from available GIS coverages using the Tools extension for Arcview, or from data collected by Ecology, USFS, USGS, Interagency Vegetation Mapping Project (IVMP), and other data sources. Detailed spatial data sets were developed for the following parameters:

- Rivers and tributaries were mapped at 1:3,000 scale from 1-meter-resolution Digital Orthophoto Quads (DOQ),
- West, east, and south topographic shade angle calculations were made from the 10-meter DEM grid using ODEQ's Tools extension for Arcview,
- Stream elevation was sampled from the 10-meter DEM grid with the Arcview Tools extension. Gradient was estimated from the topographic contours on the USGS 7.5-minute Quad maps.

- Aspect (stream flow direction in decimal degrees from north) was calculated by the Tools extension for Arcview.
- Stream widths were estimated from USFS data (see Figure 3.11).
- Estimation of current vegetation conditions along the Greenwater River was derived from GIS datasets provided by the Interagency Vegetation Mapping Project (IVMP) (Western Cascades Version 2.0). This data was obtained from the following Bureau of Land Management (BLM) web page - (http://www.or.blm.gov/gis/projects/vegetation/ivmp/). These GIS coverages describe the vegetation species, tree heights, size (DBH), and percent canopy closure.
- Riparian vegetation size and density was sampled from the GIS coverages along the stream at 100-foot intervals along the Greenwater River using the Tools extension for Arcview that was developed by ODEQ (ODEQ, 2001). At each stream transect location the vegetation grid was sampled orthogonal to the stream at 15'-wide intervals between the wetted edge from each bank of the stream (Figure 4.6). Figure 4.7 illustrates the results of sampled vegetation height and cover conditions along the Greenwater River. This sampled information was used as input to estimate current Effective Shade conditions along the Greenwater River (Figure 4.8).

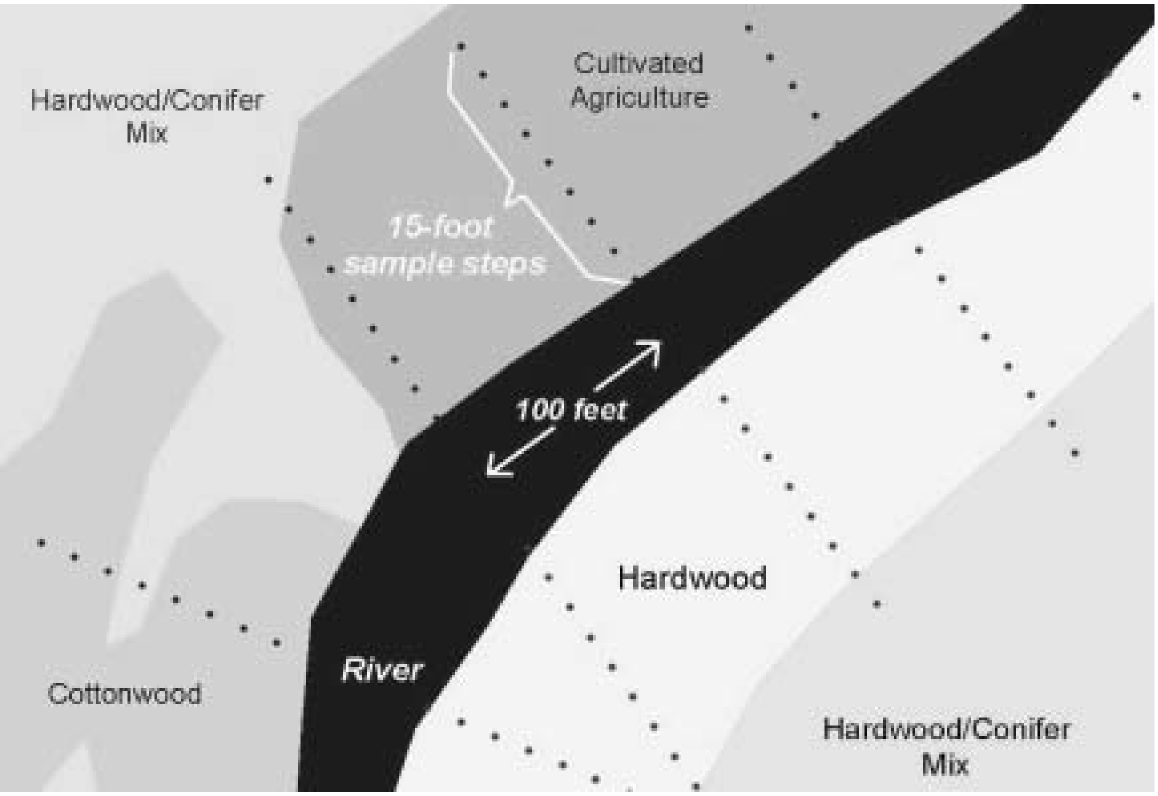
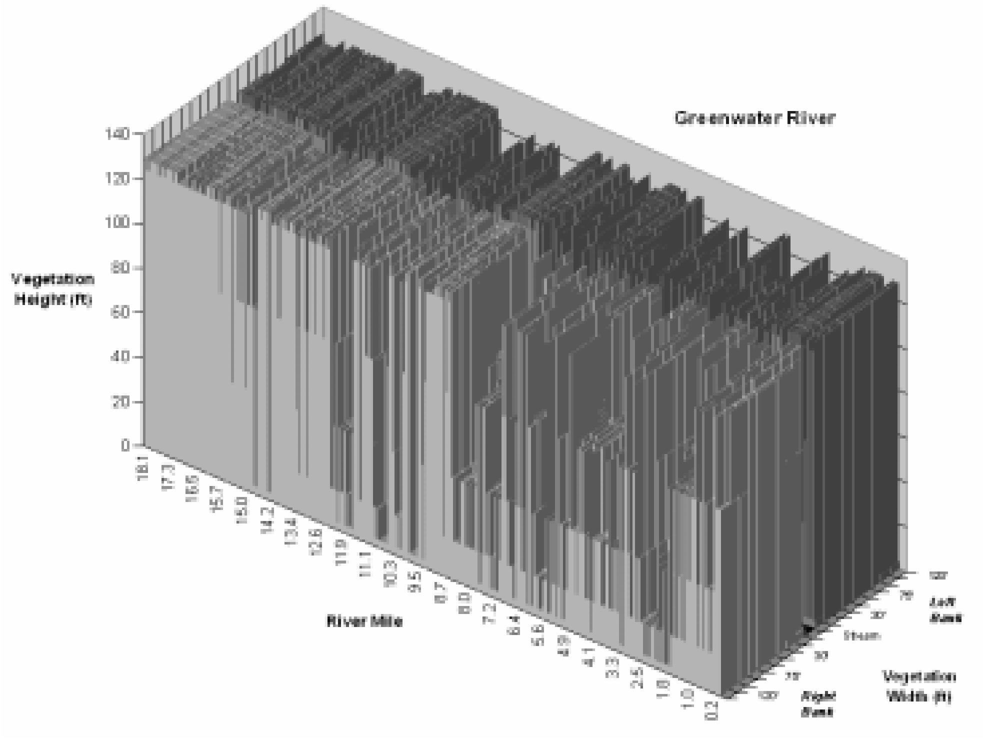


Figure 4.6. Example of Tools automated vegetation sampling methodology.



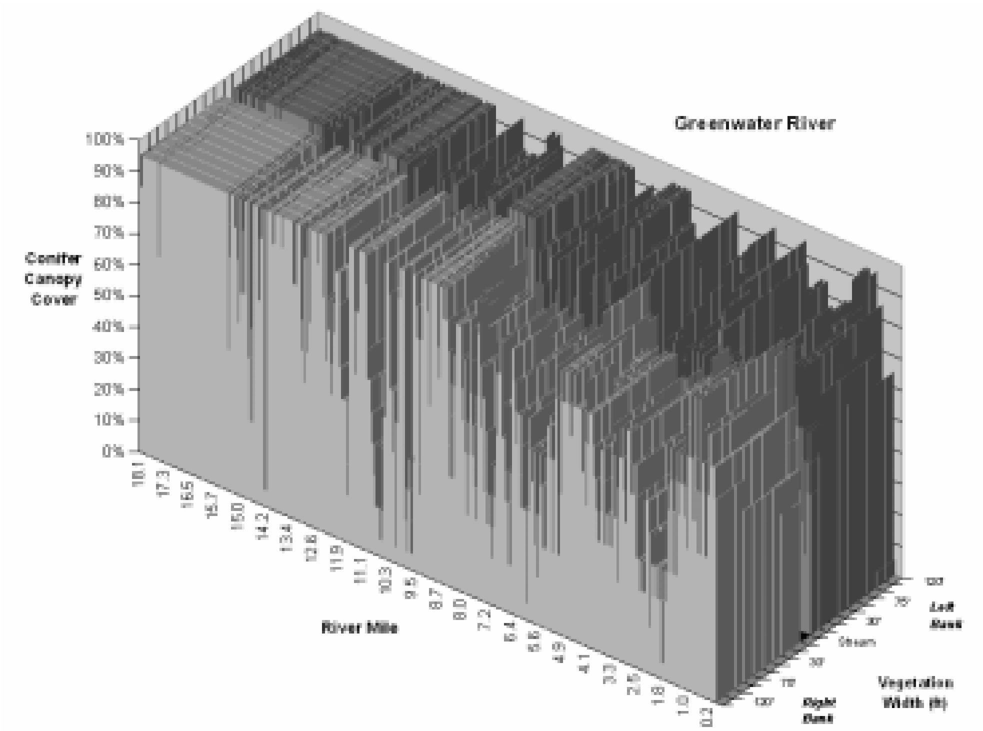


Figure 4.7. Current vegetation height and canopy cover along the Greenwater River. (Data Source: IVMP 10/24/02)

Calculated current effective shade conditions for the Greenwater River are presented in Figure 8. (The line represented the ¼ mile moving average conditions, and the small dots represent the individually calculated conditions for each 100 ft river segment.) The three triangles on this image indicate "field" measured shade conditions. Specifically, these triangles represent the reach average shade condition for 600 m sections from data collected during field work in 1995 and 1996. Figure 4.9 illustrates the range of observed shade conditions measured at these three sites. As can be seen in Figure 4.8, observed and estimated shade conditions are quite similar, indicating that the effective shade model did a good job estimating shade conditions along the river, especially predicting general trends.

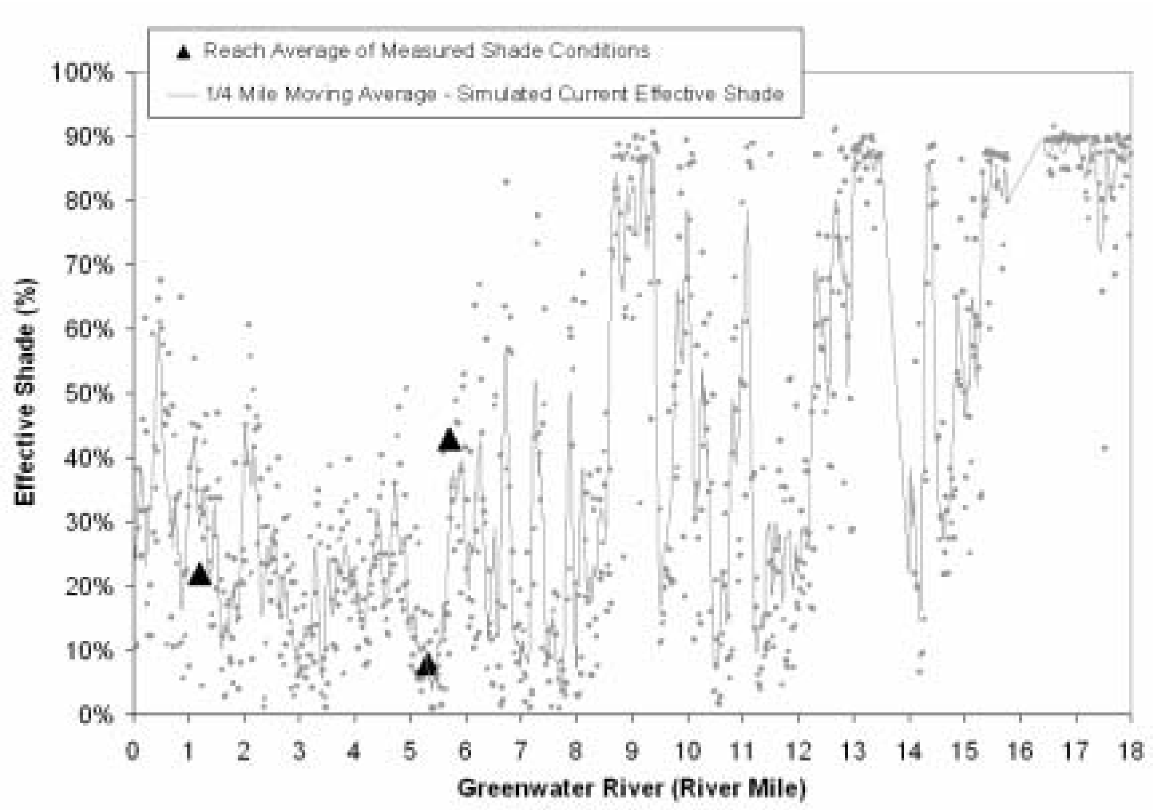


Figure 4.8. Current effective shade in the Greenwater River

It must be pointed out that there is a very large range, and great spatial variability, of observed effective shade conditions along the Greenwater River. For example, as can be seen in the photographic image included with Figure 4.1, riparian vegetation conditions range from no canopy (zero) to dense canopy, over very short distances. Accordingly, the area shown in Figure 4.1 would be an area with very dramatic changes in effective shade conditions. These patterns of highly variable riparian vegetation condition were observed and measured (see Figures 4.8 and 4.9), indicating that the model provided a sufficiently accurate and robust estimation of current shade conditions along the Greenwater River.

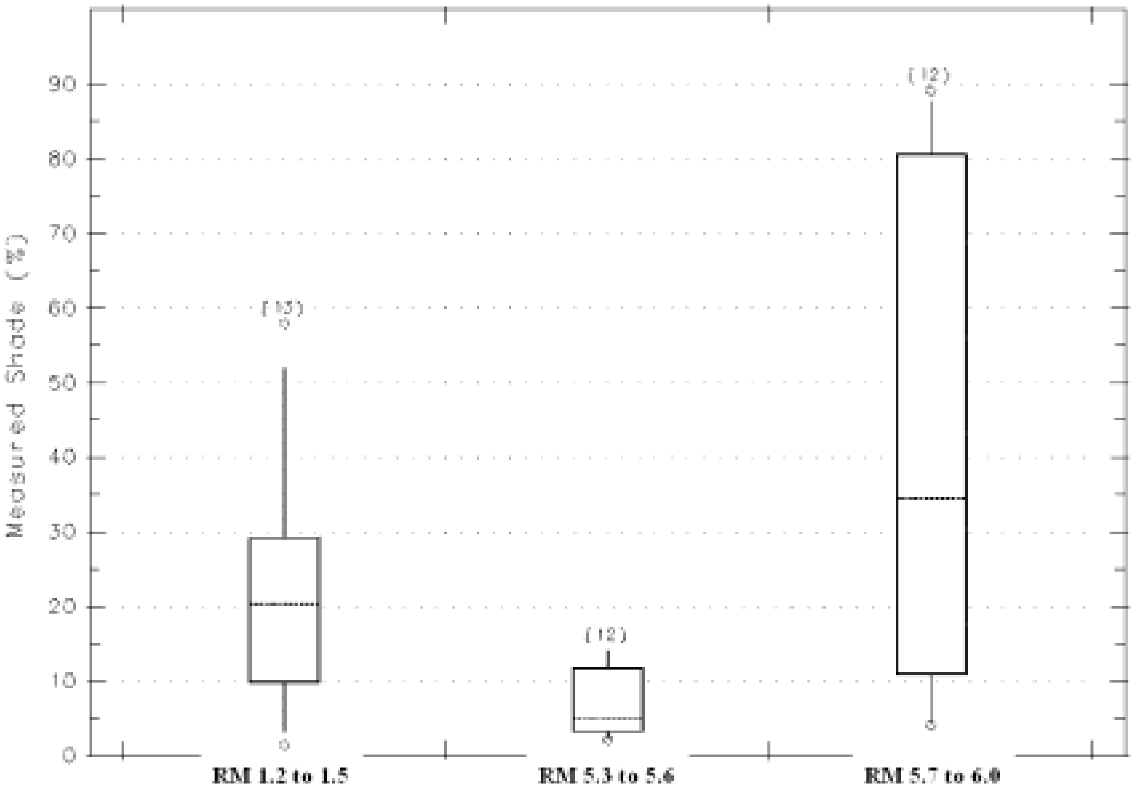


Figure 4.9. Measured shade conditions in the Greenwater.

Current Effective Shade and Cumulative Effects

Despite high levels of effective shade along much of the Greenwater River, there are many areas where shade conditions are very low. It is within these "open" areas that stream temperatures dramatically increase, and this added heat load is transferred downstream. This is an example of the temperature "cumulative effects" principle (see Appendix C). Figure 4.10 illustrates calculated current effective shade conditions through one of these "transitional open" areas. As can be seen in this image, shade levels vary dramatically through this 1.5-mile stretch of the Greenwater River.

Figure 4.11 illustrates current temperatures and current effective shade conditions along the Greenwater River. As can be seen in this figure, river segments with the lowest effective shade conditions have the highest river temperatures. This image also illustrates that stream temperatures are a response of the "cumulative effect" of upstream shade conditions. That is, water temperatures increases from these low shade areas are transported downstream and result in an overall increase of stream temperature.

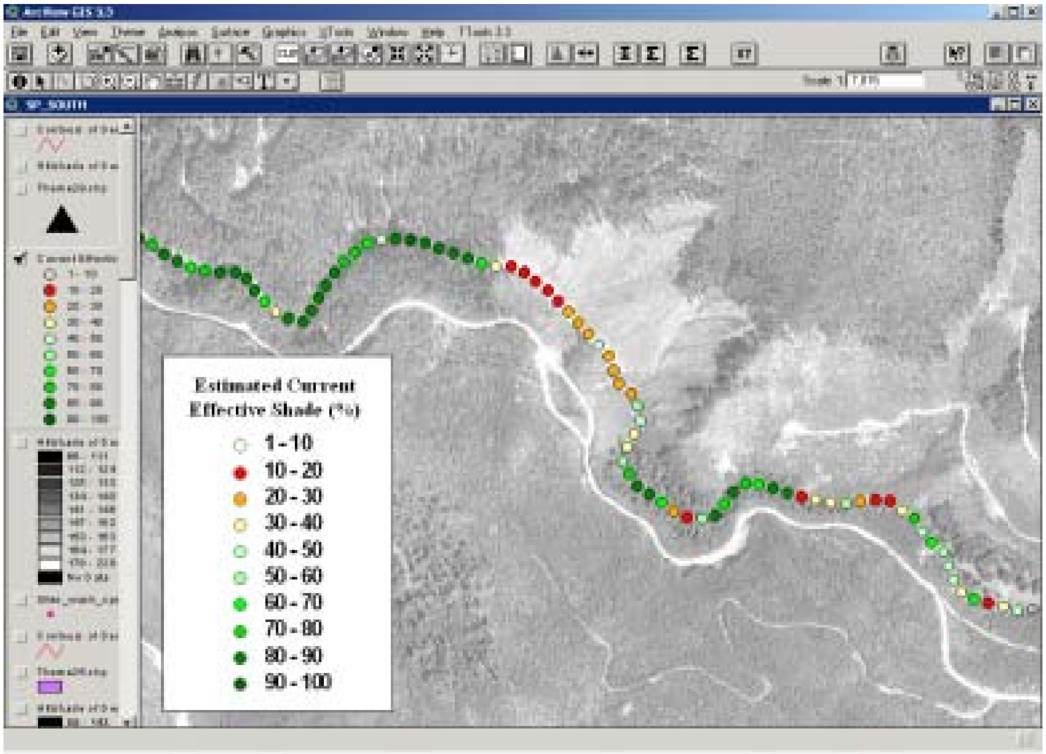


Figure 4.10. Estimated current effective shade conditions along the Greenwater River (Approximately river mile 9.0 through 10.5).

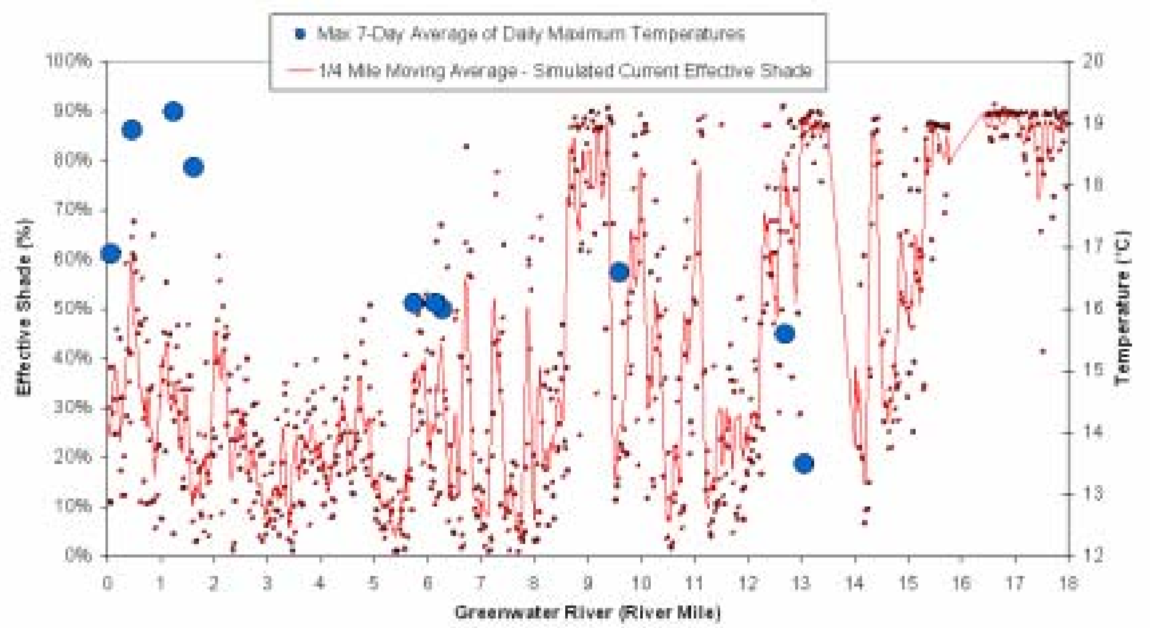


Figure 4.11. Measured temperatures and current effective shade conditions along the Greenwater River. (River miles in this figure were derived from a 1:3,000 scale stream layer. Locations for the temperature monitoring sites will therefore be slightly different than values derived from the 1:100,000 scale stream layer, e.g. see Figure 3).

4.4 Loading Capacity – 40 CFR 130.2(f)

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with standards. EPA's current regulation defines loading capacity as "*the greatest amount of loading that a water can receive without violating water quality standards*." (40 CFR § 130.2(f)). The approach used to calculate the temperature Loading Capacity for this portion of the Upper White River watershed TMDL is "**System Potential**". "**System Potential"** is achieved when (1) non-point source solar radiation loading is representative of near stream vegetation and channel morphology conditions without human disturbance, and (2) point source discharges cause no measurable temperature increases in surface waters.

4.4.1 System Potential Effective Shade - Defined

Primary factors that affect shade are near stream vegetation height and channel width (i.e. bankfull width). The maximum level of shade practical at a particular site is termed the "system potential" effective shade level. System Potential Effective Shade occurs when:

1. Near stream vegetation is at a mature life stage
    - Vegetation community is mature and undisturbed from anthropogenic sources;
    - Vegetation height and density is at or near the potential expected for the given plant community;
    - Vegetation is sufficiently wide to maximize solar attenuation; and
    - Vegetation width should accommodate channel migrations.

2. Channel width reflects a suitable range for hydrologic process given that near stream vegetation is at a mature life stage
    - Stream banks reflect appropriate ranges of stability via vegetation rooting strength and floodplain roughness;
    - Sedimentation reflects appropriate levels of sediment input and transport;
    - Substrate is appropriate to channel type; and
    - Local high flow shear velocities are within appropriate ranges based on watershed hydrology and climate.

It is important to distinguish between site potential shade, and system potential shade which is a broad scale view. It could be expected that site potential shade would be greater than system potential shade because over a large area, such as a river reach, it is unlikely that all sites will be at their potential due to localized natural disturbances (e.g., fire, flood, landslide, disease), causing some fraction of the area to be in a less than "mature" state. Accordingly, "system potential landcover" used to calculate "system potential effective shade" incorporates a natural disturbance component.

4.4.2 System Potential Land Cover

As described above, "System potential land cover" is necessary to achieve “system potential effective shade” and is defined for purposes of the TMDL as "the potential near stream land cover condition which can grow and reproduce on a site, given: climate, elevation, soil properties, plant biology and hydrologic processes." System potential does not consider management or land use as limiting factors. In essence, system potential is the design condition used for TMDL analysis that meets the temperature standard by minimizing human-related warming. In other words, system potential is an estimate of the condition where anthropogenic activities that cause stream warming are minimized.

4.4.3 Non-Point Source Loading Capacity (Non-Point Sources)

The temperature loading capacity in the Upper White River watershed is controlled by non-point source influences on heat to the system. Temperatures rise throughout much of the watershed due to accumulated heat energy. The greatest change in the heat budget has been an increase in direct solar radiation loading due to human caused reduction in shade.

System potential was estimated as August solar radiation levels that would reach the stream surface under conditions where anthropogenic activities would not measurably increase temperature. **The system potential radiation load is the loading capacity.** In other words, the Load Capacity is allocated to natural sources within the watershed and therefore the Load Capacity is equal to the Non-point source Load Allocation.

With its current implementation, Riparian Reserves provide protection of defined riparian zones, such that protection actions associated with this current management direction will facilitate the development of “system potential landcover” conditions.

4.5 Non-Point Source Load Allocations

This TMDL technical assessment for the Upper White River watershed uses riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream were calculated in this TMDL in a numerical model and expressed as Langleys/day. However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Accordingly, effective shade is used as a surrogate to thermal load as allowed under EPA regulations (defined as “other appropriate measure” in 40 CFR §130.2(i)).

The "Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program" (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

> *"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not."*

The specific surrogate used is percent effective shade (expressed as the percent reduction in potential solar radiation load delivered to the water surface). Specifically, the surrogate measure is effective shade from riparian vegetation that will grow based on average growth rates and tree heights for species in a given area. This "surrogate measure" is achieved through restoration of riparian vegetation that provides shade directly and that reduces streambank erosion.

Channel width was only evaluated within this TMDL as a function of stream effective shade production. It is expected that factors and efforts associated with surrogate measure development for effective shade will promote channel recovery and improvement. That is, effective shade allocations associated with this TMDL will achieve, through passive restoration, "system potential channel width" conditions.

4.5.1 Seral Stage Structure and Load Allocations

Seral stages are an ecological age class designation. Ecosystems are not static and they vary over time and space. The dynamic nature of ecosystems exemplifies the need to consider ranges of conditions under natural disturbance regimes, rather than single points in time. A key assumption in this concept is that when systems are "pushed" outside of the range of natural variability there is substantial risk that biological diversity and ecological function may not be maintained.

An attempt was made to include seral stage structure for each of the major forested Potential Vegetation Zones[2] (PVZs). Specifically for each PVZ, "System Potential Effective Shade Conditions" are reported for the three main seral age classes, as well as a weighted average condition based on historical seral compositions. Appendix D presents methods used to estimate these vegetation overstory conditions.

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[2] The vegetation zone model is an on-going project and continues to evolve. The ecology staff at the Mount Baker-Snoqualmie National Forest Office continue to verify the accuracy of the model with their annual ecology plot program. The components of the model also may be modified or new components may be identified and tested over time. This theme was first generated in 1994 and updates are occurring regularly.

4.5.2 System Potential Effective Shade Simulation

PVZ	Percent Area
Alpine	4.9
Parkland	18.2
Subalpine Fir	1.1
Mountain Hemlock	16.6
Pacific Silver Fir	32.5
Western Hemlock	26.5
Grand Fir	<<1
Douglas-fir	<1

System Potential Effective Shade conditions were developed from estimated “system potential landcover” conditions using the shade model. “System potential landcover” conditions were developed for potential vegetation zones (PVZs) for the Upper White River watershed (Figure 4.12), allowing resource managers to spatially apply temperature load allocations within the Upper White River watershed.

PVZs represent areas of the landscape with different ecological qualities and different potential for vegetation and plant development. PVZs are derived from a model that predicts the upper and lower elevation limits of major vegetation zones. The model incorporates data from over 3100 ecology plots, ecozones [a precipitation-based relationship], aspect, elevation, topographic moisture, and a model that predicts cold air drainage. Eight potential vegetation zones are present within the basin, however four of these zones represent less than 6.1 percent of the area.

The purpose of a vegetation classification is to describe the kinds of vegetation that occur over a landscape in both time and space. Variation over space is mostly related to the environment, and the variations over time are related to successional and climatic changes. The potential or climax successional stage is used as a benchmark for naming and comparing the basic units of the vegetation. Brief descriptions of PVZs within the Upper White River watershed are presented below.

Pacific Silver Fir Zone – Approximately 33% of the NFS lands within the analysis areas are in the Pacific Silver Fir Zone with the projected climax species Pacific silver fir (*Abies amabilis*). This zone occupies the middle elevations and mid and upper slopes up to about 6,200 feet. The climate is characterized as cool. Winter snow pack is persistent and there is a short, cool growing season.

Western Hemlock Zone - Approximately 27% of the watershed is in the western hemlock (*Tsuga heterophylla*) zone, with western hemlock the climax species. This zone extends from the valley bottoms of the Greenwater, Upper White, West Fork, and Huckleberry Creek. The climate in the western hemlock zone is characterized as warm temperature to maritime. Winter temperatures are cool and summer temperatures are moderate. Precipitation comes mainly as rain, even in the winter and is typically 60-80 inches. Snow is usually ephemeral.

Mountain Hemlock Zone – Approximately 17% of the watershed area is in the mountain hemlock zone, with the climax species mountain hemlock (*Tsuga mertensiana*). This zone is found above about 4,000 feet elevation. The climate can be characterized as cold with cool summer temperatures. Snow accumulations are high, usually averaging greater than 10 feet and winds can be significant.

Parkland Zone – Approximately 18% of the watershed is in the Parkland zone. It is structurally characterized by tree species including mountain hemlock, Alaska yellow cedar (*Chamaecyparis nootkatensis*) and/or subalpine fir growing in clumps or small "islands" of forest surrounded by open meadows, rock, snow, or ice. In drier sites, this zone can occur as low as 5,600 feet.

Subalpine Fir Zone – Only about 1% of the watershed is in the sub-alpine fir (*Abies lasiocarpa*) zone with subalpine fir as the projected climax species. This zone occupies the upper slopes at upper elevations, mostly above 5,500 feet. The climate is characterized as cold, and temperate to continental. Winter temperatures are moderate to cold and there is a moderate snow pack of 4-8 feet.

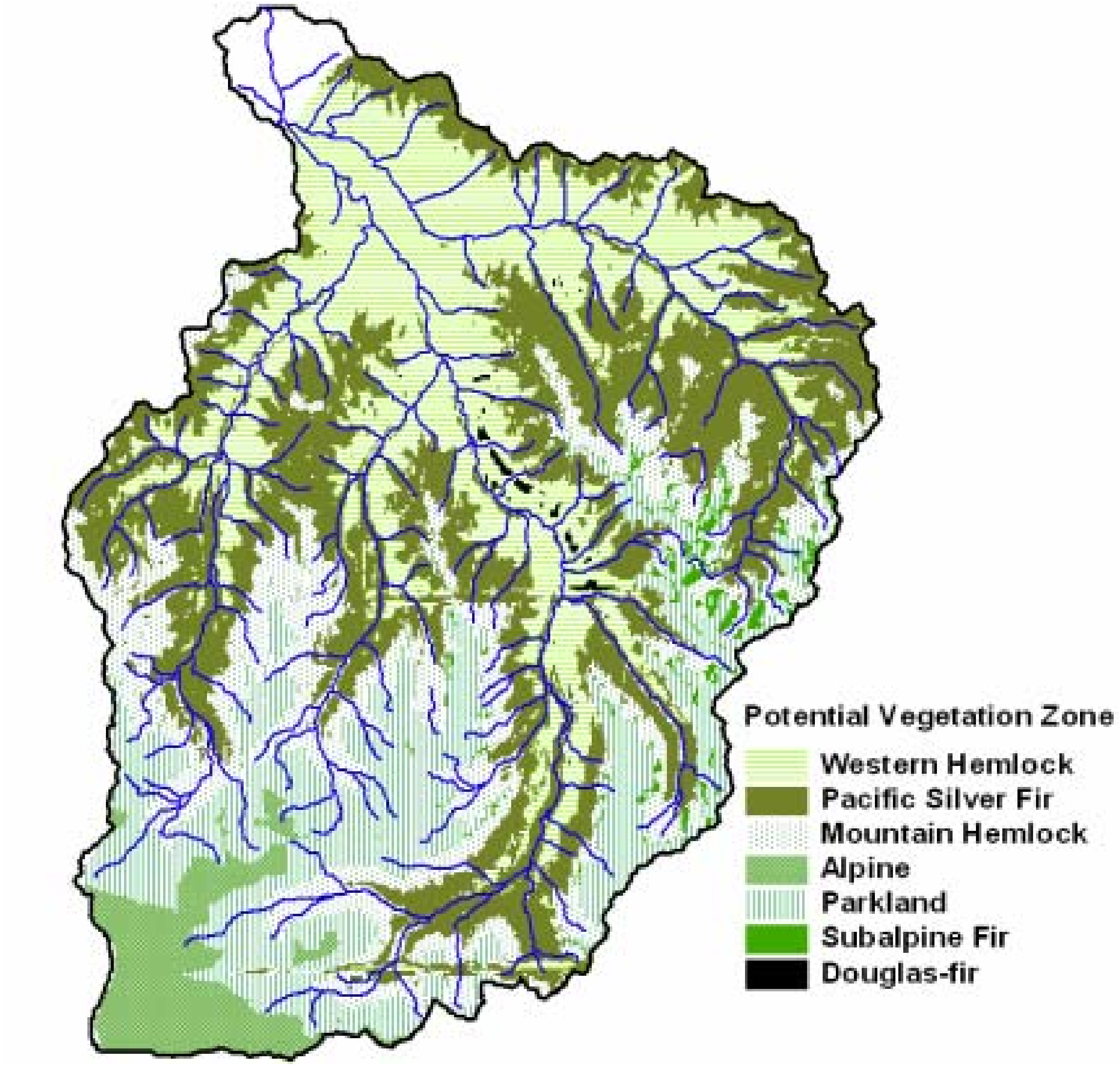


Figure 4.12. Potential vegetation zones within the Upper White River watershed.

4.5.3 Temperature Load Allocation Units And Effective Shade Curves

The temperature load allocation for this TMDL is defined in units of Langleys per day and the system potential radiation load is the loading capacity.

Langleys per day is a unit of energy that is calculated through the application of the shade calculator developed by the Washington Department of Ecology. A load allocation in terms of Langleys per day is not very useful in guiding non-point source management practices. Fortunately, percent effective shade is a directly corresponding surrogate measure that can be calculated from the loading allocation.

Temperature Load Allocations for each of the Potential Vegetation Zones in the Upper White River watershed are plotted on “Shade Curves” (Figure 4.13 and is presented in Tabular format in Appendix E). The shade curve provides a method for land managers to incorporate local conditions when determining the appropriate site-specific load allocations. Finding the load allocation on the shade curves first requires selecting the curve for the appropriate vegetation zone and stream aspect, then using site specific information to choose the appropriate channel width on the x-axis – see Figure 4.12.

This information is intended to help resource managers evaluate progress towards “system potential effective shade” conditions. Specifically, shade curves provide a means for land managers to assess the deviation of current effective shade conditions from predicted levels at “system potential landcover conditions”.

In summary, “system potential effective shade”, developed from “system potential landcover conditions”, is used as a surrogate measure of the load allocation.

In other words, calculated energy conditions (reported as Langleys per day) at “system potential landcover” conditions is the Load Allocation. The Load Allocation is also reported as “system potential effective shade”, a much more useful parameter in pollutant evaluation and management.

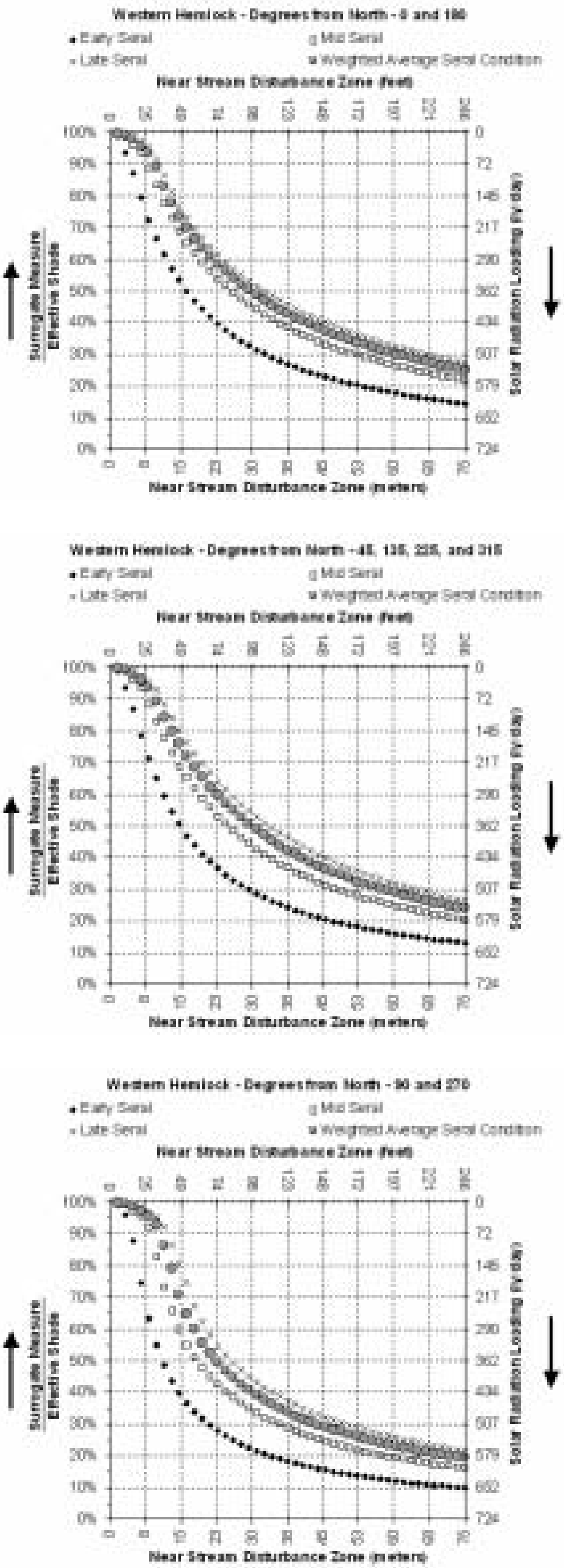


Figure 4.13. Effective shade curves – western hemlock potential vegetation zone.

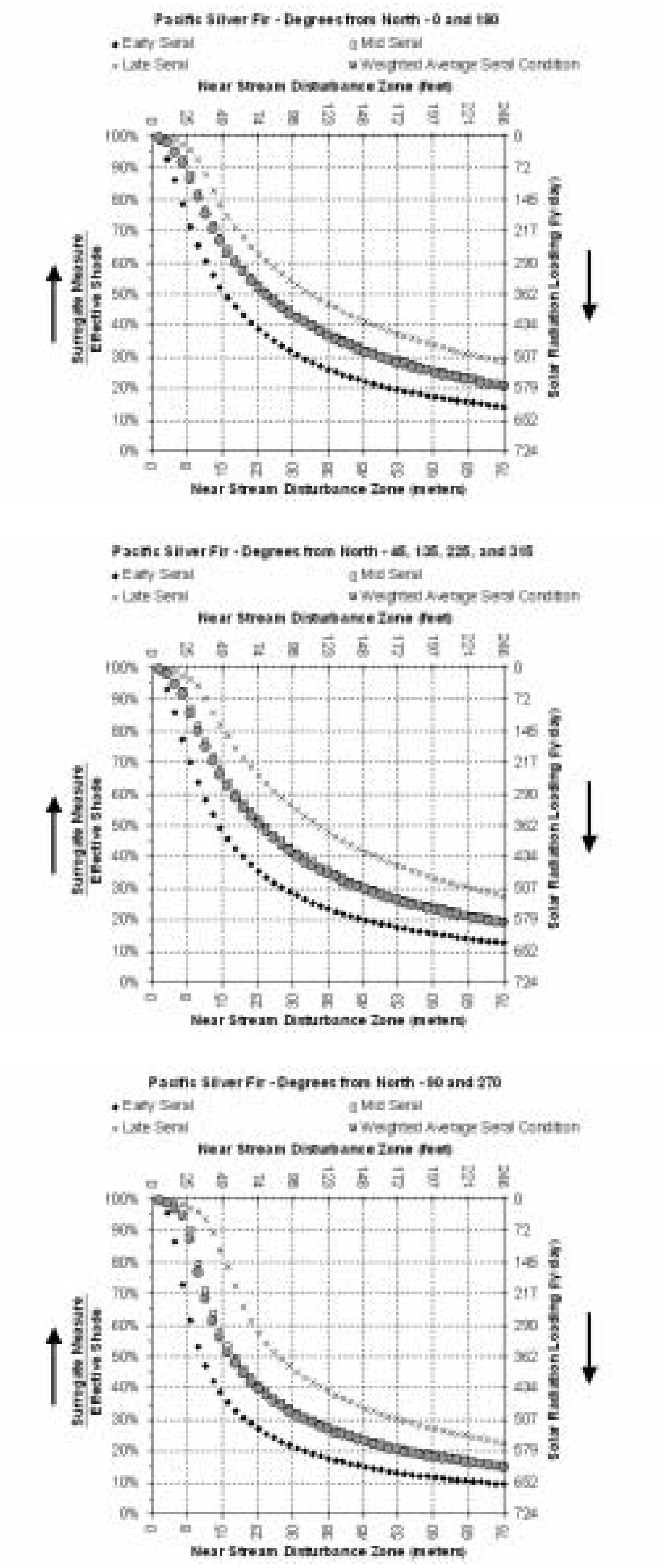


Figure 4.13 (continued). Effective shade curves – Pacific silver fir potential vegetation zone.

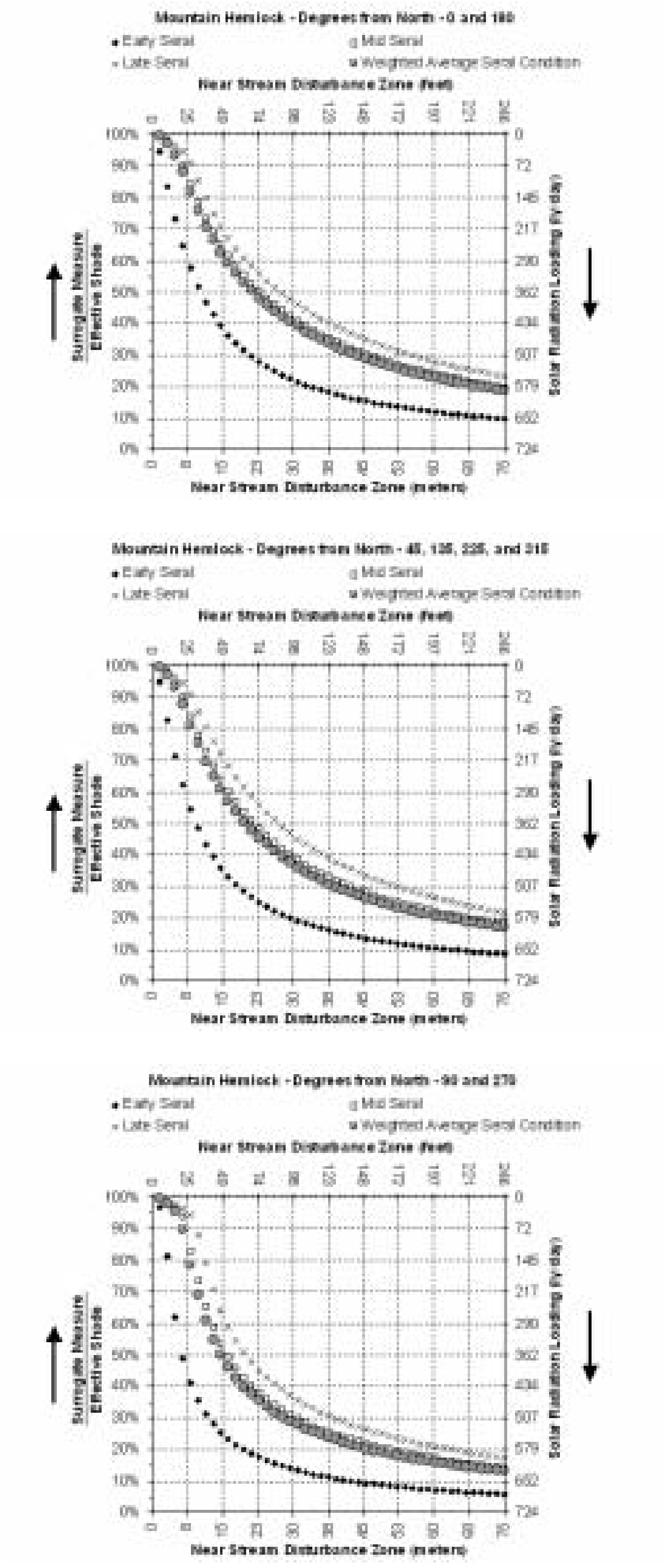


Figure 4.13 (continued). Effective shade curves – mountain hemlock potential vegetation zone.

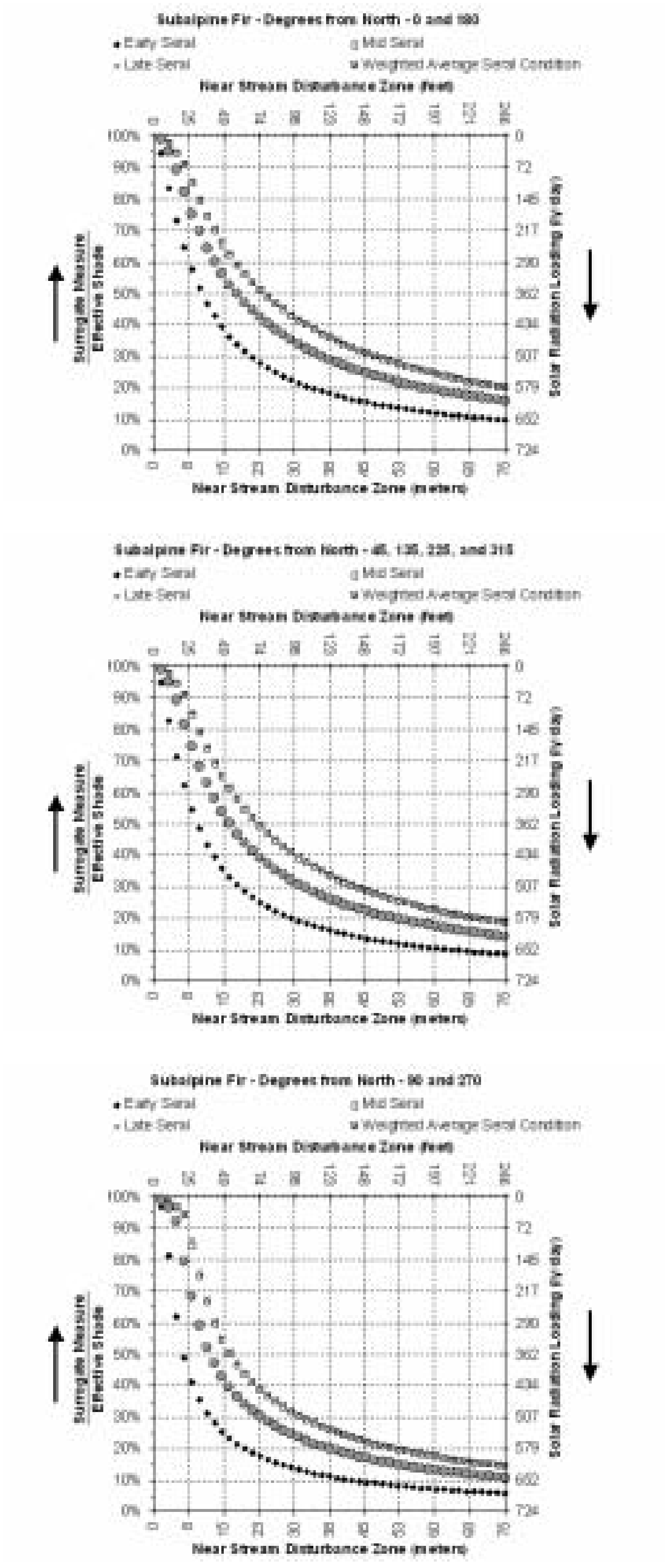
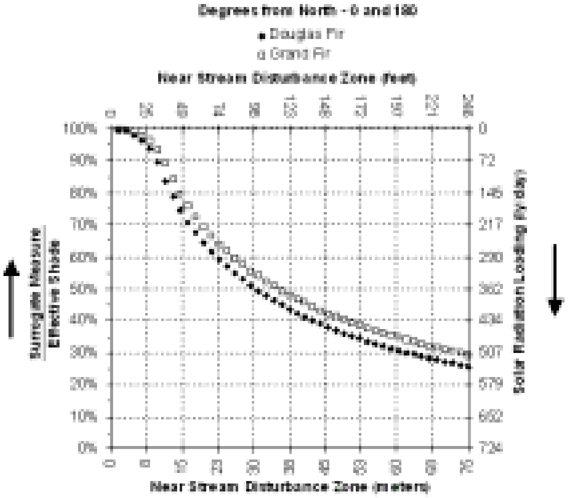
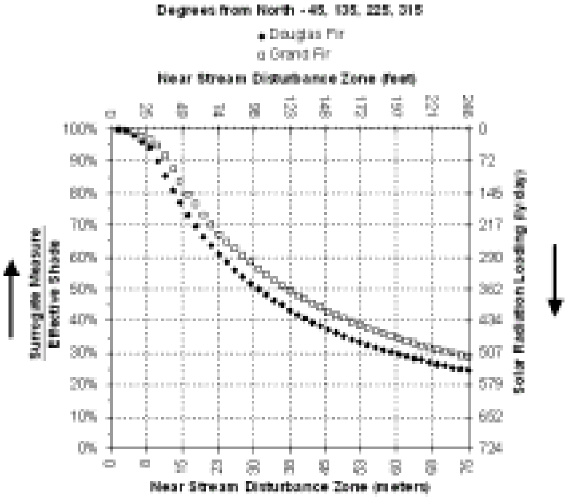


Figure 4.13 (continued). Effective shade curves – subalpine fir potential vegetation zone.





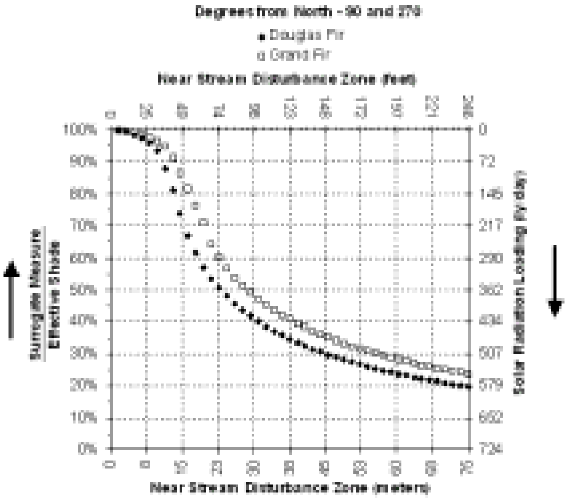


Figure 4.13 (continued). System potential effective shade curves – Douglas-fir and grand fir potential vegetation zone.

4.5.4 System Potential Effective Shade Simulation for the Greenwater River

System potential landcover conditions along the Greenwater River, based on Potential Vegetation Zones (PVZs) (see Figure 4.12), were incorporated in the shade model with local site-specific factors that influence stream shade conditions (i.e., topographic shade angle, elevation, aspect). In other words, the "shade curves" were applied to the Greenwater River. It is important to note that channel conditions included in this model application were assigned using widths no greater than "Natural Channel Design" conditions developed for the Greenwater River (Laurie, 2002) (see Figure 3.11). Figure 4.14 illustrates calculated system potential effective shade conditions for the Greenwater River. The gray zone in this image is the potential range of shade conditions possible at the various seral size classes represented in the "Shade Curves" (see Figure 4.13). The solid line represents weighted average conditions based on historical distributions of seral stages in the Upper White River watershed.

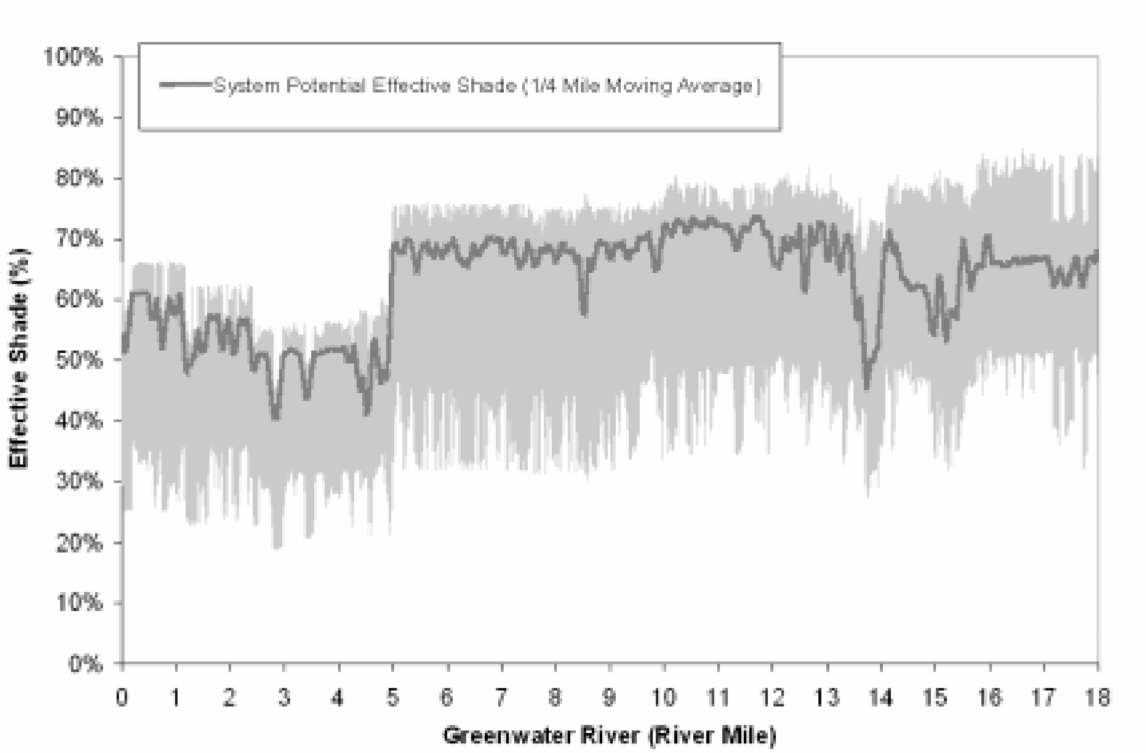


Figure 4.14. System potential effective shade conditions for the Greenwater River.

Local shifts of shade conditions along the Greenwater can be attributed to factors other than just vegetation characteristics. For example, the sudden drop of system potential shade conditions at approximately River Mile (RM) 13.5 to 14.0 results from a combination of slight channel width increase, lower topographic shade angles, and local aspect conditions, in addition to vegetation conditions. A very similar situation occurs in the lower reaches of this river (i.e., low topographic shade angles, wider channels).

As described above, the range of expected effective shade conditions at system potential conditions are represented in the gray zone in this image. Although the temperature load allocation in this TMDL is the effective shade conditions resulting from "weighted average conditions based on historical distributions of seral stages in the Upper White River watershed" (represented by the dark line in Figure 4.14), shade conditions could be expected to range within the plotted gray zone. However, this does not mean that shade conditions are allocated at the lower end of this expected zone.

4.5.5 System Potential vs. Current Effective Shade Conditions

The main utility of developing site-specific temperature load allocations for the Greenwater River is that it provides a means to evaluate the departure of current effective shade from system potential conditions. Figure 4.15 shows that current effective shade conditions along much of the river are much lower than "system potential" conditions. There are many areas where current shade conditions are within expected system potential ranges. However, other areas currently have shade greater than system potential conditions, which could be due to the very high canopy density conditions indicated in the IVMP GIS dataset (used to calculate current conditions).

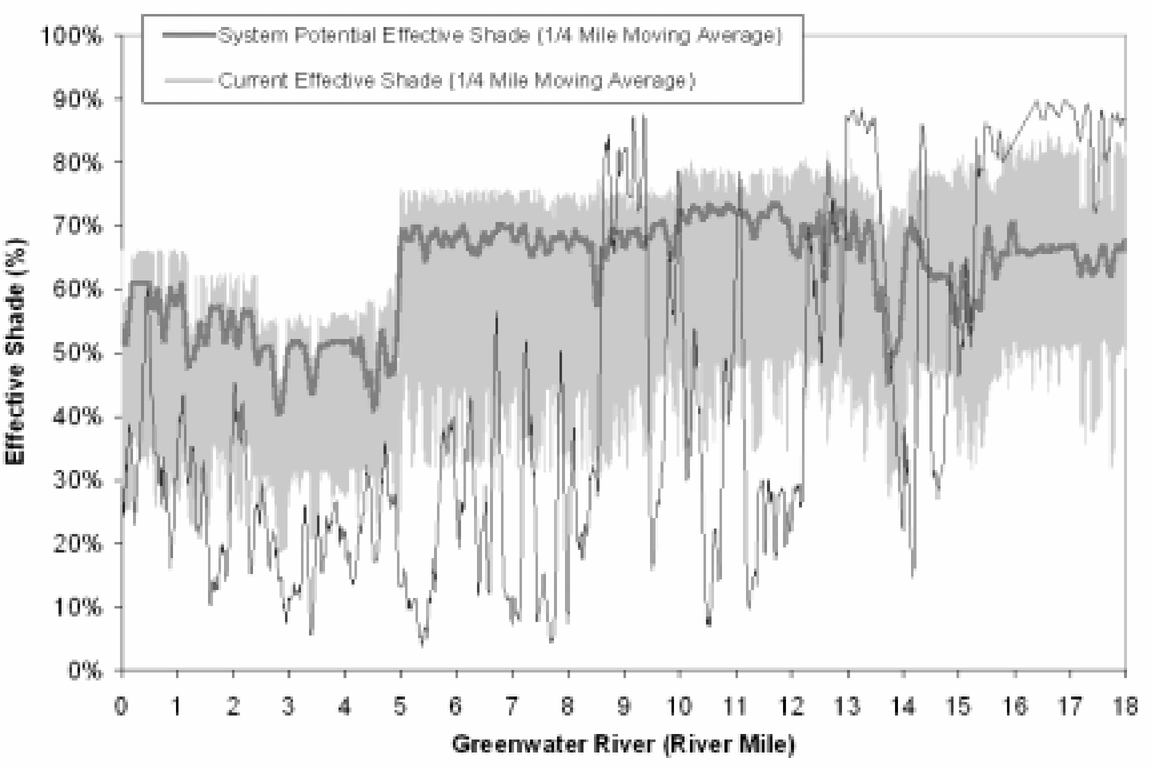


Figure 4.15. Current and system potential effective shade - Greenwater River.

4.5.6 Implementation of Temperature Load Allocations and the "Shade Curves"

Calculated system potential effective shade conditions presented above represent expected shade conditions while taking into account many of the variables that influence the production of "shade" (i.e., aspect, topographic shade angle, channel width, vegetation conditions, and location (latitude and longitude)). However, this modeling effort is only as spatially explicit as the GIS data sets it uses. Although these datasets were shown to provide an adequate means to evaluate shade conditions (see Figures 4.8, 4.10 and 4.11), they will not be able to provide the same level of spatial resolution field monitoring would provide.

GIS analysis provides a means to evaluate the general trends. Field analysis is the only method to implement site-specific application of the temperature load allocations. Accordingly, the "shade curves" (see Figure 4.13 and Appendix E), should be used as the primary means to evaluate of progress towards "system potential" shade conditions.

4.5.7 "System Potential Heat Loading" in the Greenwater River

Figure 4.16 illustrates the expected heat load at "system potential landcover conditions". This is a direct translation of expected effective shade conditions at "system potential landcover conditions" (see Figure 4.14). Similar to Figure 4.14, the gray zone in this image is the potential range of heat loading conditions at the various seral size classes represented in the "Shade Curves" (see Figure 4.13). In addition, the solid line represents weighted average conditions based on historical distributions of seral stages in the Upper White River watershed. The thin line is current heat load conditions.

The information provided in Figure 4.16 provides an estimate of heat energy loading following the implementation of the temperature load allocation and the return of the system to its potential landcover. Excessive heat energy loading is the pollutant, and therefore this analysis is necessary to satisfy requirements of the TMDL process. However, it is important to point out once again, that effective shade conditions provided in Figures 4.13 through 4.15 will be used to evaluate to implementation of the temperature load allocations.

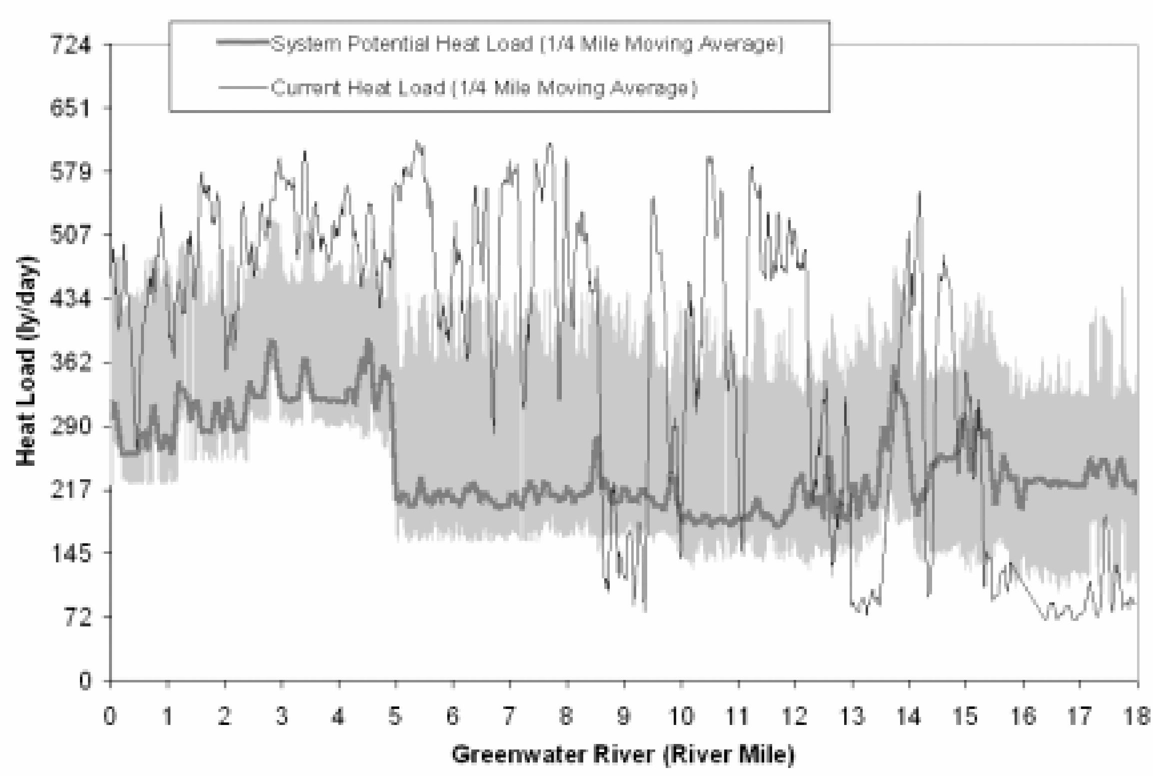


Figure 4.16. System potential heat load conditions for the Greenwater River.

4.6 Margin Of Safety – CWA §303(D)(1)

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The MOS may be implicit, as in conservative assumptions used in calculating the loading capacity, Waste Load Allocation, and Load Allocations. The MOS may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the MOS documented. The MOS is not meant to compensate for a failure to consider factors that affect water quality.

A TMDL and associated MOS, which results in an overall allocation, represents the best estimate of how standards can be achieved. The selection of the MOS should clarify the implications for monitoring and implementation planning in refining the estimate if necessary (adaptive management). The TMDL process accommodates the ability to track and ultimately refine assumptions within the TMDL implementation-planning component.

Calculating a numeric MOS is not easily performed with the methodology presented in this document. However, the TMDL accounts for uncertainties in the analysis by incorporating an implicit margin of safety. Specifically, by definition, system potential effective shade, developed from system potential vegetation conditions, is the best feasible or reasonable condition expected in the watershed. Therefore, this is the "Margin of Safety" for this temperature TMDL analysis.

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APPENDIX A

Summary Implementation Strategy

Appendix A -- Summary Implementation Strategy

Introduction

The purpose for this Summary Implementation Strategy (SIS) is to provide an overview of how agencies (primarily) and the private sector will work together to restore aquatic system health and thus achieve water quality standards in the Upper White watershed. The TMDL studies and additional information included within this report provide the framework and targets for implementation activities and long-term monitoring (i.e. load allocations and suggested habitat parameters). This section summarizes the strategy and elements that should ensure effective actions to meet the established targets, and therefore restore compliance with water quality sediment, temperature, and habitat standards. It includes: implementation strategies, assurances that needed actions will occur, how monitoring and adaptive management will occur, and potential funding sources.

There are four ownership/land management categories applicable to the TMDL in the watershed. These are:

1. USFS lands within the Mt. Baker Snoqualmie National Forest,
2. Mount Rainier National Park,
3. Privately owned timberland, and,
4. Other privately owned land (e.g. residences along the Greenwater River).

Whereas all lands in the Upper White watershed are included in this SIS, the USFS lands are the primary focus for the TMDL study and, following approval of the TMDL by the EPA, will be the focus of Water Quality Restoration Plan development and restorative actions. There are several reasons for this focus:

<u>Federal lands are 94% of the watershed.</u> Of these:

A. The USFS is the major landowner of managed lands within the Upper White watershed that are in need of restorative actions.
B. Mount Rainier National Park is managed largely for natural ecosystem processes and this SIS is not recommending management changes by the park. However, continued diligence in road management and cooperative monitoring is encouraged.

<u>Private lands comprise 6% of the watershed.</u> Of these:

D. The Forest and Fish Report, which covers management of private and state timberlands, specifically provides a Clean Water Act assurance that until the year 2009, TMDLs will be a lower priority on these lands due to the upgraded level of water quality protection afforded by the Forest and Fish rules. As a result, the TMDL is advisory and voluntary for the private timber lands.
E. Privately owned residential lands are a very small part of the watershed. The TMDL is advisory and voluntary for this land use, however, we encourage the participation of this group of landowners and residents in restorative and protection efforts.

Implementation strategies for the USFS, private timber, and privately owned residential lands are further discussed in this SIS.

Because of the importance of the Upper White watershed to salmonid recovery, restoration planning needs to occur in coordination with recovery efforts. This is currently occurring on several fronts, and opportunities to continue this coordination need to be encouraged. An initial discussion has occurred between Ecology, USFS and EPA with Pierce County and Mobrand Biometrics to begin a process for sharing information for prioritization of implementation elements. The Pierce Conservation District has been collaborating with the USFS to address restoration needs. Furthermore, the watershed technical review committee for this TMDL includes representatives for the agencies and tribes who are actively involved in salmonid recovery, thus providing an important forum for information exchange.

In addition, the Puyallup Watershed Council has recently completed the "Upper Puyallup Watershed Characterization and Action Plan" (The Upper Puyallup Watershed Committee 2002). This plan provides a strong focus and cooperative framework for protection and restoration of water quality, aquatic integrity, and stream habitat in forest lands of the upper watershed.

Implementation Strategies

USFS Implementation

There are three pieces that will comprise the USFS implementation. These are the Mt Baker-Snoqualmie Forest Plan, the Water Quality Restoration Plan (WQRP), and Crystal Mountain Resort Management Plan. The Mt. Baker-Snoqualmie Forest Plan allocates most of the Upper White Watershed to Late Successional Reserves and wilderness. In addition, the riparian reserves, a component of the Aquatic Conservation Strategy applies to all streams on National Forest System Lands. These plan elements and included protection levels were used as a benchmark starting level for design of the TMDL assessments and are fundamental components of the TMDL implementation.

Within one year after approval of this TMDL report by EPA, the USFS will develop a WQRP. The plan will use sediment budget (including additional information that extends the budget to smaller drainage areas allowing focus on local problem areas) and temperature assessment results from this report to develop implementation measures and timelines for achieving load allocations for sediment and temperature. The WQRP will include a monitoring and adaptive management plan. The monitoring plan development will include coordination with the Puyallup Watershed Council monitoring activities.

The Crystal Mountain Resort has been undergoing a master planning process with a final EIS nearing completion. Monitoring of sediment and temperature, along with adaptive management are part of the master plan.

Private Timberlands

Private and state timberlands are governed through WAC 222, implementing regulations (RCW 76.09), and additional provisions contained in the Forest and Fish Report (www.wa.gov/dnr/htdocs/fp/fpb/forests&fish.html). The goals of the forestry module of the Forests and Fish Report are fourfold:

- Provide compliance with the Endangered Species Act for aquatic and riparian-dependent species on non-federal forest lands
- Restore and maintain riparian habitat on non-federal forest lands to support a harvestable supply of fish
- Meet the requirements of the Clean Water Act for water quality on non-federal forest lands
- Keep the timber industry economically viable in the State of Washington.

To achieve the overall objectives of the Forests and Fish initiative, significant changes in current riparian forest management policy were prescribed. The goal of riparian management and conservation recommended in the Forests and Fish report is to achieve restoration of high levels of riparian function and maintenance of these levels once achieved. For west-side forests such as those in the Upper White River watershed, the Forests and Fish Report specifies riparian silvicultural treatments and conservation measures that are designed to result in "desired future conditions." Desired future conditions are the stand conditions of a mature riparian forest, agreed to be 140 years of age, and the attainment of resource objectives. These desired future conditions are a reference point on the pathway to restoration of riparian functions, not an endpoint of riparian stand development.

The riparian functions addressed by the recommendations in the Forests and Fish report include bank stability, the recruitment of woody debris, leaf litter fall, nutrients, sediment filtering, shade, and other riparian features that are important to both riparian forest and aquatic system conditions. The diversity of riparian forests across the landscapes is addressed by tailoring riparian prescriptions to the site productivity and tree community at specific sites.

Load allocations in this TMDL for private forest lands in the Upper White River watershed are in accordance with the section of Forests and Fish entitled “TMDLs produced prior to 2009 in mixed use watersheds”. Consistent with the Forests and Fish report, implementation of load allocations established in this TMDL for private forestlands will be accomplished via implementation of the forest practice regulations. The effectiveness of the Forests and Fish rules is being monitored as part of an adaptive management process.

Washington State Department of Natural Resources (DNR) is encouraged to condition forest practices to prohibit any further reduction of stream shade and not waive or modify any shade requirements for timber harvesting activities on private lands. Ecology is committed to assisting DNR in identifying site-specific situations where reduction of shade has the potential for or could cause material damage to public resources. Within one year of approval of the TMDL, Ecology will develop a pamphlet for the riparian shade target implementation. This will be distributed to the DNR and to Hancock Forest Management Company.

New rules for roads also apply. Under the new rules, roads must provide for better control of road-related sediments, provide better streambank stability protection, and meet current Best Management Practices. DNR is responsible for oversight on these activities.

Private Residences

Because the focus of the TMDL report is USFS land, and due to the limited extent of private residences in the Upper White Watershed, a formal implementation strategy for these residences is not being required as part of this plan. However, for residences along rivers, voluntary participation in riparian restoration and other measures to promote recovery of watershed processes is important. Pierce and King Counties, county conservation districts, and the Puyallup Watershed Council are local entities that may be able to provide restoration guidance and other assistance for these areas. For example, The Upper Puyallup Watershed Committee (2002) has priority action items such as (1) create an interdisciplinary team to help landowners reestablish riparian zones, and (2) expand stream team, land/water stewardship programs and other volunteer monitoring opportunities. Ecology Centennial Grant funds and State Salmon Recovery Funding Board grants are potential sources of implementation dollars for private lands.

Within one year of approval of the TMDL, Ecology will develop a pamphlet for the riparian shade target implementation. This will be distributed to the Pierce and King County planning departments.

Reasonable Assurances

Operational assurances that the USFS WQRP will be carried out fall within several avenues including the Mt. Baker Snoqualmie National Forest Land and Resource Management Plan (as amended by The Northwest Forest Plan), and the Ecology/USFS MOA. These are the regulatory tools for Clean Water Act compliance of forest management activity in Washington State. The Aquatic Conservation Strategy is a major component of the Northwest Forest Plan designed to maintain and restore the ecological health and aquatic ecosystems at the watershed and landscape scale to protect habitat for fish and other riparian dependent species and resources. The USFS consults with the EPA when there are revisions to the Forest Land and Resource Management Plan. These consultations will include any Plan revisions that may affect TMDL implementation.
The Mt. Baker Snoqualmie National Forest adheres to the agency responsibilities set forth in the Memorandum of Agreement between the USDA Forest Service, Region 6 and the Washington State Department of Ecology for meeting federal and state water quality regulations. Ecology and the USFS meet annually to determine compliance with the

MOA. These programs provide reasonable assurance for TMDL implementation and restoration of water quality for federal lands.

Private timberlands are required through WAC 222 Forest Practices to comply with the new Forest and Fish regulations.

The Puyallup Watershed Council through implementation of The Upper Puyallup Watershed Characterization and Action Plan (The Upper Puyallup Watershed Committee 2002) provides an example of a local effort that may be able to provide support to private residences for implementation of the TMDL.

Monitoring and Adaptive Management

The monitoring strategy for the temperature and sediment load allocations, and habitat parameters will be developed as part of the WQRP. Recommended monitoring habitat parameters and their linkages to watershed processes (and therefore also to load allocations for sediment and system potential shade) are included in this TMDL report (Table 2.5, Table 2.6). During the WQRP monitoring plan development, the parameters, methods, and measures within Tables 2.5 and 2.6 will be reviewed, and updated as necessary based on new information that may be available. In addition, a baseline of data and imagery has been developed for eight reaches of the Upper White watershed (Black et al. 2003).

The TMDL provides a strong basis for follow-up monitoring and adaptive management. All implementation elements in the WQRP will be evaluated at 5-year intervals, with major reviews occurring at 5, 10, 20 and 30 year intervals.

Potential Funding Sources

Potential funding sources available to the USFS are: Emergency Repair for Federally-Owned Road, Supplemental Emergency Flood, and Appropriated funds. The Department of Ecology provides funding for nonpoint implementation activities through the Centennial Clean Water Fund. Watersheds where a TMDL has been completed receive more favorable consideration for funding.

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Appendix B

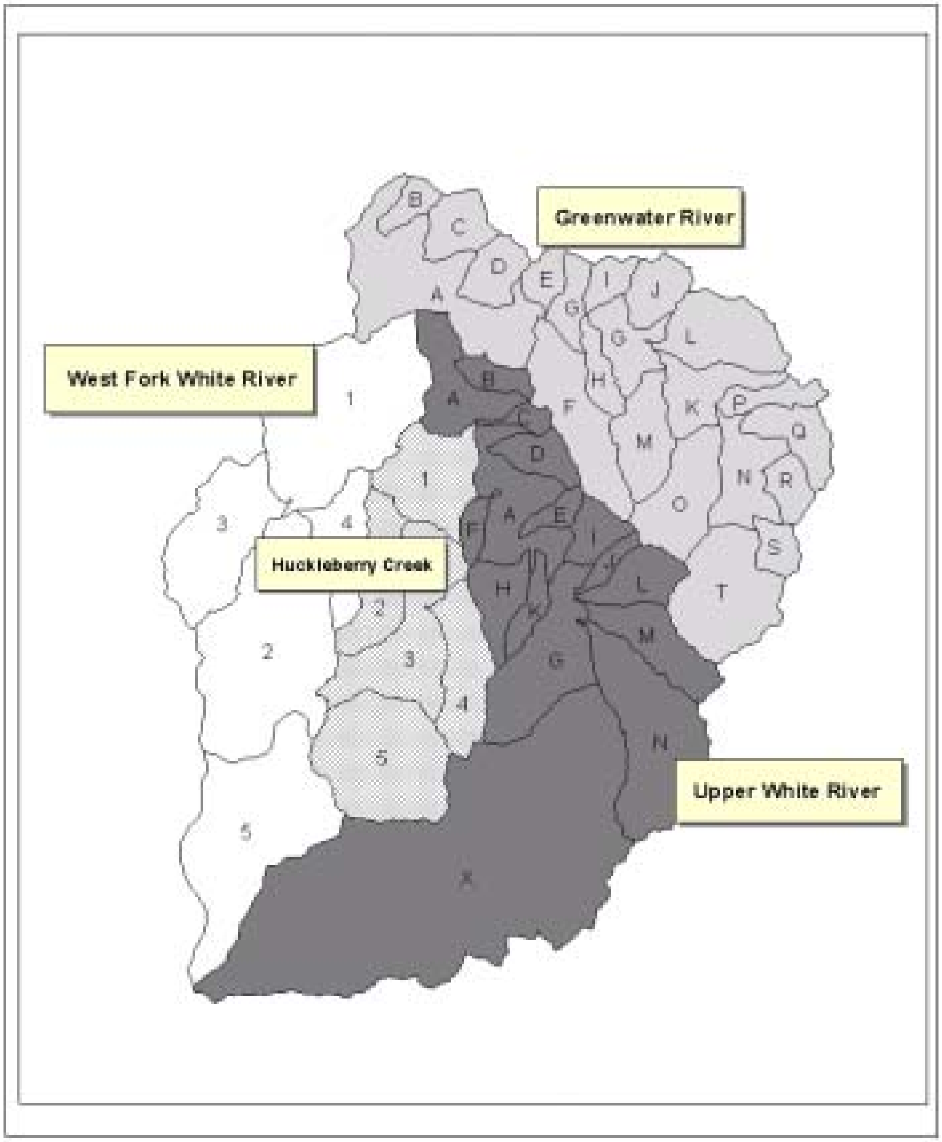
Documentation for Not-Listed but Impaired Segments

Appendix B – Documentation for Not-Listed but Impaired Segments

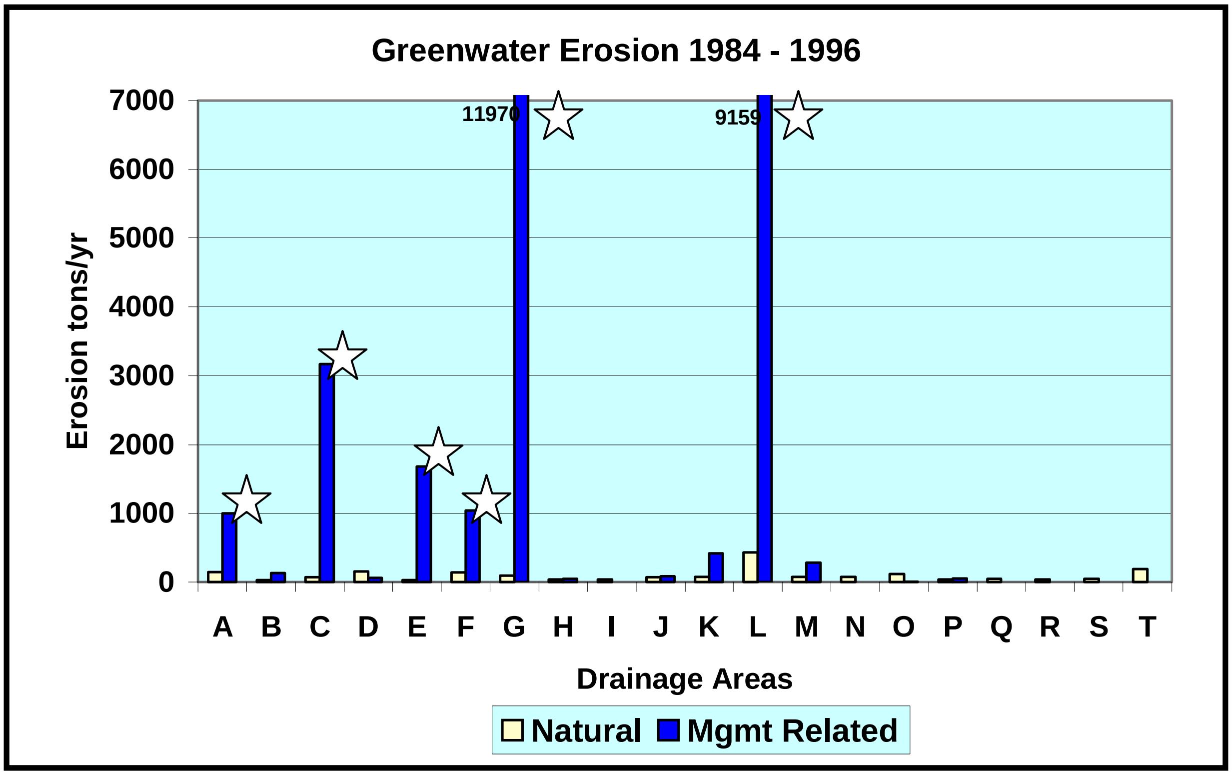
This appendix includes the supporting data, or data sources used for Tables 2.8 and 2.9. The information below is organized by category for coarse sediment, fine sediment, temperature, and habitat.

Coarse Sediment

“Starred” drainage areas shown on graphs are impaired waters for coarse sediment due to amount of anthropogenic sediment from harvest units and roads. The following charts represent the most recent time period used in the sediment budget for the Upper White River watershed. The map below shows the locations of the coded drainage areas. Data is by the Mt. Baker-Snoqualmie National Forest, May 2003.

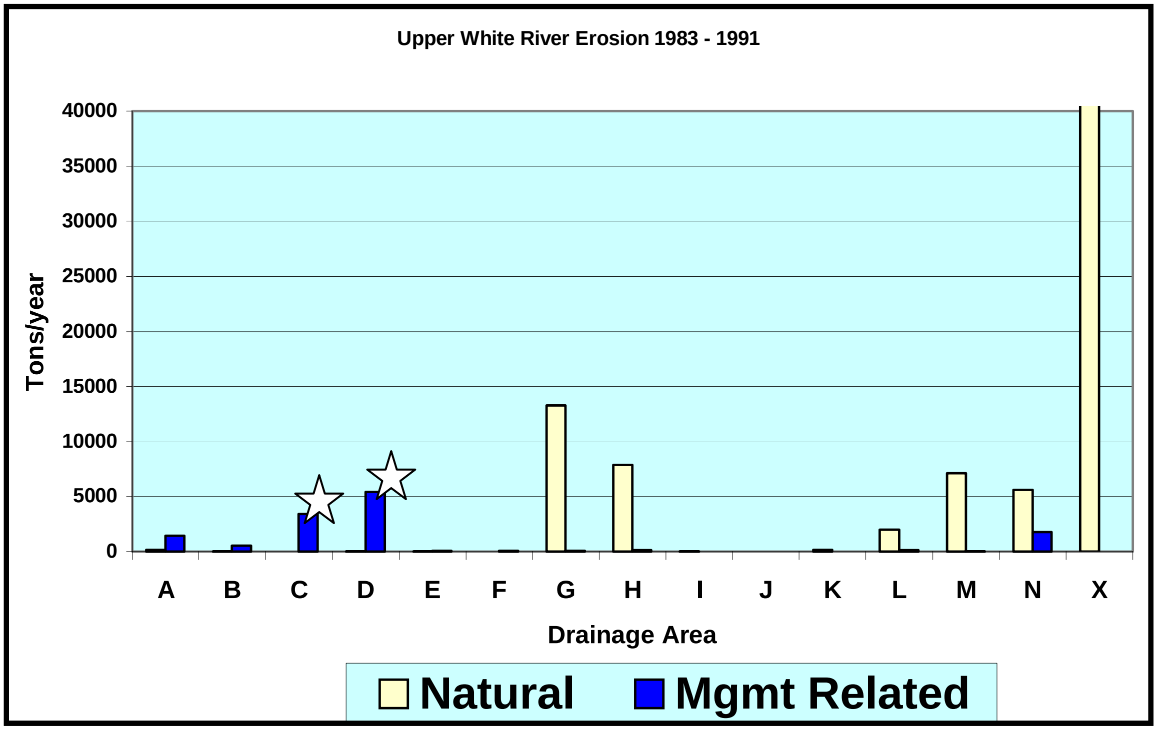


Greenwater River Subwatershed



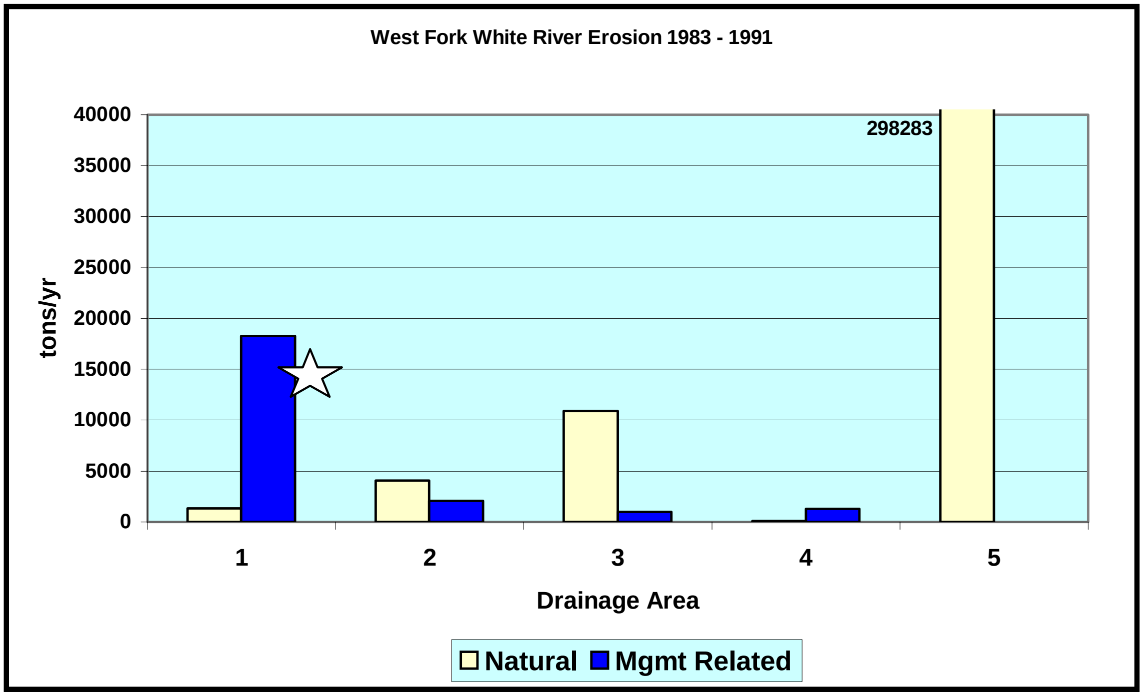
Drainage Area Code	
A	**Greenwater below Slide Creek (RM 0.0)**
B	Unnamed
C	**Unnamed (Brush, 10.0125)**
D	Unnamed (Midnight)
E	**Slide Creek**
F	**Twenty-eight Mile Creek**
G	**Greenwater above Slide Creek (RM 8.0)**
H	Forest Lake Creek
I	Burns Creek
J	Whistler Creek
K	Greenwater above George Creek
L	**Pyramid Creek**
M	George Creek
N	Greenwater above Meadow Creek
O	Lost Creek
P	Meadow Creek
Q	Maggie Creek
R	Unnamed
S	Unnamed
T	Greenwater above Echo Lake

Upper White River Subwatershed



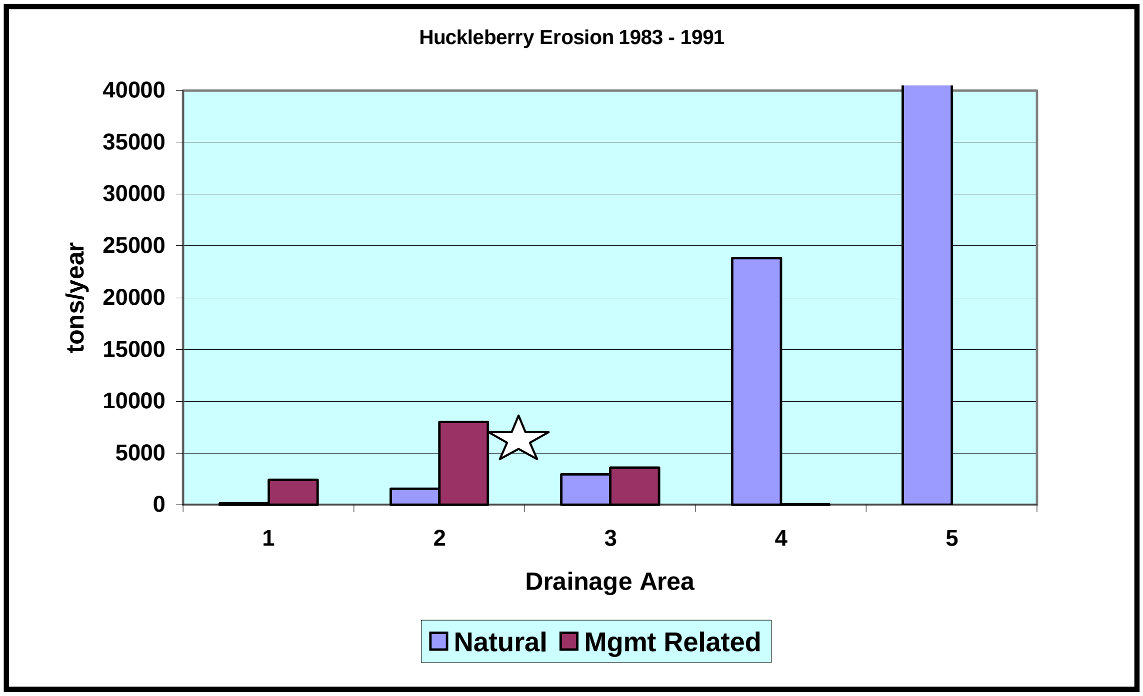
Drainage Area Code	Drainage Area Name
A	White River below Ranger Creek
B	Boundary Creek
C	**Lightning Creek**
D	**Minnehaha Creek**
E	Snoquera Creek
F	Skookum Creek
G	White River above Ranger Creek
H	Buck Creek
I	Ranger Creek
J	Dry Creek
K	Doe Creek
L	Deep Creek
M	Goat Creek
N	Silver Creek
X	Upper White River, Mt. Rainier National Park

West Fork White Subwatershed



Drainage Area Code	Drainage Area Name
1	**Lower West Fork White River (RM 0.0)**
2	Middle West Fork White River
3	Pinochle Creek
4	Mule Creek
5	Upper West Fork White River

Huckleberry Creek Subwatershed



Drainage Area Code	Drainage Area Name
1	Lower Huckleberry Creek
2	**Eleanor Creek**
3	Middle Huckleberry Creek
4	Lost Creek
5	Upper Huckleberry Creek

Fine Sediment

Spawning Gravel Fine Sediments – data are in the following publication:

Keown, C. and J.H. Summers VII. 1998. Upper White River spring chinook habitat assessment study; Interim report on 1995 water temperatures and spawning gravel composition. Publication No. 98-304. Washington Department of Ecology. Olympia.

The following spawning gravel fine sediment segment is impaired:

River And Legal Description	River Mile(s) and Segment	Entity Responsible for Data	Data Value	Justification for Impairment	Anthropo-genic Causes?	QA/QC Plan? Where?
Greenwater T19NR9E Sec3,4,10	0.00 – 0.6 Seg. 1 (part)	Ecology	14.2 % fines <0.85mm	State Watershed Analysis for forest practices categorizes this as "fair" habitat quality. Increased levels of mortality to incubating salmonid embryos occurs.	Yes, see USDA Forest Service Watershed Analysis for the Greenwater and Upper White.	Yes, in cited document.

Temperature

Water Temperature – data are in the following publication: Schuett-Hames, J.P., C. Keown, C.M. James. 2003. Draft. Upper White watershed temperature data report: 1989 to 2002. Washington Department of Ecology. Olympia, WA.

Based on the included data, the Greenwater River at river miles 1.2, 1.5, 5.3 and 5.5, and Brush Creek at river mile 0.2 exceed the 7dadm criterion of 16.0 C, have QAQC documentation, and overall meet the listing criteria for the CWA Section 303(d) list. The Greenwater River at river mile 0.5, Straight Creek at river mile 0.3, Whistler Creek at river mile 0.4, Pyramid Creek at river mile 0.4, and the West Fork White River at river mile 4.3 meet the criteria for state listing as waters of concern. These waters either exceed the 16 C criterion for the 7dadm but have no QAQC documentation, or exceed the state standard of 16 C, but do not exceed the 7dadm.

Habitat

Channel Scour – data are in the following publication:

Schuett-Hames, J.P and D.S. Adams. 2003. Upper White watershed spring chinook redd, scour, and cross-section assessments: 1995 – 2001. Washington Department of Ecology. Olympia, WA.

The following stream segment is impaired:

River And Legal Description	River Mile(s) and Segment	Entity Respon-sible for Data	Data Value	Justification for Impairment	Anthropo-genic Causes?	QA/QC Plan? Where?
Greenwater T19NR9E Sec11	1.5 – 2.4 Seg. 3	Ecology	Annual incubation peak discharges predicted to scour ≥50% of monitors to egg pocket depth are occurring at a 3-year return frequency versus a 6-year return frequency for the historic period.	Rates of scour to chinook egg pocket depth (which thus affect embryo survival to emergence), are occurring significantly more often post watershed management (1970 to 2000), versus during the pre-1970 historical flow period.	Yes, see USDA Forest Service Watershed Analysis for the Greenwater and Upper White.	Yes, within methods section of report.

Other Habitat Parameters – As part of the Washington State Clean Water Act 303(d) integrated assessment for the year 2002, Ecology staff reviewed the salmon recovery limiting factors analyses, on a state-wide basis, to determine where habitat conditions existed that met the conditions for impairment by a non-pollutant.

For WRIA 10, the following report was reviewed: Washington Conservation Commission. 1999. Salmon habitat limiting factors report for the Puyallup River Basin (Water Resource Inventory Area 10). Washington Conservation Commission. Olympia, WA.

With the exception of the Greenwater River for scour, all other streams listed for habitat impairments in Table 2.9 are from this source.

Appendix C

Overview of Stream Heating Processes

Appendix C -- Overview of Stream Heating Processes

At any particular instant in time, a defined stream reach is capable of sustaining a particular water column temperature. Stream temperature change that results within a defined reach is explained rather simply. The temperature of a parcel of water traversing a stream/river reach enters the reach with a given temperature. If that temperature is greater than the energy balance is capable of supporting, the temperature will decrease. If that temperature is less than energy balance is capable of supporting, the temperature will increase. Stream temperature change within a defined reach, is induced by the energy balance between the parcel of water and the surrounding environment and transport of the parcel through the reach. The general relationships between stream parameters, thermodynamic processes (heat and mass transfer) and stream temperature change is outlined in the flow chart below (Figure C-1).

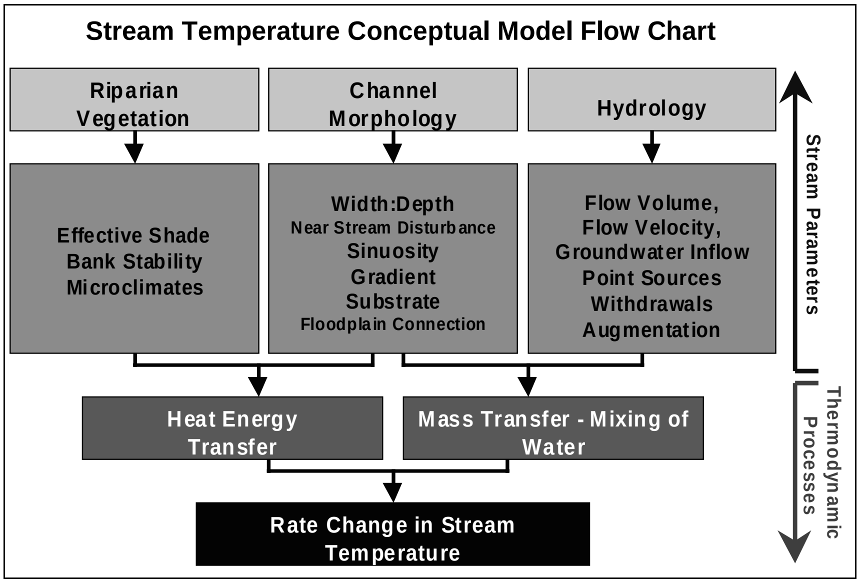


Figure C-1. Stream temperature conceptual model flow chart.

Cumulative Effects

It takes time for the water parcel to traverse the longitudinal distance of the defined reach, during which the energy processes drive stream temperature change. At any particular instant in time, water that enters the upstream portion of the reach is never exactly the temperature that is supported by the defined reach. And, as the water is transferred downstream, heat energy and hydraulic process that are variable with time and space interact with the water parcel and induce water temperature change. Further, heat energy is stored within this parcel of water and its temperature is the result of the heat energy processes upstream. This is commonly referred to as a cumulative temperature effect, where conditions at a site contribute to heating of an already heated parcel of stream water. The described scenario is a simplification; however, understanding the basic processes in which stream temperature change occurs over the course of a defined reach and period of time is essential.

Thermal Role of Riparian Vegetation: The role of near stream land cover in maintaining a healthy stream condition and water quality is well documented and accepted in scientific literature (Beschta et al. 1987). Riparian vegetation plays an important role in controlling stream temperature change. The list of important impacts that near stream land cover has upon the stream and the surrounding environment is long and warrants listing.

- Near stream vegetation height, width and density combine to produce shadows that when cast across the stream, reduce solar radiant loading.
- Near stream land cover creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity and lower wind speeds along stream corridors.
- Bank stability is largely a function of near stream vegetation. Specifically, channel morphology is often highly influenced by land cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris and influencing sedimentation, stream substrate compositions and stream bank stability.

The warming of water as a stream travels and drops in elevation (longitudinal heating) is a natural process. However, rates of heating can be dramatically reduced when high levels of shade exist and solar radiation loading is minimized. The overriding justification for a reduction in solar radiation loading is to minimize longitudinal heating. A limiting factor in reducing longitudinal stream heating is that there is a natural maximum level of shade that a given stream is capable of attaining.

Stream Surface Shade – Defined: Stream surface shade is an important parameter that controls the stream heating derived from solar radiation. Solar radiation has the potential to be the largest heat transfer mechanism in a stream system. Human activities can degrade near stream land cover and/or channel morphology, and in turn, decrease shade. It follows that human-caused reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Stream shade levels can also serve as an indicator of near stream land cover and channel morphology condition. For these reasons, stream shade is a focus of this analytical effort.

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography above a stream. Shade is expressed in units of energy per unit area per unit time, or as a percent of total possible energy. Canopy cover is the percent of the sky covered by vegetation or topography. Shade producing features will cast a shadow on the water while canopy cover may not. In order to assess the ability of riparian land cover to shield a stream from solar radiation, two basic characteristics of shade must be addressed: *shade duration* and *shade quality*. The length of time that a stream receives shade can be referred to as *shade duration*. The density of shade that affects the amount of radiation blocked by the shade producing features is referred to as *shade quality*. Effective shade

(Figure C-2) is amount of potential solar radiation not reaching the stream surface and is a function of *shade duration* and *shade quality*.

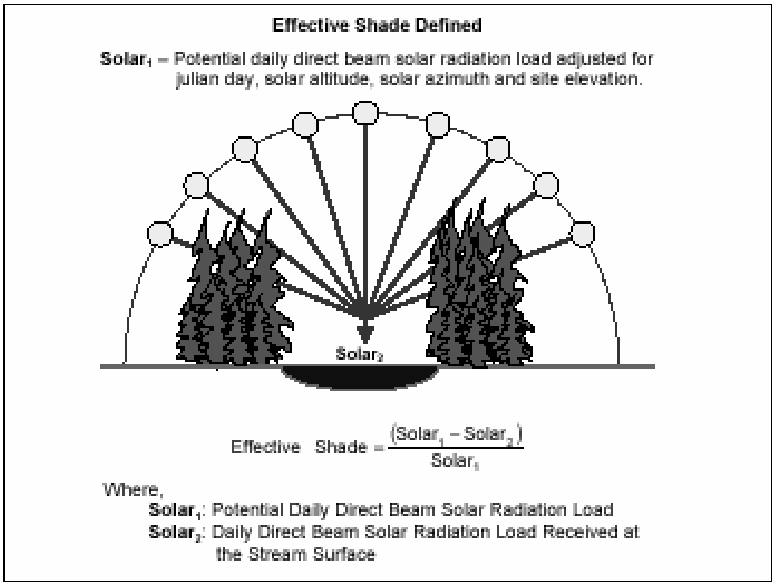
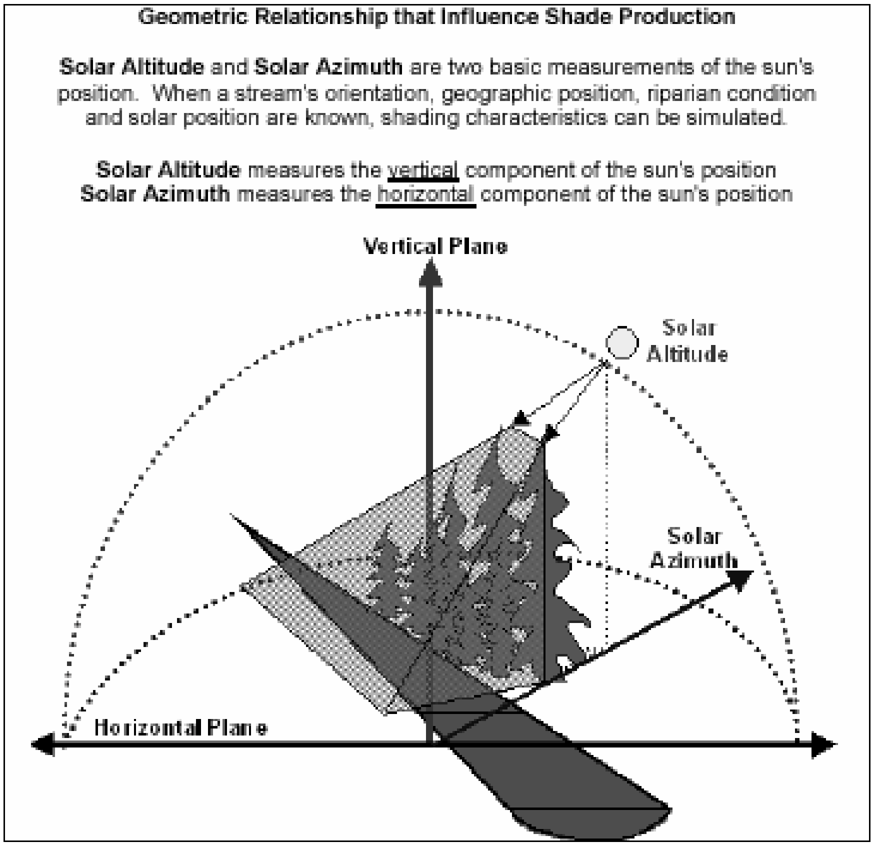


Figure C-2. Definition of effective shade.

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summertime months causing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun) (Figure C-3). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation. Near stream land cover height, width and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e., produce shade) (Table C-1). The solar position has a vertical component (i.e., solar altitude) and a horizontal component (i.e., solar azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation (i.e., hour angle measured as 15^o per hour).

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The measured solar load at the stream surface can easily be measured with a Solar Pathfinder© or estimated using mathematical shade simulation computer programs (Boyd, 1996 and Park, 1993).



Geometric Relationship that Influence Shade Production

Solar Altitude and **Solar Azimuth** are two basic measurements of the sun's position. When a stream's orientation, geographic position, riparian condition and solar position are known, shading characteristics can be simulated.

Solar Altitude measures the vertical component of the sun's position
Solar Azimuth measures the horizontal component of the sun's position

Figure C-3. Parameters that affect shade and geometric relationships.

Table C-1. Factors that influence stream shade.

Description	**Parameter**
Season/Time	Date/Time
Stream Characteristics	Aspect, **Channel Width**
Geographic Position	Latitude, Longitude
Vegetative Characteristics	**Near Stream Land Cover Height, Width, and Density**
Solar Position	Solar Altitude, Solar Azimuth

bold type - influenced by human activities

Microclimate - Surrounding Thermal Environment

A secondary consequence of near stream vegetation is its effect on the riparian microclimate. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures. Relative humidity increases result from the evapotranspiration that is occurring by riparian plant communities. Wind speed is reduced simply by the physical blockage produced by riparian vegetation. Riparian buffers commonly occur on both side of the stream, compounding the edge influence on the microclimate.

Brosofske et al. (1997) reported that a minimum stream buffer width of 150 feet was required to maintain soil temperatures that reflect those of a normal microclimate. Ground temperatures can be a source of heat energy to the stream. When the ground is warmer than the stream, heat will transfer from the stream bank to the water column. In fact, ground surfaces can conduct heat to the stream hundreds of times faster than that of the air column surrounding the stream. Solids (ground surfaces) have conductivities on the order of 500 to 3,500 times greater than gases (air) (Halliday and Resnick 1988). Impoverished riparian areas that allow excessive stream bank warming will introduce heat into the stream faster than cooler, highly vegetated stream banks. Riparian condition is again implicated as a controlling factor in stream temperature dynamics in part because ground/soil temperatures are a function of the shading.

Air affects stream temperatures at a slower *rate*. Nevertheless, this should not be interpreted to mean that air temperatures do not affect stream temperature. Air can deliver heat to a stream via the convection/conduction pathway, which is the slowest of the water energy transfer processes (Bowen 1926; Beschta and Weatherred 1984; Boyd 1996). However, prolonged exposure to air temperatures warmer than the stream can induce gradual stream heating. Thus, a cooler microclimate will induce less stream warming.

Thermal Role of Channel Morphology

Changes in channel morphology, namely channel widening, impacts stream temperatures. As a stream widens, the surface area exposed to radiant sources and ambient air temperature increases, resulting in increased energy exchange between the stream and its environment (Boyd 1996). Further, wide channels are likely to have decreased levels of shade due to the increased distance created between vegetation and the wetted channel and the increased surface area to shade. Conversely, narrow channels are more likely to experience higher levels of shade. An additional benefit inherent to narrower/deeper channel morphology is a higher frequency of pools that contribute to aquatic habitat.

Channel widening is often related to degraded riparian conditions that allow increased stream bank erosion and sedimentation of the streambed, both of which correlate strongly with riparian vegetation type and condition (Rosgen 1996). Riparian vegetation contributes to rooting strength and flood plain/stream bank roughness that dissipates erosive energies associated with flowing water. Established/Mature woody riparian vegetation adds the highest rooting strengths and flood plain/stream bank roughness. Annual (grassy) riparian vegetation communities offer less rooting strength and flood plain/stream bank roughness.

Channel morphology is not solely dependent on riparian conditions. Sedimentation can deposit material in the channel, fill pools and aggrade the streambed, reducing channel depth and increasing channel width. Flow events play a major role in shaping the stream channel. Channel modification usually occurs during high flow events. Naturally, land uses that affect the magnitude and timing of high flow events may negatively impact channel width and depth. Riparian vegetation conditions will affect the resilience of the stream banks/flood plain during periods of sediment introduction and high flow. Disturbance processes may have drastically differing results, depending on the ability of riparian vegetation to shape and protect channels. Channel morphology is related to riparian vegetation composition and condition by:

- **Building stream banks:** Trap suspended sediments, encourage deposition of sediment in the flood plain and reduce incoming sources of sediment.
- **Maintaining stable stream banks:** High rooting strength and high stream bank and flood plain roughness prevent stream bank erosion.
- **Reducing flow velocity (erosive kinetic energy):** Supplying large woody debris to the active channel, high pool:riffle ratios and adding channel complexity that reduces shear stress exposure to stream bank soil particles.

Thermal Role of Hydrology

Brown (1969) proposed that water temperature change is a proportional function of heat exchange per unit volume,

$$\Delta T_w \propto \frac{\Delta \text{Heat Energy}}{\text{Volume}}$$

It follows that large volume streams are less responsive to temperature change, and conversely, low flow streams will exhibit greater temperature sensitivity. Specifically, stream flow volume will affect the wetted channel dimensions (width and depth), flow velocity (and travel time) and the stream assimilative capacity. Human-related reductions in flow volume can have a significant influence of stream temperature dynamics, most likely increasing diurnal variability in stream temperature.

Groundwater inflow has a cooling effect on summertime stream temperatures. Subsurface water is insulated from surface heating processes. Groundwater temperatures fluctuate little and are cool (45^oF to 55^oF). Many land use activities that disturb riparian vegetation and associated flood plain areas may affect the surface water connectivity to groundwater sources. Groundwater inflow not only cools summertime stream temperatures, but also augments summertime flows. Reductions or elimination of groundwater inflow will have a compounding warming effect. The ability of riparian soils to capture, store and slowly release groundwater is largely a function of floodplain/riparian area health.

The effects of hydrology were not analyzed in the TMDL effort. Targets developed as part of this TMDL are intended to passively promote the protection and creation of groundwater areas, and the connectivity of these areas with the stream.

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Appendix D

Seral Stage Class Calculation Methods

Appendix D – Seral Stage Class Calculation Methods

Vegetation Disturbance and Vegetation Seral Stage Structure

The Upper White watershed is located within the Puyallup River basin. Historically, vegetation was comprised of large contiguous blocks of old growth forests, with very old forest in the most fire-resistant areas. Fire was the major agent of vegetation disturbance before the 1900s. Fire suppression activities since the early 1900s have interrupted the natural fire cycle by keeping fires small.

Accordingly, the major agent of disturbance changed from fire to timber harvest during the 20th century. This changed the manner in which patches of vegetation in different age classes are distributed across the landscape. Specifically, habitat fragmentation is residual of timber harvests between the 1930s and 1980s. Fragmentation is considerable within the Greenwater, the West Fork White, and Huckleberry Watersheds, especially along the main river corridors. As a result, the majority of all three of these watersheds have a high mixed early and mid seral habitat component, intermixed with some small patches of late-seral habitat. In the Greenwater watershed, intermixed federal and private ownerships have led to timber clear-cuts of entire land sections, **including the riparian areas**. In many of these areas, short rotation of timber harvest has limited the availability of down wood and snags for habitat. Outside the Mt Rainer National Park and wilderness areas, road construction (also associated with timber harvest) has led to high road densities, reduced habitat connectivity and fragmented late seral habitat throughout the analysis area.

Calculated current and historical ranges of successional stage distribution by vegetation zones within the Puyallup River Basin were presented within the REAP report for the period between 1600 and 1990. This comparison gives perspective with which to view changes in vegetation patterns over time. Table D-1 presents representative current and historical age class distribution conditions within the Upper White watershed.

Finally, the approximate ages of successional vegetation stages within the Upper White watershed were developed based upon parameters presented in the REAP report (Peter 1993) and are summarized in Table D-2.

Table D-1. Current and historical ranges of successional stage distribution by vegetation zone (Peter 1993).[3]

Seral Stage Name	**Western Hemlock**	**Pacific Silver Fir**	**Mountain Hemlock**	**Subalpine Fir**
Current				
Early	14%	23%	6%	0%
Mid	41%	22%	64%	48%
Late, Single Story	28%	52%	4%	15%
Late, Multiple Story	13%	1%	12%	0%
Historic Range				
Early	0 – 30%	0 – 40%	0 – 65%	0 – 95%
Mid	0 – 55%	55 – 95%	30 – 69%	5 – 95%
Late, Single Story	5 – 65%	0 – 3%	0 – 30%	0 – 5%
Late, Multiple Story	2 – 5%	1 – 2%	1 – 5%	0%

Table D-2. Age of successional stages by vegetation series (years) by vegetation zone (Peter 1993).

Seral Stage Name	**Western Hemlock**	**Pacific Silver Fir**	**Mountain Hemlock**	**Subalpine Fir**
Early	0 –25	0 – 40	0 – 100	0 – 37
Mid	26 – 174	41 – 299	101 – 349	38 – 199
Late, Single Story	175 – 399	300 – 499	350 – 499	200 – 999
Late, Multiple Story	400+	500+	500+	1000+

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[3] Extreme conditions resulting from rare events were eliminated from this analysis through calculating values based on the median 80th percent range of the values.

Seral Stage Vegetation Height Conditions

Estimated Site Potential Tree Heights for PVZs

Reported site potential tree heights for vegetation conditions within the Upper White watershed are listed in Table D-3. These data are reported for Plant Association Groups (PAG), which represent aggregates of Plant Associations based on similarities in floristics, environment and productivity. Tree height values presented in Table D-3 correspond closely with "Mature" vegetation height information reported in the USDA Fire Effects Information System (fs.fed.us/database/feis) (Table D-4).

Table D-3. Reported site potential tree heights for plant association groups.
(Source: MBS Forest Plan)

	Name	**Site Potential Tree Height (ft)**
Western Hemlock	dry western hemlock salal beargrass	114.2
	mesic western hemlock salal Oregon grape	140.1
	mesic western hemlock sword fern	175.9
	moist western hemlock sword fern	205.1
	wet western hemlock shrub	187.0
Median Value		**175.9**
Pacific Silver Fir	cool Pacific silver fir big huckleberry	109.9
	dry Pacific silver fir big huckleberry	124.0
	mesic Pacific silver fir big huckleberry	124.0
	dry Pacific silver fir Alaska huckleberry	135.2
	mesic Pacific silver fir salal Alaska huckleberry	138.1
	warm moist Pacific silver fir sword fern	169.0
	moist Pacific silver fir Alaska huckleberry	150.9
	wet Pacific silver fir shrub	163.1
Median Value		**136.5**
Mountain Hemlock	dry mountain hemlock big huckleberry	90.9
	mesic mountain hemlock big huckleberry	96.1
	mountain hemlock red heather blueleaf huckleberry	65.9
	moist mountain hemlock-Alaska huckleberry	106.0
	mountain hemlock wet shrub	123.0
Median Value		**96.1**
Subalpine Fir	mesic subalpine fir herb	77.1
Median Value		**77.1**

Table D-4. Mature vegetation height condition.

Vegetation Type	Height (ft)	Average value (ft)
Grand fir	131 – 164	148
Douglas-fir	100 – 130	115
Subalpine fir	60 – 100	80
Pacific silver Fir	100 – 230	165
Mountain hemlock	75 – 100	88
Western hemlock	100 – 150	125

Measured Vegetation Conditions within PVZs in the Upper White Watershed

Ecology staff at the Mt. Baker-Snoqualmie National Forest (MBSNF) collected vegetation data at over 60 plots within the White River Ranger District boundaries, which included the collection of vegetation height and age class information. Table D-5 summarized the percentile range of measured height conditions for seral age class for each of these PVZ units. Measured vegetation conditions are illustrated in Figure D-1.

Table D-5. Observed tree height (feet) by seral class within EcoZones of the Upper White watershed.

Seral Class	Count	Median	Lower 10th Percentile	Lower 25th Percentile	Upper 75th Percentile	Upper 90th Percentile
Western Hemlock						
Early	72	32	19	24	46	61
Mid	239	63	24	40	87	119
Late	336	103	56	81	129	155
Subalpine Fir						
Early	17	19	14	17	26	48
Mid	46	59	33	41	75	84
Late	0	-	-	-	-	-
Mountain Hemlock						
Early	19	18	11	12	26	44
Mid	64	57	25	41	73	88
Late	0	-	-	-	-	-
Pacific Silver Fir						
Early	169	33	17	22	44	54
Mid	344	63	20	39	83	103
Late	187	118	75	99	138	152

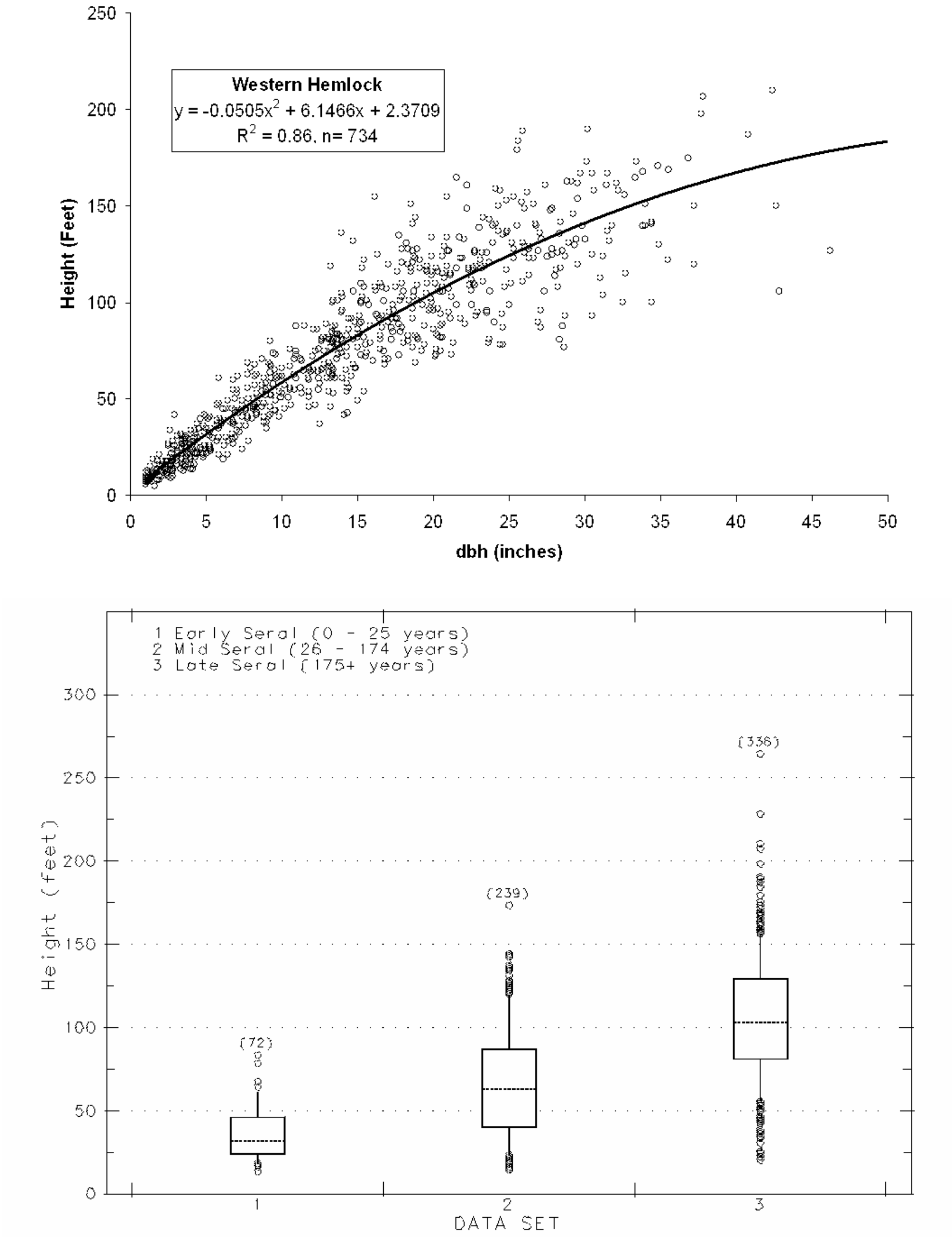


Figure D-1. Observed tree height conditions within the White River Ranger District for the western hemlock EcoZone.

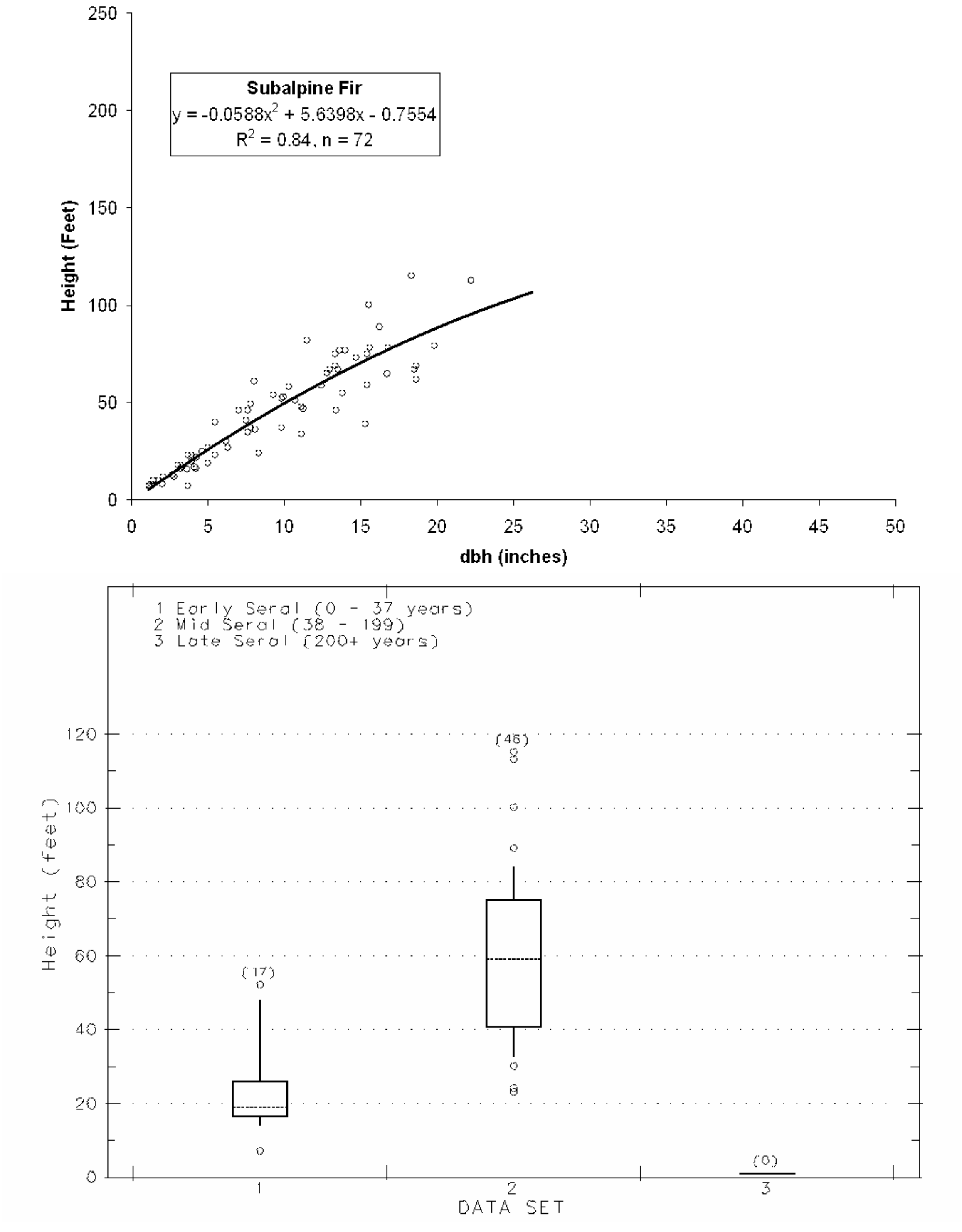
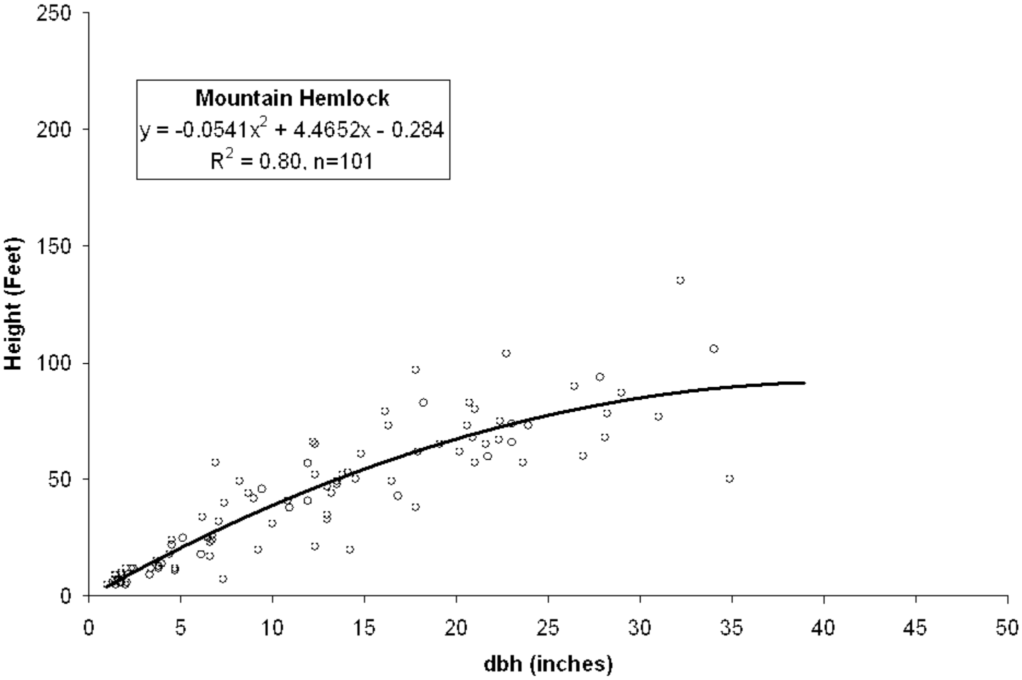


Figure D-1 (continued). Observed tree height conditions within the White River Ranger District for the subalpine fir EcoZone.



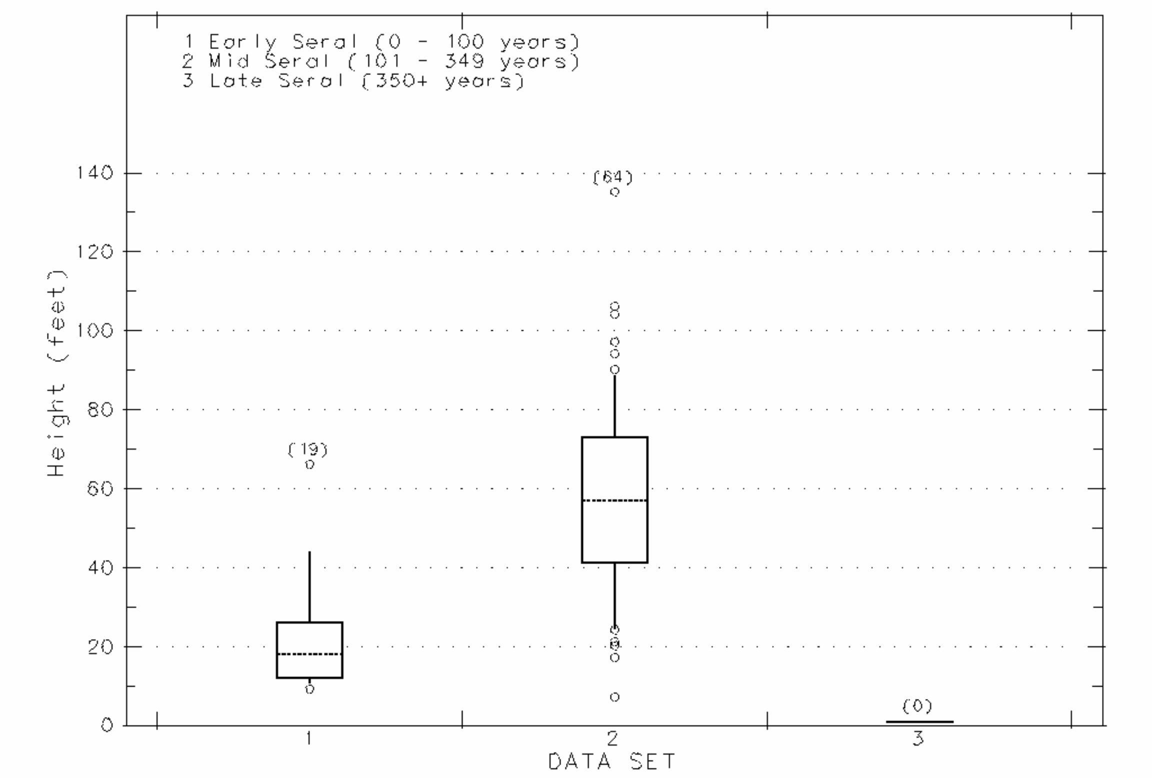
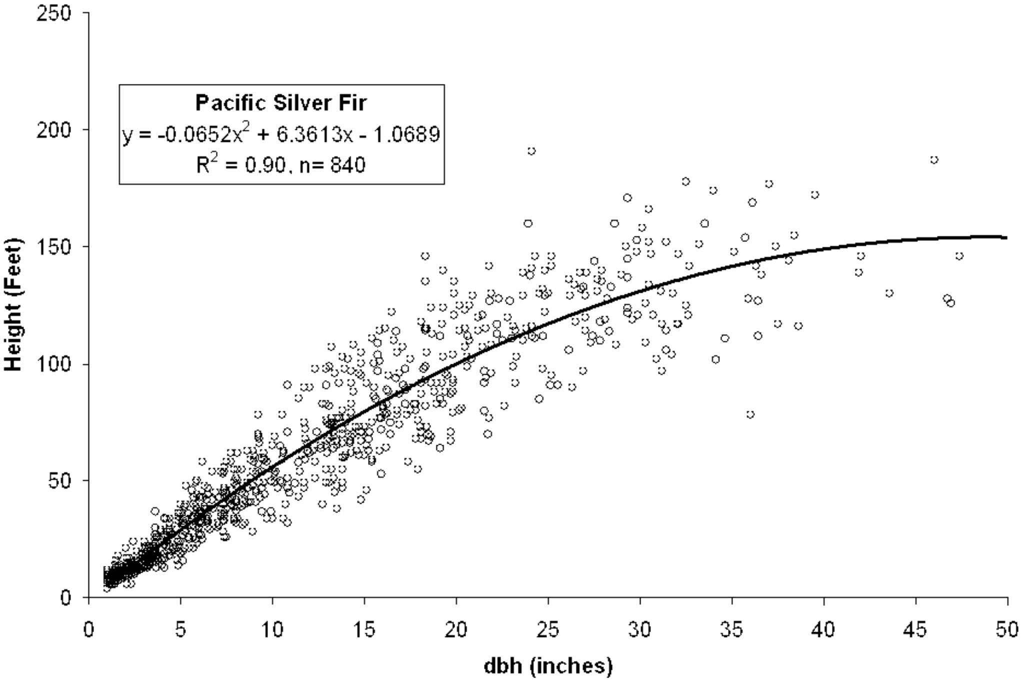


Figure D-1 (continued). Observed tree height conditions within the White River Ranger District for the mountain hemlock EcoZone.



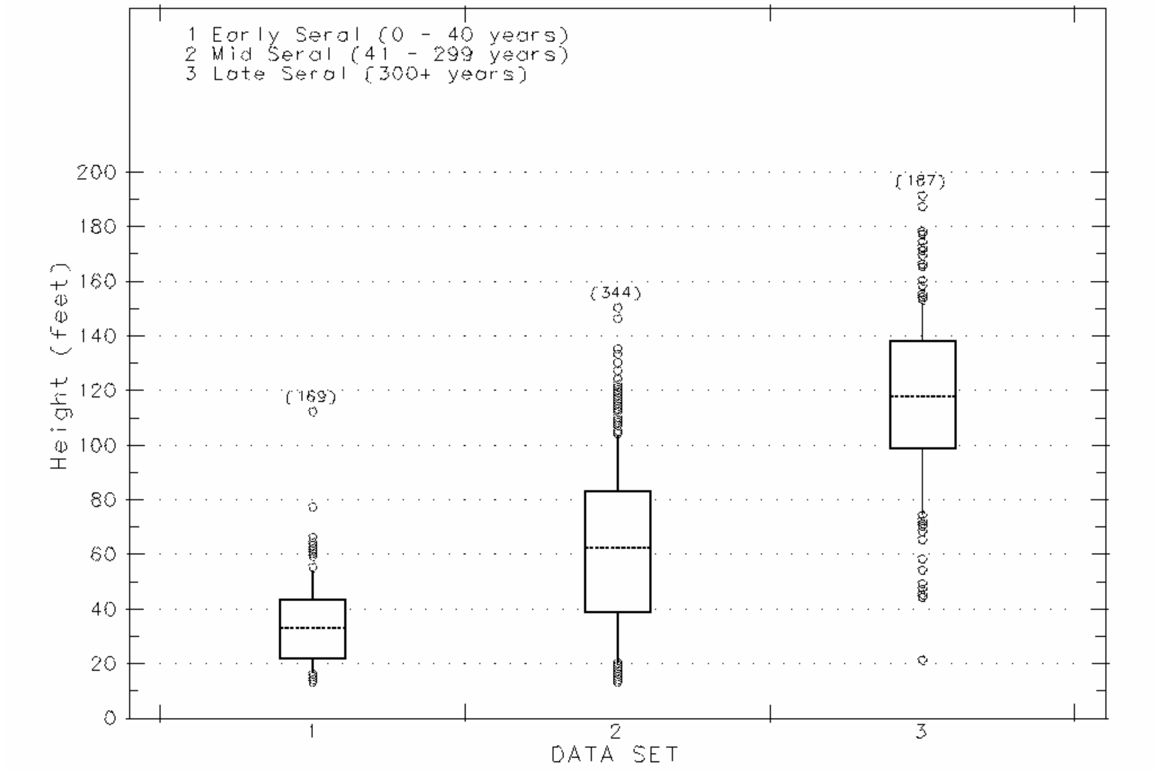


Figure D-1 (continued). Observed tree height conditions within the White River Ranger District for the Pacific silver fir EcoZone.

System Potential Effective Shade Simulation Calculations

System Potential Effective Shade conditions were developed using the Washington Department of Ecology's shade calculator for each of the major forested PVZs in the Upper White watershed.

Tree height conditions used to develop an estimation of System Potential Effective Shade were assigned the 75th percentile condition reported in Table D-5. This height condition was observed at high frequencies within the basin, and it is at the upper end of measured values. In addition, this level also incorporates the variability of specific site conditions that may influence potential height condition. It is important to note that observed 75th percentile conditions correspond closely with reported mature height conditions presented in Table D-4. As can be seen in Table D-5, samples for late seral within the Mountain Hemlock and Subalpine Fir PVZs were not collected during field monitoring activities. Accordingly, the medians of site-potential tree height conditions, reported in Table D-3, were used to define height conditions for late seral stands within these PVZs.

Weighted Average Condition

A weighted average condition was developed from information about the various age classes distributed within each PVZs. This effort was done to in order to develop an estimate of a broad scale view of "System Potential Shade Conditions". It could be expected that site potential shade would be greater than system potential shade because over a large area, e.g., a river reach, it is unlikely that all sites will be at their potential at the same time. Localized natural disturbances (e.g., fire, flood, landslide, disease, etc.) will cause some fraction of the area to be in a less than "mature" state. The development of a weighted average "System Potential Shade Condition" incorporates a disturbance component.

Specifically, the weighted average distribution was established proportional to "historic" levels presented in Table D-1. It must be noted that proportions presented in this table are ranges, and therefore the summation of these values is greater than 100%. Accordingly, the following rule set was used to allocate the "historic" ranges for weighted average conditions:

1) Maximum value for "Late" seral (both single and multi story);

2) Average of the reported range for "Early" seral, and

3) Remaining (from 100%) attributed to "Mid" seral class.

Finally, seral stage age ranges reported in Table D-2 were used to define age classes for the particular PVZs.

Canopy cover condition used in shade curve development was assigned a value of 80%.

Grand Fir and Douglas-Fir Potential Vegetation Zone

As noted above, the Grand fir and the Douglas fir PVZs comprise only a tiny fraction of land cover within the TMDL area (much less than 1%). Accordingly, very little site-specific information is available for these areas within the Upper White Watershed. Therefore, the average of reported “Mature” vegetation height conditions presented in Table D-4 was used during shade curve calculations for these two PVZs. Canopy cover was assigned 80%.

Parkland and Alpine Potential Vegetation Zone

The Parkland Potential Vegetation Zone comprises over 18% of Upper White Watershed (see Figure 12). Vegetation is characterized within this PVZ in clumps or small “islands” of forest surrounded by open meadows, rock, snow, or ice.

The Alpine Potential Vegetation Zone is located in the highest elevations of the watershed. This area is dominated by snow accumulation throughout the year. Glaciers are also present within this zone. Vegetation is not a major component of this zone.

Accordingly, shade curve development was not possible for these PVZs. However, the load allocation is still “system potential effective shade”, developed from “system potential landcover” condition, resulting from the implementation of the “Riparian Reserve” protection associated with the NW Forest Plan.

Appendix E

Calculated Load Capacity and Load Allocations (for Temperature)

Appendix E – Calculated Load Capacity and Load Allocations (for Temperature)

Western Hemlock Effective Shade –Degrees from North - 0 and 180				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	99%	100%	100%	100%
11	94%	99%	100%	99%
16	87%	96%	99%	98%
21	79%	94%	97%	96%
27	73%	89%	95%	93%
32	67%	83%	92%	89%
37	62%	78%	87%	83%
43	57%	73%	81%	78%
48	53%	69%	77%	74%
54	50%	65%	73%	70%
59	47%	62%	70%	67%
64	44%	59%	67%	64%
70	42%	56%	64%	61%
75	40%	54%	61%	58%
80	38%	52%	59%	56%
86	36%	50%	57%	54%
91	34%	48%	55%	52%
96	33%	46%	53%	50%
102	31%	44%	52%	49%
107	30%	43%	50%	47%
112	29%	41%	48%	46%
118	28%	40%	47%	44%
123	27%	39%	46%	43%
128	26%	37%	44%	42%
134	25%	36%	43%	40%
139	24%	35%	42%	39%
144	23%	34%	41%	38%
150	23%	33%	40%	37%
155	22%	32%	39%	36%
160	21%	32%	38%	35%
166	21%	31%	37%	35%
171	20%	30%	36%	34%
177	20%	29%	35%	33%
182	19%	28%	35%	32%
187	19%	28%	34%	31%
193	18%	27%	33%	31%
198	18%	27%	33%	30%
203	17%	26%	32%	29%
209	17%	25%	31%	29%
214	17%	25%	31%	28%
219	16%	24%	30%	28%
225	16%	24%	29%	27%

Appendix E (Continued)

Western Hemlock Effective Shade - Degrees from North - 45, 135, 225, 315

Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	99%	100%	100%	100%
11	94%	99%	100%	99%
16	87%	96%	99%	98%
21	79%	94%	97%	96%
27	71%	89%	95%	94%
32	65%	83%	93%	89%
37	60%	78%	88%	84%
43	55%	73%	84%	80%
48	51%	69%	80%	76%
54	47%	65%	76%	72%
59	44%	62%	73%	69%
64	41%	59%	70%	65%
70	39%	56%	67%	62%
75	36%	53%	64%	60%
80	35%	51%	61%	57%
86	33%	49%	59%	55%
91	31%	46%	57%	53%
96	30%	45%	55%	51%
102	28%	43%	53%	49%
107	27%	41%	51%	47%
112	26%	40%	49%	45%
118	25%	38%	48%	44%
123	24%	37%	46%	42%
128	23%	36%	45%	41%
134	23%	34%	44%	40%
139	22%	33%	42%	39%
144	21%	32%	41%	37%
150	20%	31%	40%	36%
155	20%	30%	39%	35%
160	19%	30%	38%	34%
166	19%	29%	37%	33%
171	18%	28%	36%	33%
177	18%	27%	35%	32%
182	17%	27%	34%	31%
187	17%	26%	33%	30%
193	16%	25%	33%	29%
198	16%	25%	32%	29%
203	16%	24%	31%	28%
209	15%	24%	30%	28%
214	15%	23%	30%	27%
219	15%	23%	29%	26%
225	14%	22%	29%	26%

Appendix E (Continued)

Western Hemlock Effective Shade – Degrees from North - 90 and 270				
Bankfull Width (ft)	**Early Seral**	**Mid Seral**	**Late Seral**	**Weighted Average Stand Condition**
5	99%	100%	100%	100%
11	96%	99%	100%	100%
16	88%	98%	99%	99%
21	75%	96%	98%	97%
27	63%	92%	97%	96%
32	55%	83%	96%	93%
37	49%	73%	92%	86%
43	44%	66%	87%	79%
48	40%	60%	81%	71%
54	37%	55%	74%	65%
59	34%	51%	67%	60%
64	32%	48%	62%	56%
70	30%	45%	58%	52%
75	28%	42%	55%	49%
80	26%	40%	52%	47%
86	25%	38%	49%	45%
91	24%	36%	47%	43%
96	23%	35%	45%	41%
102	22%	33%	43%	39%
107	21%	32%	42%	38%
112	20%	31%	40%	36%
118	19%	30%	39%	35%
123	18%	29%	37%	34%
128	18%	28%	36%	33%
134	17%	27%	35%	32%
139	16%	26%	34%	31%
144	16%	25%	33%	30%
150	15%	25%	32%	29%
155	15%	24%	31%	28%
160	14%	23%	30%	27%
166	14%	23%	30%	27%
171	14%	22%	29%	26%
177	13%	21%	28%	25%
182	13%	21%	28%	25%
187	13%	20%	27%	24%
193	12%	20%	26%	24%
198	12%	19%	26%	23%
203	12%	19%	25%	23%
209	11%	19%	25%	22%
214	11%	18%	24%	22%
219	11%	18%	24%	21%
225	11%	17%	23%	21%

Appendix E (Continued)

Pacific Silver Fir Effective Shade –Degrees from North - 0 and 180				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	99%	100%	100%	100%
11	93%	99%	100%	98%
16	86%	96%	99%	95%
21	78%	93%	97%	92%
27	71%	88%	96%	86%
32	66%	82%	93%	81%
37	61%	77%	88%	76%
43	56%	72%	83%	71%
48	52%	68%	78%	67%
54	49%	64%	75%	63%
59	46%	61%	71%	60%
64	43%	58%	68%	57%
70	41%	55%	65%	54%
75	39%	53%	63%	52%
80	37%	51%	60%	50%
86	35%	49%	58%	48%
91	33%	47%	56%	46%
96	32%	45%	55%	44%
102	31%	43%	53%	42%
107	29%	42%	51%	41%
112	28%	40%	50%	39%
118	27%	39%	48%	38%
123	26%	38%	47%	37%
128	25%	37%	46%	36%
134	24%	35%	44%	34%
139	24%	34%	43%	33%
144	23%	33%	42%	32%
150	22%	32%	41%	31%
155	21%	32%	40%	31%
160	21%	31%	39%	30%
166	20%	30%	38%	29%
171	20%	29%	37%	28%
177	19%	28%	37%	28%
182	19%	28%	36%	27%
187	18%	27%	35%	26%
193	18%	26%	34%	26%
198	17%	26%	34%	25%
203	17%	25%	33%	24%
209	16%	25%	32%	24%
214	16%	24%	32%	23%
219	16%	24%	31%	23%
225	15%	23%	31%	22%

Appendix E (Continued)

Pacific Silver Fir Effective Shade - Degrees from North - 45, 135, 225, 315

Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	99%	100%	100%	100%
11	93%	99%	100%	98%
16	86%	96%	99%	95%
21	77%	93%	98%	92%
27	70%	87%	96%	86%
32	64%	82%	94%	80%
37	58%	77%	90%	75%
43	53%	72%	86%	70%
48	49%	68%	82%	66%
54	46%	64%	78%	62%
59	43%	61%	75%	59%
64	40%	58%	72%	56%
70	38%	55%	69%	53%
75	35%	52%	66%	50%
80	34%	50%	63%	48%
86	32%	47%	61%	46%
91	30%	45%	59%	44%
96	29%	43%	57%	42%
102	28%	42%	55%	40%
107	26%	40%	53%	39%
112	25%	39%	51%	37%
118	24%	37%	49%	36%
123	24%	36%	48%	34%
128	23%	35%	47%	33%
134	22%	33%	45%	32%
139	21%	32%	44%	31%
144	20%	31%	43%	30%
150	20%	30%	42%	29%
155	19%	30%	40%	28%
160	19%	29%	39%	28%
166	18%	28%	38%	27%
171	18%	27%	37%	26%
177	17%	27%	36%	25%
182	17%	26%	36%	25%
187	16%	25%	35%	24%
193	16%	25%	34%	24%
198	15%	24%	33%	23%
203	15%	23%	32%	22%
209	15%	23%	32%	22%
214	14%	22%	31%	22%
219	14%	22%	30%	21%
225	14%	21%	30%	21%

Appendix E (Continued)

Pacific Silver Fir Effective Shade – Degrees from North - 90 and 270				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	99%	100%	100%	100%
11	96%	99%	100%	99%
16	87%	97%	99%	97%
21	73%	95%	98%	95%
27	62%	90%	97%	87%
32	53%	79%	96%	77%
37	47%	71%	94%	68%
43	42%	64%	89%	61%
48	39%	58%	84%	56%
54	36%	54%	78%	51%
59	33%	50%	73%	48%
64	31%	46%	66%	45%
70	29%	44%	61%	42%
75	27%	41%	57%	40%
80	26%	39%	54%	38%
86	24%	37%	52%	36%
91	23%	35%	49%	34%
96	22%	34%	47%	33%
102	21%	32%	45%	31%
107	20%	31%	43%	30%
112	19%	30%	42%	29%
118	18%	29%	40%	28%
123	18%	28%	39%	27%
128	17%	27%	38%	26%
134	16%	26%	37%	25%
139	16%	25%	36%	24%
144	15%	24%	35%	23%
150	15%	24%	34%	23%
155	14%	23%	33%	22%
160	14%	22%	32%	21%
166	14%	22%	31%	21%
171	13%	21%	30%	20%
177	13%	21%	30%	20%
182	12%	20%	29%	19%
187	12%	20%	28%	19%
193	12%	19%	28%	18%
198	12%	19%	27%	18%
203	11%	18%	26%	18%
209	11%	18%	26%	17%
214	11%	18%	25%	17%
219	10%	17%	25%	16%
225	10%	17%	24%	16%

Appendix E (Continued)

Mountain Hemlock Effective Shade –Degrees from North - 0 and 180				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	95%	100%	100%	100%
11	84%	98%	99%	97%
16	73%	94%	97%	93%
21	65%	91%	95%	88%
27	58%	85%	91%	82%
32	52%	79%	86%	76%
37	47%	74%	80%	71%
43	43%	69%	75%	66%
48	39%	65%	71%	63%
54	36%	62%	67%	59%
59	34%	58%	64%	56%
64	32%	56%	61%	53%
70	30%	53%	58%	51%
75	28%	51%	56%	48%
80	26%	48%	54%	46%
86	25%	46%	51%	44%
91	24%	44%	50%	42%
96	23%	43%	48%	41%
102	22%	41%	46%	39%
107	21%	39%	45%	37%
112	20%	38%	43%	36%
118	19%	37%	42%	35%
123	18%	36%	40%	34%
128	18%	34%	39%	33%
134	17%	33%	38%	31%
139	16%	32%	37%	30%
144	16%	31%	36%	30%
150	15%	30%	35%	29%
155	15%	30%	34%	28%
160	14%	29%	33%	27%
166	14%	28%	32%	26%
171	14%	27%	31%	26%
177	13%	27%	31%	25%
182	13%	26%	30%	24%
187	13%	25%	29%	24%
193	12%	25%	29%	23%
198	12%	24%	28%	23%
203	12%	23%	27%	22%
209	11%	23%	27%	22%
214	11%	22%	26%	21%
219	11%	22%	26%	21%
225	11%	22%	25%	20%

Appendix E (Continued)

Mountain Hemlock Effective Shade - Degrees from North - 45, 135, 225, 315				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	95%	100%	100%	100%
11	83%	98%	99%	97%
16	72%	95%	97%	93%
21	62%	91%	95%	88%
27	55%	84%	91%	81%
32	48%	78%	86%	75%
37	43%	73%	81%	70%
43	39%	68%	76%	65%
48	36%	64%	72%	61%
54	33%	60%	68%	57%
59	31%	57%	65%	54%
64	28%	54%	62%	51%
70	27%	51%	59%	48%
75	25%	48%	56%	45%
80	24%	46%	54%	43%
86	22%	44%	51%	41%
91	21%	42%	49%	39%
96	20%	40%	47%	38%
102	19%	39%	45%	36%
107	18%	37%	44%	35%
112	18%	36%	42%	33%
118	17%	34%	40%	32%
123	16%	33%	39%	31%
128	16%	32%	38%	30%
134	15%	31%	37%	29%
139	14%	30%	35%	28%
144	14%	29%	34%	27%
150	14%	28%	33%	26%
155	13%	27%	32%	25%
160	13%	26%	32%	25%
166	12%	26%	31%	24%
171	12%	25%	30%	23%
177	12%	24%	29%	23%
182	11%	24%	28%	22%
187	11%	23%	28%	22%
193	11%	23%	27%	21%
198	10%	22%	26%	21%
203	10%	22%	26%	20%
209	10%	21%	25%	20%
214	10%	21%	25%	19%
219	9%	20%	24%	19%
225	9%	20%	24%	18%

Appendix E (Continued)

Mountain Hemlock Effective Shade – Degrees from North - 90 and 270				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	97%	100%	100%	100%
11	81%	99%	99%	98%
16	62%	96%	98%	96%
21	49%	94%	96%	90%
27	41%	83%	94%	78%
32	36%	74%	88%	69%
37	31%	65%	79%	61%
43	28%	59%	71%	55%
48	25%	54%	64%	50%
54	23%	49%	59%	46%
59	22%	46%	54%	43%
64	20%	43%	51%	40%
70	19%	40%	48%	38%
75	17%	38%	45%	35%
80	16%	36%	43%	34%
86	15%	34%	41%	32%
91	15%	33%	39%	30%
96	14%	31%	37%	29%
102	13%	30%	36%	28%
107	13%	29%	34%	27%
112	12%	28%	33%	26%
118	12%	26%	32%	25%
123	11%	26%	31%	24%
128	11%	25%	30%	23%
134	10%	24%	29%	22%
139	10%	23%	28%	21%
144	10%	22%	27%	21%
150	9%	22%	26%	20%
155	9%	21%	26%	19%
160	9%	20%	25%	19%
166	8%	20%	24%	18%
171	8%	19%	24%	18%
177	8%	19%	23%	17%
182	8%	18%	22%	17%
187	8%	18%	22%	17%
193	7%	18%	21%	16%
198	7%	17%	21%	16%
203	7%	17%	20%	15%
209	7%	16%	20%	15%
214	7%	16%	20%	15%
219	6%	16%	19%	14%
225	6%	15%	19%	14%

Appendix E (Continued)

Subalpine Fir Effective Shade –Degrees from North - 0 and 180				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	95%	100%	100%	99%
11	84%	98%	98%	95%
16	73%	95%	95%	90%
21	65%	91%	92%	82%
27	58%	85%	86%	76%
32	52%	80%	80%	70%
37	47%	75%	75%	65%
43	43%	70%	71%	60%
48	39%	66%	67%	56%
54	36%	62%	63%	53%
59	34%	59%	60%	50%
64	32%	56%	57%	47%
70	30%	53%	54%	45%
75	28%	51%	52%	42%
80	26%	49%	49%	40%
86	25%	47%	47%	39%
91	24%	45%	45%	37%
96	23%	43%	44%	35%
102	22%	42%	42%	34%
107	21%	40%	40%	32%
112	20%	39%	39%	31%
118	19%	37%	38%	30%
123	18%	36%	36%	29%
128	18%	35%	35%	28%
134	17%	34%	34%	27%
139	16%	33%	33%	26%
144	16%	32%	32%	25%
150	15%	31%	31%	25%
155	15%	30%	30%	24%
160	14%	29%	30%	23%
166	14%	28%	29%	22%
171	14%	28%	28%	22%
177	13%	27%	27%	21%
182	13%	26%	27%	21%
187	13%	26%	26%	20%
193	12%	25%	25%	20%
198	12%	24%	25%	19%
203	12%	24%	24%	19%
209	11%	23%	24%	18%
214	11%	23%	23%	18%
219	11%	22%	23%	18%
225	11%	22%	22%	17%

Appendix E (Continued)

Subalpine Fir Effective Shade - Degrees from North - 45, 135, 225, 315				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	95%	100%	100%	99%
11	83%	98%	98%	95%
16	72%	95%	95%	89%
21	62%	91%	92%	82%
27	55%	85%	85%	75%
32	48%	79%	80%	68%
37	43%	74%	75%	63%
43	39%	69%	70%	58%
48	36%	65%	66%	54%
54	33%	61%	62%	50%
59	31%	58%	59%	47%
64	28%	55%	55%	44%
70	27%	52%	52%	41%
75	25%	49%	50%	39%
80	24%	47%	48%	37%
86	22%	45%	45%	35%
91	21%	43%	43%	34%
96	20%	41%	42%	32%
102	19%	39%	40%	31%
107	18%	38%	38%	29%
112	18%	36%	37%	28%
118	17%	35%	35%	27%
123	16%	34%	34%	26%
128	16%	32%	33%	25%
134	15%	31%	32%	24%
139	14%	30%	31%	24%
144	14%	29%	30%	23%
150	14%	29%	29%	22%
155	13%	28%	28%	22%
160	13%	27%	27%	21%
166	12%	26%	27%	20%
171	12%	25%	26%	20%
177	12%	25%	25%	19%
182	11%	24%	25%	19%
187	11%	24%	24%	18%
193	11%	23%	23%	18%
198	10%	22%	23%	17%
203	10%	22%	22%	17%
209	10%	21%	22%	17%
214	10%	21%	21%	16%
219	9%	21%	21%	16%
225	9%	20%	20%	15%

Appendix E (Continued)

Subalpine Fir Effective Shade – Degrees from North - 90 and 270				
Bankfull Width (ft)	Early Seral	Mid Seral	Late Seral	Weighted Average Stand Condition
5	97%	100%	100%	99%
11	81%	99%	99%	97%
16	62%	97%	97%	92%
21	49%	94%	95%	80%
27	41%	85%	87%	68%
32	36%	75%	76%	59%
37	31%	67%	68%	52%
43	28%	60%	61%	47%
48	25%	54%	55%	43%
54	23%	50%	51%	39%
59	22%	47%	47%	37%
64	20%	44%	44%	34%
70	19%	41%	42%	32%
75	17%	39%	39%	30%
80	16%	37%	37%	29%
86	15%	35%	35%	27%
91	15%	33%	34%	26%
96	14%	32%	32%	25%
102	13%	30%	31%	23%
107	13%	29%	30%	22%
112	12%	28%	29%	22%
118	12%	27%	27%	21%
123	11%	26%	26%	20%
128	11%	25%	26%	19%
134	10%	24%	25%	19%
139	10%	24%	24%	18%
144	10%	23%	23%	17%
150	9%	22%	23%	17%
155	9%	21%	22%	16%
160	9%	21%	21%	16%
166	8%	20%	21%	15%
171	8%	20%	20%	15%
177	8%	19%	20%	15%
182	8%	19%	19%	14%
187	8%	18%	19%	14%
193	7%	18%	18%	13%
198	7%	17%	18%	13%
203	7%	17%	17%	13%
209	7%	17%	17%	12%
214	7%	16%	17%	12%
219	6%	16%	16%	12%
225	6%	16%	16%	12%

Appendix E (Continued)

Douglas Fir Effective Shade			
Bankfull Width (ft)	Degrees from North - 0 and 180	Degrees from North - 45, 135, 225, 315	Degrees from North - 90 and 270
5	100%	100%	100%
11	99%	100%	100%
16	98%	98%	99%
21	96%	96%	98%
27	94%	94%	96%
32	90%	90%	94%
37	84%	85%	88%
43	79%	81%	81%
48	75%	77%	74%
54	71%	73%	67%
59	68%	70%	62%
64	64%	67%	57%
70	62%	64%	54%
75	59%	61%	51%
80	57%	58%	48%
86	55%	56%	46%
91	53%	54%	44%
96	51%	52%	42%
102	49%	50%	40%
107	48%	48%	39%
112	46%	46%	37%
118	45%	45%	36%
123	44%	43%	35%
128	42%	42%	33%
134	41%	41%	32%
139	40%	39%	31%
144	39%	38%	31%
150	38%	37%	30%
155	37%	36%	29%
160	36%	35%	28%
166	35%	34%	27%
171	34%	33%	27%
177	34%	33%	26%
182	33%	32%	25%
187	32%	31%	25%
193	31%	30%	24%
198	31%	30%	24%
203	30%	29%	23%
209	29%	28%	23%
214	29%	28%	22%
219	28%	27%	22%
225	28%	27%	21%

Appendix E (Continued)

	Grand Fir Effective Shade		
Bankfull Width (ft)	Degrees from North - 0 and 180	Degrees from North - 45, 135, 225, 315	Degrees from North - 90 and 270
5	100%	100%	100%
11	100%	100%	100%
16	99%	99%	99%
21	98%	98%	99%
27	97%	97%	98%
32	94%	95%	97%
37	90%	92%	95%
43	85%	88%	92%
48	80%	84%	87%
54	76%	80%	82%
59	73%	77%	76%
64	69%	73%	71%
70	67%	70%	65%
75	64%	67%	60%
80	62%	65%	57%
86	60%	63%	54%
91	58%	60%	51%
96	56%	58%	49%
102	54%	56%	47%
107	53%	55%	45%
112	51%	53%	44%
118	49%	51%	42%
123	48%	50%	41%
128	47%	48%	39%
134	46%	47%	38%
139	44%	46%	37%
144	43%	44%	36%
150	42%	43%	35%
155	41%	42%	34%
160	40%	41%	33%
166	40%	40%	32%
171	39%	39%	32%
177	38%	38%	31%
182	37%	37%	30%
187	36%	36%	29%
193	35%	35%	29%
198	35%	35%	28%
203	34%	34%	28%
209	33%	33%	27%
214	33%	32%	27%
219	32%	32%	26%
225	32%	31%	26%

Appendix F

Public Involvement

Appendix F – Public Involvement

Formal public involvement actions for this TMDL included two public meetings, a public comment period, and a web site where TMDL documents and meeting information were posted. In addition, a technical work group of agency, tribal, and environmental group participation provided feedback to the TMDL development team at key points during TMDL development. Other outreach included holding a meeting with Muckleshoot Tribal staff to discuss an early draft of the TMDL document. Information about the public meetings and the technical workgroup meetings is presented below.

Public Meetings

The first public meeting was held June 27, 2001. This meeting was held at the Sumner City Hall, as a component of a regularly scheduled Puyallup Watershed Council meeting. The purpose of the meeting was to brief the Council and other interested attendees about the purpose for the TMDL, and the planned TMDL study approach. Outreach done for this meeting was through a mailing of the agenda to a joint Council and Ecology mail-list of approximately 160 persons, and through meeting notices sent to the Tacoma News Tribune, Pierce County weeklies, and the Enumclaw Herald. An information sheet, the meeting notice, and a newspaper article that reported the meeting are found at the back of this appendix. Meeting attendance was 39 people. Ecology and USFS representative presented information about the TMDL. Afterwards, there was a question and answer period. The following questions subjects were discussed: the boundaries of the TMDL, the relationship of the TMDL to the Forest and Fish state forest practices regulations, the schedule for the restoration plan, the importance of linking the TMDL with the Upper Puyallup Watershed Plan, and the relationship of this TMDL to others within the Puyallup Basin.

A second public meeting was held May 1, 2003 at the Enumclaw Public Library. The purpose for this meeting was to present the temperature and sediment analyses, their respective load allocations, and the draft summary implementation strategy, as well as to informally take comments and answer questions. Outreach for this meeting was through a meeting announcement that was mailed to approximately 80 people on an Ecology list of potentially interested persons, to approximately 90 persons through an e-mail announcement sent out for us by Barbara Skinner, Secretary of the Puyallup Watershed Council, and through notification of the meeting to the Enumclaw Herald, and the Tacoma News Tribune. A copy of the meeting announcement is located in the back of this appendix. There were a total of 14 persons that attended the meeting. An overview of questions, comments, and answers follows.

There were a number of questions that were asked for clarification during the temperature and sediment presentations. These included: (**question**) how many hours the temperature peaks occurred (**answer**, 1 hr., temperatures peak then drop), (**question**) longitudinal distance used for shade model sampling (**answer**, 100 ft), (**question**) where did temperature modeling on the Greenwater stop (**answer**, at the Greenwater Lakes), and, (**question**) what year was the landsat data taken that was used for the temperature modeling (**answer**, late 1990s).

Following the presentations, questions and comments were discussed. **Question**, what is the level of influence of Greenwater water temperature on the water temperature of the White River? **Answer**, during summer the White has glacial flow and has much more flow than the Greenwater. Thus the Greenwater temperature would be expected to have very little effect on the mainstem. **Question**, has there been temperature data taken on the Greenwater River since 1995, e.g. is the temperature data old and therefore the temperature problems may not exist anymore? **Answer**, temperature data taken in 2001 indicated temperature standard exceedences were still present. **Question**, has EPA accepted this work, where are you in the process? **Answer**, not yet, following the public review period, the TMDL report will be completed, with submission to EPA planned for mid-June 2003. **Question**, will the TMDL monitoring be coordinated with state forest practices cooperative monitoring, evaluation and research (CMER)? **Answer**, it is not expected to be, but Ecology will recommend to our CMER representative that TMDL monitoring be considered by CMER. **Comment**, involvement with the Puyallup Watershed Council, for TMDL implementation will be important. **Answer**, we will look forward to working with the Council.

Comment Period for Draft TMDL Document

The comment period for the draft TMDL was from April 21, 2003 to May 21, 2003. The announcement for the comment period was part of the May 1, 2003 meeting announcement, and distribution information was the same as presented in the above section about the meeting. The draft report was available for review at the Enumclaw Library, Wapiti Woolies in Greenwater, and on the Ecology internet site. There were no written comments received.

Technical Workgroup

The purpose for the technical workgroup was to provide the TMDL team with feedback at various stages along the process of TMDL development. Meetings were held March 22, 2001, July 15, 2002, and March 28, 2003. At the first meeting existing information was reviewed, data gaps that would need to be filled for TMDL development were discussed, and the general approach that was planned for the TMDL technical analysis was covered. At the second meeting, a status report on temperature and sediment budget work, the bed scour and redd study, and bull trout information were presented and discussed. During the third (final) meeting, the draft temperature, sediment and summary implementation strategy were discussed. Persons that attended at least one of the workgroup meetings were: David Adams (Tahoma Audubon), John Coulthard (Pierce Conservation District), Roy Huberd (Pierce County), Tom Kantz (Pierce County), Russ Ladley (Puyallup Fisheries), Don Nauer (WDFW), Tyler Patterson (USFS), and David Renstrom (Pierce County). Some persons were additionally included in meeting notices and minutes but were unable to attend. These included representatives of the Muckleshoot Tribe, and Mt. Rainier National Park.

Upper White River at Risk: First Steps Toward Restoration

The Upper White River flows from the glaciers and snowfields of Mount Rainier, through a forested valley that is largely undeveloped to the Mud Mountain Reservoir. The Upper White appears pristine. But it has water quality problems.

Land management has changed the river in ways that threaten the health of native spring chinook salmon, bulltrout and other aquatic species. Two streams in the Upper White River basin fail to meet state water quality standards for temperature. The Clearwater and Greenwater Rivers are on a list of waters that must be restored to meet standards. Other areas have also been identified as having problems for temperature and fish habitat.

The U.S. Forest Service, the U.S. Environmental Protection Agency (EPA) and the state Department of Ecology (Ecology) produced this newsletter to let you know about the work we're doing to address these issues and how you can participate.

Human activities have threatened fish and other aquatic life

Salmonids need cool, clean water and diverse natural habitats. The Upper White River has historically provided spawning and rearing habitat for a native run of spring chinook, as well as bull trout. It has also provided habitat for other aquatic species such as tailed frogs.

The fish lay their eggs in the gravel of streams and rivers in the Upper White basin. When the eggs hatch, the tiny fish (called alevin at this stage) live for a while in the small spaces between the rocks in the riverbed. As the fish grow, they move out of the riverbed and into the river itself. They need the food and shelter that are provided by a healthy river basin.

But years of logging, road building, and recreation use have changed the natural processes of the Upper White River basin, threatening the health and survival of the salmonids. Both the spring chinook and bull trout are listed species under the federal Endangered Species Act.

Logging removed areas of forest that acted to slow the flow of water to the streams. Stream banks were logged causing loss of shade that cooled the water. Large wood in the water was removed and could not be replaced naturally, making the streambed unstable and less able to provide a variety of fish habitats.

June 2001 Publication Number 01-10-038

Roads further disturbed the water runoff processes and caused extensive landslides. Slides from collapsing slopes and roads put sediment into streams. Sediment can fill the spaces between rocks, smothering fish eggs and newly hatched fish, and other aquatic animals that fish need for food.

Unstable channel conditions created by too much sediment, loss of wood, channel confinement, and increased flows can lead to other serious effects. These include scouring of streambeds that destroys eggs, channel changes that leave eggs exposed to dry out, loss of safe habitat during flooding, and loss of cover from predators.

Too much sediment makes the river shallower and wider. More surface area exposed to air and sunlight warms the water. Changes in water temperature can affect timing of early development of fish, and may cause them to emerge from the riverbed when risk from flooding and predators are greater. Bull trout are very sensitive to warmer waters, with reduced survival rate of both eggs and juveniles.

What's being done?

The U.S. Forest Service, in cooperation with EPA and Ecology, has conducted a watershed analysis of the Upper White including the Greenwater, Huckleberry, and West Fork White Rivers. This study is intended to help us better understand how the watershed processes of sediment, wood, water, and heat affect water quality and salmonid habitat.

At the same time a cooperative monitoring effort is underway to define current conditions on the river. Ecology, the Puyallup Tribe, U.S. Forest Service, Weyerhaeuser, the Muckleshoot Tribe, USGS, Tahoma Audubon, and state Fish and Wildlife are helping.

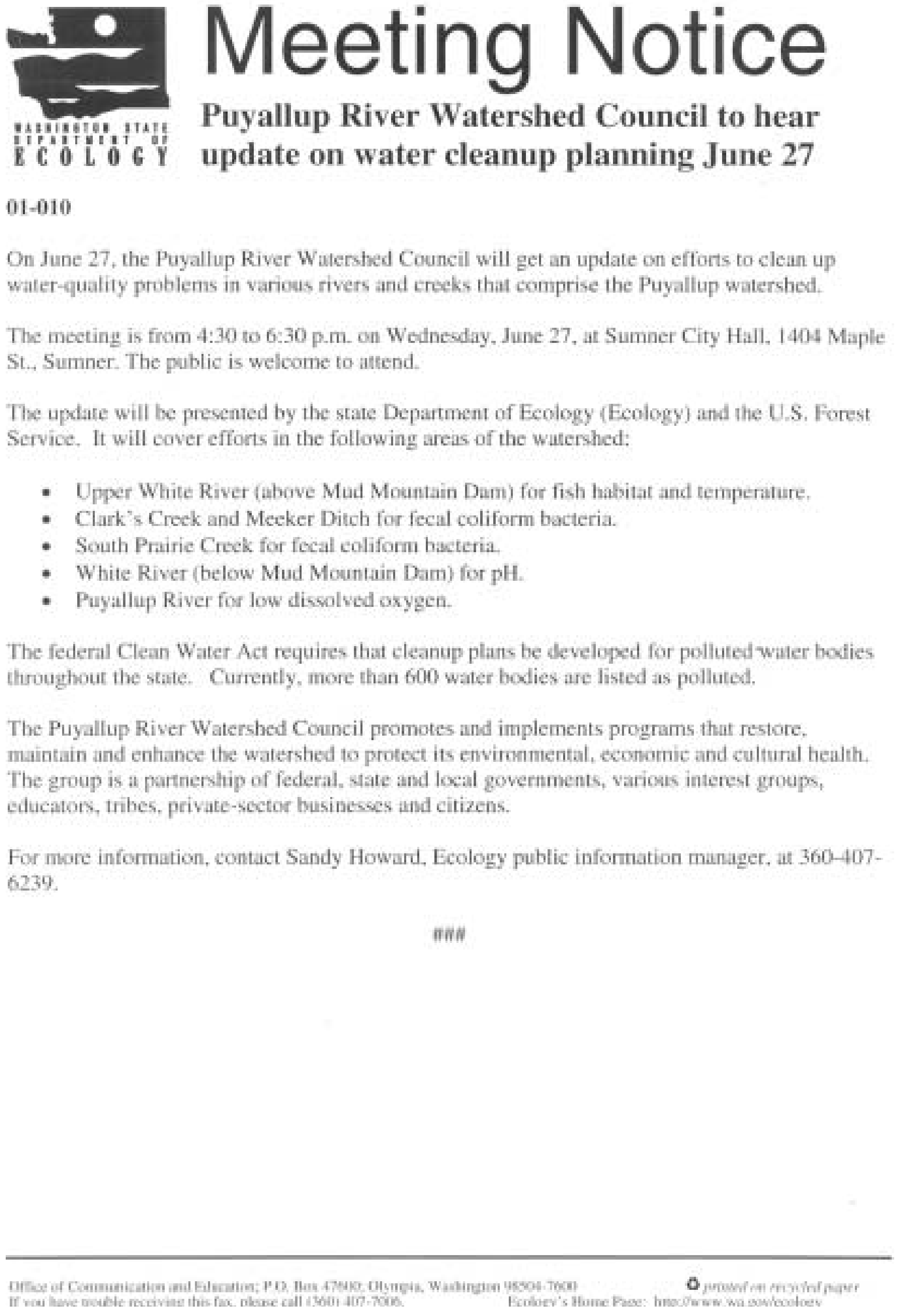
In addition, we have formed a technical workgroup of representatives of interested agencies and groups. This workgroup is helping guide the technical aspects of water restoration planning.

From the information being gathered and analyzed, we will develop a plan for restoring the watershed processes to normal levels.

How you can get involved

We expect to complete the technical work on the water quality restoration planning effort around late spring in 2002. We will hold a public meeting at that time to discuss the restoration plan and hear what you think.

For more information, or to get on the mailing list to receive notice of the public comment period and meeting, please contact Joanne Schuett-Hames at Department of Ecology, PO Box 47775, Olympia WA 98504-7775, (360) 407-6296, email jsch461@ecy.wa.gov



WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Meeting Notice

Puyallup River Watershed Council to hear update on water cleanup planning June 27

01-010

On June 27, the Puyallup River Watershed Council will get an update on efforts to clean up water-quality problems in various rivers and creeks that comprise the Puyallup watershed.

The meeting is from 4:30 to 6:30 p.m. on Wednesday, June 27, at Sumner City Hall, 1404 Maple St., Sumner. The public is welcome to attend.

The update will be presented by the state Department of Ecology (Ecology) and the U.S. Forest Service. It will cover efforts in the following areas of the watershed:

- Upper White River (above Mud Mountain Dam) for fish habitat and temperature.
- Clark's Creek and Meeker Ditch for fecal coliform bacteria.
- South Prairie Creek for fecal coliform bacteria.
- White River (below Mud Mountain Dam) for pH.
- Puyallup River for low dissolved oxygen.

The federal Clean Water Act requires that cleanup plans be developed for polluted water bodies throughout the state. Currently, more than 600 water bodies are listed as polluted.

The Puyallup River Watershed Council promotes and implements programs that restore, maintain and enhance the watershed to protect its environmental, economic and cultural health. The group is a partnership of federal, state and local governments, various interest groups, educators, tribes, private-sector businesses and citizens.

For more information, contact Sandy Howard, Ecology public information manager, at 360-407-6239.

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Office of Communication and Education; P.O. Box 47600; Olympia, Washington 98504-7600 ♻ *printed on recycled paper*
If you have trouble receiving this fax, please call (360) 407-7006. Ecology's Home Page: http://www.wa.gov/ecology

Newspaper article
from 6-27-01 public meeting
at Puyallup River Council

Schuett-Hames, Joanne

From:	Howard, Sandy
Sent:	Monday, July 02, 2001 1:32 PM
To:	Barreca, Jeannette; Hempleman, Christine; Anderson, Darrel; Schuett-Hames, Joanne; Duffy, Bob
Subject:	Rob Tucker's story about TMDLs

7-1-01 - The News Tribune

Officials must find way to cool sun-soaked rivers

FISH HABITATS: White River and tributaries suffer from recreational use, loss of shade

by Rob Tucker

But two key tributaries of the upper White River, the Greenwater and Clearwater rivers, are too warm and could threaten fish. Years of logging removed shade trees that cooled the water. And on the Greenwater River, campers and other outdoor enthusiasts are further damaging stream banks.

Federal and state laws require restoration of cooler waters. Both rivers are spawning grounds for spring chinook salmon, which must be protected under the federal Endangered Species Act.

"We need water-quality restoration programs," said Gary Ketcheson, a U.S. Forest Service hydrologist who is doing a water-quality study of the Upper White River Basin.

After pinpointing the causes of the problem, officials can implement protective measures that could include road closures and bans on camping alongside some fish-bearing streams. It's too early to determine specific measures, and implementation could take years, officials said.

The 187,000-acre basin includes the Greenwater River, the White River, West Fork of the White River and Huckleberry Creek. The state Department of Ecology and federal Environmental Protection Agency also are involved in the study. The Muckleshoot and Puyallup tribes, Weyerhaeuser Co., and the state Fish and Wildlife Department are helping.

The Clearwater River isn't part of this study, but is on the state list of waters that must be restored to meet water-quality standards.

The public owns most of the basin under study. The Forest Service administers about half of the area, and the National Park Service administers most of the remaining lands. About 21,000 acres are privately owned, mostly by the Weyerhaeuser Co. The study area includes parts of Mount Rainier National Park and the Crystal Mountain ski area.

The public parts of the basin are used heavily by hunters, fishermen, off-road vehicle users, skiers, snowmobilers, campers and hikers. The White River area of the national park, where some recreational uses aren't permitted, had about 212,000 visitors last year.

Ketcheson gave a summary of the study recently to the Puyallup River Watershed Council. The study focuses on stream flows and sediment loads as well as stream temperatures. It already shows that years of logging have threatened fish in some of the basin's streams.

Logging eliminated shade trees, and some streams warmed up. Experts are concerned that warmer streams can make fish hatch early when the risk of destruction from spring flooding is greater.

Logging also created more erosion, and logging roadbeds slid into streams, increasing sediments that smother incubating eggs and prevent juvenile fish from emerging from river gravel. Sediment buildups also reduce aquatic insects that fish feed upon.

Large logging operations are a thing of the past on most of the lands in the study area, said Ron DeHart, spokesman for the Mount Baker-Snoqualmie National Forest.

"These aren't logging stories anymore," DeHart said. "The issues are, recreation of different kinds and people management in a forest open to the public. People don't recognize that by sheer numbers they can cause problems."

People continue to use the logging roads for recreation, causing more dirt slides into streams. Heavy road use by recreationalists occurs mostly in the West Fork of the White River and the Greenwater River valleys, Ketcheson said. Also, people camp on stream banks, compacting and denuding the areas and altering streams.

Restoration, which may begin next year, could include adding more shade trees along streams, bank stabilization, repairing or closing roads and placing no-camping buffers along fish-bearing streams.

Restoration activities on private forest lands also are governed by the state Forest-Fish law, said Kathy Budinick, a Weyerhaeuser spokeswoman. The agreement allows private forest landowners to continue harvesting while monitoring the effects of forest practices like logging and road-building. Landowners must take fish protection measures under the law.

Gary Sprague, a fish biologist for the state Department of Fish and Wildlife, said he wasn't surprised at the temperature problems in the Greenwater and Clearwater rivers. The White River spring chinook salmon prefer to spawn in clearer waters of the White River's tributaries, including the Clearwater and Greenwater rivers and Huckleberry Creek, he said.

"Warm water may not be as much a problem for adults as it is for the juveniles," he said.

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* Reach staff writer Rob Tucker <mailto:rlt@p.tribnet.com> at 253-597-8374 or rob.tucker@mail. tribnet.com.

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SIDEBAR: Conditions of specific streams

The state Department of Ecology updated its findings on local streams with water quality problems at a recent Puyallup River Watershed Council meeting. They included:

nSouth Prairie Creek: Carbon River tributary holds wild steelhead trout, including threatened spring chinook salmon. The creek is too warm and contains too much fecal coliform. Sources may include livestock and pet waste and runoff from failing septic systems. State officials trying to find pollution sources and will develop cleanup program.

nClarks Creek-Meeker Ditch: A tributary of Puyallup River that is polluted and must be cleaned up. The City of Puyallup, Puyallup Tribe of Indians and state will determine if water is cool enough and contains enough dissolved oxygen to maintain healthy fish stocks. Study also will measure levels of fecal coliform.

nWhite River below Mud Mountain Dam. Levels of phosphorus are too high near Enumclaw and Buckley, creating excessive nutrient concentrations that threaten fish, including protected run of spring chinook salmon. State, federal and Muckleshoot and Puyallup tribal officials developing ways to reduce the pollution. Enumclaw and Buckley must upgrade sewage treatment.

nWilkeson Creek: Stream contained too much copper and threatened fish. Town of Wilkeson has upgraded its sewage treatment, and new tests show no copper problem.

nPuyallup River: Water at times lacked enough dissolved oxygen for a healthy fish population. The state, Puyallup Tribe and the U.S. Geological Survey will study lower river to determine if water still lacks dissolved oxygen. No new discharges into river allowed from stormwater or other man-made sources. River holds steelhead trout and salmon, including spring chinook that must be protected.

The state Department of Ecology has until 2013 to implement cleanup plans for 643 polluted water bodies in Washington.

- Rob Tucker <mailto:rlt@p.tribnet.com>, The News Tribune

Meeting and Comment Period
Announcement

Strategy for Restoring Aquatic Habitat in the Upper White River: Technical Assessments and Summary Implementation Strategy

Meeting

Where: **Enumclaw City Library**
1700 First Street, Enumclaw

When: **Thursday, May 1, 2003**
6:15 p.m. to 9:00 p.m.

Why: **To present information from sediment and temperature technical studies, the summary strategy, and to answer questions and take comments.**

Public Comment Period

April 21 to May 21 -- You may submit formal comments in writing, either by mail to the contact person listed below or at the May 1 meeting.

Watershed Restoration is Needed

The Upper White River appears pristine, but it has water quality problems. Land management has changed the river in ways that threaten the health of native spring chinook salmon, bull trout and other aquatic species. The Greenwater River is on a list of waters that must be restored to meet state temperature standards. Other streams within the Upper White River also have temperature and fish habitat problems.

What We Have Done

The Department of Ecology, the U.S. Forest Service, and the U.S. Environmental Protection Agency have completed technical assessments and a summary implementation strategy. This work focused on the upper watershed upstream from the town of Greenwater, and includes the Greenwater, West Fork White and White Rivers and Huckleberry Creek. Future work will include more detailed restoration planning for Forest Service managed lands.

How You Can be Involved

This is a public meeting where you can ask questions and provide comments on technical assessments for sediment and temperature conditions, and on the summary implementation strategy. If you are not able to attend, please send written comments to the contact person listed below. If you would like the opportunity to participate in the development of the U.S. Forest Service Water Quality Restoration Plan, or would like to be on a mail list to receive future information, send your name, email, address, and phone number to the contact person listed below.

You can obtain a copy of the draft plan at the public meeting or from Ecology's Southwest Regional Office. You can review a copy after April 20, 2003, at the Enumclaw City Library or Wapiti Woolies in the town of Greenwater. You can also download a copy off the internet at:

http://www.ecy.wa.gov/programs/wq/tmdl/watershed/whitervr.html

For more information please contact Joanne Schuett-Hames at Department of Ecology, PO Box 47775, Olympia WA 98504-7775, (360) 407-6296, email josc461@ecy.wa.gov.

Ecology is an equal opportunity agency. If you have special accommodation needs, please call Joanne Schuett-Hames at (360) 407-6296. The TTY number is 711 or 1-800-833-6388.