A STRATEGY TO IMPLEMENT WATERSHED ANALYSIS MONITORING:

ASSESSMENT OF PARAMETERS AND METHODS
MONITORING MODULE OUTLINE
RECOMMENDATIONS FOR PROGRAM DEVELOPMENT

By

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TIMBER/FISH/WILDLIFE

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EXECUTIVE SUMMARY

The purpose of this project is to examine the need for a monitoring component in Watershed Analysis (WSA) and provide AMSC/CMER with information and recommendations to aid in development and implementation of the WSA Monitoring Module. Our approach was to attempt to answer six fundamental questions: 1) what is the purpose of monitoring in the context of WSA?; 2) is it possible to build a monitoring plan that fulfills these purposes using information provided in the Watershed Analysis reports?; 3) what monitoring situations are likely to be encountered in forested watersheds around the state?; 4) what parameters and methods are needed to conduct WSA monitoring?; 5) what components should the WSA monitoring module contain?; and 6) what tasks need to be integrated into the AMSC/CMER work-plan to develop and implement WSA monitoring?

Watershed Analysis Monitoring needs to be designed to fulfill three potential missions. First, it should provide feedback to assist in adaptive management. Feedback from monitoring should help Watershed Analysis assessment teams evaluate and refine their analyses. It should also help the module design teams improve WSA methods. Secondly, monitoring data should help the Department of Natural Resources in their periodic evaluation of the effectiveness of completed Watershed Analyses under WAC 222-22-090(4). Finally, monitoring data could help the Department of Ecology to evaluate the effectiveness of WSA used in the implementation of section 303(d) of the Clean Water Act.

To accomplish these missions Watershed Analysis Monitoring must focus on two areas. First, triggering mechanisms and input processes must be monitored to evaluate the effect of WSA prescriptions. This type of input monitoring is important because it provides valuable feedback on the performance of "prescriptions" and allows early identification of potential problems before they are translated into detectable adverse channel and resource effects. Next, the response of stream channel, habitat and water quality conditions should be monitored to determine if the resource protection objectives of WSA are being met. Development of a channel/resource recovery prognosis will help to evaluate the response of systems that have been disturbed by past management or natural events.

A completed Watershed Analysis makes an excellent foundation for developing a monitoring plan, because each "causal mechanism report" provides a monitoring hypothesis that links input processes with channel and resource responses and can be used to identify appropriate monitoring parameters and specific monitoring locations. The WSA causal mechanism reports (supplemented by resource assessments) are the key source of information for developing a monitudng plan, however they must be thoroughly written with input from all assessment team members to provide adequate detail. Most causal mechanism reports (CMRs) contain adequate information on triggering mechanisms. Treatment of channel effects was less consistent, and many CMRs lacked adequate information on specific habitat effects. This problem could be prevented by providing better guidance in preparing CMRs.

About 100 causal mechanisms were examined from WSAs completed in 1993 to identify

potential monitoring situations and parameters. We condensed this information into seven input/response "hypothesis" that occurred frequently in the CMRs. Three hypotheses focused on mass wasting, and there was one each for surface erosion, large woody debris (LWD) recruitment, stream temperature, and peak flows. We used these to identify the potential monitoring parameters we predict will be in greatest demand, however other less common situations occur and will need to be addressed on a case-by-case basis.

Based on this analysis, we identified 29 basic monitoring parameters, including 7 for triggering mechanisms, 7 for channel effects, and 15 for habitat. No water quality parameters are listed because they were infrequently identified in the CMRs due to lack of a water quality module. Water quality parameters will be better identified when the Water Quality Module is completed. Potential monitoring parameters were evaluated based on estimated demand and the amount of work required to develop an acceptable method. Based on estimates of future demand and the amount of work required to develop a suitable method, we recommended development in the next year of the following high priority parameters: slope stability, road assessment, surface erosion, channel substrate size (fining or coarsening), channel aggradation or degradation, channel widening, braiding, lateral migration and bank erosion (aerial photo method), sediment storage features, spawning grovel availability and macro-invertebrate production. We also recommend initiating work on the following parameters (high demand/extensive work): fine sediment delivery, site-specific peak flow runoff monitoring, channel widening, braiding, lateral migration and bank erosion (field methods), spawning gravel scour, pool refuge habitat, and LWD accumulations.

Our next task was to scope out information that would need to be included in the monitoring module. We determined that the most effective WSA monitoring approach would have local stakeholders develop and implement watershed-specific monitoring plans based on the WSA causal mechanism and resource assessment reports. The role of the Watershed Analysis Monitoring Module will be to provide information and guidance in preparation and documentation of the monitoring plans. Specific issues that need to be addressed in the plans include identifying goals and objectives, developing a sampling plan, quality assurance, and data processing and interpretation.

Technical assistance from the TFW Ambient Monitoring Program is necessary to support the local monitoring efforts and ensure consistent data collection on a state-wide basis. The role of the TFW Ambient Monitoring Program in implementing Watershed Analysis Monitoring will include developing standard methods, conducting training, providing quality assurance, assisting with data processing and analysis, and maintaining the state-wide database.

The tasks that need to be done to successfully implement WSA Monitoring include writing the monitoring module, developing standard methods, providing support services (training, quality assurance, etc.), clarifying procedures for use of WSA monitoring data in adaptive management, improving linkages with other WSA components, improving capability to interpret monitoring information, and developing future funding sources. Recommendations for incorporating these tasks into the AMSC/CMER work-plan are provided.

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STRATEGY TO IMPLEMENT WSA MONITORING

INTRODUCTION

Development of a monitoring module for Watershed Analysis (WSA) is a high priority project for the TFW Cooperative Monitoring, Research and Evaluation Committee (CMER). The Department of Natural Resources asked CMER's Ambient Monitoring Steering Committee (AMSC) to prepare a monitoring module by August 1994 for inclusion in the next version of the Watershed Analysis manual. In order develop a successful monitoring module, many fundamental technical issues must be addressed. For example, AMSC must determine what monitoring information will be needed for WSA, the scope, purpose and content of the monitoring module, and the standard methods needed to conduct monitoring.

PURPOSE OF THE REPORT

The purpose of this project is to examine the need for a monitoring component in Watershed Analysis and provide AMSC/CMER with information and recommendations to aid in development and implementation of the WSA monitoring module. This information is integrated into a proposed strategy and work-plan for producing the WSA monitoring module and for developing a program to implement and support the module.

METHODS

To focus the gathering and presentation of information, we attempt to answer the six questions.

1. What is the purpose of monitoring in the context of Watershed Analysis?
2. Is it possible to build a monitoring plan that meets these requirements using information provided in the Watershed Analysis reports?
3. What monitoring situations are likely to be encountered in forested watersheds in the state?
4. What parameters and methods should be used to monitor these situations? Are methods available or will they need to be developed?
5. What components should the WSA monitoring module contain?
6. What tasks need to be accomplished to develop and implement a WSA monitoring module/program and how should these tasks be integrated into the AMSC/CMER work-plan?

Each question is discussed in detail in the results section. The answers to these questions provide valuable guidance in developing an appropriate WSA monitoring program and form the basis for the conclusions and recommendations at the end of the report.

The methods used to answer the questions varied. Limitations of time and resources required us to prioritize our efforts and prevented us from going into great depth areas such as methods, however we were able to put adequate effort into answering each of the six questions.

To identify the purpose of WSA monitoring, we examined the Washington Forest Practices Rules (WFPB, 1993a), the Watershed Analysis manual (WFPB, 1993b), and the WDOE/WDNR 303(d) proposal to the Washington Forest Practices Board (Riveland and Cottingham, 1994). Input was also solicited from WSA team leaders and participants.

To determine if adequate monitoring plans can be based on completed Watershed Analysis documents, we read the causal mechanism and resource assessment reports of WSAs completed in 1993. We examined situation sentences to determine if they provided coherent process/response hypotheses that could be used as a framework for identifying monitoring questions, parameters and sampling locations.

To identify monitoring situations likely to be encountered in forested watersheds around the state, we reviewed approximately 100 separate causal mechanisms contained in the Causal Mechanism Reports (CMRs) from completed watershed analyses including the Tolt, Alps, Connelly Creek, and Nanuem. We examined the situation sentences to identify triggering mechanisms and the associated channel, fish habitat and water quality effects. The frequency of various causes and effects were tabulated to determine what types of situations have been the most common, and uncommon, to date. We also identified triggering mechanisms and effects that were not identified in either the CMRs or resource assessment reports, but that we thought should have been. This information was supplemented with information from other monitoring efforts in forested areas around the state to identify situations likely encountered as Watershed Analysis is implemented.

We attempted to identify potential parameters and monitoring methods for each of the common situations encountered in the causal mechanism reports. We examined existing methods manuals and surveyed knowledgeable individuals to determine if methods are currently available or need to be developed. Then we prioritized future method development based on the need for each parameter/method and how much work would be required to bring it on line.

To determine what components the WSA monitoring module should contain, we prepared an proposed outline for a WSA monitoring module that will satisfy the institutional requirements for Watershed Analysis in a logical and efficient manner.

Finally, we identified specific tasks that need to be done to develop and implement a WSA monitoring module and program based on our proposed module structure, and arrayed them in a logical sequence to develop a proposed work-plan for AMSC/CMER.

RESULTS

The following section provides the results of our search for answers to the six basic questions.

The Purpose of Monitoring in the Context of Watershed Analysis

We identified three potential, inter-related missions that Watershed Analysis Monitoring should be designed to fulfill:

1) WSA monitoring should provide feedback to WSA participants and designers for adaptive management. WSA designers, assessment and prescription teams and Watershed Administrative Unit (WAU) stakeholders need monitoring information to evaluate if each WSA accurately assesses input processes, trigger mechanisms and resoume effects; to determine if the prescriptions worked as expected; and to identify how WSA could be improved.
2) WSA monitoring could provide data to help Washington Department of Natural Resources (WDNR) evaluate each WSA. WDNR needs monitoring information to evaluate the effectiveness of WSA prescriptions in achieving protection or recovery of resource characteristics, and to determine if WSA should be redone.
3) WSA monitoring could provide data to help Washington Department of Ecology (WDOE) evaluate the effectiveness of each WSA used in the implementation of the Clean Water Act section 303(d) process and to verify reduction in nonpoint pollution load and to evaluate progress in attaining water quality standards.

All three missions require an evaluation of whether WSA correctly assesses problems and applies effective measures to protect or allow recovery of public resources. However each function differs to some degree in type and amount of information required. Details on the specific requirements of each mission are discussed below.

Mission 1: Provide feedback to WSA participants and designers **for adaptive** management

Adaptive management is a fundamental part of the TFW/Watershed Analysis approach to cumulative effects. The Washington Forest Practices Rules Washington Administrative Code (WAC) 222-22-010 *(2) state: "adaptive management in a watershed analysis process requires advances in technology and cooperation among resource managers. The board finds that it is appropriate to promulgate roles to address certain cumulative effects by means of the watershed analysis system, while recognizing the pioneering nature of this system and the need to monitor its success in predicting and preventing adverse change to fish, water, and capital improvements of the state and its political subdivisions" (Washington Forest Practices Board [WFPB], 1993a). Monitoring information is used "to determine if goals are being met" and allows "implementation of an adaptive management process in which assessment tools, management and regulation are revised based upon experience and the feedback from monitoring" (WFPB, 1993a).

The Watershed Analysis Manual (WFPB, 1993b) states that monitoring following completion of a Watershed Analysis is encouraged to "track the effectiveness of the prescriptions and the assessment on which they were based. Monitoring is designed to provide feedback on where resources were actually protected or improving as a result of prescriptions".

To support adaptive management in Watershed Analysis, monitoring data must help evaluate: 1) whether the processes, trigger mechanisms, and inputs were correctly identified and linked to the condition of the resources; 2) whether the prescriptions are effective in protecting resources and/or promoting their recovery; 3) if assumptions incorporated in the analysis were valid; and 4) if unexpected changes in processes or resource conditions have occurred since the original Watershed Analysis.

The adaptive management process must occur on two levels. On the local level WAU stakeholders need monitoring feedback to determine what is and isn't working in order to refine and improve Watershed Analysis over time. On the statewide level, CESC and the designers of the Watershed Analysis procedure need feedback from all Watershed Analyses done around the state to identify parts of the process that are working well, weakness and omissions in the procedure that need improvement, and regional differences. This information can be used to refine the Watershed Analysis procedure and to identify needed research and development projects.

Mission 2: Provide data to help WDNR evaluate each WSA

A process for WDNR to evaluate the effectiveness of WSA is sketched out in WAC 222-22-090- Use and review of watershed analysis (WFPB, 1993a). In cases where the resource characteristics in a WAU are fair or poor, section *(4) requires WDNR to evaluate the effectiveness of WSA prescriptions in providing for protection or recovery of resource characteristics after a three year period. If WDNR finds that the prescriptions are not effective, they are required to repeat the WSA. Section *(4)(c) requires revision of the WSA if there is a deterioration in the condition of the resource characteristic in the WAU measured over a 12 month period, unless there is a determination that a longer period is necessary to allow the prescriptions to produce improvement.

The WAC specifies that WDNR will evaluate WSAs based on trends in condition of resource characteristics. Collection of this information through WSA monitoring would be invaluable in helping WDNR come to an informed decision. To fulfill this function, we recommend that WSA monitoring be designed:

* to produce information on the effectiveness of WSA prescriptions in providing for protection or recovery of resource characteristics;
* to identify changes in resource conditions;

* to develop a prognosis for resource recovery that will help WDNR determine appropriate time-frames necessary to allow recovery of resource characteristics.

Mission 3: Provide data to help WDOE evaluate each WSA used in the implementation of the Clean Water Act section 303(d) process

The federal Clean Water Act requires that states assess surface waters to determine if water quality standards are being met. Where water quality standards are not met due to human activities, and it is determined that the standard technology and/or best management practices (BMP)-based approach is not capable of achieving the standards, the water-bodies are placed on the section 303(d) list. An alternative "water quality based" approach to pollution control is applied to stream segments on the 303(d) list. The water quality-based approach requires establishment of a Total Daily Maximum Load (TMDL). To establish the TMDL, a basin-specific analysis is done to determine how much pollution the water-body can handle without exceeding standards or impairing beneficial uses. This load, minus a margin of safety and allowances for future uses, is allocated among sources (Environmental Protection Agency, 1991).

The Washington Department of Ecology (WDOE) and WDNR have proposed using Watershed Analysis to establish TMDLs for pollutants originating on forest lands (Riveland and Cottingham, 1994). They requested that the Washington Forest Practices Board adopt rules to establish the Watershed Analysis WAC as the implementation mechanism for the 303(d) process on forest lands in Washington State. The Forest Practices Board has not as yet made a decision on this proposal. When TMDLs are applied to nonpoint sources such as forest practices, a high level of uncertainty is often involved due to limited availability of information and the variable nature of input processes. Therefore, EPA requires a phased approach to nonpoint TMDLs with a conservative margin of safety, a schedule for implementation of control mechanisms, follow-up monitoring to provide assurance that water quality standards are met, and revision of the TMDL when attainment is not achieved (USEPA, 1991). To meet EPA guidelines for the TMDL process, the WDOE proposal requires development of a monitoring component for WSA.

Monitoring data for a 303(d) stream segment could help determine if water quality standards are being met, if the control mechanisms are effective in achieving the expected pollutant load reductions, and when to remove streams from the 303(d) list. This would require monitoring of water quality parameters identified in the Water Quality module under preparation, and is likely to include some monitoring of Type 4 and 5 waters and wetlands.

Summary

To accomplish these missions Watershed Analysis monitoring must focus on two areas. First, the status of triggering mechanism and input processes must be monitored to evaluate the effect of WSA prescriptions on input processes. This type of input monitoring is important because it provides valuable feedback on the performance of prescriptions and allows early identification of potential problems before they are translated into detectable adverse channel and resource effects. Next, the response of the stream channel, habitat and water quality conditions should be monitored to determine if the resource protection objectives of WSA am being met. The WDNR review of WSA effectiveness and the WDOE 303(d) evaluation will require both types of monitoring data to determine if the prescriptions am working effectively and if resource goals/water quality standards are being met. The WDNR evaluation requires a recovery prognosis in order to establish an appropriate time-frame for recovery of degraded resources. This information would also be useful in evaluating TMDL performance. More detailed information is required to fuel adaptive management in Watershed Analysis. Given extreme variability in site-specific conditions on forest lands around the state, monitoring data is essential to evaluate whether WSA methods consistently and correctly identify input processes and trigger mechanisms, and establish functional linkages to channel and resource conditions. In addition, monitoring data should assist in identification of patterns in the effectiveness of prescriptions relative to the settings in which they were applied, the magnitude of processes they are subjected to, and the type of trigger mechanisms active in the hazard mapping unit.

The Feasibility of Using Watershed Analysis Causal Mechanism Reports to Build Monitoring Plans

The Watershed Analysis process is a powerful tool for developing effective monitoring programs based on site-specific practices, processes, and resource conditions. The causal mechanism reports (WFPB, 1993b) are particularly useful tools because they provide a linkage between specific forest practices, triggering mechanisms, input processes, and associated channel, habitat and water quality responses. Each causal mechanism is a testable cause/effect hypothesis about a specific forest practices and/or natural event that may alter input processes, causing a change in channel conditions, salmonid habitat or water quality. Using the causal mechanism repons in conjunction with the prescription repons and the more detailed resource assessments, a series of potential monitoring parameters along each cause-effect pathway can be identified. Table 1 shows an example of a causal mechanism report, with potential monitoring parameters attached to triggering mechanisms, input processes, and potential channel, fish habitat and water quality effects.

Each causal mechanism identifies a specific location (hazard mapping unit) where monitoring of triggering mechanisms and input process initiation should occur. Monitoring of the interaction between prescriptions and triggering mechanisms in the hazard mapping unit will provide information needed to evaluate the effectiveness and performance of prescriptions relative to the initiation or rate of input process.

Each causal mechanism also identifies specific response segments, stream reaches where channel, habitat or water quality would be expected to change in response to the processes initiated in the associated hazard mapping unit. Monitoring of channel, habitat and/or water quality parameters in the response reach provides a means of evaluating the overall effectiveness of WSA in meeting public resource protection objectives and attainment of water quality standards.

Table 1. Example of potential monitoring parameters based on the trigger mechanisms, channel and resource effects identified in a causal mechanism report (from WFPB, 1993b).

Monitoring Program Identification

Situation Sentence for the Resource Sensitivity: Coarse sediment from past inner gorge failures in unit 3 is reducing pools in Segments 1 and 2, and as a result is degrading summer rearing habitat.

Rule Call: Prevent

Triggering Mechanism: Landslides associated with timber removal and possible loss of root strength on inner gorge terrain features.

Prescriptions: Avoid new roading; limit overstory removal to 50% no partial suspension of logs during yarding - use skyline or helicopter yarding.

Prescription Objective: Reduce landslides from recent levels.

Long-term Resource Objective: Improve degraded salmon rearing habitat resulting from coarse sediment loading.

Possible Monitoring Measures

Effectiveness of Prescriptlon: Rate of landsliding

Trends in Resource Condition:

Habitat indicators:	Pool to riffle ratio, pool depth.
Channel Indicators:	Channel width, bed composition.
Public Resources:	Smolt output (due to presence of smolt traps in watershed).

In addition, the Fish Habitat Module provides a list of diagnostic parameters that serve as potential indicators or resource characteristics used by WDNR to evaluate the effectiveness of WSA under WAC 222.

Several limitations in the use of Watershed Analysis as a foundation for monitoring were identified. First, we observed an inconsistency in the amount of detail provided in the causal mechanism reports, which could impede the development of monitoring plans. In some cases the causal mechanism reports did not provide enough detail to identify potential monitoring parameters, for example when the resource effect was listed as "rearing habitat". Some situation sentences appeared to have been prepared by only one analyst, because detail was provided in part of the sentence and not the rest. This probably reflected the writer's relative expertise and familiarity with the subject matter. More detailed information was always available in the resource assessment report, however it required more time and effort to find it there. We recommend that each causal mechanism report be prepared with participation by all relevant assessment teams, to provide a more thorough and consistent product. We also recommend using a reporting format similar to that used in the Alps WSA (Table 2) to encourage full treatment of more complex causal mechanisms.

To evaluate the effectiveness of Watershed Analysis, it appears likely that testing of assumptions (routing, for example) will be necessary in some cases. Validation of assumption through monitoring will result in more accurate assumptions in future efforts. We recommend explicit statement of assumptions that would benefit from testing through monitoring so that they can be readily identified by the monitoring team and incorporated into monitoring plans.

For stream segments where WSA is being used as a TMDL by WDOE, monitoring of the water quality or habitat parameter out of compliance with water quality standards will be required. We are unclear exactly how the monitoring team will identify specific TMDL parameters. When WSA is used in the TMDL context, analysts should identify these parameters in the WSA document, so they will not be overlooked in development of the monitoring program. An alternative approach would be to refer the monitoring team to WDOE for this information.

Table 2. Example of a causal mechanism report format that provides adequate detail on specific channel and resource effects to form the basis for development of a monitoring plan (from the Alps WSA).

CAUSAL MECHANISM REPORT SUMMARY

WAU:	Alps
Sub-basin:	Paris Creek, Cle Elum
Sensitive Area:	Mass-Wasting Map Unit 5-Steep slopes over sandstone bedrock
Module:	Mass-Wasting Module, Map A-2

SITUATION SENTENCE:

Input:	Coarse and frae sediment
Time Frame:	from past
Watershed Process:	consequences of snow avalanches originating in
Unit Location.	Mass-Wasting Map Unit 5
Activity:	associated with clear-cutting on
Conditions:	slopes of gradient greater than 25 degrees that are upslope of low-order channels (MWMU1) have caused

Channel Effects	*Stream Segment*	*Vulnerable Resources*
localized channel aggradation and widening, infilling of pools, and substrate fining	in stream segments 134 and 135, (deeply incised, moderate gradient tributaries of the lower watershed)	resulting in a reduction of summer-and winter-rearing habitat and negatively impacting spawning.
increased fine sediment deposition	in stream segment 13 (very low gradient lake outlet	potentially negatively impacting spawning
increased sediment input	to water supply facilities located in stream segments A-3	increasing maintenance costs and frequency.

TRIGGERING MECHANISMS:

Clear cutting increases the potential snow-accumulation area susceptible to avalanching. Avalanches entering a low-order channel draining to a Type 14 stream will likely stop only when incident upon the stream channel. The devegetated avalanche track has increased susceptibility to shallow-rapid landsliding and debris flow initiation.

RULE CALL:

Delivered hazard .... .Moderate
Resource Vulnerability.......High
Rule call .... Prevent or Avoid

ADDITIONAL COMMENTS:

Snow avalanches were associated with two clear cuts units larger than 100 acres, and were initialed in mid-or upper slopes above elevations of 4400'.

The moderate hazard rating for this MWMU arises in part because of the many low-order (headwater) channels and tributary zero-order basins (hollows) associated with MWMU 1 that traverse the slopes of MWMU 5. Many of these low-order channels and zero-order basins do not appear on map A-2. Care must be taken to identify and delineate these high hazard zones on site.

Monitoring Situations Likely to be Encountered in Forested Watersheds

To help identify monitoring situations likely to be encountered in WSA, we examined approximately 100 separate causal mechanisms extracted from the causal mechanism reports (CMRs) for the Tolt, Alps, Connelly Creek, and Nanuem WAUs. These watersheds provide a sample of the diverse conditions around the state, however data from a larger sample of watersheds is desirable once more analyses have been completed. Information extracted from the CMRs is presented in tables that break down the situation sentences into triggering mechanisms, channel effects, and resource effects. The frequency of various causes and effects were tabulated to determine what types of situations have been the most common, and uncommon, to date. Some triggering mechanisms and effects were not identified in the CMRs, however we thought they should have been. They are either more specific than those identified in the CMRs or were not identified at all. These are noted because they identify potential holes that should be filled by future modifications to the Watershed Analyses assessments, and should be evaluated for inclusion in monitoring. This section includes presentation of seven common process-response hypotheses compiled from situation sentences that occurred repeatedly in the CMRs examined.

Triggering Mechanisms

A triggering mechanism is defined in the Watershed Analysis Manual (WFPB, 1993b) as "the factor that contributes to the potential to change a watershed process sufficiently to create the sensitivity." In simpler terms, the triggering mechanism initiates or accelerates a physical process in a watershed that leads to the input of specific factors (water, wood, sediment, or energy), resulting in a channel or resource (fish habitat or water quality) effect.

Approximately 50% of the mass wasting triggering mechanisms identified in CMRs were associated with harvest units (Table 3). Roads were associated with approximately one-third of the triggering mechanisms, while natural disturbance and in-channel initiation accounted for the remaining 20%.

Table 3. Mass wasting triggering mechanisms.

Triggering Mechanism	**Number**	**Percent**
In-harvest unit	50	50%
Roads	31	31%
Natural	12	12%
Channel	7	7%
TOTAL	100	I 100%

Greater than 70% of the mass wasting triggering mechanisms identified in causal mechanism reports (CMRs) are either debris flows or shallow-rapid landslides. The remaining 30% include deep-seated landslides and snow or rock avalanches. Table 4 provides a more detailed summary of information on mass wasting triggering mechanisms compiled from the CMRs.

Table 4. Summary of mass wasting triggering mechanisms identified in the causal mechanisms reports.

	Debris flows/ shallow rapid landslides	**Dam-break** floods/debris **torrents**	**Deep-seated** landslides	**Snow** avalanches/ **rock avalanches**	**Sub-** total	**%** TOTAL
In-unit Root strength	20	4	3	0	27	27%
In-unit Ground-water disturb	16	2	2	0	20	20%
In-unit Ground disturb	2	0	0	1	3	3%
Road Sidecast failure	8	0	1	0	9	9%
Road Culvert block	2	2	0	0	4	4%
Road Water Concent	8	0	3	0	11	11%
Road Ground disturb	5	0	1	1	7	7%
Misc. Natural	7	1	3	1	12	12%
Channel Bank erosion	5	0	2	0	7	7%

In-harvest unit mass wasting triggering mechanisms

The frequency that major in-harvest unit triggering mechanisms occurred in the CMRs is shown in Table 5. Over half of the CMRs with in-harvest unit triggering mechanisms identify root strength as a primary mechanism, while another 40% of the CMRs identify groundwater increase as a primary mechanism. Both mechanisms were identified in 94% of all CMRs reviewed.

Table 5. In-harvest unit mass wasting triggering mechanisms.

Triggering Mechanism	Number	Percent
Root strength	27	55%
Groundwater concentration	20	41%
Ground disturbance	2	4%
TOTAL	49	100%

Road-related mass wasting triggering mechanisms

The frequency that major road-related triggering mechanisms occurred in the CMRs is shown in Table 6. Approximately 64% of the CMRs with roads as a triggering mechanisms identified either an increase in water concentration or sidecast failures as the primary causes of mass wasting. Ground disturbance and culvert blockages made up approximately 32% of all the primary causes. Many road-related CMRs include all four of the triggering mechanisms because more than one triggering mechanism applied.

Table 6. Road-related mass wasting triggering mechanisms.

Triggering Mechanism	Number	Percent
Water concentration	11	37%
Sidecast failures	9	30%
Ground disturbance	6	20%
Culvert blockage	4	13%
TOTAL	30	100%

__Other triggering__ mechanisms

Triggering mechanisms identified for the processes of surface erosion, LWD recruitment, solar energy (stream temperature) and peak flow hydrology were not as numerous or complex as those for mass wasting. The primary triggering mechanism identified for surface erosion was soil disturbance associated with logging and logging road construction, use and maintenance. The primary triggering mechanism for changes in LWD recruitment and solar energy input was past or potential harvest of streamside timber stands. Clearcut harvest of timber stands in the rain-on-snow zone was the primary triggering mechanism identified for changes in peak flow hydrology.

Triggering mechanism __conclusions__

Root strength, increases in groundwater, and surface-water concentration make up approximately 60% of all mass wasting triggering mechanisms. Although ground disturbance is commonly perceived as one of the main causes of mass wasting, it was identified as a primary mechanism in less than 10% of all the CMRs examined. Root strength and increase or alteration in water concentration play a critical role in slope stability. Although we are making strides towards modeling slope stability, we also need to consider monitoring it, especially in the context of Watershed Analysis.

Channel Effects

Channel effects can be defined as changes in rate, magnitude, or frequency of channel-forming processes or morphology related to natural or human-induced disturbance of input factors. Major channel effects were linked to mass wasting, riparian disturbance, peak flows, or surface erosion,. The number of causal mechanisms that linked channel effects to each of these processes is shown in Table 7.

Table 7. Processes linked to channel effects.

Causes of Channel Effects	**Number**	**Percent**
Mass Wasting	58	50%
Riparian Disturbance	32	27%
Peak Flows	12	10%
Surface Erosion	15	13%
TOTAL	117	100%

Approximately five out of every six causal mechanism reports identify either mass wasting or lack of LWD in the channel as a cause of a channel effect. Approximately one-half of all channel effects were due to mass wasting. Riparian disturbance made up approximately one-quarter of all channel effects. Almost 75% of the channel effects associated with riparian disturbance identified reduction of LWD resulting in loss of pools or sediment storage sites. Surface erosion and peak flows produced the remaining effects. Table 8 provides a detailed summary of channel effects compiled from the CMRs.

Table 8. Summary of channel effects identified in causal mechanism reports.

	Mass Wasting	Surf nee Erosion	Large Woody Debris	Shade	Peak Flows	Sub-Totals	% TOTAL
Scour	4	0	0	0	5	9	8%
Aggradation	9	0	0	0	2	11	9%
Degradation	I	0	0	0	0	1	
Interstitial Space	1	4	0	0	0	5	4%
Channel Roughness	0	0	0	0	0	0	0%
LWD	1	0	0	0	1	2	2%
Substtate Coarsening	0	0	0	0	0	0	0%
Substrate Fining	6	4	2	0	0	12	10%
Widening	2	0	I	0	0	3	2.5%
Narrowing	0	0	0	0	0	0	0%
Incision	**0**	**0**	**2**	**0**	**0**	**2**	**2%**
Braiding	6	0	0	0	0	6	5%
Migration	3	0	0	0	2	:5	4%
Sediment Storage	0	0	9	0	0	9	8%
LWD	0	0	0	0	0	0	0%
Pool Volume	15	I	0	0	0	16	14%
Pool Area	2	1	2	0	0	5	4%
Pool Frequency	1	0	2	0	0	3	2.5%
Pool (General)	7	5	9	0	0	21	18%
Bank Erosion	0	0	5	0	2	7	6%

Channel effects were put into two categories. Channel bed effects refer to changes to the channel substrate alone, while active channel effects typically refer to changes in channel morphology. The distribution of channel effect types in the CMRs is shown in Table 9.

Table 9. Types of channel effects related to mass wasting.

Channel Effect Type	Number	Percent
Channel bed	40	34%
Active channel	77	66%
TOTAL	117	100%

Active channel and channel bed effects due to mass wasting were dominant. Two out of three channel effects identified in CMRs were active channel effects such as loss of pools or channel widening. Pool effects seemed to dominate the CMRs, approximately 38% of all CMRs identify pool alteration as the major effect. Specific pool effects were due to mass wasting, riparian disturbance, surface erosion or peak flows.

Channel bed effects

Channel bed effects were less common than active channel effects. Major channel bed effects are shown in Table 10.

Table 10. Frequency of channel bed effects.

Channel Bed Effect	Number	Percent
Fining of substrate	12	31%
Increase in magnitude & frequency of scouring	9	24%
Increase in magnitude & frequency of aggradation	11	29%
Loss of interstitial space	5	14%
Degradation	1	1%
LWD	2	1%
TOTAL	40	100%

The fining of the channel bed accounted for one-third of all channel bed effects in the CMRs reviewed. Channel substrate fining and aggradation make up more than 60% of ail channel bed effects in the reviewed CMRs. Increase in scour magnitude and frequency accounted for approximately 24% of ail effects, while loss of interstitial space made up 13% of all effects. Coarse sediment input was the main cause of scour and aggradation, while fine sediment input was the primary cause of loss of interstitial space. Both coarse and fine sediment inputs were identified as playing a role in the fining of channel substrate.

Active channel effects

Active channel effects were the most common channel effects. Major active channel effects are shown in Table 11.

Table 11. Frequency of active channel effects.

Active Channel Effects	**Number**	TOTAL
Loss of pool volume, area, frequency, or general	45	58%
Channel widening	9	12%
Loss of sediment storage features	9	12%
Bank erosion	7	9%
Incision & Migration	7	9%
TOTAL	77	100%

Over half of the active channel effects identified were pool related. Loss of pool area or volume were identified more often than the loss of pool frequency. Channel widening and loss of sediment storage features such as LWD accounted for 22% of all effects. Although bank erosion was commonly discussed in resource assessment reports, it was identified as a channel effect less than 10% of the time in the CMRs.

Channel effects conclusions

A monitoring program that results from Watershed Anaiysis should include parameters **that** incorporate channel bed and active channel. Channel bed parameters to monitor include changes in channel substrate, channel morphology and interstitial gravel spaces. Active channel parameters to consider include changes in pool dimensions and frequency, channel morphology, and channel stored sediment.

Resource and Water Quality Effects

A resource effect is defined as change in the quantity or quality of salmonid habitat for a specific life stage, or a change in water quality. Changes in fish habitat and water quality in managed forests can occur because of natural and human-induced disturbance. Over 80% of resource effects identified were related to the spawning/incubation or summer rearing life stages. The overall distribution of resource effects is shown in Table 12.

Table 12. Frequency of resource effects by life stage.

Resource Effect	Number	Percent
Spawning/Incubation Habitat	61	42%
Rearing Habitat	58	40%
Winter Refuge Habitat	18	12%
Migration Habitat	1	1%
Water Supply	8	5%
TOTAL	146	100%

Many of the situation sentences in the CMRs did not provide enough information to identify specific resource effects. We categorized almost half of all effects as "general", merely identifying the life stage (e.g. rearing) without specific effects (e.g. reduction in pools, macro-invertebrate decrease, etc.). This points out that we may not truly know what the site-specific effects to fish habitat in a basin are, or that we have not taken the time to fully describe them in the CMRs and subsequently to the prescription team. This makes the task of developing a monitoring plan more difficult, because we have not identified potential variables to monitor. Specificity was greater for winter refuge and spawning/incubation habitat than for rearing, which may be due to a greater understanding of those life stages.

Water quality effects were infrequently identified in the WSA reviewed. All water quality effects were water supply related.

Table 13 provides a detailed summary of fish habitat and water quality effects compiled from the CMRs.

Table 13. Summary of resource effects identified in the causal mechanism reports.

	MW	SE	LWD	Shade	Peak Q	Sub-	%
General	18	0	1	0	10	29	20%
Sedimentation/entomb	12	0	0	0	0	12	8%
Redd scour	0	1	0	0	0	1	1%
Gravel decrease	0	10	9	0	0	19	13%
Redd de-watering	0	0	0	0	0	0	0%
General	26	0	7	0	0	33	23%
Temp increase	1	0	1	6	0	8	5%
Pool decrease	0	1	5	0	0	6	4%
Macro-invertebrate	0	0	4	0	0	4	3 %
Cover decline	0	0	1	6	0	7	5%
De-watered habitat	0	0	0	0	0	0	0%
General	0	0	5	0	0	5	3%
Pool refuge	0	0	1	0	0	1	1%
LWD	0	0	12	0	0	12	8%
Interstitial space loss	0	0	0	0	0	0	0%
Off-channel	0	0	0	0	0	0	0%
General	1	0	0	0	0	1	1%
Holding pool dec	0	0	0	0	0	0	0%
Passage	0	0	0	0	0	0	0%
Water Supply							
Turbidity	0	8	0	0	0	8	5%

*Spawning/incubation habitat **effects***

The frequency that major spawning/incubation effects were identified in the CMRs is shown in Table 14.

Table 14. Frequency of spawning/incubation effects.

Spawning/Incubation Habitat Effects	Number	Percent
General	29	48%
Spawning gravel availability	19	31%
Spawning gravel sedimentation/ redd entombment	12	20%
Redd scour	1	1%
Redd de-watering	0	0%
TOTAL	**61**	100%

Approximately 50% of spawning/incubation effects were general and the other 50% identified a decline in suitable spawning gravel or sedimentation/entombment. Although redd scour may play a critical role in terms of effects, the CMRs did not specifically identify it, even though it was often discussed in resource assessment reports and channel effects section of the CMRs.

Summer rearing habitat effects

The frequency that major summer rearing effects were identified in the CMRs is shown in Table 15. More than half of the summer rearing effects identified fell under the general category. Specific rearing habitat effects were not commonly identified. Cover and shade related impacts constituted more than 26% of all rearing effects. In the channel assessments, loss of pool frequency, volume, or area were identified as a common channel effect, however this was not put into the context of salmonid habitat as evidenced by only 12% of the CMRs identifying pool loss as a summer rearing effect.

Table 15. Frequency of summer rearing effects.

Summer Rearing Effects	Number	Percent
General	33	57%
Water temperature increase	8	14%
Decline in cover	7	12%
Pool decrease	6	10%
Macro-invertebrate decrease	4	7%
De-watered rearing habitat	0	0
TOTAL	58	100%

Winter refuge habitat effects

The frequency that major winter refuge habitat effects appeared in the CMRs is shown in Table 16.

Table 16. Frequency of winter refuge habitat effects.

Winter Refuge Habitat Effects	Number	Percent
General	5	28%
LWD decrease	12	67%
Pool refuge habitat decrease	1	5%
Interstitial space loss	0	0%
Off-channel habitat decrease	0	0%
TOTAL	18	100%

About 67% of all winter refuge habitat effects were LWD related. Loss of interstitial space was identified as a channel effect, but was not related to either a decrease in fish habitat quantity or quality. This may be due to the fact that salmonid use of interstitial spaces for winter refuge is not well documented in Washington State.

Migration habitat effects

The frequency that migration habitat effects were identified in the CMRs is shown in Table 17.

Migration Habitat Effects	Number	Percent
General	1	100%
Holding pool decrease	0	0%
Passage blockage	0	0%
TOTAL	1	100%

The only migration habitat effect identified was general. Fish passage is an issue that needs to be quantified in the fish habitat module, so it can be included as part of the CMRs, prescription, and possible restoration efforts in a basin.

***Water** quality effects*

Few water quality effects were identified in the causal mechanism reports we reviewed, reflecting the absence of a water quality module when these WSAs were done. The effect of turbidity on water supplies was the only issue specifically identified, however stream temperature increase was identified as a habitat effect. When there is a mass wasting and/or surface erosion hazard above reservoirs, the monitoring parameters selected must address the water quality issue as well as any fish habitat effects. We anticipate broader identification of **water** quality effects after the water quality module is incorporated in version 3.0 of the WSA manual. AMSC intends to work closely with the water quality module work group to identify water quality parameters and methods once the water quality module is completed.

***Resource/water** quality conclusions*

Most resource effects identified in the CMRs lacked specificity. This needs to be improved in order to better identify monitoring program objectives and context. Identifying specific habitat effect parameters from the CMRs we examined would often be difficult because the majority of habitat effects listed were too general. It is important to identify specific fish habitat effects and link them with channel effects and triggering mechanisms in the CMRs in order to provide an adequate hypothesis for developing an effective monitoring plan.

Causal Mechanism Summary

The majority of the causal mechanism reports (CMRs) from Watershed Analyses to date have similar process/response hypotheses. This is, in part, due to the situation sentence structure, as well as the emphasis on specific watershed processes such as mass wasting. The detail needed to develop a cost-effective and substantive monitoring program is found in the resource assessments and prescriptions. However, CMRs are a good "first cut" which help identify the most frequent, largest, and most common physical processes occurring in a basin.

Trigger mechanisms from some process, such as LWD recruitment and peak flows, were linked to only one or two causes. However, trigger mechanisms related to sediment, such as mass wasting and surface erosion, were more complex in their causes. Subtle changes in a landscape result in differences in the magnitude, frequency and distribution of sediment-related hazard units. This is not evident from the CMRs, but is evident through the resource assessment reports and can only be truly captured through rough sediment budgets. Resource assessment teams that did empirical sediment budgets had a better understanding (magnitude, spatial, and temporal) of hazard input and segment specific impacts that would result in clearer monitoring objectives. For example, fines from roads were identified as a key issue in one east-side Watershed Analysis. The assessment identified how fines from roads related to natural, or background, rates of fine sediment generation; where the impacts occur, and how long they may be felt. This type of effort is the basis for a monitoring program, because it establishes specific questions that can be quantified over time. A sediment budget also helps clarify routing issues, which are critical to synthesis, prescriptions, and can be the foundation for a monitoring program. Due to the lack of a routing module, the majority of Watershed Analyses tend to generalize the effects of the input factors to fish and fish habitat. The exceptions include those that completed a rough sediment budget. Quantitative routing also helped certain Watershed Analyses efforts because they identified specific monitoring needs during the synthesis and prescription phase of the analysis. This is an important exercise that future Watershed Analyses should consider.

Frequent CMR Hypotheses

We used the results generated from analysis of the causal mechanism reports and resource assessments to create example hypotheses (in situation sentence format) for the most frequently occurring triggering mechanisms, and the channel and resource effects potentially linked to them. These formed the basis for identifying the parameters and methods that will be in the greatest demand for WSA monitoring.

· Hypothesis 1. Debris flows in steeply incised inner gorge areas, triggered by a decrease in root strength or an increase in groundwater concentration in the harvest unit, or road failures due to an increase in surface-water concentration or sidecast failure, results in the delivery of coarse and fine sediment to the stream channel. Potential channel effects include local/zed pools filling, loss of pool area, an increase in the magnitude and frequency of aggradation, and the £ming of channel substrate. Potential fish habitat effects include spawning/incubation effects (more scour, de-watering, sedimentation and entombment of redds, loss of spawning gravel); summer rearing effects (temperature increase, de-watered habitat, reduced pool habitat and macro-invertebrate production), winter refuge effects (reduced in refuge pools, LWD, interstitial spaces) and migration effects (reduced holding pools, more blockages).

· Hypothesis 2. Debris flows and snow avalanches, triggered by increased sub-surface flow or concentration of surface flow, due to road construction and clear-cutting on steep slopes and hollows above headwater channels, results in the delivery of coarse and fine sediment to the stream channel. This results in channel effects such as widening, aggradation, pool filling, channel braiding, and possibly increased bedload transport rates. Potential fish habitat effects include spawning/incubation effects (more scour, de-watering, sedimentation and entombment of redds, loss of spawning gravel); summer rearing effects (temperature increase, de-watered habitat, reduction in pool habitat and macro-invertebrate production), winter refuge effects (reduced in pool refuge habitat, LWD cover and interstitial space), and migration effects (fewer holding pools, more passage blockages).

· Hypothesis 3. Increased movement of deep-seated landslides, triggered by changes in sub-surface water concentrations or drainage patterns associated with timber harvest or road construction, results in increased delivery of predominantly fine and some coarse sediment to the stream channel. (Lateral movement of the channel can independently trigger landslide movement by undercutting the toe). Increased sediment delivery alters channel morphology by reducing pool volume and fining the channel substrate in downstream segments, increasing turbidity and reducing the quality and quantity of rearing and spawning habitat. Potential fish habitat effects include spawning/incubation effects (more scour, sedimentation and entombment of redds, loss of spawning gravel), summer rearing effects (de-watered habitat, reduced pool habitat and macro-invertebrate production), winter refuge effects (reduced pool refuge habitat and interstitial space) and migration effects (reduced holding pools, blockages).

· Hypothesis 4. Surface erosion from soils exposed by roads (road surfaces, cutbanks and fill-slopes) or timber harvest activities (skid trails, yarding), where location and design allow delivery to the stream channel, causes accumulation of fine sediment in the stream channel. Potential fish habitat effects include spawning/incubation effects (more sedimentation and entombment of redds, reduced spawning gravel), summer rearing effects (reduced pool habitat and macro-invertebrate production), and winter refuge effects (reduction in pool refuge habitat and loss of interstitial spaces).

· Hypothesis 5. Timber harvest or road construction in the riparian zone reduces the amount and size of large woody debris (LWD) recruitment to the stream channel. This results in channel effects such as reduced bank stability, reduced stability of channel-step profile due to the lack of log jams, loss of sediment storage features and associated gravel deposits, increased bedload transport and scour, and a decrease in the amount and size of pools. Potential habitat effects include spawning/incubation effects (more scour, reduced spawning gravel), summer rearing effects (reduced pool habitat and cover), winter refuge effects (less pool refuge habitat and LWD cover) and migration effects (fewer holding pools).

· Hypothesis 6. Timber harvest or road construction in the riparian zone reduces overhead canopy cover, resulting in an increase in solar energy reaching the stream channel. Potential summer rearing habitat effects include increased summer temperatures and reduced overhead/instream cover.

· Hypothesis 7. Clear-cut harvest of timber stands at elevations where rain-on-snow events occur, increases peak flows during rain-on-snow events. Channel effects potentially include changes in channel morphology such as increased magnitude and frequency of bed scour, bank erosion, and lateral channel migration. Potential habitat effects include spawning/incubation effects (more redd scour, reduced spawning gravel), summer rearing effects (reduced pool habitat, macro-invertebrate production and instream cover), winter refuge effects (reduced pool refuge habitat and LWD cover) and migration effects (fewer holding pools).

These WSA hypotheses are listed in Table 18. We used these hypotheses to develop the list of potential monitoring parameters discussed in more detail in the following section.

Table 18. Process/response hypotheses generated from WSA.

Debris flows in steeply inched inner gorge areas	Root strength decline Ground-water concentration in areas where topography converges Sidecast failure	Timber harvest Roads Natural (back-ground rate)	Coarse sediment (more over time) Fine sediment (more initially)	Loss of pool area Aggradation Substrate fining	Spawinng/incubation (more redd scour, de-watering, sedimentation/entomb-meat, spawning gravel loss) Summer rearing (temp increase, de-watered habitat, reduced macro-invert, reduced pool habitat) Winter Refuge (reduced pool, interstitial, LWD refuge) Migration (reduced holding pools, blockages)
Debris flows and snow avalanches in zero-order basins	Ground-water increase Concentration of surface water Sidecast failure	Timber harvest (leas0 Roads (more) Natural (mos0	Coarse sediment Fine sediment	Channel widening Aggradation Loss of pool area Channel braiding Bedload transport rate	same as for debris flows (above)
Deep-seated landslides associated with weak underlying material & interrupted drainage	Alteration of ground-water concentrations or sub-surface flow patterns Under- cutting of toe by stream due to aggradation and widening	Timber harvest in ground-water recharge areas Road construction or above landslide Channel widening and lateral migration	Fine sediment Coarse sediment	Loss of pool volume Fining of channel substrate	Spawn/Inc (redd scour, sedimentation and entombment, reduced spawning gravel) Summer Rearing (reduced pools and macro-invertebrates) Winter refuge (reduced pools and interstitial spaces)

Table 18 (cont.). Process/response hypotheses generated from WSA.

Process	**Trigger** Mechanism	Cause	Inputs	Channel Effects	Habitat **Effects**
Surface erosion	Runoff over bare and exposed soils such as road prisms, cutbanks, fill-slpoes and ground disturbed during logging	Construction, maintenance and use of roads and landings Exposure and compaction of soils during skidding or yarding	Fine sediment	Channel substrate fining Loss of pool volume	Spawning/incubation (sedimentation and entombment of redds, reduced spawning grovel) Summer rearing (reduced pools, macro-invertebrates) Winter refuge (reduced pool refuge, interstitial spaces)
LWD recruitment	Reduction in number and size, or change in composition of riparian stands)	Timber harvest Road construction	LWD	Bank stability decrease Channel-step reduction Reduced sediment storage Increased scour Increased bedload transport Loss of pool frequency and volume	Spawning/Incubation (redd scour, reduced spawning gravel) Summer rearing (reduced pools, cover) Winter refuge (reduced pool refuge and LWD cover) Migration (reduced holding pools)
Increased solar radiation to stream	Reduced riparian canopy cover	Timber harvest Road construction	Solar energy (heat)		Summer rearing habitat 0ncreased summer temps,reduced overhead/ instream cover)
Peak flows runoff	Rain-on-snow runoff events	Timber harvest in rain-on-mow zone	Water	Increase in bed scour Increased bank erosion rates Ira:reused lateral channel migration Reduction in LWD	Spawning/Incubation (redd scour, reduced spawning gravel) Summer rearing (reduced pools, instream cover, macro-invertebrates) Winter refuge (reduced pool refuge, LWD) Migration (reduced holding pools)

Monitoring Parameters and Methods for Watershed Analysis

In this section we discuss potential monitoring parameters for the input triggering mechanisms, channel effects and resource effects that were (or should have been) identified in the causal mechanism reports we examined. For each parameter we discuss: 1) how frequently it was identified; 2) if there are existing methods; and 3) a recommended approach to develop a method suitable for Watershed Analysis Monitoring.

Triggering Mechanism Parameters and Methods

Mass Wasting

In-harvest unit failures were often identified in mass wasting CMRs. Approximately 94% in-harvest unit CMRs identify root strength and groundwater concentration as a primary mechanism. Current TFW Ambient Monitoring methods do not document mass wasting and the trigger mechanisms associated with it. A variety of analyses and methods have been developed to document and analyze mass wasting on the watershed and single landslide scale (Gray and Megahan, 1981; Selby, 1982; Sidle, 1985; Sidle and Swanston, 1982; Benda and Cundy, 1990; Watershed Analysis Mass Wasting Module [WFPB, 1993b]). Mass wasting can be monitored remotely, using aerial photos to develop landslide inventories and erosion maps. More intensive, site-specific techniques exist for shallow-rapid landslides, such as a sensitivity analysis (Gray & Megahan, 1981), factor of safety analysis (Sidle, 1985), and shallow sub-surface flow analysis (Wilson and Dietrich, 1987) are also used. Additional work is needed to develop methods to monitor deep-seated landslides (Communication with Dan Miller, 1994).

· Iterative Landslide Inventory. A good starting point for monitoring mass wasting is to conduct an annual or biennial landslide inventory using the methods identified in the Watershed Analysis Mass Wasting Manual (WFPB, 1993b). The landslide inventory can be compared to the erosion map created during the Watershed Analysis mass wasting assessment to identify if landslide frequency or distribution has changed over time. Climatic conditions (extreme precipitation events) and management activities need to taken into account when interpreting mass wasting monitoring information over time. The cost for doing the inventory include aerial photographs and labor. Actual hours to do the inventory will be a function of the size of the basin, the geomorphic complexity of the watershed, aerial photo quality, and the amount of field time needed to ground truth new failures. We predict high demand for this monitoring parameter because of the high frequency it occurred in the CMRs and the overall of mass wasting as a sediment source in forested mountain drainage basins in the Pacific Northwest.

· Slope Stability Analysis. More intensive mass wasting monitoring may be needed, depending on the results of interactive landslide inventories. For mapping units where prescriptions are not reducing landslide frequency, slope stability analysis on a site-specific scale can be used to develop a more fundamental understanding of the factors that lead to hill-slope instability and subsequent slope failure. Using this approach, it is possible to identify and monitor the primary variables influencing slope stability.

Variables that influence stability include hill-slope gradient, the material strength of rock and soils, water, and vegetation. Cohesive and frictional forces are the main properties that contribute to the material strength of rock and soil. There are two types of cohesion, effective and apparent. Effective cohesion is due to the chemical bonding of rock and soil particles (Selby, 1982). Apparent cohesion includes the surface tension of clay particles, rock and soil particle size and "packaging," and the tensile strength of roots. Apparent cohesion plays an important role in forest lands.

Tree roots enhance slope stability because they are a primary source of apparent cohesion in forested areas (Gray and Megahan, 1981; Sidle and Swanston, 1982). Burroughs and Thomas (1977) found that fine roots (less than lcm) along the "lateral edges of the root mass and across the bottom of the root systems" are the most effective in increasing slope stability. The root mass acts as a "reinforcement network" in the soil (Burroughs and Thomas, 1977). Apparent cohesion from trees roots is a major factor determining the stability of thin soils on steep, forested hillslopes in coastal Alaska (Sidle and Swanston, 1982). Approximately 75% of fine lateral Douglas fir *(Psuedotsuga menziesii)* roots can be lost within 24 months after harvest (Burroughs and Thomas, 1977). This can translate into a reduction in tensile strength of up to 86% (Burroughs and Thomas, 1977). The result can be a large increase in mass wasting frequency within the first three years after harvest.

Internal angle of friction is an important variable in determining hill-slope stability. Where cohesion is zero, the friction of rock and soil may be the only stable force acting upon a hill-slope. Angle of internal friction is based upon the grain attributes of the rock or soil and how resistant they are to sliding. This is primarily a function of the volume of voids and particle size in the soil (Selby, 1982). As void space in a soil decreases, the angle of internal friction will increase. It is important to note that angle of internal friction also depends on the type of rock and soil, and decreases with an increasing amount of clay in the soil. Soil depth is a factor in determining hillslope stability only when the soil exhibits either effective or apparent cohesiveness. As soil depth increases, the angle of internal friction will increase. With increasing soil depth, you normally also get a decrease in pore space and permeability due to a decrease in bio-perturbation (e.g. tree rooting, mixing due to animals, a decrease inorganics) and an increase in solids (e.g. bedrock).

Soil saturation is a very important determinant of slope stability in forested areas because an increase in water content tends to increase pore-water pressure and increase the amount of soil saturation. High antecedent soil moisture conditions can contribute to landslide initiation during a normal storm event because of elevated pore-pressure. Sidle and Swanston (1982) found that small debris slides in coastal Alaska forests were due to the combination antecedent soil conditions, the distribution of rainfall, and maximum short-term intensity; not total storm quantity.

· Deep-seated landslides. Additional research is needed to help understand the effects of land-use on deep-seated landslides and to develop monitoring methods (Communication with Dan Miller, 1994). Potential monitoring parameters include water input into the groundwater recharge area, movement of the slide block, and pore pressure (Communication with Dan Miller, 1994).

· Road Assessment Procedure. Roads were commonly identified as a mass wasting triggering mechanism. Current TFW Ambient Monitoring methods do not document road-related failures. A variety of triggering mechanisms, such as water concentration, sidecast failure, ground disturbance and culvert blockage are relatively well distributed in the CMRs, which means an multi-faceted method would be useful to assess and monitor road-related triggering mechanisms. Road surveys have be done for many years (Beschta and others, 1993; Zander, 1993). Recently, a standard, repeatable, risk-based road assessment procedure (RAP) has been developed in Washington State (Kennard, 1994). This method appears promising for use in Watershed Analysis monitoring.

RAP uses a series of office and field screens, based on landscape and land use factors, to quickly identify low hazard road segments. Additional efforts are then focused on assessing high hazard areas, predicting landslide run outs, and ranking risks to off-site resources (Kennard, 1994). RAP examines all aspects of road failures, incorporating information from past mass wasting research (e.g. Reid, 1981; Benda and Cundy, 1990; Coho and Burges, 1993; Montgomery, 1993; and Zeimer, 1981). RAP can be modified to include surface erosion to produce a complete road assessment, and could be expanded to include other concerns such as fish passage at road culverts and bridges.

Although the accuracy and repeatability of the method have not been rigorously tested, it is being used in the Tolt and other basins in 1994. Another, related approach to monitoring road-related mass wasting and sediment production is the methodologies developed for the TFW sediment BMP study (Rashin et al., 1993). This study has developed, among other things, a survey methodology to document culvert condition and blockage that could be modified to cover a greater length of road.

Development of a road-related mass wasting monitoring methodology is a priority based on the high frequency of occurrence in the CMRs, and it appears an adequate method could be developed by combining aspects of existing methods.

Riparian Vegetation (LWD recruitment and solar radiation)

Parameters and methods for monitoring of LWD recruitment and canopy closure are discussed together here because in both cases the triggering mechanisms are the same, timber harvest or road construction in riparian areas.

· Aerial photo survey of riparian vegetation. The level 1 aerial photo assessment described in the Watershed Analysis Riparian Module (WFPB, 1993b) is suitable as an initial, low-intensity monitoring method for triggering mechanisms associated with LWD recruitment and solar radiation input. This method provides quick basin-wide monitoring of the status of streamside vegetation. It adequately identifies areas where riparian vegetation has been disturbed, and can be used to track gross changes in riparian stand age, density composition and canopy closure over the stream. In situations where more detailed site-specific monitoring of changes in canopy closure is needed, the TFW Ambient Monitoring Stream Temperature Survey provides methods for collecting data on average canopy closure and stream temperatures for stream segments.

· LWD recruitment. There is likely to be a limited need for a more detailed and quantitative site-specific method to monitor LWD recruitment from specific riparian stands. Such a method would involve collection of data on the characteristics of riparian stands and physical site conditions affecting LWD recruitment rates, and could include measurement of LWD recruitment over time. Methods from several recent studies might prove adaptable to an intensive WSA LWD recruitment monitoring method.

Peak Flow Hydrology

· R-O-S vegetative class. Timber harvest in the rain-on-snow zone was the only triggering mechanism identified in the CMRs for changes in peak flow hydrology. Aerial photo assessment of stand age, described in the Watershed Analysis Hydrology Module (WFPB, 1993b), provides a low-intensity monitoring method for this triggering mechanism.

· Site-specific peak flow monitoring. Intensive site-specific monitoring methods would require extensive testing and development, and may require additional basic research since many questions regarding the effects of forest practices on peak flow hydrology remain. Potential site-specific methods to assess rain-on-snow runoff could include measurement of precipitation and snow melt rates from intensive monitoring plots, collecting discharge data from small un-gaged streams or assessing channel disturbance associated with peak flows. We are unsure how much demand will exist for intensive methods to monitoring changes in peak flow hydrology.

Surface Erosion

· Surface Erosion Survey. Surface erosion was often identified as a triggering mechanism for fine sediment production and linked with channel and fish habitat effects. Current TFW Ambient Monitoring Methods do not document erosion of fine sediment from hill-slopes and roads.

A method for initial monitoring of surface erosion should identify potential problem areas relatively quickly and efficiently, because potential surface erosion sites are often widespread and dispersed. The cutbank/filslope survey method developed by Rashin et al. (1993) uses photo documentation coupled with observation of gullying, cutbank, sidecast, and ditches. It could potentially be adapted to harvest units to provide a basic surface erosion monitoring method. Annual evaluation of surface erosion could test hypotheses generated in the Watershed Analysis are valid and help identify which prescriptions are working.

· Fine sediment delivery. Once the location of sites producing large amounts of surface erosion is known, more intensive monitoring such as event-based measurement of suspended sediment concentration and/or turbidity above and below source areas could be used to quantify erosion rates over time. Sampling location, intensity, and timing need consideration prior to starting such a monitoring effort.

Channel Effects Parameters and Methods

Monitoring channel effects can be done either through re-sampling of permanent reference reaches (as described in the TFW Ambient Monitoring Reference Point survey) or non-permanent random reaches (Communication with Ed Salminen, 1994). Permanent reference reaches have the advantage that any changes seen in the channel conditions will be due to either actual changes or measurement error (Communication with Ed Salminen, 1994). Changes in randomly selected reaches may also be due to variability in channel conditions within a reach (Communication with Ed Salminen, 1994) associated with factors such as geology, gradient, and sediment supply v. transport capacity. Permanent reference points stratified by variables such as geology, gradient, confinement, entrenchment (floodplain development), and sediment supply v. transport capacity provide a more robust understanding of the spatial and temporal variability in channel response to input factors. This approach has resulted in an exceptional understanding of physical and biological processes at Redwood National Park (RNP) in northern California, where monitoring has developed information used in management, research and restoration efforts for over twenty years.

A single variable will probably not suffice for a channel effects component to any monitoring program. MacDonald et al. (1991) note that "a combination of several channel parameters may be the best approach to evaluate and understand observed changes in the stream channel."

Channel Bed Effects

· Fine sediment accumulation and interstitial gravel space. Parameters and methods to monitor fmc sediment accumulation in spawning gravel and interstitial gravel space are discussed under spawning gravel sedimentation and redd entombment, and interstitial space habitat, respectively, in section on resource effects parameters and methods.

· Substrate scour. Parameters and methods to monitor substrate scour are discussed under spawning gravel scour in the section on resource effects parameters and methods.

· Channel substrate size (fining or coarsening). Fining of the substrate was the most frequently identified channel bed effect. TFW Ambient Monitoring methods currently document changes in substrate using the McNeil sampling method, however they do not include methods to collect data suitable for geomorphic analyses such as the ratio between surface and subsurface bed particle size. Additional techniques to document changes in channel substrate are described in the Watershed Analysis Stream Channel Assessment Module (WFPB, 1993b). Parameters and methods that would be useful for monitoring purposes include bed particle distribution analysis surveys using pebble counts, the Q* method for documenting the relationship between sediment supply and transport capacity, and the V* method for documenting pool filling with fine sediment.

Channel substrate monitoring should be done in the same places where initial samples were taken for Watershed Analysis, if that data is to be used as a baseline. Data should be stratified by stream segments and geomorphic units, at a minimum. It is also important that sediment sampling using pebble counts or bulk sediment samples be done in the same places, or same types of places within a channel. Permanent sampling points coupled with reference points, as identified in the TFW Ambient Monitoring Reference Point Survey, would help increase consistency and repeatability.

The priority for developing methods to document changes in the channel substrate is high, based on high demand and ready availability of methods.

· Channel aggradation or degradation. Channel bed aggradation was frequently documented as an effect in CMRs. The TFW Ambient Monitoring methods does not currently document channel aggradation and degradation. However, the Ambient Monitoring Reference Point Survey lays out a systematic sampling network that can be modified to incorporate channel cross-sections and thalweg profiles. Numerous sources discuss the use of cross-section and longitudinal profile data (MacDonald et al., 1991; Platts et al., 1983; Dunne and Leopold, 1978). Cross-sections, combined with thalweg profiles allow for evaluation of channel erosion and deposition rates, as well as bank erosion rates. Such information is also useful to evaluate sediment transport rates over time. Cross-sections should be concentrated in segments where the channel assessment predicts a response to a change in input factors.

Other sources of information on hydraulic geometry can help document channel aggradation and degradation. The United States Geologic Survey (USGS) collects cross-section data while periodically calibrating the rating curves at gaging stations. Data is recorded on a form called 9-207. A change in a rating curve can mean there has been a change in the channel cross-section, which could be due to channel aggradation or degradation. Cross-sections at gaging stations can provide valuable monitoring information, however it is important to find out if the cross-section has been moved or if there have been channel changes prior to using the information.

Active Channel Effects

· Channel widening, braiding, lateral migration and bank erosion. Large-scale changes in channel morphology and sinuosity were identified approximately in one-fifth of all CMRs. There is currently no TFW Ambient Monitoring method to document such changes.

An low intensity office approach can be used to initially document large scale-changes **in** channel dimensions. Aerial photographs can be used to document changes in sinuosity (channel length v. valley length), lateral migration rates, bank erosion and gravel bar area (Collins, 1994).

If large-scale changes are observed during initial aerial photo monitoring, then more intensive field methods can be used to document site-specific changes. Field surveys can be used to collect more accurate data on changes in channel dimensions, as well as site-specific information factors such as bank erosion and changes in channel-stored sediment using a variety of methods such as erosion pins, radial cross-sections around meander bends and photo-points (Dunne and Leopold, 1978; Buer et al., 1989; MacDonald et al., 1991; Rosgen, 1993; Collins, 1994; Communication with Ed Rashin, 1994).

Monitoring large scale channel-changes is given a high priority, even though the frequency of occurrence is relatively low in the CMRs. Examination of aerial photographs is an easy, low cost first step, if photos are available. Site specific methods need to have better linkage with fish habitat effects.

· Loss of sediment storage features. Loss of sediment storage features was identified in 10% of all CMRs reviewed as a channel effect. Sediment storage features such as logs, roots, rocks, stumps, and other debris are critical to sediment transport and channel stability. A method to inventory sediment accumulations behind natural obstructions was devised by Megahan et al. (1983). This method appears suitable for use in WSA monitoring.

This parameter is rated as a high priority because a method has already been developed. There is a need to develop a way to link the method to fish habitat features (e.g. spawning area, side channels, and holding pools), in order to gain a better understanding of the role of obstructions in creating fish habitat.

· Pool volume, area, frequency, or general,. Over half of the active channel effects identified were related to changes in pool volume, area, or frequency. The TFW Ambient Monitoring Habitat Unit Survey contains a methodology to measure pool length, width, residual pool depth and pool forming factors (e.g. LWD, debris jams, rootwads, boulders, bedrock, beaver dams, etc). This survey can be used to determine if there has been segment-scale change in pool area or depth over time. In addition, the diameter of obstructions can also be measured in order to determine the size of obstructions needed to create pools of specific depth or size. Monitoring of pool frequency and dimensions are given a high priority because it was mentioned frequently in the CMRs and there already is a method available to gather data.

Resource Effects Parameters and Methods

Spawning/Incubation Habitat

· Spawning gravel scour. Scour was frequently associated with mass wasting and changes in peak flow hydrology in WSA, although it was usually identified as a channel effect rather than a habitat effect in causal mechanism reports (CMRs). Current TFW Ambient Monitoring methods do not document scour. A variety of methods have been developed to monitor scour (Tripp and Poulin, 1986; Lisle and Eads, 1991; Nawa and Frissel, 1993). These methods involve insertion of scour monitoring devices into the gravel along cross-sections or at redd locations. Changes in bed elevations are typically documented with surveying techniques at the same locations to augment scour data. The techniques for measuring scour and fill are readily available and would be easily adaptable to WSA. Additional work is needed to develop: 1) a statistically sound methodology for selecting sites; 2) a method to determine the magnitude and recurrence interval of peak discharge events in un-gaged streams (scour depth typically increases with the magnitude of peak discharges); and 3) interpretational tools to differentiate management-induced alterations in scour depth or pattern from natural scour regimes.

· Redd de-watering. Redd de-watering was not a commonly identified effect in the CMRs. Current TFW Ambient Monitoring methods do not document redd de-watering. Development of a methodology to document redd locations and monitor de-watering due to movement of the channel should not be difficult. Redd locations can be documented with surveying techniques and can be relocated at intervals during the incubation period to document factors such as channel change or deposition that would cause redds to de-water. Incorporation of redd de-watering into a scour module would be relatively easy.

· Spawning gravel sedimentation and redd entombment. This was a frequently identified situation in WSA causal mechanism reports. The TFW Ambient Monitoring Salmonid Spawning Gravel Composition Module documents the overall composition of spawning gravel and the fine sediment levels (<0.85mm) on a stream segment scale. Although more intensive methods are available (such as intra-gravel dissolved oxygen, gravel bed permeability or fry emergence) they do not appear to be justified for WSA monitoring at this time. Spawning gravel frae sediment appears to be an adequate indicator of spawning gravel sedimentation for WSA, and the interpretation and management response for fine sediment data is provided by the WSA Fish Habitat Module.

· Spawning gravel availability. Reduction in suitable spawning gravel was a frequently identified effect in WSA. Current TFW Ambient Monitoring methods do not document changes in the availability of spawning gravel. The TFW Ambient Monitoring Habitat Unit Survey can be used to identify habitat units that provide potential salmonid spawning habitat (riffles and pool tailouts), however this is during the summer low flow period. Reeves et al., (1989) recommend collecting data on spawning gravel availability using a separate survey during the spawning season. Additional work would be needed to develop a method to characterize and document substrate suitability in potential spawning habitats. Spawning habitat preferences are species-specific, however use of a generic large salmonid substrate criteria appears to be suitable for monitoring to support a level 1 fish habitat analysis, while criteria for a particular species could be used to support a level 2 analysis. Total spawning area (at the survey discharge) and the percentage of total surface area with suitable spawning substrate could be calculated. Another approach for addressing spawning grovel availability would be to combine it with the Spawning Gravel Composition Module, which requires a foot survey of potential spawning locations throughout the segment during the sampling site selection process. For example, failure to find a minimum number of sampling sites with suitably-sized gravel could be used as an indicator of the lack of suitable spawning gravel.

Summer Rearing Habitat

· Water temperature. Increase in water temperature was a frequently identified effect in CMRs. The TFW Ambient Monitoring Stream Temperature method is designed to document summer stream temperatures and related factors such as canopy closure, elevation, and wetted area. This methodology should be adequate to meet WSA monitoring needs. In cases where stream temperature problems have been documented due to removal or disturbance of streamside vegetation, use of canopy closure measurements, or possibly even aerial photo interpretation of riparian vegetation, could be used to monitor recovery over a period of years, augmented with periodic collection of stream temperature data.

· De-watered habitat (sub-surface flow). This was not identified as an effect in any of the CMRs reviewed, however this condition does occur in rapidly aggrading reaches and should occasionally be identified in mass wasting causal mechanisms. The TFW Ambient Monitoring Habitat Unit Survey currently documents the length of primary channel dry due to subsurface flow. This method should be adequate to initially identify reaches with de-watered habitat. A more intensive follow-up method is needed to determine the cause of the de-watered condition observed (see discussion of channel aggradation in previous section on Channel Bed Effects).

· Macro-invertebrate production. Reduction in macro-invertebrate production was infrequently identified as an effect in CMRs. This parameter was usually associated with reduction in LWD and not with fine sediment accumulation. Macro-invertebrate production should be more frequently identified as a parameter in CMRs once the Water Quality Module is completed. Current TFW Ambient Monitoring methods do not document changes in macro-invertebrate production, however a TFW methodology that includes sampling methods and interpretive tools has been developed for the Water Quality Steering Committee (Plotnikoff, 1992). Testing of these methods for use in the water quality assessment module is underway. If successful, it is likely that Plotnikoff's method will form the basis for a WSA monitoring methodology. Further development of the macro-invertebrate monitoring method needs to be closely coordinated with the WSA Water Quality Module.

· Pool rearing habitat. Reduction in pool rearing habitat was identified with moderate frequency as a habitat effect in the CMRs, however pool loss was frequently identified as a channel effect. This indicates inconsistent follow-through from channel to habitat effects in the WSAs reviewed. The TFW Ambient Monitoring Habitat Unit Survey is currently used to document rearing pool habitat during summer low-flow conditions. Pool surface area, pool habitat as a percentage of total surface area, and maximum and residual pool depth are calculated. This method is adequate to meet WSA monitoring needs, with the addition of a cover component (see next item, below).

· Overhead/instream cover. Decrease in overhead and instream cover was identified as a habitat effect with moderate frequency in the CMRs. The TFW Ambient Monitoring LWD Survey documents LWD within the bankfull channel. A method that evaluates overhead and instream cover in addition to LWD is needed. Most existing methods of evaluating cover are qualitative rather than quantitative. Platts et al. (1983) describe methods for measuring instream cover and cover from overhanging banks and vegetation along transects, however observers had difficulty consistently defining what constituted adequate cover for young-of-the-year salmonids.

Winter Refuge Habitat

· Pool refuge habitat. Lack of pool winter refuge habitat was infrequently identified as a habitat effect in the CMRs, however loss of pools was frequently identified as a channel effect. The TFW Ambient Monitoring Habitat Unit Survey is not designed to document habitat availability during winter flows. Selective winter use of instream habitats with low velocities and low turbulence such as alcove pools, dammed pools and beaver pools was observed in coastal Oregon (Nickelson et al., 1992a). Because there is a seasonal shift in habitat preference and a seasonal change in flow-related habitat conditions, summer habitat data does not predict winter habitat use. A separate habitat survey conducted during winter base-flow conditions is necessary to assess winter refuge habitat (Nickelson et al., 1992a). This survey could also be combined with a spawning habitat inventory.

· Interstitial space refuge habitat. Loss of interstitial refuge habitat (hiding areas for young fish in the spaces between larger substrate particles) was not identified as a habitat effect in any CMRs, however loss of interstitial spaces was identified as with moderate frequency as a channel effect. TFW Ambient Monitoring methods do not currently document interstitial refuge habitat. Extensive work has been done in other states such as Idaho on development of methods to measure the effects of sedimentation on interstitial space. Little information is available on the importance of interstitial habitat for over-wintering salmonids in Washington State, however it is more likely to be important in areas with snowmelt-dominated hydrology such as eastern Washington rather than in coastal rainfall-dominated areas. Peterson et al. (1992) recommend sampling on transects using the interstitial space index (ISI) method.

· LWD accumulations. Winter coho abundance is greatest in low velocity habitats with abundant cover from woody debris (Nickelson et al., 1992b; Reeves et al., 1989). This appears to be due to the reduction in turbulence and overhead cover LWD accumulations can provide. LWD was frequently identified as a habitat and channel effect in the CMRs. The TFW Ambient Monitoring LWD survey documents abundance and volume of in-channel LWD and large logjams. Although this method does not specifically identify LWD that functions as refuge habitat during winter high flows, surveys that measure LWD abundance and volume should be adequate to identify cumulative effects from forest practices (Peterson et al., 1992). Documentation of LWD associated with winter pool habitat (above) would provide more detailed information.

· Off-channel refuge habitat. Loss of off-channel rearing habitat was not identified as a habitat effect in the CMRs. We are not sure if this is because of lack of resolution in the habitat module to identify off-channel rearing habitat impacts, or because the analysts do not believe they occur. Coho make heavy use of off-channel habitats such as wall-based channels and riverine ponds during the winter in coastal Washington (Peterson and Reid, 1984). The TFW Ambient Monitoring Habitat Unit survey documents habitat in side-channels at summer low flow, however summer surveys do not adequately assess winter habitat conditions. A methodology for documenting wall-based channels, spring-fed ponds, wetlands and other off-channel refuge habitat needs to be developed.

Migration Habitat

· Adult holding pools. Loss of adult holding pools was not identified as a habitat effect in the CMRs, however loss of pools was a frequently identified channel effect. The TFW Ambient Monitoring Habitat Unit survey documents pool habitat at low flow conditions. It is adequate to identify pool surface area, maximum water depth and residual pool depth during the summer/early fall period critical for species where adults hold for extended periods in freshwater prior to spawning such as spring chinook and summer steelhead. To characterize suitability for adult holding, addition of temperature and cover parameters would be useful.

· Passage blockage. Blockage of fish passage was not identified as a habitat effect in any of the CMRs identified. It appears that the Fish Habitat Module does not adequately address this issue. The TFW Ambient Monitoring methods do not formally document passage blockages, although this information is often recorded in the field notes. Determining if a barrier is impassable is sometime difficult. This issue needs more work in both the Fish Habitat Module and the Monitoring Module.

Water Quality

Water quality parameters and methods are not presented because to do so, prior to development of the Water Quality Module, was deemed premature. Some fish habitat parameters, such as stream temperature and macro-invertebrate production, partially address water quality issues, however as fish habitat parameters they would only be applied to fish-bearing waters. Once the Water Quality Module is completed, identification of the parameters and methods needed to monitor potential water quality effects will be more straight-forward.

Priorities for development of monitoring methods

In order to help prioritize development of the WSA monitoring methods discussed above, we have sorted potential methods into categories based on the estimated work needed to finalize the method for use in Watershed Analysis Monitoring and estimated future demand. The categories are defined as follows:

- Complete methods (ready for use in Watershed Analysis),
- Category I methods (high demand/low-moderate work),
- Category 2 methods (high demand/extensive work),
- Category 3 methods (low demand/low-moderate work),
- Category 4 methods (low demand/extensive work).

The following list shows the category each potential Watershed Analysis monitoring parameters was placed in.

Triggering mechanisms

- Aerial photo landslide inventory- Complete
- Slope stability analysis- Category 1
- Deep-seated landslides- Category 2
- Road assessment procedure- Category 1
- Surface erosion survey- Category 1
- Fine sediment delivery- Category 2
- Aerial photo survey of riparian vegetation- Complete
- LWD recruitment- Category 3
- Aerial photo survey of R-O-S zone vegetation- Complete
- Site-specific peak flow runoff monitoring- Category 2

Channel effects

- Channel substrate size (fining or coarsening)- Category 1
- Channel aggradation or degradation- Category 1
- Channel widening, braiding, lateral migration and bank erosion
  - Aerial photo method- Category 1
  - Field methods- Category 2
- Sediment storage features- Category 1

Fish habitat effects

- Spawning gravel scour- Category 2
- Redd de-watering- Category 3
- Spawning gravel sedimentation and redd entombment- Complete
- Spawning gravel availability- Category 1 (94-95)
- Water temperature- Complete
- De-watered habitat (sub-surface flow)- Complete
- Macro-invertebrates- Category 1 (if WSA test of Plotnikoff method is successful) (94-95)
- Pool rearing habitat- Complete

Overhead/instream cover- Category 3
Pool refuge habitat- Category 2 (94-95)
Interstitial refuge habitat- Category 4
LWD refuge cover- Category 2 (94-95)
Off-channel refuge habitat- Category 3
Adult holding pools- Category 3
Passage blockage- Category 3

Priority Methods for Development

The list in Table 19 represents our best estimate of the WSA monitoring tools that are needed to support the current assessment. Development of the complete list will be a multi-year task because of many methods needed. We recommend incorporating the complete methods into the WSA Monitoring Program, initiating work on the high demand (Category 1 and 2) parameters in the next year, deferring work on the low demand parameters (Categories 3 and 4) and re-assessing priorities in a year.

The list of parameters with completed methodologies now available as standard WSA monitoring methods include:

Aerial photo landslide inventory
Aerial photo survey of riparian vegetation
Aerial photo survey of R-O-S zone vegetation
Spawning gravel sedimentation and redd entombment
Water temperature
De-waterod habitat (sub-surface flow)
Pool rearing habitat

Within the next year we should be able to develop standard methods for the Category 1 parameters (high demand/low-moderate work):

Slope stability analysis
Road assessment procedure
Surface erosion survey
Channel substrate size (fining or coarsening)
Channel aggradation or degradation
Channel widening, braiding, lateral migration and bank erosion (aerial photo method)
Sediment storage features
Spawning gravel availability
Macro-invertebrates

Also within the first year we should initiate work on the following Category 2 parameters (high demand/extensive work):

Deep-seated landslides
Fine sediment delivery
Site-specific peak flow runoff monitoring
Channel widening, braiding, lateral migration and bank erosion (field methods)
Spawning gravel scour
Pool refuge habitat
LWD accumulations (refuge cover)

Suggested Structure for the WSA Monitoring Module

Implementation of a Watershed Analysis Monitoring Program in Washington State will be a challenging but workable task. The task is complex because of the large numbers of unique watersheds across the state that will have WSA and the large number of organizations and people who will potentially be involved in monitoring. The challenge is to accomplish the thorough planning, careful design and consistent implementation necessary to make WSA monitoring successful.

The WSA Monitoring Module we are proposing is based on some basic principles that give it unique characteristics. WSA monitoring will require a watershed-based approach. The scope potentially includes monitoring the effect of prescriptions on triggering mechanisms and input processes, and monitoring the response of stream channel, fish habitat and water quality conditions. Monitoring plans will be developed and implemented at the local WAU level and cooperative monitoring efforts will be encouraged. Monitoring parameters will reflect local conditions, processes and resources. They will be selected based on information in the WSA causal mechanism, resource assessment and prescription reports as well as segment-specific TMDL parameters (where applicable). Quality assurance plans will be required for sampling and data processing. Standard methods will be developed and used, and statewide training, quality assurance and database support will be provided to assist local teams to insure statewide consistency. Data will be shared among WAU-stakeholders and TFW participants and meaningful feedback loops established to use monitoring data in the evaluation and revision of Watershed Analyses.

Two key elements are necessary to create a functional monitoring component for WSA. First, monitoring must be planned and implemented at the WAU level by members of the assessment team and stakeholders in the watershed. The people and organizations involved, and their background and skills, will vary in each WAU. In order to ensure that monitoring products are consistent and useful, a standard methodology must be developed and documented. The methodology should provide guidance in preparing and implementing of WAU-specific monitoring plans. Development of a monitoring module for inclusion in the WSA manual will fill this function.

Second, once a WAU-specific monitoring plan is ready to implement, other issues such as training, quality assurance and data handling need to be addressed to produce high quality results. Adaptation and utilization of the existing TFW Ambient Monitoring Program appears to be the most efficient means to deliver these services.

Table 19 outlines the steps necessary to develop and implement a WSA plan. Steps that require guidance and would be discussed in the monitoring module are noted with an M. Steps that require support services from the statewide monitoring program are noted with an S. The monitoring module and monitoring program support are discussed in more detail below.

Table 19. Watershed Analysis monitoring module components.

1. Develop a WSA Monitoring Plan (M, S*)

1.1. Organize a WSA monitoring team (M)

1.2. Identify WAU-specific monitoring goals and objectives (M,S)

1.3. Develop a sampling plan (M, S)

1.4. Determine personnel and budgetary resources (M)

1.5. Evaluate feasibility, prioritize objectives and modify sampling plan if needed (M)

1.6. Develop a quality assurance (QA) plan (M, S)

1.7. Document the monitoring plan (M, S)

2. Implement the WSA Monitoring Plan (M, S)

2.1. Procure equipment (S)

2.2. Training (S)

2.3. Collect data; implement sampling & QA plans (M, S)

2.4. Process, analyze and interpret data (M, S)

2.5. Share data with WAU stake-holders and the TFW statewide monitoring database (M, S)

2.6. Use data results to evaluate WSA through feedback mechanisms (M, S)

2.7. Evaluate/modify the monitoring program periodically (M, S)

* The letters in parenthesis identifies the program elements needed to accomplish each step.
M = monitoring module (written guidelines), S = support services (training, quality assurance, trouble-shooting, database management).

Recommended Outline for the Watershed Analysis Monitoring Module

We suggest that the Watershed Analysis (WSA) monitoring module consists of two sections. The first section should describe how to develop a monitoring plan that will accomplish specific objectives and data needs, and will insure that the data will be reliable and replicable. The second section should discuss implementation of the plan and procedures for collecting, interpreting and using monitoring data.

Section 1. Developing a Watershed Analysis Monitoring Plan

Monitoring plans need to be tailored to the watershed-specific conditions and concerns documented in the WSA resource assessment, causal mechanism, and prescription reports. The Monitoring Module cannot provide the local information needed to develop a monitoring plan, but should guide local monitoring teams using information from Watershed Analysis and other local sources to develop effective monitoring plans. Identifying WAU-specific monitoring objectives and developing a sampling plan that produces data to accomplish those objectives is an important part of an effective monitoring effort. The module should ensure that thought is given to how the data will be analyzed and interpreted prior to sampling to avoid wasted effort. Development of a Quality Assurance plan prior to sampling will help insure that the data is reliable, and will allow it to be used with confidence. The following paragraphs briefly describe the contents of Section 1.

· <u>Organizing the WSA monitoring team.</u> The monitoring module needs to provide instructions for assembling a monitoring team for the WAU and organizing the team so that necessary tasks are accomplished. Issues that need to be discussed include: 1) designating a team leader; 2) notifying stakeholders and members of the assessment and prescription teams; and 3) identifying, delegating and scheduling tasks. Members of the assessment and prescription teams that participated in synthesis will be familiar with conditions in the WAU, however team members just entering the process will need to become familiar with information from WSA and other sources.

· <u>Identifying WAU-specific monitoring goals and objectives.</u> The potential goals of Watershed Analysis monitoring are: 1) to provide feedback back to the WSA process to show where the prescriptions have been effective and where it is necessary to revise the WSA to achieve resource objectives; 2) to evaluate effectiveness of the WSA in achieving/maintaining good resource conditions; and 3) to monitor water quality in stream segments listed or designated by WDOE under section 303(d). This part of the module needs to describe how to translate these broad goals into WAU-specific monitoring objectives using the Watershed Analysis documents and knowledge of team members as resources.

The causal mechanism reports should be used as tools to develop monitoring objectives relating to effectiveness of Watershed Analysis. For each situation sentence (hypothesis) in the causal mechanism report, identify specific questions that can be answered with monitoring data. Examples of useful questions include:

1) What is the trend in the condition of resources that WSA is trying to improve/protect? Is there evidence of a recovery/disturbance trend?
2) If the water-body is listed or designated under section 303(d): is there a recovery trend in the water quality impairment? Should the water-body be removed from the 303(d) list?
3) Are the prescriptions working? Are the triggering mechanisms and input processes responding as expected? Are they continuing to function satisfactorily or to recover from past disturbance?

Some monitoring issues are not directly addressed in the causal mechanism reports. The resource assessments, causal mechanism reports and prescription are based on assumptions about linkages between forest practices, input processes and effects, and their spacial and temporal distributions. The monitoring module should provide guidance in determining: a) if assumptions made in the analysis need to be tested and validated by monitoring; or b) if there are critical issues or resources not specifically addressed in the causal mechanism report that should be monitored (such as critical salmonid stocks).

· Developing a sampling plan. The sampling plan should be designed to achieve the monitoring objective(s) and answer critical questions. There are several important steps in developing a sampling plan.

Determining monitoring parameters. Each situation sentence provides a monitoring hypotheses that can be used to design a sampling plan to evaluate the effectiveness of Watershed Analysis. Each triggering mechanism or effect in the situation sentence can be evaluated as potential monitoring parameter. Each situation sentence also identifies locations where the process/effects are predicted to occur.

The WSA Habitat Assessment Module identifies potential resource condition indices (diagnostics) that can be linked to each of the situation sentences if the CMRs lack specificity. If the stream is listed or designated by DOE in the 303(d) process, use that information to determine appropriate monitoring parameters.

Determining sampling location. The situation sentences in the causal mechanism reports identify locations where triggering mechanisms and effects are likely to occur. The resource assessment reports provide more detailed information on potentially affected stream reaches.

Determining monitoring methods. The monitoring module should specify sources of standard methods for parameters likely to be selected for WSA monitoring.

Determining sampling frequency. Sampling frequency and time frame will vary for each parameter. Guidance on sampling frequency should be provided with the methods.

· Determine analytic procedures. Methods for processing and error-checking data need to be identified in each monitoring plan. Standard procedures for processing and error-checking data should be incorporated in the description of methods. The monitoring plan should identify the end products of data analysis and the method for interpreting the results to fulfill the original monitoring objective.

· Determining personnel and budgetary resources. The monitoring plan should identify participating organizations and individuals, personnel, equipment and money that can be committed to implement the monitoring plan.

· Evaluating feasibility, prioritizing objectives and modifying the sampling plan. Depending on the resources available to implement the plan, it may be necessary to adjust the monitoring strategy, prioritize objectives, or implement the plan in stages. If the plan is modified due to limitations in resources, it is important to determine if the information produced will still meet the objectives.

· Developing a quality assurance plan. A Quality Assurance (QA) plan should be required as part of each monitoring plan to insure the reliability of monitoring data. To meet the requirements of the 303(d) process, the QA plan should address sampling methods, instrumentation and data error-checking. Continued use of the QA service provided by TFW Ambient Monitoring program will help to accomplish WSA QA objectives consistently and efficiently. The WSA Monitoring Module should discuss QA requirements and provide a format for documenting the QA plan.

°Documenting the monitoring plan. The monitoring plan for each WAU should be formally documented. The monitoring module should discuss what to include in this document to adequately describe the monitoring plan. A completed example would be useful.

Section 2. Implementing the WSA Monitoring Plan

This section should cover getting organized for field surveys, gathering and analyzing data, and using the information to evaluate the WSA and modify the monitoring plan.

· Procuring equipment. The equipment needed should be discussed in the monitoring methods.

° Training. Training in how to develop a WSA Monitoring plan could be included in the general WSA training sessions, or could alternately be offered as a separate training session conducted by the TFW Ambient Monitoring Program. Training on the monitoring methods should be covered by an expanded TFW Ambient Monitoring training program, including both group and on-site training components.

° Collecting data. Data should be collected as specified in each monitoring plan, which identifies sampling locations, times and methods. In addition, data collection should include implementation of the procedures specified in the QA plan, utilizing the TFW Ambient Monitoring QA Program when appropriate.

· Processing, analyzing and interpreting data. Data should be processed, analyzed and interpreted according to procedures documented in each monitoring plan. The TFW Ambient Monitoring program should continue to provide assistance in processing and analyzing data. The WSA manual also contains guidance for interpreting resource condition indices.

· Sharing monitoring information with WAU stake-holders and the TFW statewide monitoring database. Once data collection, processing and interpretation is complete, information should be made available to other interested parties. The monitoring plan should include a list of local WAU stake-holders and their contact persons for distribution. Data should also be forwarded to the TFW Ambient Monitoring program for storage in the TFW statewide monitoring database. Finally, information should be given to WDNR to assist in their evaluation of the WSA. The mechanisms for transmitting information to WDNR needs to be identified.

· Using data results and interpretation to evaluate WSA through feedback mechanisms. Monitoring results are important feedback for evaluating and refining WSA, however the WSA manual does not specify how this information will be used. Clarification of role of monitoring information in WSA evaluation is needed. A local adaptive management process conducted by WAU stakeholders or the resource assessment teams has not been developed, to our knowledge. The only reference to WAU-specific WSA evaluation and adaptive management procedure is contained in WAC 222-22-090. It is not clear IF the evaluation process required by WAC 222-22-090 *(4) will work, however it appears to be conducted solely by WDNR. Cumulative Effects Steering Committee (CESC) should consider whether evaluating the effectiveness of individual WSAs should be performed exclusively by the WDNR. A procedure to hand-off data and recommendations from the WAU-based monitoring team to WDNR will reduce confusion and make monitoring more meaningful.

In the case of 303(d) listed or designated stream segments, data on water quality impairment needs to be transmitted to WDOE for evaluation of segment status. Clarifying the procedure for doing this in the WSA monitoring module will reduce confusion.

Finally, it is important that information from WAU-specific monitoring get back to the CESC and the WSA design team. It is unclear how this will occur in a systematic fashion or how the information will be used in adaptive management. Clarification of these issues in the WSA monitoring module is important. Input from CESC and the WSA module leaders is needed on this.

· Evaluating and modifying the monitoring plan periodically. As collection and analysis of monitoring information progresses, it is important to evaluate the utility of the monitoring program. Examples of questions that may be useful include: a) is the sampling strategy feasible and appropriate? b) is the sampling frequency and coverage adequate? and c) are the information useful and does it fulfill objectives? The WSA Monitoring Module should provide guidance on evaluating monitoring plans.

Integrating Development and Implementation of WSA Monitoring Into the AMSC/CMER Work-plan

In this section we identify tasks necessary to develop a WSA monitoring program. A brief description of each task, the parties that involved, and a time-line are also presented. Abbreviations used for organizations include Ambient Monitoring Steering Committee (AMSC), Ambient Monitoring Program (AMP), Cumulative Effects Steering Committee (CESC), Department of Natural Resources (WDNR) and Department of Ecology (WDOE).

WSA Monitoring Module

Task 1.1. Write the monitoring module for version 3.0 of WSA manual.

Tune-line: The draft module needs to be submitted to CESC/CMER for review on July 1, with a final version to WDNR on August 1, 1994.

Participants: AMSC, AMP.

Task 1.2. Test and ratine procedures in the WSA monitoring module.

Time-line: Initial testing should be completed by December 1994 so revisions can be included in version 4.0 of WSA manual.

Participants: AMSC, AMP.

Task 1.3. Test and refine data analysis and interpretation procedures.

Time-line: Initial testing should be completed by December 1994 so revisions can be included in version 4.0 of WSA manual.

Participants: AMSC, AMP.

Task 1.4. Revise the monitoring module for version 4.0 of WSA manual.

Time-line: We anticipate that changes for version 5.0 of the WSA manual should be ready by spring of 1995.

Participants: AMSC, AMP.

Develop Standard Monitoring Methods

Task 2.1. Develop additional high priority new methods.

Time-line: Development of the highest priority methods should be completed by March 1995 so they can be included in the 1995 monitoring methods manual and training. Development should continue over a period of years until the methods needed have been developed.

Participants: AMSC, AMP.

Task 2.2. Test and ratine existing methods.

Time-line: Testing and refinement of the habitat unit, LWD and spawning gravel frae sediment survey modules should continue during the summer and fall of 1994, so changes can be incorporated in the 1995 monitoring methods manual and training. We anticipate a continuing need for testing and refinement of new and existing methods.

Participants: AMSC, AMP.

Provide WSA Monitoring Support Services

Task 3.1. Continue the TFW Ambient Monitoring Quality Assurance Program. As new monitoring methods axe developed, QA protocols and procedures need to be developed.

Time-line: We anticipate that QA protocols will need to be developed for several new monitoring methods between January-June 1995.

Participants: AMSC, AMP.

Task 3.2. Conduct QA surveys.

Time-line: There is an on-going year-round need to conduct and analyze QA surveys. Most QA visits are requested during the summer-fall field season, but some QA for spawning gravel processing occurs year-round. Analysis of QA results takes place primarily in the winter.

Participants: AMP.

Task 3.3. Develop databases for new parameters and methods. As new monitoring methods are developed, databases will need to be developed.

Time-line: We anticipate that databases will need to be developed for several new monitoring parameters by July of 1995.

Participants: AMP.

Task 3.4. Assist cooperators in data entry and processing.

Time-line: There is an on-going year-round need to assist cooperators in data entry and processing. Most data entry and processing occurs primarily in the winter.

Participants: AMP.

Task 3.5. Training: revise and distribute monitoring methods manual.

Time-line: The monitoring methods manual is revised annually prior to the summer field season to include new methods that have been developed as well as improvements in existing methods.

Participants: AMP.

Task 3.6. Training: conduct group training sessions.

Time-line.: Ongoing. Group training sessions are held in the late spring and early summer.

Participants: AMP.

Task 3.7. Training: provide on-site field assistance.

Time-line: Ongoing. There are year-round requests for field assistance visits. Most request occur during the summer and fail.

Participants: AMP.

Clarify, Procedures for Using WSA Monitoring Data in Adaptive Management

Task 4.1. Clarify procedures for the use of monitoring data to evaluate WSA effectiveness at the WAU level.

Time-line: This task should be completed March 1995 so that procedures can be included in version 4.0 of the WSA manual.

Participants: AMSC. CESC, WDNR.

Task 4.2. Clarify procedures for the use of monitoring data to refine Watershed Analysis methods.

Time-line: This task should be completed March 1995 so that procedures can be included in version 4.0 of the WSA manual.

Participants: AMSC, CESC, WSA module leaders.

Task 4.3. Clarify procedures for the use of monitoring data in the WDNR WSA evaluation under WAC 222-22-090.

Time-line: This task should be completed March 1995 so that procedures can be included in version 4.0 of the WSA manual.

Participants: AMSC, CESC, WDNR.

Task 4.4. Clarify procedures for use of monitoring data in WDOE TMDL evaluation.

Time-line.: This task should be completed March 1995 so that procedures can be included in version 4.0 of the WSA manual.

Participants: AMSC, CESC, WDOE, WDNR.

Improve Linkages With Other WSA Components

Task 5.1. Improve causal mechanism report documentation.

Time4ine: This task should be completed June 1994 so that procedures can be included in version 3.0 of the WSA manual.

Participants: CESC.

Task 5.2. Integrate parameters and methods supporting the Water Quality module into WSA monitoring.

Time-line: This task should be initiate as soon as the water quality module is available (August 1, 1994).

Participants: AMSC, CESC, Water Quality Module work group.

Improve Capability to Interpret Monitoring Data

Task 6.1. Develop a regional network of reference sites representing natural conditions/productive habitat.

Time-line: This project would require 2-4 years to implement. Initial design should begin as soon as possible.

Participants: AMSC, AMP.

Task 6.2. Develop a procedure for preparing resource recovery prognoses to help interpret Watershed Analysis monitoring data.

Time-line: This task should be completed as soon as possible so that procedures can be included in version 3.0 of the WSA manual.

Participants: AMSC, CESC.

Develop Funding for WSA Monitoring Activities

Task 7.1. Find funding for WSA monitoring program development and services.

Time-line: Work should begin as soon as possible.

Participants: AMSC, AMP.

Task Z2. Help fred funding for monitoring cooperators.

Time-line: Work should begin as soon as possible.

Participants: AMSC, AMP.

CONCLUSIONS AND RECOMMENDATIONS

1. Watershed Analysis Monitoring should be designed to fulfill three potential missions. First, it must provide feedback to assist in adaptive management. It must help Watershed Analysis assessment teams evaluate and refine their analyses and help module design teams improve WSA methods. Second, it should provide data needed by the Department of Natural Resources to evaluate the effectiveness of completed Watershed Analyses under WAC 222-22-090 (4). Finally, it could provide data needed by the Department of Ecology to evaluate the effectiveness of each WSA used in the implementation of section 303(d) of the Clean Water Act, if the FPB decides to implement the DNR/DOE proposal.

2. To accomplish these missions Watershed Analysis monitoring must evaluate the status of triggering mechanisms and input processes (input monitoring) to determine the effectiveness of WSA prescriptions on input processes. This type of input monitoring is important because it provides valuable feedback on the performance of prescriptions and allows early identification of potential problems before they are translated into detectable adverse channel and resource effects. The response of the stream channel, fish habitat and water quality conditions must also be monitored to determine if the resource protection objectives of WSA are being met.

3. A completed Watershed Analysis is an excellent foundation for developing a watershed-specific monitoring plan. Each causal mechanism report provides monitoring hypotheses that link input processes with channel and resources responses. These can be used to identify appropriate monitoring parameters and locations. The WSA causal mechanism reports (supplemented by resource assessments) are the key source of information, however they must be thoroughly written with input from all assessment team members to provide adequate detail.

4. Most causal mechanism reports (CMRs) contained adequate information on triggering mechanisms. Treatment of channel effects was less consistent, and many CMRs lacked adequate information on specific habitat effects. This problem should be prevented by providing better guidance in preparing CMRs in the WSA manual and training.

5. Most causal mechanisms fit into one of seven generic input/response "hypotheses" that occurred frequently in the CMRs we examined. Three of these hypotheses focused on mass wasting, and there are one each for surface erosion, large woody debris (LWD) recruitment, stream temperature, and peak flows. We used them to identify potential monitoring parameters we predict will be frequently identified in future CMRs and subsequent monitoring plans. Other, less common, situations will need to be addressed on a case-by-case basis.

6. Based on estimates of future demand and the amount of work required to develop a suitable method, we recommend development in the next year the following high priority parameters: slope stability, road assessment, surface erosion, channel substrate size (timing or coarsening), channel aggradation or degradation, channel widening, braiding, lateral migration

and bank erosion (aerial photo method), sediment storage features, spawning gravel availability and macro-invertebrate production. We also recommend initiating work on the following parameters (high demand/extensive work): deep-seated landslides, fine sediment delivery, site-specific peak flow runoff monitoring, channel widening, braiding, lateral migration and bank erosion (field methods), spawning gravel scour, pool refuge habitat and LWD accumulations (refuge cover).

7. Water quality parameters were rarely identified in the CMRs due to lack of a Water Quality Module. Water quality parameters need to be identified and integrated into the program to develop methods when the Water Quality Module is completed.

8. To implement WSA Monitoring effectively, local stakeholders should develop and implement watershed-specific monitoring plans based on the WSA causal mechanism and resource assessment reports. The Watershed Analysis Monitoring Module should provide guidance in preparation and documentation of local monitoring plans. Specific issues that need to be addressed in the monitoring plans include identifying goals and objectives, developing a sampling plan, quality assurance, data processing and data interpretation.

9. Technical assistance from the TFW Ambient Monitoring Program is needed to support the local monitoring teams and ensure consistent data collection on a state-wide basis. The appropriate role of the TFW Ambient Monitoring Program in implementing Watershed Analysis Monitoring includes developing standard methods, conducting training, providing quality assurance, assisting with data processing and analysis, and maintaining the state-wide database.

10. To successfully implement WSA Monitoring, some important tasks need to be completed. They include writing the monitoring module, developing standard methods, providing support services (training, quality assurance, etc.), clarifying procedures for use of WSA monitoring data in adaptive management, improving linkages with other WSA components, improving capability to interpret monitoring information, and developing future funding sources. These tasks need to be incorporated into the AMSC/CMER work-plan.

11. A methodology to develop channel/resource recovery prognoses is needed in WSA. A recovery prognosis, in conjunction with monitoring data, will allow better evaluation of the response of systems recovering from past disturbance associated with management or natural events. Developing credible recovery prognoses will require a good understanding of disturbance/recovery cycles in natural systems. CESC needs to evaluate whether adequate information exists to develop recovery prognosis, or if additional research is needed.

12. Clarification is needed concerning procedures for the use of WSA monitoring data in adaptive management. Specific issues include: 1) use of monitoring data to evaluate WSA effectiveness at the WAU level; 2) use of monitoring data to refine Watershed Analysis methodology; 3) use of monitoring data in the WDNR WSA evaluation under WAC 222-22-090; and 4) use of monitoring data in WDOE's TMDL evaluation. It is important that

procedures are clearly defined to avoid confusion and misunderstandings.

13. To successfully implement WSA monitoring, a stable long term funding source for the monitoring program needs to be secured.

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