Washington State Department of Natural Resources
Land Management Division
Habitat Conservation Plan Implementation

Effectiveness Monitoring of Water Quality
Mill Creek and Abernathy Creek sub-basins
Columbia HCP Planning Unit

by

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A. **Introduction**

In managing state forest land, essential timber harvest activities, by their very nature, create disturbances to the soil through existing and/or new roads, landings, skid trails, slash burns, etc. It has been demonstrated that logging activities generate sediment that may be delivered to the aquatic ecosystem thus potentially degrading habitat for fish and other species.

National concern for the quality of our surface waters led to the enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act (CWA). Sediment runoff from forest operations is classified as "Non-point Source of Pollution" and the Department of Ecology (DOE) has been designated as the state agency for enforcing the provisions of the CWA. In 1973 the Endangered Species Act (ESA) was passed by Congress and now includes threatened and endangered aquatic species in forest streams and rivers. Washington State responded by passing the Forest Practices Act (FPA) in 1974 and in 1997 the Department of Natural Resources (DNR) implemented a Habitat Conservation Plan (HCP) for 1.6 million acres of state trust lands in Western Washington. The HCP provided for effectiveness and validation monitoring of the riparian systems and development of conservation strategies for harvest operations.

In order to resolve contentious forest practices problems, in February, 1987, the Timber Fish Wildlife (TFW) agreement was negotiated between the tribes, the state, timber industry, and the environmental community. Although TFW members continued to work cooperatively on policy, local, and technical levels, native run fish populations continued to decline. In 1999 the TFW caucuses came together to produce the Forest and Fish Agreement (FFA) after salmonids and bull trout were added to the ESA listings. Additionally, 660 streams in Washington State were identified with water quality problems and tabulated in section 303(d) of the CWA. A key strategy of the FFA, passed by the Legislature as House Bill 2091, is adaptive forest management based on effectiveness and validation monitoring (U.S. Fish & Wildlife Service, et al, 1999). In 2001 the Legislature passed Substitute Senate Bill 5637 requiring development of a state agency action plan that phases in full implementation of a monitoring strategy by June 30, 2007. Guidance for implementation has been published as "The Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery" (Monitoring Oversight Committee, 2002). In May, 2001, the Forest Practices Board adopted permanent rules (Chapter 222 WAC) implementing the FFA to ensure compliance with the CWA and ESA. Surface water quality standards were established by DOE, as amended, on July 1st, 2003 (Chapter 173-201A WAC).

On March 2nd, 2004, the Board of Natural Resources passed Resolution No. 1110 which authorizes the DNR to prepare the Final Environmental Impact Statement for Sustainable Forest Management of State Trust Lands in Western Washington. Section 4 (L) of the resolution states: "The Department shall annually report to the Board of Natural Resources its assessment of the environmental and economic results of implementing the Preferred Alternative. The Department shall employ a structured monitoring and reporting program."

B. **Background**

It was during the late 1940s at the Coweeta Hydrologic Research Laboratory that the first studies documented the effect of uncontrolled logging on stream turbidity and suggested harvest practices to mitigate runoff (Lieberman and Hoover, 1948). At the H.J. Andrews Experimental Forest in Oregon and the Hubbard Brook Experimental Forest in New Hampshire, during the 1950s, studies raised the awareness of forest ecologists that roads are the major source of fine sediment from runoff and road related landslides.

Following the passage of the FPA in 1974, there was a surge of research in Washington's commercial forests by the College of Fisheries and College of Forest Resources at the University of Washington as well as the U.S. Geological Survey. Similar studies were taking place by USDA Forest Service in northern California, Oregon, and Idaho. During 1975, the U.S. Environmental Protection Agency (EPA) released a 312 page report on logging roads, sediment generation from roads, and suggested best management practices to reduce run-off (EPA, Arnold, Arnold & Assoc., Dames & Moore, 1975). In British Columbia a long-term watershed study project was initiated at Carnation Creek to study the effect of harvest practices. All of these studies incorporated management techniques into scientific/engineering experiments and monitoring activities that measured sediment generation and delivery to the aquatic system. The western part of the Olympic Peninsula provided fertile ground for research with the opening up of DNR's Clearwater Basin for harvest. Numerous benchmarked studies followed and established a direct link to degradation of salmon habitat through siltation (Cederholm and Lestelle, 1974; Fiksdal, 1974; Larson, 1976; Larson and Jacoby, 1978; Larson, 1979; Osborn, 1980; Wooldridge, 1980; Wooldridge and Larson (1980); Wasserman, Cederholm and Salo, (1984). In the Clearwater Basin, the natural sediment delivery rate from bank erosion and natural landslides was calculated at an average of 82 $t/km^2/yr$ with increased sediment production rate in the basin from roads and road induced landslides by a factor of 3.4 to 4.9 over the natural rate. Specifically, road surface erosion accounts for 47 $t/km^2/yr$ and road induced landslides 115 to 194 $t/km^2/yr$. Although landslides produced a greater volume of sediment, the contribution of fine sediment (less than 2 mm) detrimental to fish was of equal quantity from roads (cut bank, fill slope, ditch, road surface) and road-induced landslides (Reid, 1981).

In a landmark Clearwater Basin study covering the years 1972 to 1978, Cederholm and Salo (1979) conducted validation monitoring on the effects of fine sediments (less than 0.850 mm in diameter) on the physical condition of spawning beds and the survival of salmon eggs. Levels of fine sediment increased from a mean of 8.36% (controls) to 10.69% in Stequaleho Creek and from 8.36% to 9.12% in the main Clearwater River below Stequaleho Creek. Salmonid survival to emergence from the gravel beds decreased by about 11.60% in Stequaleho Creek and 3.80% in the main Clearwater River over the six year period. The buildup of intra-gravel sediments was positively correlated with percent of sub-basin clear-cut, miles of logging road per basin square mile, and percentage of basin area in roads.

Other studies in Washington State were conducted in the Skagit River Basin (Wooldridge, 1978; Wooldridge, 1979); the Snohomish River forested sub-basins where suspended sediment yields ranged from 50 to 1,290 tons per square mile per year for the water years 1967 and 1968 (Nelson, 1971); the Deschutes and Nisqually basins (Nelson, 1974); the Kalama River Basin (Wooldridge, 1978); and the Quillayute River Basin (Nelson, 1982). A direct link was established between logging truck traffic and suspended sediment yields in the Clearwater Basin (Wald, 1975) with additional research at Coal Creek (western Olympics) and Meadow Creek on the east slope of the Cascades (Wooldridge, 1979). Actual sediment loss from ten road segments was measured for one year in the Clearwater Basin and linked to rain intensity, timing of discharge, type of road, and traffic to sediment concentration in runoff (Reid and Dunne, 1984). The studies showed that sediment discharge is very sensitive to even minor increases in stream flow. Similar studies were under way in the Ouachita Mountains, Arkansas and where a direct relationship was demonstrated between road grade and sediment loss. With an average 1 % gradient for a road segment, 12.4 tons/mile/year of suspended solids were produced; at a 4% grade, suspended solids averaged 32.6 tons/mile/year; and, at a 6% grade, suspended solids averaged 57.8 tons/mile/year (Beasley, Miller and Gough, 1984). A excellent summary of causes and effects from forestry operations was described by Anderson (1996).

During 1980, DNR put in place a forest management plan for 90,000 acres in Capitol Forest near Olympia. The plan prescribed timber harvest BMP's, road construction and maintenance methods, and riparian system protection. It also required hydrologic monitoring to determine the effectiveness of the management plan in protecting water quality. To that end, since 1982, monitoring of stream flows, suspended sediment, and water temperature have been conducted for the Porter Creek, Cedar Creek, Waddell Creek, and Mima Creek watersheds. Although timber harvest and road management activities have continued over the last 20 years, monitoring results show no increasing trends in sediment loading or detrimental changes in peak flows (Ryan and Donda, 2001).

The 1990's brought on a series of efforts to determine compliance with Forest Practices on all industrial forest land utilizing a field survey. This work, conducted in 1991, had limited value due to inadequate damage assessment protocols and was not focused on DNR managed lands (Timber Fish & Wildlife Field Implementation Committee, 1991, rev. 1992). During 1998, a road maintenance survey was conducted by the Forest Practices Division to determine if BMP's are protecting water resources on timber lands. They found significant amounts of sediment entering streams in 70% of the surveyed areas due to lack of road maintenance. Approximately 65% of the surveyed areas had direct delivery of sediment from roads to streams and individual roads were found to exceed natural sediment input by 40 times (Schuttie and Ramsdell, 1999). This report was not released, and as above, did not focus on DNR managed HCP lands. During that same period, from 1992 to 1995, the DOE conducted a series of site specific effectiveness evaluations of forest road and timber harvest best management practices and published them through TFW (Rashin, et al, 1993, 1994, and 1999). The case study results and protocols for collecting 1992-1995 data, with respect to sediment-related water quality impacts, were published by TFW as Appendices I and J (Rashin, et al, 1999). A proposal for TFW monitoring to determine effectiveness of forest practices (Schuett-Hames, et al, 1996) was not implemented. Since 1998, effectiveness or compliance monitoring has not been conducted by the Forest Practices Division.

The 1990's also saw the advent of computer technologies, digital elevation models, and their application to managing a large set of variables in a spatial context. This further fueled research into the various factors affecting the flow of surface and subsurface water, the cause and frequency of landslides, and the transport of sediment from roads or timber harvesting. The linkage of detailed field measurements with a predictive computer model, "Distributed Hydrology-Soil-Vegetation Model" (DHSVM) was effectively demonstrated in a study of Hard and Ware creeks, Vail Tree Farm, Washington (Bowling and Lettenmaier, 1997). With the generation of more detailed field data and links to sedimentation, a proliferation of computer models were created that are being used to predict unstable ground and run-off. The Department of Natural Resources developed and uses the Slope Morphology (SMORPH) model on HCP managed lands and Forest Practice applications. The SMORPH model was compared against the SHALSTAB model in eight watersheds (Shaw and Vaugeois, 1999). Numerous other computer programs were created, such as SINMAP, LISA, TOPMODEL, DSLAM, SEDMOL, X-DRAIN, WEPP, R1-R4, BOISED, BASINS2, and many others. For comparison of some of the models, see Morrissey, et al (2001) and Haneberg (2001 ?). For Washington State, Northwest Indian Fisheries Commission staff is recommending the use of the WARSEM model for effectiveness monitoring of sediment run-off from roads (Raines, et al, 2004) and for road stability analysis, DNR Engineering Div. has recommended the XSTABL software package.

Safeguarding the natural environment is fundamental to the mission of the EPA. As a result, there are major programs conducted by the EPA that relate to water quality. Of significance is the EPA list of impaired waters as per Section 303(d) of the CWA. In 1999, for Washington State, the list reported 1,322 impaired waters with the Puget Sound watershed accounting for 14.5% of the total (EPA, 1999). In order to assist federal, state, and local agencies in monitoring water quality for compliance with the CWA, the EPA Water Division or Office of Water has published water monitoring guidelines and protocols. Two of the significant documents are MacDonald, et. al. (1991) and EPA (1999). Partnering with states, the EPA has undertaken major regional sampling and monitoring projects, titled Environmental Monitoring and Assessment Program (EMAP), to determine the environmental health of our aquatic systems (EPA, 2001). Starting in 1994, pilot study sites were initiated in Washington State in the Coast Range (1994-1997), the Upper Chehalis Basin (1997), the Yakima River Basin (1994-1995), and the Western Cascades Ecoregion (1999-2000) with DOE as a partner (EPA, 2003). A catalog of validated water chemistry, suspended solids, and turbidity data from the pilot studies is available on line (EPA, 1999). Based on 47 sampled streams in Washington and 57 in Oregon, during 2000, EPA released a monograph on the ecological condition of the Coast Range Ecoregion (Herger and Hayslip, 2000). The newest EPA regional research program is EMAP-West. From 1999 through 2005, EMAP-West will develop and demonstrate tools needed to measure the ecological condition of aquatic resources in 14 western states. In Washington State 110 sites on perennial streams have been selected for sampling (EPA, 2001) and the Wenatchee Basin is being monitored as a focus area with 33 sample stations developed in 2002 and an additional 17 sample sites added in 2003 (EPA, 2003).

Washington's Department of Ecology is the state agency, by statute, accountable for carrying out federal CWA requirements. This is accomplished through the current Environmental Performance Partnership Agreement – State Fiscal Years 2003-2005. The overall goal between DOE and the EPA is stated as: "Protect, preserve, and enhance Washington's surface and ground water quality, and promote the wise management of our water for the benefit of current and future generations and the natural environment" (Zimmerman, 2003). A major component of DOE's Environmental Assessment Program is environmental monitoring with the Washington Department of Fish and Wildlife (WDFW). To carry out the provisions of the partnership agreement, DOE has established a statewide environmental monitoring network to assess the current status of state waters, identify threatened or impaired waters for CWA Section 303(d) listings, and evaluate trends in water quality over time. Water monitoring data, threatened and endangered aquatic species, Section 303(d) listings, and other pertinent information is compiled by DOE for each Water Resource Inventory Area (WRIA) covering the entire state and made available through DOE's web site. The WRIA data sets were invaluable in planning a monitoring program for state lands under the HCP. Besides statewide monitoring, DOE conducted major EMAP projects with funding from the EPA. These projects produced comprehensive scientific data, conclusions, and recommendations that were published as monographs by DOE (Joy and Patterson, 1997; Merritt, Dickes, and White, 1999). As part of their mission and to provide for consistency in water quality monitoring, DOE has released stream sampling protocols for environmental monitoring and trend analysis (Ward, 2001) and a useful citizen's guide to suspended solids and turbidity in streams (Michaud, 1991).

The U.S. Geological Survey (USGS) also has a key role in monitoring Washington state waters. The USGS operates the most extensive satellite network of stream gauging stations in the state, many of which form the backbone of flood-warning systems. The USGS National Assessment of Water Quality (NAWQA) program, initiated in 1991, studies and monitors the nation's water quality including non-point-source contamination of ground and surface waters. The long-term records of concentrations and transport of sediments in streams and rivers are vital in characterizing changes in geomorphology and to evaluate the effects of best management practices as well as the health of the state's aquatic ecosystem. Together with the state's NAWQA stations and the current 44 USGS water quality assessment projects in Washington, approximately 300 stations on rivers and streams are being monitored (personal communication, Wiggins, USGS, 2004). Significant projects cover the Puget Sound basin, the Columbia Basin, and the Hanford Nuclear Reservation. Gauging and monitoring stations, their locations, and real time data, can be accessed through a link on DOE's web site for the state's WIRAs.

The Northwest Forest Plan (NWFP) covers all federal lands in Washington, Oregon, and northwestern California. The Interagency Regional Monitoring Program conducts and coordinates regional-scale monitoring of 250 watersheds on behalf of eight federal agencies. In western Washington the key agencies are the US Forest Service and the National Park Service. A significant part of the department's HCP lands are adjacent to such federal lands. The NWFP monitoring program, titled Aquatic and Riparian Effectiveness Monitoring Plan (AREMAP), characterizes the ecological condition of watersheds and aquatic ecosystems by determining watershed conditions based on upslope, riparian, and in-channel attributes. Federal watershed conditions are being assessed by analyzing indicator values using an Ecosystem Management Decision Support Model which incorporates physical, chemical, and biotic relationships (Reynolds and Hohler, 2002). Success of the AREMAP relies on partnerships with federal and state agencies, research organizations, universities, and on public involvement.

Since 1986, dozens of publications, issued by TFW and the Northwest Indian Fisheries Commission, describe monitoring of state's waters. Currently, to provide the science needed to support adaptive management, the Forest Practices Board established the Cooperative Monitoring, Evaluation and Research Committee (CMER) that is empowered to implement research, effectiveness, and validation monitoring as per the guidelines in the FFA. With numerous local government, state government, and federal agency programs, a proliferation of water quality and related databases has resulted. The WDFW Watershed Recovery Inventory Project (WDFW, 1997) published a directory listing 270 databases that are of value to salmon recovery planning. By 2003, a survey of 77 agencies and organizations for Washington state identified 145 different water monitoring programs. A fact sheet for each water monitoring database was compiled by the Monitoring Oversight Committee of the Governor's Salmon Recovery Office and published (Crawford, et al, 2003).

C. HCP Effectiveness Monitoring Strategy

The HCP Riparian Ecosystem Conservation Strategy for the west-side HCP units (North Puget, South Puget, Columbia, South Coast, and Straits) consists of five components that address specific adverse impacts to salmonid habitat caused by forest management (Wilhere and Bigley, 2001). There is a separate strategy for the Olympic Experimental State Forest (OESF). The five components for the west-side units are:

- riparian area management
- road management
- wetland management
- unstable hill slopes
- and, rain-on-snow events

In the HCP, the direction for DNR's road construction, maintenance, and abandonment program is defined as coming from Forest Practices regulations (WAC-222-24) and the 1992 Forest Resource Plan. The objectives of DNR's road management program are (DNR, 1997):

- "minimize further road related degradation of riparian, aquatic, and identified species habitat;
- plan, design, construct, use, and maintain a road system that serves DNR's management needs; and
- remove unnecessary road segments from the road net."

The HCP further states that the design, construction, and maintenance specifications must "meet or exceed Forest Practices regulations and hydraulic code requirements". With the FFA of 1999, Forest Practices regulations (WAC-222-045) now include the concept of adaptive management. The resources objective in the FFA is stated as follows:

- "Prevent the delivery of excessive sediment to streams by protecting stream bank integrity, providing vegetative filtering, protecting unstable slopes, and preventing the routing of sediment to streams."

Monitoring observations are a key element in an adaptive management strategy and provide the information necessary to achieve anticipated habitat conditions. There are three commonly accepted types of monitoring with each providing answers to unique questions (Raines, 2002):

Table 1. Ranking by per cent DNR HCP managed lands per WRIA

HCP Unit	HCP acres	WRIA	WRIA Name	DNR HCP acres per WRIA	Total WRIA land area	% of WRIA DNR acres	Rank	Note
N. PUGET	**413,816**	1	Nooksack	100,561	812,710	12.4	**M**	
Acres in HCP	362,000	2	San Juan	1,680	113,063	1.5	L	
from 1997 table		3	L. Skagit/Samish	52,668	370,682	14.2	**M**	
Difference	51,816	4	UpperSkagit	46,125	1,567,121	2.9	L	
		5	Stillaguamish	71,266	451,626	15.8	**H**	
		6	Island	1,837	134,924	1.4	L	
		7	Snohomish	139,803	1,194,293	11.7	**M**	
S. PUGET	**147,092**	8	Cedar/Sammamish	9,402	403,482	2.3	L	
Acres in HCP	144,000	9	Duwamish/Green	19,354	345,682	5.6	**M**	
from 1997 table		10	Puyallup/White	1,334	663,999	0.2	N	
Difference	3,092	11	Nisqually	59,470	489,371	12.2	**M**	
		12	Chambers/Clover	5	105,132	0.0	N	
		13	Deschutes	4,562	170,245	2.7	L	
		14	Kennedy/Goldsborough	12,427	212,391	5.9	**M**	
		15	Kitsap	39,712	428,445	9.3	**M**	
COLUMBIA	**291,893**	25	Grays/Elochoman	51,668	302,315	17.1	**H**	
Acres in HCP	286,000	26	Cowlitz	80,429	1,593,461	5.0	**M**	
from 1997 table		27	Lewis	88,624	834,486	10.6	**M**	
Difference	5,893	28	Salmon/Washougal	50,642	305,831	16.6	**H**	
		29	Wind/White Salmon	20,437	569,609	13.2	**M**	(a)
OESF	**267,284**	19	Lyre/Hoko	28,416		22.3	**H**	(b)
Acres in HCP	264,000	20	Soleduck/Hoh	133,526	766,238	17.4	**H**	
Difference	3,284	21	Queets/Quinault	105,342	745,113	15.0	**H**	(c)
STRAITS	**115,741**	16	Skokomish/Dosewallips	30,400	388,300	7.8	**M**	
Acres in HCP	112,000	17	Quilcine/Snow	31,519	257,287	12.3	**M**	
from 1997 table		18	Elwha/Dungeness	27,452	451,414	6.1	**M**	
Difference	3,741	19	Lyre/Hoko	26,411	246,095	22.3	**H**	(b)
		21	Queets/Quinault	6,272		15.0	**M**	(c)
S. COAST	**253,143**	22	Lower Chehalis	19,602	842,805	2.3	L	
Acres in HCP	234,000	23	Upper Chehalis	156,893	830,805	18.9	**H**	
from 1997 table		24	Willipa	71,132	629,187	11.3	**M**	
Difference	19,143	45	Wenatchee	7,738	877,625	0.9	L	
CHELAN	**19,069**	46	Entiat	6,778	303,567	2.2	L	
Acres in HCP	15,000	47	Chelan	1,373	665,985	0.2	N	
from 1997 table		48	Methow	3,221	1,358,111	0.2	N	
Difference	4,069	38	Naches	22,142	707,019	3.1	L	
YAKIMA	**111,257**	39	Upper Yakima	70,136	1,368,958	5.1	**M**	
Acres in HCP	81,000	40	Alkaki/Squilchuck	18,441	520,887	3.5	L	
Difference	30,257	29	Wind/White Salmon	54,658		13.2	**M**	(a)
KLICKITAT	**141,981**	30	Klickitat	58,792	916,840	6.4	**M**	
Acres in HCP	132,000	37	Lower Yakima	29,027	1,861,630	1.6	L	
Difference	9,981							

Notes: (a) Wind/White River WRIA is in both Columbia & Yakima HCP units
(b) Lyre/Hoko WRIA is in both Straits and Olympic Experimental State Forest
(c) Queets/Quinault WRIA is in both Olympic Experimental Forest and South Coast HCP Unit
Rank: N=insignificant, L=low, **M**=moderate, **H**=high

- Implementation monitoring asks if management practices have been conducted in compliance with Forest Practices and in-house forest management prescriptions;

- Effectiveness monitoring, the focus of this proposal, asks if the management practices and activities are meeting the performance targets by improving water quality and habitat;

- Validation monitoring asks if the performance targets produce an improvement in the number and type of aquatic species.

Implementation, effectiveness, and validation monitoring for lands under the HCP has been summarized in annual reports to the NOAA Fisheries and the U.S. Fish and Wildlife Service (DNR, 1999, 2000, 2001, 2002, 2003) and a 5-year review during 2004 (DNR, 2004). A HCP implementation monitoring pilot project was conducted by DNR during 2002 (Donda, et al, 2003) and a preliminary unstable slopes implementation pilot project was completed during 2003 (Hanell, 2003). During 2003, instead of stratifying implementation monitoring by management activity, the samples for all eight HCP Planning Units were stratified by HCP conservation strategy. Implementation monitoring is being conducted for the following conservation strategies during 2003: spotted owl conservation strategy, riparian conservation strategy with a focus on stream typing, riparian management zone buffer widths, mineral springs, and balds (Bruce Livingston, pers. communication, 2004). Since the signing of the HCP in 1997, a long term monitoring program to determine effectiveness of controlling sediment from landslides and roads has not been implemented although a proposal was presented in 1998 to monitor 24 sites as part of the HCP road management strategy (Ryan, 1998). An effectiveness monitoring plan of activities within the HCP riparian management zones and conservation strategies was drafted by Wilhere and Bigley, (2002). They equated highest risk or uncertainty with highest priority for effectiveness monitoring. The priority components are: 1) riparian buffers; 2) wind buffers; and, 3) road design.

Factors related to sedimentation and affecting Pacific Northwest forested riparian ecosystems are numerous and very complex. The biggest technical challenge faced by monitoring and research is distinguishing ecosystem natural variability from changes caused by forest management activities and the size of the area included in the 1997 HCP at 1.6 million acres with 14,000 stream miles (DNR, 2003). Factors include different geomorphologic settings, varied soils and geology, differing climatic conditions including unpredictable storm event years and temperature shifts, pre and post-HCP forest management activities, unpredictable wildfire, changing patterns of public use, and a changing regulatory environment. Due to all these factors, a stratified approach, commonly known as priority setting, had to be applied to select areas for effectiveness monitoring. The focus would be to monitor watersheds or stream segments that potentially pose the greatest risk to public resources from sediment entering the aquatic ecosystem.

Washington State is divided into Water Resource Inventory Areas (WRIA) as formalized under WAC 175-500-040. The selection of WRIAs for effectiveness monitoring was facilitated by the large body of current spatial and tabular data available from DOE through their internet web site. There are 38 WRIAs that cover DNR’s HCP planning units (Table 1). The HCP WRIAs were stratified for effectiveness monitoring using two main factors.

First, forest roads are a major chronic contributor of fine sediment to streams. For DNR managed lands within the HCP, the median density of roads is 3.3 miles per square mile of managed forest within a WRIA. The range, per HCP Unit, is 3.0 miles per square mile in the South Puget Unit to a high of 4.6 miles per square mile in the South Coast HCP Unit (Pollock, et al, 2001). As there is a direct link between acres of managed land and forest roads, the percent of DNR 1997 HCP acres per WRIA was tabulated for ranking purposes (Table 1). The results were stratified with *insignificant* ranking (less than 1% DNR managed land), *low* (1% to 4.9%), *moderate* (5% to 14.9%), and *high* (15% or greater DNR managed land). See Table 1 for results. Ranking shows a high potential for sediment from roads for seven WRIAs including three in OESF. See Table 2.

Table 2. Percent of WRIA in DNR managed lands with *high* ranking

WRIA	WRIA name	HCP Unit	Percent
# 19	Lyre/Hoko	OESF	22.3 %
# 23	Upper Chehalis	South Coast	18.9 %
# 20	Soleduck/Hoh	OESF	17.4 %
# 25	Grays/Elochoman	Columbia	17.1 %
# 28	Salmon/Washougal	Columbia	16.6 %
# 5	Stillaguamish	North Puget	15.8 %
# 21	Queets/Quinault	OESF	15.0 %

Note: OESF = Olympic Experimental State Forest

Second, an important measure of risk of a public resource is the direct link to the health of the riparian ecosystem and endangered fish species. Endangered species listings by geographic Evolutionary Significant Unit (ESU) were plotted for the HCP covered WRIAs and then tabulated. The following candidate and listed species for ESUs were used to develop ranking of WRIAs: coho salmon, Chinook salmon, chum salmon, sockeye salmon, steelhead, and bull trout. See Table 3. Ranking was determined by the number of specific wild run species for each WRIA: *insignificant* with no listings, a *low* ranking for 1 to 2 listings, *moderate* risk with 3 listings, and *high* risk for 4 or more listed individual species per WRIA. The top five WRIAs of concern for listed fish species are given in Table 4.

Table 4. WRIAs with *high* risk for listed species

WRIA	WRIA name	HCP units	No. of listings
# 29	Wind/White Salmon	Columbia & Yakima	5
# 16	Skokomish/Dosewallips	Straits	4
# 18	Elwha/Dungeness	Straits	4
# 26	Cowlitz	Columbia	4
# 28	Salmon/Washougal	Columbia	4

Table 3. Endangered Species Act listings by Evolutionary Significant Unit (ESU) and ranking of WRIAs

SPECIES	**STATUS**	**ESU**	**WRIA**																																					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	25	26	27	28	29	19	20	21	16	17	18	22	23	24	45	46	47	48	38	39	40	30	37
Coho Salmon	Candidates	Puget Sound/Straight of Georgia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X												
		Lower Columbia/Southwest WA																X	X		X	X			X				X	X	X									
Chinook Salmon	Listed:	Puget Sound	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X												
		Lower Columbia River																X	X		X	X																		
		Upper Columbia R. Spring run																														X	X		X					
Chum Salmon	Listed:	Hood Canal Summer run															X									X	X	X												
		Columbia River																X	X		X	X																		
Sockeye Salmon	Listed:	Ozette Lake																						X																
Steelhead	Listed:	Upper Columbia River																														X	X		X			X		
		Middle Columbia River																																		X	X		X	X
		Lower Columbia River																	X		X	X																		
Bull Trout	Listed		X		X	X	X		X	X	X	X	X							X		X		X	X	X		X	X	X		X	X		X	X	X		X	X
	ESA listings and candidates per WRIA		3	2	3	3	3	2	3	3	3	3	3	2	2	2	3	3	4	1	4	5	0	2	2	4	3	4	2	2	1	3	3	0	3	2	2	1	2	2
	Rank		**M**	L	**M**	**M**	**M**	L	**M**	**M**	**M**	**M**	**M**	L	L	L	**M**	**M**	**H**	L	**H**	**H**	N	L	L	**H**	**M**	**H**	L	L	L	**M**	**M**	N	**M**	L	L	L	L	L

Table 5. Preliminary list of WRIAs in descending priority order for water quality Effectiveness Monitoring
based on per cent of DNR managed land and
number of ESA listings or candidate species per WRIA

Priority	WRIA	Name
1	28	Salmon/Washougal
2	26	Cowlitz
3	5	Stillaguamish
4	25	Grays/Elochoman
5	29	Wind/White Salmon
6	16	Skokomish/Dosewallips
7	18	Elwha/Dungeness
8	23	Upper Chehalis
9	7	Snohomish
10	20	Soleduck/Hoh
11	21	Queets/Quinault
12	1	Nooksack
13	11	Nisqually
14	3	L. Skagit/Samish
15	15	Kitsap
16	9	Duwamish/Green
17	27	Lewis
18	24	Willipa
19	39	Upper Yakima
20	4	Upper Skagit
21	30	Klickitat
22	17	Quilcine/Snow
23	14	Kennedy/Goldsborough
24	8	Cedar/Sammamish
25	45	Wenatchee
26	46	Entiat
27	37	Lower Yakima
28	19	Lyre/Hoko
29	38	Naches
30	40	Alkaki/Squilchuck
31	22	Lower Chehalis
32	13	Deschutes
33	48	Methow
34	6	Island
35	2	San Juan
36	10	Puyallup/White
37	47	Chelan
38	12	Chambers/Clover

A descending priority list of WRIAs for water quality effectiveness monitoring was produced by combining the weigh factors of percent DNR managed land and the number of ESA listings or candidate species. See table 5 for results listing all prioritized HCP WRIAs.

The six top priority WRIAs have been selected for an initial HCP effectiveness monitoring program. Each WRIA was then further evaluated by Watershed Administrative Units (WAU) to stratify the area to a drainage with maximum state land and where sediment would pose the greatest risk to public resources. Although not a consideration that prompted the HCP, water for domestic consumption is a public resource that needs to be considered in any monitoring program. In Washington state, the Department of Health (DOH) issues permits for surface water consumption. To assist DNR in developing a HCP monitoring strategy, DOH produced a tabulation of all surface water hook-ups (one hook-up is a single family residence) by customer, water source, and WRIA (Leibenguth, pers. communication, 2004). Examination of WAUs within *high* priority WRIAs showed that specific communities depend on domestic water supplies from watersheds with extensive DNR land holdings. This information will be used to select for monitoring one WAU over another within a *high* priority WRIA. See Table 6 for surface water use in *high* priority WRIAs.

Table 6 – Domestic surface water use by *high* priority WRIA and source

Rank	WRIA	WRIA name	No. of hook-ups	type	use location	water source
1st	#28	Salmon/Washougal	3	S	camp	surface
			6	P	Biz Point	creek
2nd	#26	Cowlitz	938	P	Castle Rock	Cowlitz R.
			282	P	Ryderwood	Campbell Cr.
			4	P	Box Canyon	Nickel Cr.
			243	P	Ohanapecosh	unnamed cr.
			243	S	Ohanapecosh	Laughingwater Cr.
			2	P	Mt. Rainier	Falls Cr.
3rd	#5	Stillaguamish	1	P	Danger Lake	
4th	#25	Grays/Elocheman	578	P	Cathlamet	Elochoman R.
			9	P	Sleepy Hallow	spring
5th	#29	Wind/White Salmon	925	P	Carson	Bear Cr.
			44	P	G. Mineral Spr.	unnamed cr.
			640	P	Stevenson	La Bong Cr.
			640	S	Stevenson	Cedar Springs
			640	S	Stevenson	Rock Cr.
			640	E	Stevenson	Iman Spring
			21	E	Maple Hill	Burnt Cr.
6th	#16	Skokomish/Dosewal.	53	E	domestic	unnamed
			10	P	Indian Beach	surface

Note: how water source is used – P = permanent data as of 2/11/04
S = seasonal
E = emergency back-up

The selection of a WAU for long term effectiveness monitoring was further guided by the presence of water monitoring programs by DOE and WDFW. In those watersheds there are opportunities for utilizing existing data for development of long-term trends while at the same time achieving efficiencies by sharing resources and expertise. An excellent example is WRIA #25 containing the Abernathy WAU within which Mill Creek and headwaters of Abernathy Creek consist of DNR HCP managed lands. The Abernathy WAU and adjacent Germany Creek WAU comprise one of five focus areas in Washington state for study and monitoring by DOE and DFW as part of their Intensive Monitoring Watershed (IMW) program (Salmon Index Watershed Monitoring Redesign Group, 2003). Since 2001, the Abernathy Cr. and Germany Cr. WAUs have been undergoing intensive validation monitoring for aquatic species and their habitat. Recommendations have been made to the Salmon Recovery Board for expanding the validation IMW program monitoring within the five focus watersheds. Funded, current fiscal year IMW studies (July ’04 to June, ’05) in WRIA #25 will accomplish the following (Intensively Monitored Watershed Scientific Oversight Committee, 2004):

- install basic monitoring infrastructure
- implement monitoring of variables as per Table 7
- collect data regarding source of sediment and hydrologic connectivity between roads and streams
- collect water quality data and aluminum impacts on aquatic biota
- conduct basin-wide habitat assessment on anadromous fish stream reaches

Table 7 – Variables measured in all coho, steelhead, and cutthroat watersheds (Intensively Monitored Watershed Scientific Oversight Committee, 2004)

	Frequency	**Data collection**
Water/climate		
Flow	Continuous	Begin June, 2004
Climate	Continuous	Begin August, 2004
Water temperature	Continuous	Begin April, 2005
Water chemistry	Monthly	Begin October, 2004
Habitat		
Hankin and Reeves survey	Annual	July - August
Fish		
Smolt production	Annual	March - June
Juvenile abundance	Annual	July - August
Spawners	Annual	(varies by species)

One unique aspect of WRIA #25 is the high aluminum content of waters. The WRIA #25 watersheds are known to contain ferruginous bauxite as a result of lateritic weathering of Columbia River basalts. Several thousand samples of laterite in Cowlitz County taken by Aluminum Company of America averaged 38.8% Al_2O_3 and 28.7% Fe_2O_3 (Livingston, 1966). Using this WRIA as a HCP effectiveness monitoring pilot project will not only provide an opportunity for partnerships to gain expertise but also to study the source and effects of aluminum on the aquatic ecosystem.

There have been other attempts at prioritizing WRIAs. The most comprehensive study, at the direction of the Joint Natural Resources Cabinet, was conducted by the Interagency Science Advisory Team (ISAT). The objective was to: "develop and refine scientific principles for determining which WRIAs are the highest priorities for use of new funding for salmonid habitat protection and restoration in western Washington." The results of this prioritization exercise identified high and low priority WRIAs for a recovery strategy. The analysis showed that the most beneficial results from recovery efforts emphasizing restoration would occur in WRIAs #1, 3, 7, 11, and 14. On the other end of the scale, WRIAs #4, 16, 19, and 21 are in relatively good condition and would benefit most from a protection approach (Interagency Science Advisory Team, 1999). The ISAT report provides a useful description of the variables that were considered for each WRIA such as road density, fish passage barriers, land use, fish stocks, etc.

The scale at which monitoring is to take place is determined by asking specific questions and identifying meaningful variables that are influenced by protection, mitigation, and restoration actions. Four commonly used monitoring spatial scales (Ralph and Poole, 2003) are:

- *Basin-scale* incorporating major river drainages such as Puget Sound or the Columbia River Basin

- *Watershed-scale* focusing on major tributaries and specific WAUs

- *Segment-scale* includes a specific stream reach or sub-watershed

- *Site-scale* encompasses a single management action such as culvert replacement, a section of road, a specific landslide, etc.

The EPA, USGS, and DOE monitor for long term trends at the *basin-scale* to evaluate the health of the nation's and state's waters. Their monitoring targets pollutants from all sources and is designed to evaluate cumulative effects. Monitoring by DOE and WDFW at the *watershed-scale* addresses response to land use such as industrialization, urbanization, forest management, and other effects on the state's waters. *Watershed-scale* and *segment scale* (sub-watershed) monitoring is also being proposed by CMER for monitoring of forest road performance and abandonment (Raines, et al, 2002, and 2004) as well as implementation and effectiveness monitoring for compliance with FPA (Sasich, 1998). *Site-scale* studies are conducted to evaluate individual forest management activities and their effects on a watershed. Knowledge of site response is needed to develop a meaningful interpretation of trends at the *watershed-scale*. Also, *site-scale* studies are designed to test specific BMPs through paired experiments with the intent of using the data in the adaptive iterative management process.

It is recommended that DNR HCP effectiveness and validation monitoring be conducted at the *watershed and sub- watershed scales* to measure long term water quality trends resulting from cumulative impacts of forest management activities. Concurrent with *watershed-scale* monitoring, *site-scale* qualitative surveys would take place to evaluate various sediment sources, both natural and management related, in order to interpret the factors influencing water quality changes. *Site-scale* surveys would also be used to test compliance with FPA and for conducting experiments to improve management performance.

There are numerous measures and methods used to monitor pollutants in water. Many researchers have expressed frustration with data sources that can't be integrated into regional monitoring programs. Both qualitative and quantitative data from a HCP monitoring program needs to conform to national and state standards as to metrics and methods used to gather the information. Washington State Substitute Senate Bill 5637, signed into law in 2001, relates to monitoring of watershed health. The resulting "Comprehensive Monitoring Strategy and Action Plan", Executive Report, recommends a 90% confidence level that monitoring can detect a 10% change over time. Therefore, the sampling methods need to be designed specifically for trend analysis by collecting monthly water quality data over a minimum of five years or longer (Monitoring Oversight Committee, 2002). Sampling should also focus on high discharge events when a majority of suspended sediment is being transported and the quantitative data has to be such, that it can be incorporated into total maximum daily loading requirements (TMDL) established by DOE and EPA. In the "Comprehensive Strategy", Volume 2, of the above cited report, Table 18 lists the reference to be used for sample measurement protocols for effectiveness and validation monitoring. Measures for dissolved oxygen, temperature, pH, and turbidity are established by reference in "Stream Sampling Protocols for the Environmental Trends Section" by William J. Ward (2001). To further emphasize the need for standardization of data gathering, during the 2004 Regular Session of the State Legislature, ESSB 5957 passed, that directs DOE to establish, by policy, proper collection of credible water quality data by any monitoring group in Washington State.

Additional references describing monitoring protocols, including field methods, have been published by the EPA, USFS, DOE, and TFW. These are: "Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska" by MacDonald, Smart, and Wissmar (1991); "Effectiveness of Forest Road and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts" by Rashin, et al (1999); "Methodology for Road Erosion Monitoring" (Veldhuisen and Periann, Skagit River System Coop, written commun., 1998); "Measuring Suspended Sediment in Small Streams" by Thomas (1985); and, "A Method for Measuring Sediment Production from Forest Roads" by Kahklen (2001).

The unit of measure to be used to monitor water quality depends on the questions to be answered. The simplest and least costly measure is *turbidity* that measures the amount of light blocked by colloidal matter and reported in Nephelometric Turbidity Units (NTUs). The DOE has set performance standards for water in NTUs as the measure takes into account industrial waste, algae, and other pollutants. Measuring NTUs can be accomplished with automatic samplers in the field at a cost of approximately $5/sample. However, a NTU does not measure the total content of sediment in water. *Total Suspended Solids* (TSS) is the preferred method as it approximates the actual weight of material per volume of water and is directly linked to detrimental effects on salmonids and other fish. In cases of slow moving water such as irrigation canals, a good correlation can be established through regression analysis between NTUs and TSS

(Joy and Patterson, 1997). However, in forest mountain streams silt and fine sand carried by water makes any correlation between NTUs and TSS suspect. In the Wildhorse Creek watershed, Kalama River basin, the conclusion was that a relationship does exist between NTUs and TSS, but not sufficiently accurate to use NTUs as a surrogate for TSS values (Wooldridge, 1978).

Laboratory methods for measuring TSS introduce a bias if the sample contains more than 25% sand sized material because of the difficulty of withdrawing an aliquot from a sample that accurately represents suspended material. Exhaustive studies by the USGS and American Society for Testing and Materials have demonstrated that the traditional measure *Suspended-Sediment Concentration* (SSC) used by the USGS does measure all of the suspended material because the entire sample is processed. Based on 3,235 paired samples, results show that the TSS analytical method tends to produce data that is negatively biased from 25% to 34% with respect to SSC analysis collected at the same time (Gray and Glysson, 2001 ?). By 2002, the USGS had studied 14,466 paired TSS and SSC samples and showed that the differences can be significant. For instance, the Skagit River near Mount Vernon was evaluated with 83 paired samples with the following results (Glysson, Gray, and Conge, 2000 ?): TSS at mg/L gave 0 (minimum flow), 10 (median), and 321 (maximum); for same site and time SSC at mg/L gave 8 (minimum flow), 52 (median), and 800 (maximum). It is clear that to calculate actual total sediment load in water, the SSC method needs to be used.

Impaired waters listed by DOE and EPA utilize the TSS measure and as a result, their Manchester Laboratory only uses the TSS analytical methods at a cost of $23/sample. Since the HCP monitoring program will need to employ the Manchester Laboratory, a correlation will need to be established between TSS and SSC. Analysis by the USGS of paired samples does indicate that a relation between TSS and SSC can be developed for a specific site. At least 30 paired sample points at a site, evenly distributed over 80 to 85% of the range of concentrations and flows, would be needed to define such a correlation (Gray, et al, 2000; Glysson, Gray, and Conge, 2000 ?; Horowitz, 2002).

D. Adaptive Management

Successful forest management practices and restoration programs depend on rejecting actions with potential detrimental ecosystem effects and adapting or modifying practices that show positive trends or outcomes. This style of management has been defined as *Adaptive Management.* First, a statistically and scientifically sound monitoring plan is vital in order to document long-term ecosystem responses to changes in forest management and restoration programs. Second, a key to adaptive management is: the ability to test alternative practices through rigorous paired experiments that, with monitoring, demonstrate the benefits of one practice over another; and, have in place a functioning feed-back loop for implementation of change. “Adaptive management is not the end of a process, instead it is comprehensively integrated into the planning process and makes that process continuous” (Boswell, 2000).

The Forest Practices Act, RCW 76.09.020, defines *Adaptive Management* as “reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately.” An expanded description is found in WAC 222-12-045. However, recent debates on adaptive management have recognized the limited usefulness of the scientific adaptive management method due to societal and economic interests that influence the final management approach. “Adaptive management represents a challenge far beyond the technical traditions of science and rational planning.” (Kepay, 2002).

E. Recommendations

A water quality effectiveness monitoring program is recommended as required by the HCP. It is not feasible to monitor all 1.6 million acres under the HCP, so a prioritization approach was used to select the top six WRIAs with the most public resources at risk from forest activities. The following WRIAs are recommended for a long-term monitoring program: #28 (Salmon/Washougal); #26 (Cowlitz); #5 (Stillaguamish); #25 (Grays/Elochoman); #29 (Wind/White Salmon); and, #16 (Skokomish/Dosewallips). Within each one of the WRIAs, at least one WAU shall be selected, taking into consideration the maximum amount of DNR managed land and potential public resources at risk.

Long-term monitoring shall be for a minimum of six years to determine water quality trends effected by forest management activities. Monitoring shall follow DOE and EPA protocols for the following variables: climate (precipitation), flow, water temperature, and amount of fine sediment carried by the water. In order to link water quality monitoring with forest management activities, the following data will be tracked and compiled by DNR: soils, geology, active and inactive landslides; harvest levels (volume and acres); road construction, maintenance, abandonment and other RMAPS activities. Where appropriate, site-scale experiments shall be conducted to test forest management BMPs. A FY05-07 biennium budget of $188,375 is proposed to monitor seven WAUs in six priority WRIAs (see Appendix C).

It is recommended that a phased pilot project be initiated as soon as practical in WRIA #25 by offering to partner with DOE. For that WRIA, DOE has had a validation monitoring program in place since 2001, and, starting in June, 2004 DOE has initiated an intensive long-term monitoring program for climate, water, habitat, and fish. This is one of the five focus areas chosen by DOE and DFW in Washington State. Within WRIA #25, the Mill Creek and Abernathy Creek WAUs consist of major DNR land holdings and would greatly benefit in efficiencies and expertise by providing funds to DOE to include instrumentation and monitoring as part of their total program in WRIA #25. It is recommended that $25,662 be provided to DOE to add instrumentation and monitoring of Mill and Abernathy Creek WAUs for the water year October, 2004 through September, 2005. See Appendix A for details.

Phase 1 would sample Mill and Abernathy creeks for turbidity, TSS, and during high flow events, SSC using established EPA/Ecology protocols. The physical samples would be processed at EPA/Ecology's Manchester Laboratory. DOE staff would perform data and using regression analysis develop correlation factors between turbidity and TSS results. Phase 1 would start in December, 2004 and continue through March, 2005.

During Phase 2, Mill and Abernathy creeks would be instrumented in April, 2005 with pressure transducers, turbidity equipment, and temperature monitors wired to a data logger. The information would be downloaded once a month by DOE staff, analyzed, and entered into DOE's water quality database. An annual report would be produced for DNR on the monitoring results by November 1st of each year.

An additional $24,900 would be needed to fund a DNR mass wasting team to compile geology, soils, and landslide data for the Mill and Abernathy WAUs (Appendix B).

Appendix A

HCP WATER QUALITY EFFECTIVENESS MONITORING
BUDGET
Water year October, 2004 to September, 2005
Grays/Elochoman WRIA #25
Mill Creek and Abernathy Creek sub-basins
by
Washington Department of Ecology
for
Washington Department of Natural Resources

Phase 1 – Water Quality (December, 2004 through March, 2005)

Personnel (sample collection, data analysis & integration)……$2,432
Travel (crew already in field, low cost)…………………….. 210
Supplies (sample containers, misc.)…………………………… 120
Laboratory analytical costs (Ecology/EPA Manchester lab.…….………
incl. turbidity, TSS, QA, & SSC samples)……………1,000
Sub-total…….**$3,762**

Phase 2 – Flow & Water Quality (April, 2005 to September, 2005)

Personnel (2 stations, data download, analysis, & maint.)……..$8,500
Flow equp. (2 installed & tested pressure transducer stations)…...7,400
Turbidity equip. (2 in situ monitors for continuous record………………..
incl. data loggers)…………………………………….6,000
Sub-total……**$21,900**

TOTAL Dept. of Ecology costs for Mill & Abernathy WAUs……………………… ..**$25,662**

An annual report, with supporting data and analysis, shall be provided by DOE to DNR by November 1st, 2005 covering the water year October, 2004 through September, 2005.

Appendix B

HCP WATER QUALITY EFFECTIVENESS MONITORING
BUDGET

WRIA 25 – Mill and Abernathy WAUs

Mass wasting team	Personnel			
		Cartographer	0.01 FTE	$ 500
		Technician 3	0.2 FTE	8,000
		Geologist 3	0.3 FTE	14,500
	Travel…………………………			1,900
December, 2004 through June, 2005……			**TOTALS**	**$24,900**

Appendix C

HCP WATER QUALITY EFFECTIVENESS MONITORING
PROPOSED BUDGET

WRIA 28, 26, 5, 25, 29, and 16 for FY period July 2005 through June, 2006

Flow equipment (installed & tested transducer stations at $3,700 each for 5 WAUs)……….	$18,500
Turbidity/temperature/data loggers at $3,000 each…...	15,000
Sub-total Equipment….	**$33,500**

Monitoring team

Technician 2	0.2 FTE	$6,300	
Technician 3	0.1 FTE	4,000	
Scientist	0.06 FTE	3,000	
Transportation…………		1,200	
Cost per team……………		$14,500	
Two teams (WRIA 25 covered by DOE) …**Sub-total**			**$29,000**

Mass wasting team

Cartographer	0.01 FTE	$ 500	
Technician 3	0.2 FTE	8,000	
Geologist 3	0.2 FTE	14,500	
Transportation………..		1,900	
Cost per team……………		$24,900	
Two teams……………………………….**Sub-total**			**$49,800**

Analytical costs – Manchester Laboratory

For calibration of turbidity (NTU) readings
with suspended sediment concentration (SSC)
30 sample sets/WAU at $23/sample= $690
5 WAUs ……………………**Sub-total** **$3,450**

TOTAL FY monitoring costs for period July, 2005 through June, 2006…$115,750

WRIA 28, 26, 5, 25, 29, and 16 for FY period July, 2006 through June, 2007

DOE monitoring/data analysis – WRIA 25 (two WAUs)
personnel for 12 months…………………. **$17,000**

DNR monitoring team

Technician 2	0.2 FTE	$6,300
Technician 3	0.1 FTE	4,000
Scientist	0.06 FTE	3,000
Transportation		1,200
Cost per team		$14,500

Two teams……………………………………**Sub-total…** **$29,000**

DNR mass wasting team

Cartographer	0.01 FTE	$500
Technician 3	0.2 FTE	8,000
Geologist 3	0.2 FTE	14,500
Transportation		1,900
Cost per team		**$24,900**

One team………………………………………**Sub-total..** **$24,900**

Analytical costs- Manchester Laboratory

For check analysis in comparing turbidity
and SSC results at $23/sample
15 samples…………….**Sub-total…** **$1,725**

TOTAL FY monitoring costs for period July 2006 through June, 2007….$72,625

GRAND TOTAL PROPOSED BIENNIUM HCP MONITORING COST = $188,375

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